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TEMPORAL CHANGES IN RELATIVE ABUNDANCE, DISTRIBUTION AND FOOD HABITS OF FISH COLLECTED IN SHORELINE WATERS OF EAST CENTRAL LAKE MICHIGAN, NEAR LUDINGTON, MICHIGAN

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By

Robert C. Anderson

A DISSERTATION

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ABSTRACT

TEMPORAL CHANGES IN RELATIVE ABUNDANCE,
DISTRIBUTION AND FOOD HABITS OF FISH COLLECTED IN
SHORELINE WATERS OF EAST CENTRAL LAKE MICHIGAN,
NEAR LUDINGTON, MICHIGAN

By

Robert C. Anderson

The shoreline waters of east-central Lake Michigan, near Ludington, Michigan, were intensively sampled with gill nets, seines, and sieve nets from April through November during 1976 and 1977. Comparison of catch near the Ludington Pumped Storage Power Plant (LPSPP) and a control site 4.8 km to the south were made. Food habits of adult salmonids, spottail shiner, longnose dace as well as young-of-the-year alewives and spottail shiner were determined. Available food resources were sampled as well.

Thirty-five species of fish were caught in shoreline waters. Seasonal changes in species composition were mainly related to spawning activity and subsequent hatching of eggs. Rainbow trout were most abundant in May as they moved along shore searching for an appropriate tributary in which to spawn. Spottail shiner and alewives were most abundant in late spring and summer as these species spawned along shore. The major fall spawner was lake trout in October.

Alewife and spottail shiner adults remained nearshore through summer and early fall. Alewife took advantage of abundant zooplankton populations and emerging fish larvae for food. Spottail shiner consumed mainly terrestrial insects blown into the lake and concentrated near

shore. Both species were somewhat protected from predators since the warm water near shore acted as a barrier to large salmonids.

Alewife and spottail shiner YOY remained near shore through the summer and early fall also. Alewife YOY ate mainly pelagic zooplankton such as Bosmina and Cyclops. Spottail shiner YOY ate epibenthic zooplankton such as Chydorus and Alona as well as Chironomidae larvae.

No consistent pattern was seen comparing sampling sites due to the dynamic nature of the fish community. The general patterns of fish movement to and from the shoreline waters derived from this study may, however, be used to modify operating modes of the LPSPP to lessen potential entrainment of fish.

DEDICATION

This dissertation is dedicated to

Phyllis A. Anderson

and our children Brian, Emily, and Becky

who have shared their time and patiently provided support

throughout this program.

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INTRODUCTION

During the past 120 years, the fish community of Lake Michigan has been changed through a series of man-induced perturbations. Formerly, a diverse system comprised of two large piscivores, a number of large plankton and macrobenthos feeders and a wide variety of small forage species, Lake Michigan is now dominated by five large piscivores and one small planktivorous forage species.

This dramatic change occurred due to a series of events associated with man's use of the natural resources in the Great Lakes and their drainage basin. Heavy fishing pressure by a fast growing commercial fishery in concert with the success of invading species such as rainbow smelt (*Osmerus mordax*), sea lamprey (*Petromyzon marinus*), and alewife (*Alosa pseudoharengus*) were major factors contributing to the decline in native species populations. Deterioration of water quality due to rapid industrial development and deforestation in the Lake Michigan drainage basin also contributed to this decline. Populations of the five piscivores which dominate the food chain today are maintained through federal and state stocking programs (Christie 1974, Wells and McLain 1973, Smith 1972).

Rainbow smelt were introduced and became abundant in Lake Michigan in the 1920s and 30s. The diet of young rainbow smelt, mainly invertebrates, placed them in competition with the lake herring (*Coregonus artedii*), a shallow water planktivore, resulting in a decline in herring stocks during the rainbow smelt population increase (Christie 1974). The parasitic sea lamprey spread to Lake Michigan in 1936 causing drastic reductions in two large piscivores, lake trout (*Salvelinus namaycush*) and burbot (Lota lota), and later reduced numbers of lake whitefish (Coregonus clupeaformis), deep-water ciscoe (Coregonus johannae), lake herring, sucker (Catostomus spp.), walleye (Stizostedion vitreum), yellow perch (Perca flavescens), and carp (Ciprinus carpio)(Wells and McLain 1973).

Alewives entered the system in 1949 following this decline in the large native predator populations. The alewife, through competition for food, increased pressure on lake herring and the deep-water ciscoe group (Moffett 1956). A drastic decline in abundance of the emerald shiner (Notropis athernoides), an abundant nearshore cyprinid has also been related to alewife competition (Wells and McLain 1973).

A large scale rehabilitation program for the lake trout population in Lake Michigan coordinated by the Great Lake Fishery Commission, began in 1965. An average of 2 million yearlings have been planted each year, but significant natural reproduction has not been observed. A program for the introduction of pacific salmon (Oncorhynchus spp.) into Lake Michigan began in 1966. Prior to 1970, 10.3 million coho salmon (Oncorhynchus kisutch) and 4.1 million chinook salmon (Oncorhynchus tschawytscha) young had been released. Since 1970, 2 to 3 million coho and 1 to 2 million chinook have been released annually providing a successful sport fishery. Rainbow trout (Salmo gairdneri)and brown trout (Salmo trutta) have been stocked regularly since 1960 and significant natural reproduction has occurred (Wells and McLain 1973). These stocking programs have produced a fish community with five major piscivorous species depending mainly on the alewife as a forage base. Alewife populations, despite heavy predation, have not declined greatly in abundance and are currently suspected of causing fluctuations in the yellow perch populations through displacement from preferred spawning sites and competition for food, during early development (Wells 1977).

Aspects of the aquatic community of Lake Michigan have been studied through analysis of commercial fish catches, surveys by the U.S. Fish and Wildlife Service and investigations by local universities (Wells and McLain 1973). Recently several Lake Michigan studies have been funded by utilities which own and operate power plants on the shoreline of Lake Michigan. These studies are providing further information about Lake Michigan's aquatic community (CDM Limnetics 1976). Several of these studies focus on the nearshore zone ($<$ 10 m deep) which comprises only 0.4% of the total volume of Lake Michigan yet it is the richest zone of aquatic plankton production (Beeton and Edmonson 1972). This zone also receives the majority of the domestic and industrial wastes introduced into the lake and receives the most recreational use (Smith 1970). The objective of the present study is to provide baseline data on major fish species in the shoreline waters (0-3 m deep) portion of the nearshore zone. Temporal changes in species composition, relative abundance, distribution and food habits of fish in the shoreline waters (0-3 m deep) during 1976 and 1977 are described. This report is supplemental to investigations of the effects of installing and operating a large pumped storage project on the shores of Lake Michigan (Liston and Tack 1975; Brazo and Liston 1979). Catch near the Ludington Pumped Storage Power Plant (LPSPP) is compared to the CPE at a control site in order to detect any consistent patters which may indicate avoidance of or attraction to the LPSPP.

DESCRIPTION OF THE SAMPLING AREA

The physical aspects of shoreline waters of large lakes are often extremely dynamic. Energy of wind generated waves released in this zone is partially absorbed by the substrate and partially transferred to turbulent alongshore currents which stir up and transport large quantities of sediment (Duane et al. 1975). Waves and alongshore current have produced a series of four persistent sandbars parallel to shore in Lake Michigan near Ludington (Hands 1970). These sandbars (Figure 1) are transported toward and away from shore as lake level and seasonal weather patterns change. Transport of sand by alongshore currents constantly covers and exposes submerged rock outcroppings, one of the few stable nearshore habitats available for colonization by benthic macroinvertebrates. This zone has high plankton production due to continual recycling of nutrients from the bottom into the water column, light penetration to the substrate and influx of nitrogen and phosphorous from the watershed (Smith 1970).

Sampling for this study was restricted to the trough on the inshore side of the sandbar nearest shore. This trough fluctuated from 1-3 m in depth and usually was located 60 m from shore. Two permanent sampling sites were established for the 1976 sampling season (Figure 2), station 1 located 180 m south of the LPSPP intake channel, and station 8 located 4.8 km south of the LPSPP. During 1977, another site (station 5) located 180 m north of the LPSPP intake channel was added. Substrates at stations 1 and 8 included sand and frequently exposed rock and gravel areas whereas the substrate at station 5 was sandy throughout the study.

Figure 1. Generalized Lake Michigan shoreline profile depicting four nearshore sandbars (derived from Hands 1970).

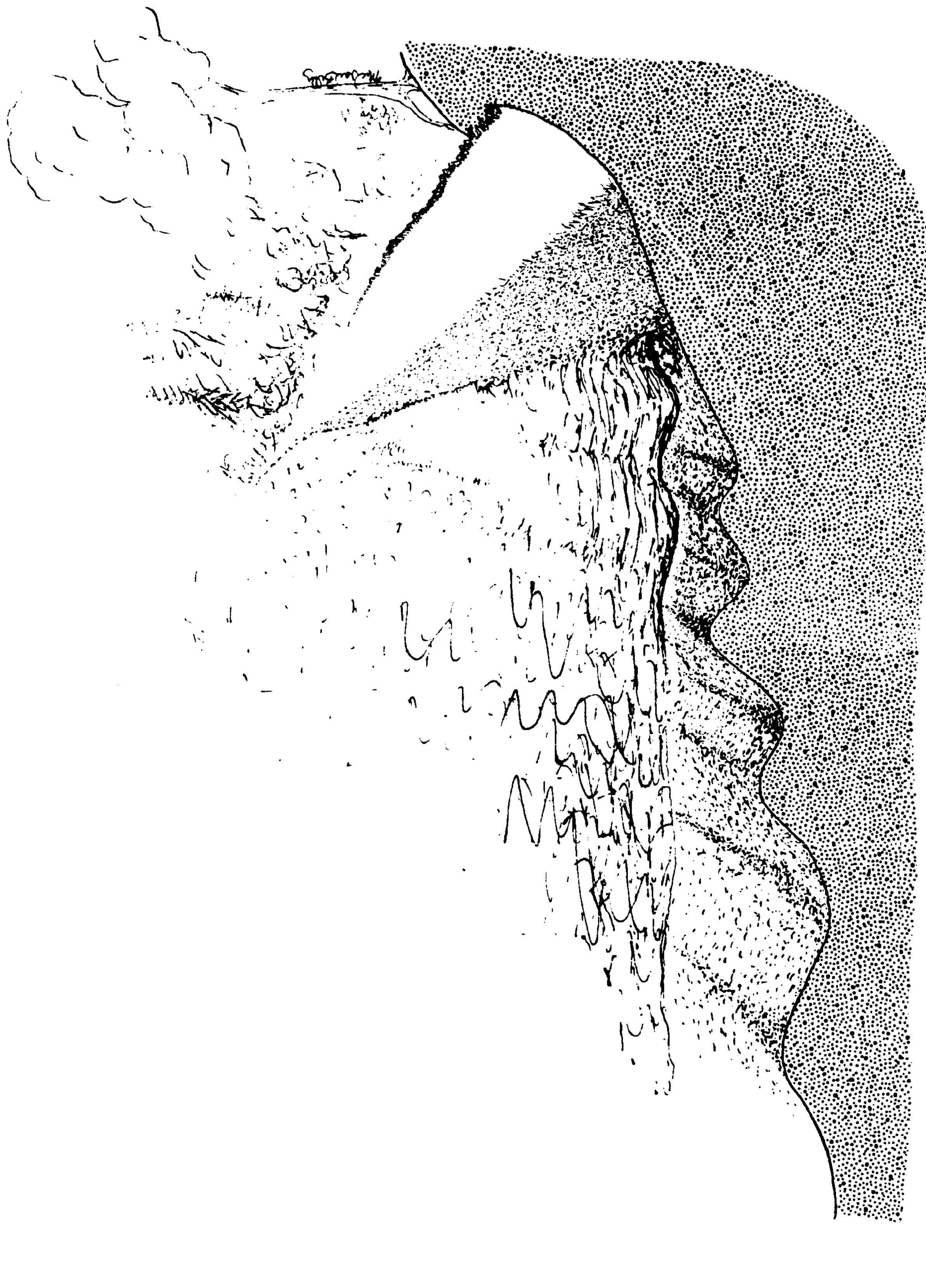
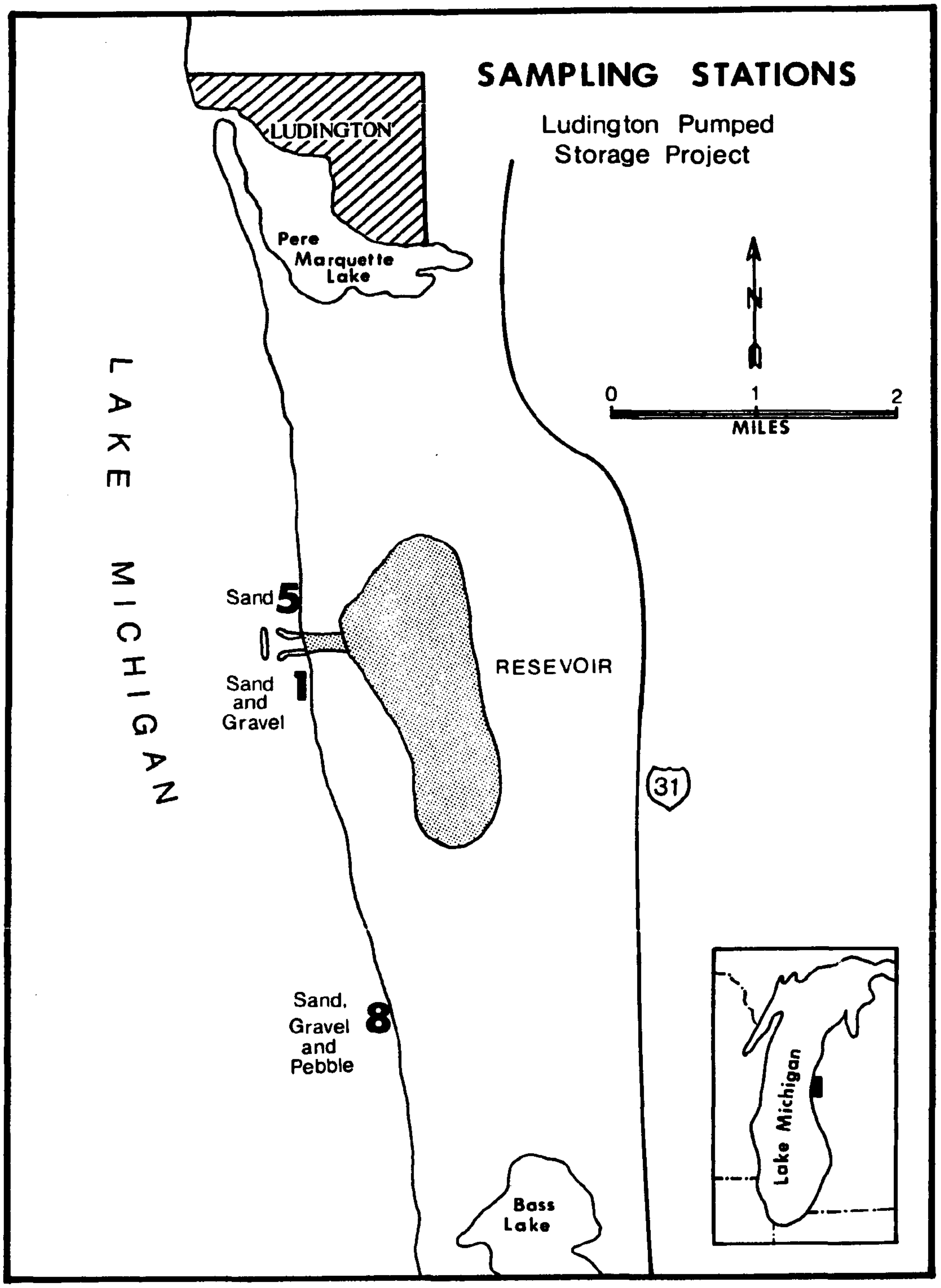


Figure 2. Diagram of the Ludington Pumped Storage Project showing shoreline sampling sites 1, 5, and 8 (control) and offshore protective rock jetties and break wall.


SAMPLING STATIONS
Ludington Pumped
Storage Project
LUDINGTON
Pere
Marquette
Lake
N
0
1
2
MILES
LAKE MICHIGAN
Sand 5
Sand and Gravel 1
RESEVOIR
31
Sand, Gravel and Pebble 8
Bass Lake
Lake Michigan

METHODS AND MATERIALS

Adult and juvenile fish were sampled from April through November during 1976 and 1977. Larval fish, zooplankton, and macroinvertebrates were sampled during 1977 only. Physical parameters including water temperature, turbidity, current direction, and wave height were measured at each station prior to sampling. Climatic parameters including wind direction and barometric pressure were obtained for each sample date and time from the U.S. Coast Guard Station at Ludington.

Gill Nets

Variable mesh gill nets comprising seven 7.6 x 1.8 m panels of 25-, 51-, 64-, 76-, 102-, 114-, and 178-mm stretched mesh for a total length of 106.7 m were used to capture adult and juvenile fish. On each sample date, one net was set perpendicular to shore at each station. The net was attached to a stationary object on the beach, pulled out by a swimmer and anchored. Nets were set twice a week for four hours at either sunrise, midday, sunset, or midnight which was randomized using latin squares to prevent a repeating pattern. Nets were retrieved from shore and large fish (particularly catostomids and salmonids) which were still alive were immediately removed, weighed (g), measured (mm), and sexed (based on external characteristics) when possible. Scale samples were also taken and the fish were tagged with a floy tag and released. Each tag had an identification number and the address of the Ludington Laboratory printed on it so that upon recapture the tag could be returned and pertinent data added to the record for that fish. Other fish were taken to the laboratory where total length (mm), weight (g), gonadal condition, and age (scale method) were determined for up to twenty individuals of each species captured at each station. Subsamples of each species were preserved for verification and possible future analysis. Stomachs were removed from the large (> 450 mm) salmonids, wrapped in cheesecloth, and preserved in a 10% formalin solution.

Beach Seine

Seine samples were taken monthly with a 3.1-mm square mesh, 15.2 x 1.8-m bag seine. On each sample date, 60-m seine hauls were made parallel to shore once every four hours at each station. Fish captured during seining were taken to the lab and processed in the same manner as fish captured in gill nets.

Sieve Nets

Three 30-m hauls were made shortly after sunset at each station with sieve nets twice each month to sample larval and juvenile fish. Drifting macroinvertebrates and zooplankton were sampled at the same time. Larval fish and macroinvertebrates were collected with a 1-mm mesh meter net with a calibrated Rigosha flow meter attached to the center of the net. A 64 micron mesh plankton net was pulled with the meter net to collect zooplankton. Nets were pulled by hand and 1/4 of the mouth of the meter net was kept above water to collect floating invertebrates. Meter net samples were fixed in 10% formalin and preserved in 70% isopropyl alcohol. Larval fish and macroinvertebrates were later sorted from samples under a lighted magnifying lens, identified and counted. The number of these organisms per m^3 of water sampled was determined using the following formula:

$$\text{Volume sampled} = 0.75\pi r^2 d$$

where 0.75 is a correction factor for the mouth of the net held out of the water, r is the radius of the mouth of the net, and d is the distance towed. Distance towed was calculated by multiplying the number of revolutions recorded by the flow meter times the number of revolutions per meter. Calibration of the flow meter was done in a current-free indoor swimming pool. For each meter pulled, 7.57 revolutions were recorded.

Larvae were examined with a binocular microscope (20-80 x magnification) and identifications were based on descriptions and keys by Lippson and Moran (1974), Nelson and Cole (1975), Hogue et al. (1976), and Dorr et al. (1976). Macroinvertebrates were examined similarly and identifications were based on keys by Usinger (1956) and Borror and DeLong (1976). Zooplankton were examined with a compound microscope (100 x magnification) and identifications were made based on keys by Pennak (1978) and Torke (1974). Plankton were subsampled until at least 100 individuals of common genera were counted. Zooplankton densities were determined by the same formula used for macroinvertebrate and larval fish density determinations and dividing volumes by 9 to account for the 1/3 meter diameter of the mouth of the plankton net.

Dredging

Triplicate substrate samples were taken monthly at each station with an Ekman dredge (24 cm^2 area sampled) at the 1-m depth contour. Each sample was placed directly into a plastic bag, taken to the laboratory, and gently washed through a 0.6-mm mesh sieve. Organisms were removed from the remaining debris and preserved in 70% isopropyl alcohol. Identifications were made with a binocular microscope (20-80 x magnification) and keys by Pennak (1978), Usinger (1956), and Borror and DeLong (1976). All taxa were counted and the number per m^2 of substrate calculated.

Stomach Analysis

Stomach contents of large salmonids (> 450 mm) were identified, counted, and assigned a volume based on water displacement.

The entire alimentary canal of young-of-the-year (YOY) spottail shiners and alewives were removed for gut analysis. Microdissecting needles were used under 40-80 x magnification to open the gut and tease out food organisms. Organisms were identified to genera when possible and enumerated. If the number of items in the gut was large, contents were subsampled by mixing in a known volume of water (usually 10 ml) and removing 1 ml samples. Volumes of small food items such as zooplankton were estimated by entering length, width, and depth measurements into formulas for geometric configurations that approximate the shape of each taxanomic group (Kenega 1975). Length-width measurements were made with an ocular micrometer and depth was calculated as a proportion of the length from ratios derived by Kenega.

Statistical Methods

A three-way analysis of variance was used to test for significant differences ($\alpha = 0.1$) among time (sunrise, midday, sunset, and midnight), season (spring, summer, and fall) and station (1, 5, and 8) for catch per unit effort (CPE) of major fish species in gill nets. Prior to applying this test, raw data were tested for normality using a Kolmagorov-Simirnov goodness-of-fit test on the residuals (Sokal and Rohlf 1969). The data were found to be non-normally distributed and log (X + 1) transformation was found best for approaching normality. A priori contrasts were performed to determine where significant differences occurred.

Beach seine catches were not able to be normalized due to large numbers of zeros in the data. Therefore, the nonparametric Kruskal-Wallis Distribution-free test (Hollander and Wolfe 1973) was used to test for significant differences ($\alpha = 0.1$) in CPE of the major fish species captured between stations 1, 5, and 8.

A partial correlation analysis (Sokal and Rohlf 1969) was performed to assess the relative importance of the climatic and water condition parameters in explaining changes in CPE of the major fish species captured in gill nets.

RESULTS

Thirty-five species of fish were collected in the shoreline waters during this study (Table 1). Of the commonly occurring nearshore fish species in the Ludington area (Brazo and Liston 1979), only the burbot was not collected in shoreline waters. The burbot, however, does spawn along shore under the ice when sampling was not possible (Scott and Crossman 1973).

Gill Net Collections

During April - November, 1976 and 1977, 59 and 67 gill net sets, respectively, were made at each station. During both years, spottail shiners and alewives were the most abundant species collected; however, lake trout comprised the greatest biomass (Table 2). Total catch per effort (CPE) was greatest in June and least during April and November (Tables 3 and 4). Increased CPE during late spring and early summer corresponds with reported spawning migrations of alewives, spottail shiners, trout-perch, and yellow perch (Brazo et al. 1975; Wells 1968; Reigle 1969).

On a diel basis, gill net CPE was greatest at sunrise and sunset during both years of the study (Tables 5 and 6).

The effect of the Ludington Pumped Storage Project on shoreline fishes is inferred from catch comparisons between the control site (station 8) and the impact sites (stations 1 and 5) for each major species (Tables 7 and 8).

Table 1. A list of the common and scientific names of all fish collected in shoreline waters of east-central Lake Michigan, near Ludington, Michigan in order of abundance.[1]

Common Names	Scientific Names
Alewife	*Alosa pseudoharengus*
Spottail shiner	*Notropis hudsonius*
Rainbow smelt	*Osmerus mordax*
Lake trout	*Salvelinus namaycush*
White sucker	*Catostomus commersoni*
Rainbow trout	*Salmo gairdneri*
Longnose dace	*Rhinichthys cataractae*
Brown trout	*Salmo trutta fario*
Lake whitefish	*Coregonus clupeaformis*
Redhorse	*Moxostoma (spp.)*
Yellow perch	*Perca flavescens*
Longnose sucker	*Catostomus catostomus*
Gizzard shad	*Dorosoma cepedianum*
Chinook salmon	*Oncorhynchus tschawytscha*
Coho salmon	*Oncorhynchus kisutch*
Trout-perch	*Percopsis omiscomaycus*
Carp	*Cyprinus carpio*
Johnny darter	*Etheostoma nigrum*
Round whitefish	*Prosopium cylindraceum*
Emerald shiner	*Notropis atherinoides*
Mottled sculpin	*Cottus bairdii*
Lake chub	*Hybopsis plumbea*
Northern pike	*Esox lucius*
Fathead minnow	*Pimephales promelas*

Table 1. (cont'd.).

Common Names	Scientific Names
Ninespine stickleback	Pungitius pungitius
Sand shiner	Notropis stramineus
Pumpkinseed	Lepomis gibbosus
Bowfin	Amea calva
Bloater	Coregonus hoyi
Golden shiner	Notemigonus crysoleucas
Longnose gar	Lepisosteus osseus
Channel catfish	Ictalurus punctatus
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Black crappie	Pomoxis nigiomaculatus

1. Common and scientific names follow that of Bailey et al. 1970.

Table 2. Total number (TN), catch per effort (CPE), standard error (SE), and total weight (TW) of each fish species captured in gill nets during April - November, 1976 and 1977.

	1976				1977			
Species	TN	CPE	(SE)	TW(g)	TN	CPE	(SE)	TW(g)
Spottail shiner	2672	23.9	(4.8)	34142	2981	16.8	(2.8)	38849
Alewife	779	7.0	(1.9)	19005	504	2.9	(0.7)	20286
Rainbow trout	173	1.5	(0.3)	373580	334	1.7	(0.2)	742646
Lake trout	319	2.8	(0.6)	1208005	279	1.6	(0.3)	1030308
White sucker	277	2.5	(0.4)	214506	257	1.4	(0.2)	181612
Redhorse	70	0.6	(0.1)	76052	170	0.9	(0.2)	168020
Brown trout	168	1.5	(0.3)	386096	135	0.7	(0.1)	265998
Rainbow smelt	174	1.6	(0.4)	3361	124	0.7	(0.3)	3084
Longnose sucker	101	0.9	(0.2)	61099	106	0.6	(0.2)	67334
Gizzard shad	134	1.2	(0.3)	79269	93	0.5	(0.2)	45770
Yellow perch	148	1.3	(0.4)	17852	83	0.5	(0.2)	9541
Longnose dace	108	1.0	(0.3)	1692	65	0.4	(0.1)	1120
Coho salmon	86	0.8	(0.2)	138584	63	0.4	(0.1)	103865
Carp	33	0.3	(0.1)	134620	57	0.3	(0.06)	261779
Chinook salmon	74	0.7	(0.1)	93773	51	0.3	(0.06)	113332
Trout-perch	51	0.5	(0.1)	654	39	0.2	(0.05)	490
Round whitefish	5	0.04	(0.02)	3229	11	0.06	(0.02)	3431
Lake chub	5	0.04	(0.03)	510	4	0.02	(0.01)	235
Northern pike	2	0.02	(0.01)	2500	3	0.02	(0.01)	12230
Pumpkinseed	2	0.02	(0.01)	131	0	0.0	(0.0)	0
Largemouth bass	1	0.01	(0.01)	514	0	0.0	(0.0)	0
Bowfin	0	0.0	(0.0)	0	2	0.01	(0.01)	4820
Longnose gar	0	0.0	(0.0)	0	1	0.01	(0.01)	2640
Channel catfish	0	0.0	(0.0)	0	1	0.01	(0.01)	1520
Bloater	0	0.0	(0.0)	0	1	0.01	(0.01)	18
Smallmouth bass	0	0.0	(0.0)	0	1	0.01	(0.01)	1510
Black crappie	1	0.01	(0.01)	320	0	0.0	(0.0)	0
Totals	5383	48.24	(10.6)	2849494	5365	30.04	(5.9)	3080438

Table 3. Monthly gill net catch per effort (CPE) and standard error (SE) from April - November, 1976.

Species	April CPE	April (SE)	May CPE	May (SE)	June CPE	June (SE)	July CPE	July (SE)
Spottail shiner	0.4	(0.2)	12.1	(4.8)	90.1	(24.0)	32.8	(7.5)
Alewife	0.9	(0.5)	2.9	(2.2)	18.2	(6.0)	6.8	(2.7)
Rainbow trout	5.1	(1.2)	1.2	(0.4)	0.4	(0.2)	0.2	(0.1)
Lake trout	0.1	(0.07)	1.3	(0.4)	0.3	(0.3)	1.3	(0.9)
White sucker	1.9	(0.5)	2.2	(0.9)	1.5	(0.6)	5.1	(1.9)
Redhorse	0.05	(0.05)	0.1	(0.09)	0.4	(0.2)	1.0	(0.4)
Brown trout	1.5	(0.6)	3.8	(1.2)	1.3	(0.7)	0.7	(0.3)
Rainbow smelt	2.4	(1.0)	5.3	(2.2)	0.1	(0.1)	0.06	(0.06)
Longnose sucker	0.7	(0.5)	0.9	(0.6)	0.4	(0.2)	2.2	(0.9)
Gizzard shad	1.6	(1.0)	1.1	(0.3)	1.0	(0.4)	0.8	(0.4)
Yellow perch	0.1	(0.07)	0.0	(0.0)	1.1	(0.4)	6.0	(2.2)
Longnose dace	0.05	(0.05)	1.5	(1.2)	2.0	(0.7)	1.9	(1.4)
Coho salmon	0.1	(0.07)	0.4	(0.2)	0.2	(0.2)	0.06	(0.06)
Carp	0.2	(0.02)	0.0	(0.0)	1.0	(0.4)	0.3	(0.2)
Chinook salmon	0.1	(0.07)	0.2	(0.15)	0.6	(0.3)	2.0	(0.5)
Trout-perch	0.1	(0.07)	0.8	(0.3)	1.6	(0.7)	0.2	(0.1)
Round whitefish	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Lake chub	0.0	(0.0)	0.3	(0.2)	0.0	(0.0)	0.0	(0.0)
Northern pike	0.05	(0.05)	0.07	(0.07)	0.0	(0.06)	0.0	(0.0)
Pumpkinseed	0.05	(0.05)	0.0	(0.0)	0.06	(0.0)	0.0	(0.0)
Largemouth bass	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Black crappie	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Totals	15.55	(6.4)	34.17	(15.2)	120.26	(35.5)	61.42	(19.6)
Number of samples	19		15		16		18	

Table 3.(cont'd.).

Species	August CPE	(SE)	September CPE	(SE)	October CPE	(SE)	November CPE	(SE)
Spottail shiner	19.8	(10.6)	7.7	(4.1)	3.3	(1.9)	0.0	(0.0)
Alewife	19.3	(11.7)	0.8	(0.7)	0.1	(0.1)	0.0	(0.0)
Rainbow trout	0.3	(0.2)	1.4	(0.4)	1.0	(0.3)	10.0	(0.0)
Lake trout	3.9	(1.3)	5.6	(2.2)	9.4	(2.9)	0.0	(0.0)
White sucker	3.9	(1.6)	1.9	(0.4)	0.6	(0.4)	0.0	(0.0)
Redhorse	2.0	(0.8)	0.7	(0.4)	0.2	(0.1)	0.0	(0.0)
Brown trout	1.7	(1.0)	1.2	(0.3)	0.4	(0.2)	0.0	(0.0)
Rainbow smelt	0.6	(0.4)	1.3	(0.9)	1.1	(1.0)	0.0	(0.0)
Longnose sucker	1.3	(0.7)	0.3	(0.2)	0.3	(0.2)	0.0	(0.0)
Gizzard shad	2.3	(1.2)	1.0	(0.6)	0.6	(0.4)	0.0	(0.0)
Yellow perch	1.3	(0.7)	0.07	(0.07)	0.0	(0.0)	0.0	(0.0)
Longnose dace	0.5	(0.2)	0.1	(0.1)	0.5	(0.3)	0.0	(0.0)
Coho salmon	0.4	(0.2)	2.0	(0.6)	2.7	(0.8)	2.0	(0.0)
Carp	0.5	(0.3)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Chinook salmon	0.1	(0.1)	1.4	(0.4)	0.07	(0.07)	0.0	(0.0)
Trout-perch	0.1	(0.1)	0.4	(0.3)	0.07	(0.07)	0.0	(0.0)
Round whitefish	0.07	(0.07)	0.1	(0.1)	0.07	(0.07)	0.0	(0.0)
Lake chub	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Northern pike	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Pumpkinseed	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Largemouth bass	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Black crappie	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Totals	58.07	(31.2)	25.97	(11.8)	21.4	(8.8)	12.0	(0.0)
Number of samples	15		14		14		1	

Table 4. Monthly gill net catch per effort (CPE) and standard error (SE) from April - November, 1977.

	April		May		June		July	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	0.5	(0.3)	17.6	(8.1)	51.3	(11.6)	32.3	(9.9)
Alewife	0.0	(0.0)	2.5	(1.2)	9.3	(3.9)	2.3	(0.8)
Rainbow trout	5.4	(1.0)	2.1	(0.5)	0.1	(0.08)	0.0	(0.0)
Lake trout	0.09	(0.06)	0.7	(0.3)	0.8	(0.3)	0.8	(0.6)
White sucker	1.4	(0.3)	1.5	(0.5)	2.2	(1.1)	2.2	(0.9)
Redhorse	0.1	(0.07)	0.6	(0.3)	0.9	(0.3)	1.3	(0.4)
Brown trout	1.1	(1.8)	1.0	(0.3)	0.7	(0.3)	0.5	(0.2)
Rainbow smelt	0.9	(0.4)	0.2	(0.1)	0.05	(0.05)	0.0	(0.0)
Longnose sucker	1.3	(0.5)	1.3	(0.6)	0.5	(0.2)	0.7	(0.4)
Gizzard shad	0.2	(0.1)	0.0	(0.0)	0.1	(0.1)	0.7	(0.3)
Yellow perch	0.0	(0.0)	0.04	(0.04)	0.2	(0.2)	2.0	(1.3)
Longnose dace	0.0	(0.0)	0.7	(0.4)	0.5	(0.3)	0.2	(0.1)
Coho salmon	0.1	(0.07)	0.04	(0.04)	0.04	(0.04)	0.0	(0.0)
Carp	0.2	(0.1)	0.7	(0.02)	0.9	(0.3)	0.3	(0.2)
Chinook salmon	0.0	(0.0)	0.0	(0.0)	0.7	(0.2)	0.5	(0.3)
Trout-perch	0.05	(0.05)	0.3	(0.1)	0.6	(0.3)	0.2	(0.1)
Round whitefish	0.0	(0.0)	0.1	(0.08)	0.0	(0.0)	0.0	(0.0)
Sand shiner	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Lake chub	0.0	(0.0)	0.2	(0.07)	0.0	(0.0)	0.0	(0.0)
Northern pike	0.1	(0.07)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Bowfin	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)	0.04	(0.04)
Longnose gar	0.0	(0.0)	0.04	(0.4)	0.0	(0.0)	0.0	(0.0)
Channel catfish	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.04	(0.04)
Bloater	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.04	(0.04)
Smallmouth bass	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Totals	11.44	(4.8)	29.62	(12.9)	68.94	(19.3)	44.12	(15.6)
Number of samples	22		26		21		26	

Table 4.(cont'd.).

Species	August CPE	August (SE)	September CPE	September (SE)	October CPE	October (SE)	November CPE	November (SE)
Spottail shiner	13.8	(4.1)	11.1	(6.1)	0.6	(0.2)	0.4	(0.4)
Alewife	2.3	(0.8)	1.5	(0.8)	0.4	(0.2)	0.08	(0.08)
Rainbow trout	0.5	(0.2)	1.5	(0.5)	1.9	(0.5)	2.9	(0.6)
Lake trout	1.0	(0.8)	3.1	(0.8)	5.6	(1.7)	0.5	(0.3)
White sucker	0.8	(0.2)	1.8	(0.7)	0.5	(0.2)	0.4	(0.3)
Redhorse	1.8	(0.6)	1.9	(0.7)	0.3	(0.2)	0.2	(0.1)
Brown trout	0.4	(0.1)	1.0	(0.2)	0.6	(0.2)	0.7	(0.3)
Rainbow smelt	0.0	(0.0)	4.2	(2.0)	0.2	(0.1)	0.08	(0.08)
Longnose sucker	0.4	(0.3)	0.1	(0.1)	0.0	(0.0)	0.0	(0.0)
Gizzard shad	2.2	(1.0)	0.5	(0.3)	0.3	(0.1)	0.0	(0.0)
Yellow perch	0.5	(0.2)	0.5	(0.2)	0.1	(0.1)	0.0	(0.0)
Longnose dace	0.8	(0.3)	0.5	(0.3)	0.1	(0.1)	0.0	(0.0)
Coho salmon	0.2	(0.1)	0.5	(0.2)	1.1	(0.2)	1.5	(0.5)
Carp	0.2	(0.1)	0.1	(0.1)	0.0	(0.0)	0.08	(0.08)
Chinook salmon	0.04	(0.04)	0.7	(0.2)	0.3	(0.1)	0.0	(0.0)
Trout-perch	0.3	(0.1)	0.2	(0.1)	0.0	(0.0)	0.0	(0.0)
Round whitefish	0.04	(0.04)	0.2	(0.1)	0.09	(0.06)	0.08	(0.08)
Sand shiner	0.04	(0.04)	0.09	(0.06)	0.0	(0.0)	0.08	(0.08)
Lake chub	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Northern pike	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Bowfin	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Longnose gar	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Channel catfish	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Bloater	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Smallmouth bass	0.04	(0.04)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Totals	25.36	(9.1)	29.49	(13.5)	12.09	(4.0)	7.0	(2.9)
Number of samples	24		22		22		13	

Table 5. Gill net catch per effort (CPE) and standard error (SE) at sunrise, midday, sunset, and midnight during April - November, 1976.

	Sunrise		Midday		Sunset		Midnight	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	23.2	(7.0)	28.8	(14.6)	26.2	(9.4)	17.0	(4.8)
Alewife	11.8	(4.6)	6.7	(5.9)	3.5	(1.6)	6.0	(2.2)
Rainbow trout	1.6	(0.7)	0.8	(0.3)	1.4	(0.4)	2.3	(0.7)
Lake trout	4.0	(1.5)	0.3	(0.2)	3.3	(1.1)	3.6	(1.2)
White sucker	3.0	(0.9)	0.3	(0.1)	3.4	(1.0)	3.0	(5.2)
Redhorse	0.7	(0.3)	0.04	(0.04)	1.2	(0.4)	0.5	(0.2)
Brown trout	1.1	(0.4)	1.6	(0.7)	1.6	(0.5)	1.7	(0.6)
Rainbow smelt	1.0	(0.5)	0.2	(0.2)	2.3	(1.0)	2.7	(1.2)
Longnose sucker	2.0	(0.7)	0.1	(0.08)	0.4	(0.2)	1.1	(0.4)
Gizzard shad	0.8	(0.4)	0.2	(0.1)	2.3	(0.8)	1.4	(0.4)
Yellow perch	2.1	(1.4)	1.0	(0.5)	1.5	(0.7)	0.6	(0.2)
Longnose dace	1.0	(0.9)	0.0	(0.0)	2.0	(0.7)	0.7	(0.3)
Coho salmon	0.6	(0.2)	0.4	(0.2)	1.5	(0.5)	0.5	(0.2)
Carp	0.3	(0.03)	0.0	(0.0)	0.2	(0.1)	0.7	(0.3)
Chinook salmon	0.6	(0.3)	0.4	(0.2)	0.7	(0.2)	0.9	(0.3)
Trout-perch	0.1	(0.07)	0.04	(0.04)	0.7	(0.3)	0.9	(0.4)
Round whitefish	0.1	(0.1)	0.0	(0.0)	0.03	(0.03)	0.0	(0.0)
Lake chub	0.0	(0.0)	0.0	(0.0)	0.1	(0.1)	0.07	(0.07)
Northern pike	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.07	(0.05)
Pumpkinseed	0.0	(0.0)	0.04	(0.04)	0.03	(0.03)	0.0	(0.0)
Largemouth bass	0.04	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Black crappie	0.0	(0.0)	0.0	(0.0)	0.03	(0.03)	0.0	(0.0)
Totals	54.04	(20.0)	40.92	(23.2)	52.39	(19.09)	43.74	(18.4)

Table 6. Gill net catch per effort (CPE) and standard error (SE) at sunrise, midday, sunset, and midnight during April - November, 1977.

	Sunrise		Midday		Sunset		Midnight	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	23.5	(7.6)	10.9	(5.4)	21.9	(6.1)	11.2	(2.7)
Alewife	1.9	(1.0)	0.1	(0.1)	4.0	(1.9)	4.3	(1.2)
Rainbow trout	1.0	(0.3)	1.0	(0.3)	2.3	(0.5)	2.3	(0.4)
Lake trout	1.9	(0.6)	0.0	(0.0)	2.3	(0.8)	1.7	(0.6)
White sucker	2.0	(0.7)	0.1	(0.1)	1.9	(0.5)	1.4	(0.3)
Redhorse	0.9	(0.2)	0.2	(0.1)	1.2	(0.3)	1.3	(0.3)
Brown trout	0.5	(0.1)	0.2	(0.1)	1.2	(0.4)	0.8	(0.2)
Rainbow smelt	1.1	(0.8)	0.1	(0.1)	0.3	(0.1)	1.0	(0.6)
Longnose sucker	0.9	(0.3)	0.03	(0.03)	0.5	(0.2)	0.8	(0.3)
Gizzard shad	0.4	(0.2)	0.1	(0.1)	0.2	(0.1)	1.2	(0.4)
Yellow perch	0.3	(0.1)	0.1	(0.07)	1.2	(0.7)	0.2	(0.07)
Longnose dace	0.4	(0.2)	0.2	(0.2)	0.4	(0.2)	0.4	(0.2)
Coho salmon	0.3	(0.1)	0.4	(0.2)	0.4	(0.1)	0.3	(0.08)
Carp	0.2	(0.1)	0.03	(0.03)	0.2	(0.1)	0.6	(0.2)
Chinook salmon	0.4	(0.1)	0.1	(0.05)	0.4	(0.1)	0.3	(0.1)
Trout-perch	0.1	(0.04)	0.0	(0.0)	0.3	(0.1)	0.4	(0.1)
Round whitefish	0.1	(0.04)	0.0	(0.0)	0.04	(0.03)	0.1	(0.05)
Lake chub	0.02	(0.02)	0.0	(0.0)	0.02	(0.02)	0.04	(0.03)
Northern pike	0.02	(0.02)	0.0	(0.0)	0.0	(0.0)	0.04	(0.03)
Bowfin	0.02	(0.02)	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)
Longnose gar	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)
Channel catfish	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)	0.0	(0.0)
Bloater	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)	0.0	(0.0)
Smallmouth bass	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)
Totals	35.96	(12.6)	13.56	(6.9)	38.82	(12.9)	28.48	(8.0)
Number of samples	42		33		46		56	

Table 7. Gill net catch per effort (CPE) and standard error (SE) by season during 1976 at stations 1 and 8.

	Spring				Summer				Fall			
	1		8		1		8		1		8	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	20.2	(6.4)	47.4	(14.7)	4.6	(2.0)	36.8	(13.1)	2.1	(1.1)	8.7	(4.3)
Alewife	4.1	(2.3)	10.6	(3.2)	0.2	(0.1)	27.1	(14.2)	0.3	(0.3)	0.6	(0.2)
Rainbow trout	2.8	(0.9)	1.3	(0.3)	0.4	(0.2)	0.08	(0.08)	1.9	(0.7)	1.1	(0.4)
Lake trout	0.6	(0.2)	1.0	(0.5)	2.3	(1.3)	2.8	(1.3)	4.9	(1.5)	9.8	(3.2)
White sucker	0.9	(0.3)	4.3	(1.2)	1.5	(0.6)	5.8	(2.1)	1.1	(0.4)	1.4	(0.5)
Redhorse	0.07	(0.05)	0.4[1]	(0.1)	1.3	(0.7)	2.4[1]	(0.9)	0.2	(0.1)	0.7[1]	(0.4)
Brown trout	1.0	(0.3)	2.7	(0.7)	0.5	(0.2)	2.3	(1.3)	0.7	(0.3)	0.9	(0.3)
Rainbow smelt	2.0	(1.1)	2.3	(0.8)	0.09	(0.09)	0.8	(0.5)	0.07	(0.07)	2.4[1]	(1.3)
Longnose sucker	0.1	(0.06)	1.8	(0.6)	0.5	(0.3)	2.4	(1.1)	0.0	(0.0)	0.6	(0.2)
Gizzard shad	0.6	(0.2)	1.5[1]	(0.6)	0.8	(0.5)	3.3[1]	(1.4)	0.06	(0.06)	1.5[1]	(0.6)
Yellow perch	0.3	(0.1)	2.0[1]	(0.9)	1.0	(0.5)	5.6[1]	(2.9)	0.0	(0.0)	0.3[1]	(0.1)
Longnose dace	1.4	(0.7)	1.3	(0.8)	1.4[1]	(0.4)	0.08	(0.08)	0.5	(0.3)	0.1	(0.1)
Coho salmon	0.1	(0.08)	0.2	(0.1)	0.3	(0.1)	0.3	(0.2)	2.0	(0.4)	2.7	(0.9)
Carp	0.2	(0.07)	1.2	(0.2)	0.3	(0.2)	0.8	(0.4)	0.0	(0.0)	0.0	(0.0)
Chinook salmon	0.6	(0.3)	0.8	(0.3)	0.5	(0.4)	0.3	(0.2)	0.9	(0.4)	0.6	(0.2)
Totals	34.97	(13.1)	78.8	(25.0)	15.69	(7.6)	90.86	(39.76)	14.73	(5.63)	31.4	(12.7)
Number of samples	30		30		11		12		15		14	

1. Indicates significantly greater CPE than other station.

Table 8. Gill net catch per effort (CPE) and standard error (SE) by season during 1977 at stations 1, 5, and 8 (control).

	Spring					
Stations	1		5		8	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	21.2	(5.9)	15.5	(6.4)	5.1	(2.4)
Alewife	2.1	(1.2)	4.1[1]	(3.1)	5.2[1]	(1.7)
Rainbow trout	3.3	(1.0)	1.5	(0.4)	2.0	(0.5)
Lake trout	0.3	(0.2)	0.4	(0.2)	0.7	(0.3)
White sucker	0.6	(0.2)	1.2	(0.4)	3.6[1]	(1.0)
Redhorse	0.2	(0.1)	0.7	(0.3)	1.4[1]	(1.4)
Brown trout	0.2	(0.1)	0.4	(0.2)	2.0[1]	(0.7)
Rainbow smelt	0.3	(0.2)	0.3	(0.2)	0.4	(0.3)
Longnose sucker	0.2	(0.1)	0.9	(0.4)	2.2	(0.6)
Gizzard shad	0.1	(0.08)	0.1	(0.08)	0.2	(0.09)
Yellow perch	0.2	(0.1)	0.07	(0.05)	1.3	(1.2)
Longnose dace	0.3	(0.2)	0.04	(0.04)	0.8	(0.4)
Coho salmon	0.04	(0.04)	0.08	(0.05)	0.07	(0.05)
Carp	0.4	(0.2)	0.7	(0.2)	0.8	(0.3)
Chinook salmon	0.1	(0.06)	0.5	(0.3)	0.4	(0.2)
Totals	29.54	(9.7)	26.49	(12.3)	26.17	(11.1)
Number of samples	26		26		27	

1. Indicates significantly greater CPE than other stations.

Table 8. (cont'd.).

	Summer					
Station	1		5		8	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	5.1	(2.5)	11.5	(3.2)	16.2	(6.4)
Alewife	0.9	(0.3)	7.6[1]	(4.6)	3.6[1]	(1.2)
Rainbow trout	0.4	(0.2)	0.4	(0.2)	0.1	(0.1)
Lake trout	0.7	(0.5)	0.0	(0.0)	2.5	(1.7)
White sucker	0.4	(0.2)	1.8[1]	(1.5)	1.3[1]	(0.6)
Redhorse	0.3	(0.1)	1.1	(0.5)	2.6[1]	(1.0)
Brown trout	0.3	(0.2)	0.6	(0.2)	0.4	(0.2)
Rainbow smelt	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Longnose sucker	0.0	(0.0)	0.2	(0.2)	0.8	(0.5)
Gizzard shad	0.9	(0.5)	0.8	(0.4)	3.0[1]	(1.6)
Yellow perch	0.6	(0.3)	1.2	(0.9)	0.4	(0.2)
Longnose dace	0.9	(0.4)	0.5	(0.3)	0.1	(0.1)
Coho salmon	0.0	(0.0)	0.2	(0.1)	0.1	(0.1)
Carp	0.0	(0.0)	0.0	(0.0)	0.4	(0.2)
Chinook salmon	0.1	(0.06)	0.5	(0.3)	0.4	(0.2)
Totals	10.4	(5.3)	26.4	(12.4)	31.9	(14.1)
Number of samples	14		13		14	

1. Indicates significantly greater CPE than other stations

Table 8. (cont'd.).

	Fall					
Station	1		5		8	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)
Spottail shiner	1.2	(0.6)	1.4	(0.5)	11.2	(7.0)
Alewife	0.3	(0.2)	0.4	(0.2)	1.5[1]	(0.9)
Rainbow trout	2.0	(0.5)	1.1	(0.3)	2.7	(0.6)
Lake trout	2.1	(0.7)	3.9	(1.7)	4.6	(1.6)
White sucker	0.6	(0.3)	0.4	(0.2)	1.9[1]	(0.7)
Redhorse	0.4	(0.3)	0.4	(0.2)	2.0[1]	(0.7)
Brown trout	0.9	(0.2)	0.7	(0.3)	0.6	(0.2)
Rainbow smelt	0.4	(0.2)	0.4	(0.2)	4.4[1]	(2.4)
Longnose sucker	0.05	(0.05)	0.1	(0.09)	0.0	(0.0)
Gizzard shad	0.09	(0.09)	0.1	(0.09)	0.6[1]	(0.3)
Yellow perch	0.05	(0.05)	0.3	(0.2)	0.4	(0.2)
Longnose dace	0.5	(0.3)	0.06	(0.06)	0.05	(0.05)
Coho salmon	1.3	(0.3)	0.7	(0.2)	0.8	(0.2)
Carp	0.05	(0.05)	0.0	(0.0)	0.1	(0.07)
Chinook salmon	0.4	(0.2)	0.3	(0.1)	0.5	(0.2)
Totals	10.34	(4.0)	10.26	(4.3)	31.35	(15.1)
Number of samples	22		16		19	

1. Indicates significantly greater CPE than other stations.

Spottail Shiner

Spottail shiners were the most frequently caught fish species in the shoreline zone. They were most abundant in late spring with peak CPE occurring during June, 1976 and 1977 (Tables 3 and 4). This monthly pattern of abundance was similar to the pattern of monthly abundance of spawning spottail shiners (Appendix A, Tables 1 and 2). Thus, the seasonal pattern of gill net CPE reflects a shoreward spawning migration. A few individuals spawning in August and September indicated an extended spawning period.

ANOVA across season, time of day, and sample site indicated no significant differences in diel CPE (Table 5 and 6); however, significant differences in monthly CPE (the pattern noted above) and among sampling sites (Tables 7 and 8) were noted. During 1976 and 1977, CPE was significantly greater at the control site than near the LPSPP.

Spottail shiners were collected exclusively in the 25-mm mesh of the net. Since no smaller mesh was used, the age-length analysis (Tables 9 and 10) is truncated at the low end (age I, 90 mm). Largest spottail shiners were age IV and 149 mm total length. During 1976, most spottail shiners were 120-129 mm while in 1977, the majority were 110-119 mm.

Potential relationships between changes in CPE and physical parameters such as water temperature, barometric pressure, wave height, and turbidity were addressed with a partial correlation analysis (Figures 3 and 4). This analysis can detect concurrent patterns of variation between the dependent variable (CPE and one of the independent variables while the others are held constant. A significant positive or negative correlation does not by itself indicate a cause and effect relationship

Figure 3. Daily variation in gill net collections of spottail shiner and alewife in shoreline waters with respect to variations in water temperature, barometric pressure, wave height, and turbidity during June and July, 1976.

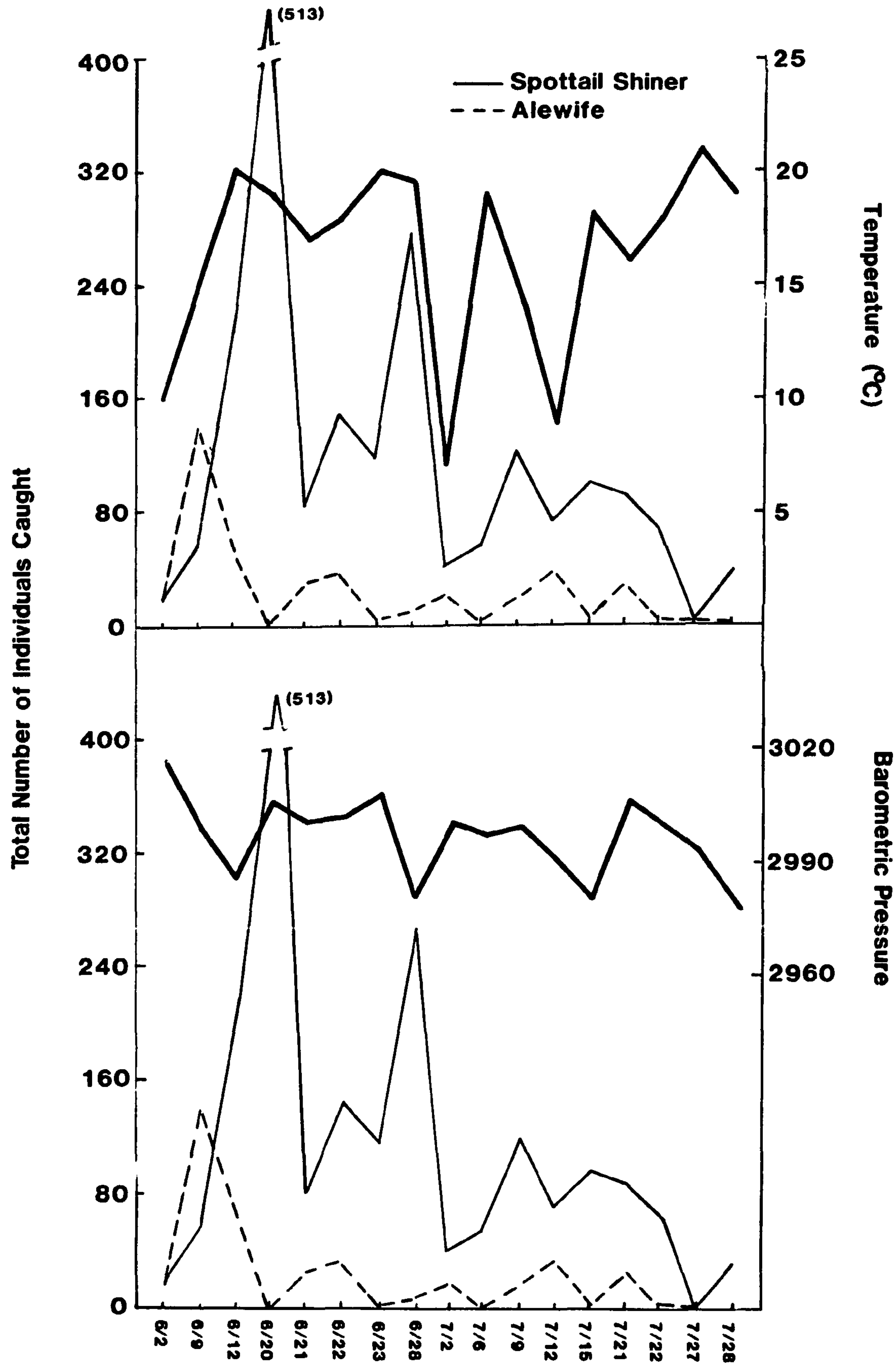
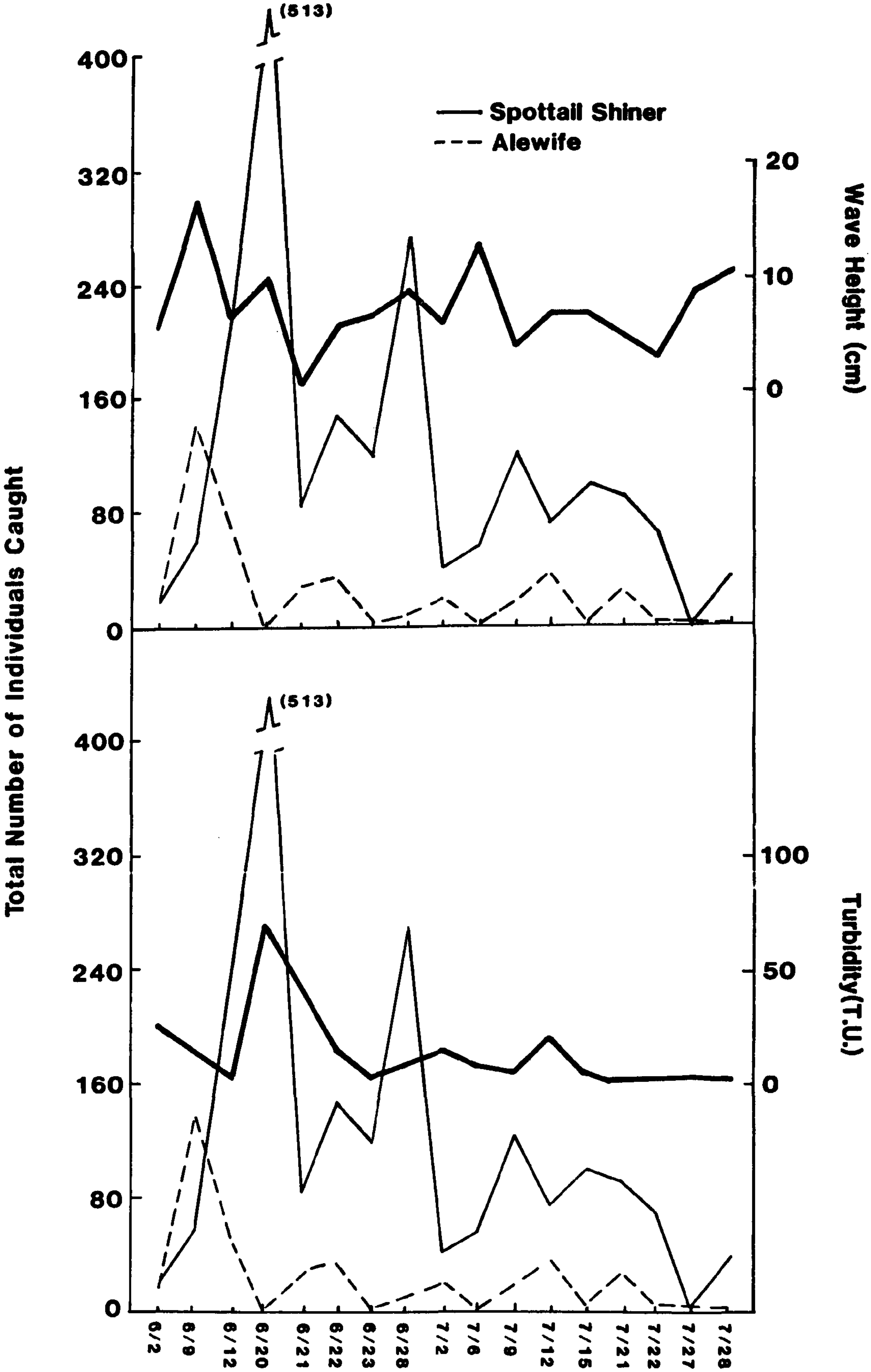
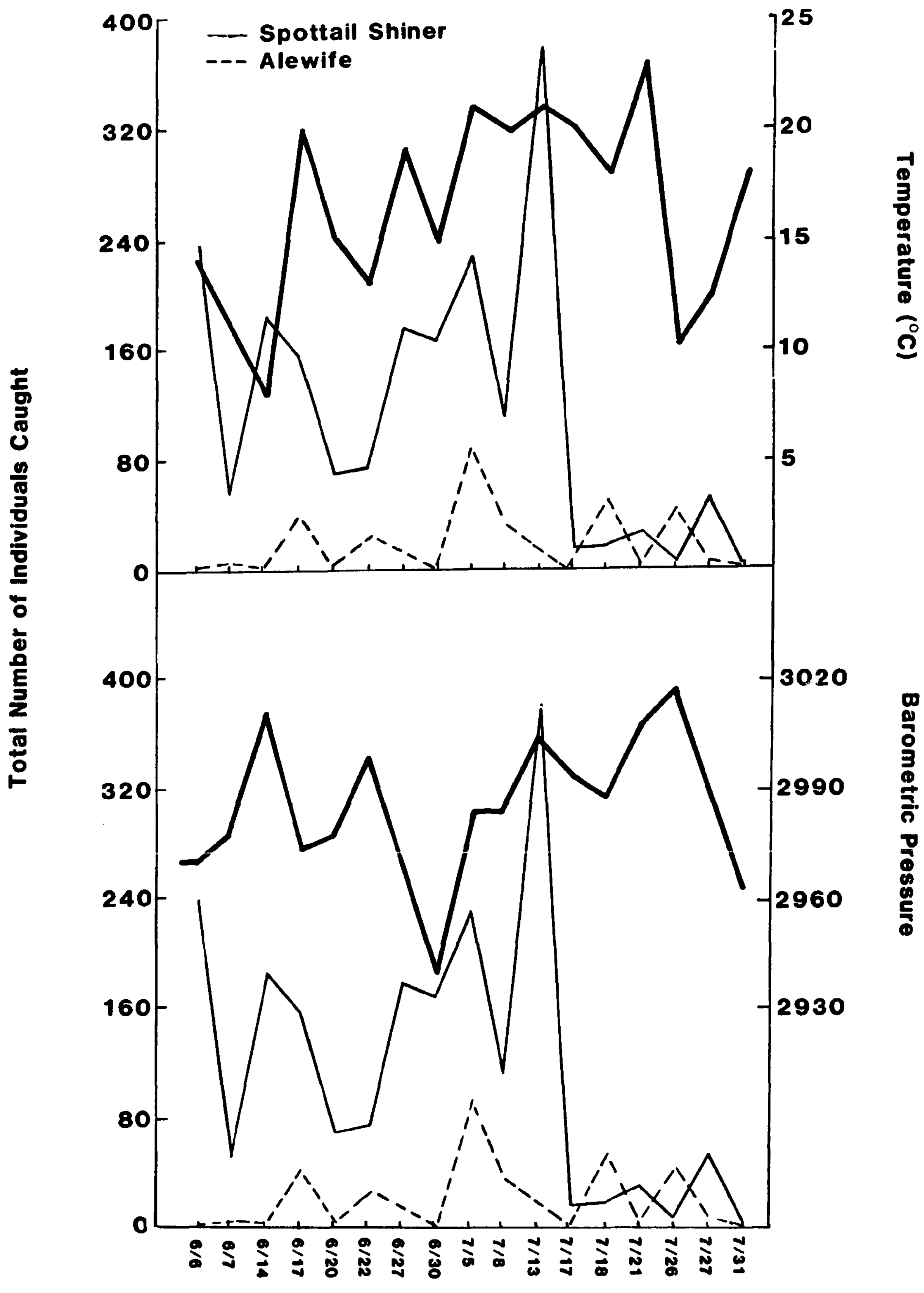

(513)
Spottail Shiner
Alewife
Total Number of Individuals Caught
400
320
240
160
80
0
25
20
15
10
5
Temperature (°C)
(513)
3020
2990
2960
Barometric Pressure
6/2
6/9
6/12
6/20
6/21
6/22
6/23
6/28
7/2
7/6
7/9
7/12
7/15
7/21
7/22
7/27
7/28

Figure 3. (cont'd.).



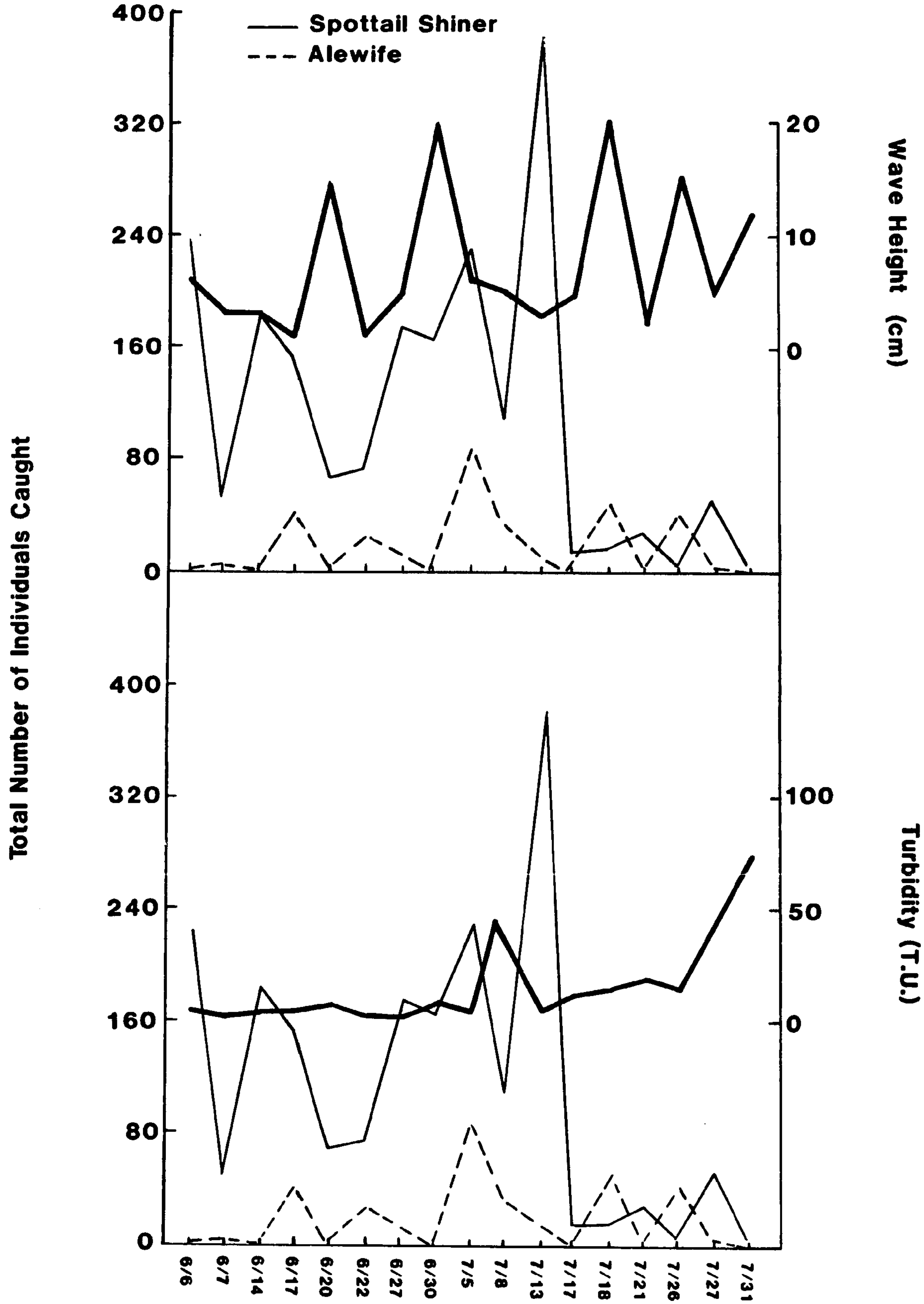
(513)
Spottail Shiner
Alewife
Total Number of Individuals Caught
Wave Height (cm)
Turbidity(T.U.)
400
320
240
160
80
0
20
10
0
100
50
6/2
6/9
6/12
6/20
6/21
6/22
6/23
6/28
7/2
7/6
7/9
7/12
7/15
7/21
7/22
7/27
7/28

Figure 4. Daily variation in gill net collections of spottail shiner and alewife in shoreline waters with respect to variations in water temperature, barometric pressure, wave height, and turbidity during June and July, 1977.



Spottail Shiner
Alewife
Total Number of Individuals Caught
Temperature (°C)
Barometric Pressure
400
320
240
160
80
0
25
20
15
10
5
3020
2990
2960
2930
6/6
6/7
6/14
6/17
6/20
6/22
6/27
6/30
7/5
7/8
7/13
7/17
7/18
7/21
7/26
7/27
7/31

Figure 4. (cont'd.).



Spottail Shiner
Alewife
Total Number of Individuals Caught
Wave Height (cm)
Turbidity (T.U.)
400
320
240
160
80
0
20
10
100
50
6/6
6/7
6/14
6/17
6/20
6/22
6/27
6/30
7/5
7/8
7/13
7/17
7/18
7/21
7/26
7/27
7/31

Table 9. Length-age frequencies of spottail shiner captured in gill nets during April - November, 1976.

Total length (mm)	I	II	III	IV	Total
90 - 99		11	1		12
100 - 109		155	36		191
110 - 119		201	252	1	454
120 - 129			138	35	173
130 - 139			7	9	16
Totals		367	434	45	846
Percent		43.4	51.3	5.3	

Table 10. Length-age frequencies of spottail shiner captured in gill nets during April - November, 1977.

Total length (mm)	I	II	III	IV	Total
90 - 99	4	10			14
100 - 109	5	239	18		262
110 - 119		392	234		626
120 - 129		2	172	8	182
130 - 139			13	5	18
Totals	9	643	437	13	1102
Percent	0.8	58.3	39.7	1.2	

however, it does indicate which physical parameters are associated with changes in CPE. Spottail shiner CPE had a significant positive correlation to turbidity in 1976 and 1977 ($\alpha = 0.05$, $r = 0.67$ and 0.55, respectively). This may indicate spottail shiners detected the nets more readily in clear water and avoided them or may have been attracted to the shoreline waters when wave action churned up benthic material.

A positive, nearly significant relationship between temperature and catch ($r = 0.46$) was noted in 1976. Shoreline water temperature occasionally cooled rapidly when strong east winds pushed warm surface waters away from shore and cool hypolimnetic waters upwelled. CPE during upwellings dropped substantially, indicating spottail shiners may move offshore with warmer water masses. A particularly striking example of this phenomenon was observed on July 2, 1976 (Figure 3) when shoreline water temperature was 7^{o}C and spottail shiner total catch was 100 individuals while 300 individuals were caught on June 28 when the water temperature was 20^{o}C. Temperature and catch were again positively correlated in 1977 but not as strongly as in 1976 ($r = 0.12$)(Figure 4). No major upwellings occurred in 1977 during peak spottail shiner abundance; thus, the relationship between spottail shiner CPE and temperature was not as striking as in 1976. A strong inverse relationship between wave height and catch was noted in 1977 but not seen in 1976. Collections in 1976 were not made when wave heights exceeded 12 cm. In 1977, however, several collections were made when wave heights were over 15 cm. The inverse relationship between catch and wave height indicate spottail shiners may move offshore when wave heights are over 12-15 cm or that the gear fished less efficiently.

Alewife

Alewives were the second most abundant species collected in shoreline gill nets. Catches were low in April and May; highest in June, July, and August; and decreased in September, October, and November (Tables 3 and 4). Increased alewife CPE in June and July appear to reflect a shoreward spawning migration since they coincide with peak spawning period (Appendix A, Tables 1 and 2). Diel collections (Tables 5 and 6) revealed low midday CPE except for one collection in August, 1976, when 161 alewives were collected in one net at midday. Most alewives were collected during sunset and midnight in 1977 but in 1976 sunrise collections were also high. An ANOVA of alewife gill net collections across season, time of day, and sample site revealed significant differences in all variables through 1976 and 1977.

In 1976 CPE was much higher at the control site (station 8) than near the LPSPP (Tables 7 and 8). In 1977, CPE at station 5 and station 8 (control site) was higher than station 1.

Alewives collected in shoreline gill nets ranged in age from I to V and from 80 to 225 mm in total length. Age I individuals (120-129 mm) were most abundant while age II alewives were nearly absent from shoreline collections (Tables 11 and 12). Second peaks were also noted for age III and IV individuals in the 140-189 mm and 200-209 mm length range.

To investigate causes for daily variation, alewife catches were compared to water temperature, barometric pressure, wave height, and turbidity (Figures 3 and 4). A partial correlation analysis between catch and these physical parameters indicated wave height ($r = 0.58$) was the only physical factor judged significant and then only in 1976.

Table 11. Length-age frequencies of alewife captured in gill nets during April - November, 1976.

Total length (mm)	I	II	III	IV	V	Total
80 - 89	1					1
90 - 99	2					2
100 - 109	40					40
110 - 119	39	4				43
120 - 129	15	8				23
130 - 139		4				4
140 - 149		3	1			4
150 - 159			7			7
160 - 169			9			9
170 - 179			13	7		20
180 - 189			6	23		29
190 - 199			8	16	3	27
200 - 219			1	9	11	21
220 - 229				4	4	8
230 - 239				3	4	7
240 - 249				1	2	3
250 - 259					1	1
Totals	97	19	45	63	25	249
Percent	39.0	7.6	18.1	25.3	10.0	

Table 12. Length-age frequencies of alewife captured in gill nets during April - November, 1977.

Total length (mm)	I	II	III	IV	V	Total
70 - 79	1					1
80 - 89	8					8
90 - 99	51	1				52
100 - 109	37	1				38
110 - 119	10	5				15
120 - 129	1	3	1			5
130 - 139		3	1			4
140 - 149		1	15			16
150 - 159			21			21
160 - 169			21	2		23
170 - 179			5	10		15
180 - 189				29		29
190 - 199				61	10	71
200 - 219				37	6	43
220 - 229				8		8
Totals	108	14	64	147	16	349
Percent	30.9	4.0	18.3	42.1	4.6	

Rainbow Trout

In shoreline waters near Ludington, rainbow trout were caught in gill nets throughout the sample season. Rainbow trout were the sixth most abundant species in gill net collections in 1976 and third in 1977. Over 70% of the rainbow trout caught in 1977 were ages III to V, and 450-649 mm in total length (Table 13). During 1976, 56% were in the same category (III-V) while 23.4% were age II (Table 14). CPE was highest in April, decreased somewhat in May, was very low during June-August, increased again in September and October and reached a second peak in November during 1977 (Table 4). A similar pattern was seen in 1976; however, the greatest CPE occurred in November rather than April (Table 3).

Gonadal condition of rainbow trout caught in gill nets (Appendix A, Tables 1 and 2) during periods of peak CPE indicated that a high percentage of these fish were either spawning or about to spawn. Thus, the seasonal pattern seen in rainbow trout catch in the gill nets reflects their spawning migrations along the shoreline. No significant difference in gill net collections of rainbow trout was found among stations during 1976 and 1977 (Tables 7 and 8); however, catch near an outfall stream at station 1 was somewhat higher during spring 1976.

Rainbow trout captured in gill nets did not demonstrate strong diel trends. A slightly lower CPE did occur at sunrise and midday than sunset and midnight in 1976 (Table 5). In 1977 (Table 6) midday CPE was again lowest while midnight was highest.

Table 13. Length - age frequencies of rainbow trout captured in gill nets during April - November, 1976.

	Age							
Total length (mm)	I	II	III	IV	V	VI	VII	Total
200 - 249	5	2						7
250 - 299	4	9						13
300 - 349		7	1					8
350 - 399								
400 - 449			2	1				3
450 - 499			2	1				3
500 - 549			2	5				7
550 - 599			5	6	2			13
600 - 649				3	5			8
650 - 699				2	3	2		7
700 - 749					2	2		4
750 - 799					2			2
800 - 849							2	2
Totals	9	18	12	18	14	4	2	77
Percent	11.7	23.4	15.6	23.4	18.2	5.2	2.6	

Table 14. Length - age frequencies of rainbow trout captured in gill nets during April - November, 1977.

	Age								
Total length (mm)	I	II	III	IV	V	VI	VII	VIII	Total
150 - 199	3								3
200 - 249	5	6							11
250 - 299		3							3
300 - 349		4							4
350 - 399		3	5	1					9
400 - 449		4	12	2					18
450 - 499		3	5	2	1				11
500 - 549		2	41	8	3				54
550 - 599		2	36	9	18				65
600 - 649			5	12	28	2			47
650 - 699				5	8	5			18
700 - 749					2	15	2		19
750 - 799						9			9
800 - 849							2	1	3
Totals	8	27	104	39	60	31	4	1	274
Percent	2.9	9.9	38.0	14.2	21.9	11.3	1.5	0.4	

Lake Trout

Annual CPE of lake trout in shoreline gill nets at Ludington ranked third in 1976 and fourth in 1977 (Table 2). Lake trout catch was very low in April through July during 1976 and 1977. 1976 lake trout collections increased in August and reached peak abundances in September and October. During 1977, the increase was seen in September and October only (Tables 3 and 4). Lake trout moved into shoreline waters during the summer only when upwellings cooled water temperatures to near 10^{o}C. Water temperature during the early part of their spawning migration in September ranged from 18.5 to 8.5^{o}C in 1976 and 19.0 to 14.0^{o}C in 1977. But in October, during peak spawning activity, shoreline temperatures ranged from 16.0 to 6.5^{o}C in 1976 and 12.0 to 8.0^{o}C in 1977 (Appendix B, Tables 1 and 2).

The major diel trend noted for lake trout was their near absence in midday collections (Tables 5 and 6). CPE at sunrise, sunset, and midnight were nearly equal during both years. Station differences were not found in shoreline gill net collections of lake trout during spring, summer, or fall (Tables 7 and 8).

White Sucker

In shoreline waters near Ludington, white suckers (*Catostomus commersoni*) ranked fourth and fifth in CPE in gill nets during 1976 and 1977, respectively. Seasonal trends were not evident based on monthly gill net CPE (Tables 3 and 4) though summer CPE tended to be higher, especially in 1976. Diel analysis (Tables 5 and 6) revealed a notable decline in catch during midday collections. Gill net catches were significantly greater at the control station than the impact station (Tables 7 and 8) possibly indicating a preference for the slightly more heterogenous substrate at the control site or perhaps avoidance of LPSPP generated currents in the impact area.

The predominant size class in shoreline nets was 420-439 mm (Table 15). Sex ratios (Table 16) in the shoreline waters favored female white suckers to a small degree in 1976 and 1977. Monthly gonadal condition (Appendix A, Tables 1 and 2) indicated spawning activity occurred, possibly along the shoreline, in April during both years when water temperatures ranged from 2.0 to 9.0^{o}C. Both ripe and spent white suckers were collected during April but only green and spent fish were collected in May indicating termination of spawning.

Brown Trout

Brown trout ranked sixth in CPE in shoreline gill nets during 1976 and seventh in 1977. Monthly CPE during 1976 (Table 3) was highest in May when water temperatures ranged from 4.0 to 10.2^{o}C and lowest catches occurred during spawning in October and November, primarily because brown trout had entered rivers and tributaries to spawn. During 1977, CPE was lower and seasonal trends were not evident (Table 4).

Diel analysis of the gill net catch of brown trout revealed no pattern in 1976 (Table 5) but in 1977 (Table 6) CPE at sunset was high while midday CPE was low. Brown trout feeding activity generally reaches a peak at sunset (Scott and Crossman 1973) which may explain the peaks.

CPE was significantly greater at the control site than the impact

Table 15. Length frequency of white suckers captured in gill nets during April - November, 1976 and 1977.

	Number Captured	
Total length (mm)	1976	1977
180 - 199	4	1
200 - 219		16
220 - 239		15
240 - 259	2	6
260 - 279	5	9
280 - 299	8	10
300 - 319	11	20
320 - 339	10	12
340 - 359	11	7
360 - 379	11	7
380 - 399	8	10
400 - 419	6	20
420 - 439	17	33
440 - 459	7	32
460 - 479	9	22
480 - 499	7	16
500 - 519	4	9
520 - 539	1	3
Totals	117	248

Table 16. Sex ratio of each fish species captured in gill nets during April - November, 1976 and 1977.

	1976			1977		
Species	Male	Female	Unknown	Male	Female	Unknown
Spottail shiner	418	426	3	529	568	8
Alewife	68	81	103	59	186	118
Rainbow trout	65	60	48	144	132	33
Lake trout	61	51	207	65	31	183
White sucker	45	55	178	48	66	134
Redhorse	8	10	52	42	31	96
Brown trout	40	78	50	50	53	29
Rainbow smelt	68	66	2	60	38	1
Longnose sucker	12	14	75	22	33	49
Gizzard shad	48	59	27	24	28	38
Yellow perch	26	73	36	22	41	10
Longnose dace	6	86	2	5	58	2
Coho salmon	40	22	24	24	21	18
Carp	18	2	13	37	7	12
Chinook salmon	14	3	57	8	3	40
Trout-perch	22	29	0	12	27	0
Round whitefish	2	3	0	5	2	4
Lake chub	1	4	0	3	1	0
Northern pike	1	1	0	0	2	1
Pumpkinseed	1	1	0	0	0	0
Largemouth bass	1	0	0	0	0	0
Bowfin	0	0	0	2	0	0
Longnose gar	0	0	0	0	0	1
Channel catfish	0	0	0	1	0	0
Bloater	0	0	0	0	0	1
Smallmouth bass	0	0	0	0	0	1

area only during spring of 1977 (Tables 7 and 8).

Age-length frequency analysis of brown trout caught in shoreline gill nets in 1976 indicated age classes III and IV and length class 550-599 mm were predominant (Table 17). This is probably a result of high stocking rates in 1973 in Lake Michigan overall and local stocking in 1973 and 1974 (Brazo and Liston 1979). In 1977 (Table 18), length class 550-599 mm was again predominant, but age classes II and III occurred most frequently. Lengths ranged from 124-749 mm and ages from I to VII during 1976 and from 200-749 mm (ages II-VI) in 1977. During 1976, 15.1% of the fish collected were age I.

The sex ratio was nearly 1:2, males to females in 1976 and 1:1 in 1977 (Table 16). Approximately 20% of brown trout caught in shoreline gill nets were immature. During July and August, 1976, juveniles comprised the majority of brown trout captured. Ripe brown trout were caught in October and November, 1977; however, during 1976 all mature individuals collected were green during the fall (Appendix A, Tables 1 and 2).

Redhorse

During 1976 and 1977, 240 redhorse (<u>moxostoma spp</u>.) were collected in shoreline gill nets (Table 2). Shoreline CPE was 0.6 in 1976 and 0.9 in 1977. This compares to a CPE of 0.07 over a six year period, 1972-1977, at the 6-12 m depth (Brazo and Liston 1979). Thus, redhorse were most abundant in shoreline waters of the nearshore area. Monthly catch analyses (Table 3 and 4) indicate increased abundance during late summer and early fall when shoreline water temperatures ranged from 8.0 - 19.0^{o}C. Diel activity was greatest at sunset and midnight in 1977 and sunset and

Table 17. Length - age frequencies of brown trout captured in gill nets during April - November, 1976.

	Age							
Total length (mm)	I	II	III	IV	V	VI	VII	Total
100 - 149	1							1
150 - 199		1						1
200 - 249	1	4						5
250 - 299	8	3						11
300 - 349	1	1						2
350 - 399		1	3					4
400 - 449		1	2					3
450 - 499			6	4				10
500 - 549			4	5				9
550 - 599			4	9	1			14
600 - 649			1	2	2			5
650 - 699				2	1	2		5
700 - 749					1	1	1	3
Totals	11	11	20	22	5	3	1	73
Percent	15.1	15.1	27.4	30.1	6.8	4.1	1.4	

Table 18. Length - age frequencies of brown trout captured in gill nets during April - November, 1977.

Total length (mm)	Age I	II	III	IV	V	VI	Total
100 - 149							
150 - 199							
200 - 249		4					4
250 - 299		7					7
300 - 349		5	4				9
350 - 399		3	3				6
400 - 449		1	12	1			14
450 - 499		1	13	1			15
500 - 549			10	5			15
550 - 599			15	5	1	1	22
600 - 649				3	3		6
650 - 699					5		5
700 - 749						2	2
Totals		21	57	15	9	3	105
Percent		20.0	54.2	14.3	8.6	2.9	

sunrise in 1976 (Tables 5 and 6).

Significantly greater numbers of redhorse were collected at the control site than near the LPSPP during all seasons in both years, possibly indicating avoidance of increased currents near the plant (Tables 7 and 8).

Redhorse collected in gill nets along shore ranged from 222-755 mm in length (Table 19). The upper end of this range was 84 mm greater than the largest of either golden or shorthead redhorse reported by Trautman (1957) from Lake Erie. Sex ratios were nearly even during both years and nearly 88% of the redhorse examined were mature.

Rainbow Smelt

Monthly summaries of rainbow smelt gill net collections (Tables 3 and 4) indicated that adults were more abundant along the shoreline in April and May and during September and October. The spring CPE was much higher in 1976 and 1977. Since high monthly collections were mainly due to a single high catch, it is possible that the shoreward migration of rainbow smelt was missed in 1977. Rainbow smelt are spring spawners which accounts for high CPE in April and May. During summer, elevated shoreline water temperatures presented a barrier to rainbow smelt since their preferred temperature is about 7.2°C (Scott and Crossman 1973). In September and October, water temperature ranged from 8.0 - 19.0°C and rainbow smelt again utilized shoreline waters. Diel analysis of the gill net catch indicated lowest shoreline CPE of rainbow smelt occurred at midday and highest CPE was at midnight (Tables 5 and 6). Jude et al. (1975) also found a tendency for onshore

Table 19. Length frequency of redhorse captured in gill nets during April - November, 1976 and 1977.

	Number Captured	
Total length (mm)	1976	1977
220 - 239		3
240 - 259		1
260 - 279		0
280 - 299		3
300 - 319		5
320 - 339		11
340 - 359	1	3
260 - 379	1	7
380 - 399	3	14
400 - 419	0	17
420 - 439	1	19
440 - 459	2	29
460 - 479	4	17
480 - 499	1	12
500 - 519	1	5
520 - 539	0	2
540 - 559	0	0
560 - 579	0	0
580 - 599	1	0
600 - 619	0	1
620 - 639	1	
Totals	16	149

Table 20. Length - age frequencies of rainbow smelt captured in gill nets during April - November, 1976.

	Age				
Total length (mm)	I	II	III	IV	Total
110 - 119	1				1
120 - 129					
130 - 139	4	6			10
140 - 149	9	25	2		36
150 - 159		49	1		50
160 - 169		12	14		26
170 - 179		3	4	1	8
180 - 189			3		3
190 - 199					
200 - 219				1	1
Totals	14	95	24	2	135
Percent	10.4	70.4	17.8	1.5	

Table 21. Length - age frequencies of rainbow smelt captured in gill nets during April - November, 1977.

	Age					
Total length (mm)	I	II	III	IV	V	Total
100 - 109						
110 - 119	1					1
120 - 129	1					1
130 - 139	1	1				2
140 - 149	7	21				28
150 - 159		35	5			40
160 - 169		11	2			13
170 - 179		5	2			7
180 - 189			1			1
190 - 199						
200 - 219				1		1
220 - 229						
230 - 239						
240 - 249						
250 - 259					1	1
260 - 269				1		1
270 - 279					1	1
Totals	10	73	10	2	2	97
Percent	10.3	75.3	10.3	2.1	2.1	

movement of adult rainbow smelt at night. Rainbow smelt CPE differed significantly only in the fall (Tables 7 and 8) when CPE at the control station was greater than at impact stations.

Age-length frequencies of rainbow smelt in gill net collections (Tables 20 and 21) indicated that over 70% were age II and the dominant size class was 150-159 mm during 1976 and 1977. Ages ranged from I to V and lengths from 111-276 mm. Brazo and Liston (1979) reported similar dominant age-length classes for rainbow smelt in gill nets fished at 6 to 24-m depth during 1972 through 1977. The sex ratio during 1976 was nearly 1:1 in gill net catches; however, in 1977, males outnumbered females 2:1 (Table 16).

Longnose Dace

Longnose dace (Rhinichthys cataractae) were also collected in gill nets with peak CPE occurring during May through July in 1976 and in August during 1977 (Tables 3 and 4). Catch was greatest at sunrise and sunset (Tables 5 and 6) and was significantly less at the control area than the impact site during the summer of 1976 (Tables 7 and 8).

Nearly all longnose dace caught in gill nets were females, indicating greater activity by females. Monthly gonadal condition of longnose dace caught in gill nets and seines (Appendix A, Tables 1 and 2) indicated an extended spawning season from May through September. Investigations of longnose dace by Brazo et al. (1978) revealed extended spawning, however, only through July.

Longnose Sucker

Longnose suckers (Catostomus catostomus) were collected in low numbers during 1976 and 1977. Catch was lowest during September through November in both years and except for a peak in July, 1976, greatest numbers were caught during the spring (Tables 3 and 4). This is the reverse of patterns found by Koehler (1979) and Brazo and Liston (1979) at 6-12-m contours. This disparity was probably due to onshore movement of spawning adults in early spring and a preference for deeper and cooler waters (6-12 m) during the remainder of the year. Gonadal data (Appendix A, Tables 1 and 2) provided evidence for this since during April nearly all longnose suckers collected were mature and many were in spawning condition.

The greatest numbers of longnose suckers were collected during midnight and sunrise along the shoreline (Tables 5 and 6) and very few were captured during midday. Catch per unit effort was significantly greater at the control site than the impact area during spring and summer of both years (Tables 7 and 8).

The majority of longnose suckers caught in 1976 were length class 220-239 mm while in 1977, length class 380-399 mm dominated the sample (lengths ranged from 115-527 mm) for both years (Table 22).

Gizzard Shad

Shoreline collections of gizzard shad (Dorosoma cepedianum) were restricted to gill nets. A total of 134 gizzard shad was collected in 1976 and 93 in 1977 (Table 2). These fish ranged from age 0 to VI and 80-559 mm in length. Age III and IV and length class 300-459 mm

Table 22. Length frequency of longnose suckers captured in gill nets during April - November, 1976 and 1977.

	Number Captured	
Total length (mm)	1976	1977
100 - 119		1
120 - 139		1
140 - 159		
160 - 179		
180 - 199		
200 - 219	2	4
220 - 239	10	10
240 - 259	5	3
260 - 279	3	1
280 - 299	2	3
300 - 319	1	7
320 - 339	2	5
340 - 359	4	5
360 - 379	7	3
380 - 399	5	17
400 - 419	2	12
420 - 439		10
440 - 459	1	10
460 - 479	1	9
480 - 499	1	2
Totals	46	103

dominated samples (Tables 23 and 24) except for a pulse of YOY caught in August, 1977. The age III through VI gizzard shad in these collections tended to be larger than those reported by Bodola (1966) for Lake Erie. Gizzard shad were most abundant in July and August (Tables 3 and 4) along the shoreline which coincides with seasonal abundances at the 6-m depth contour reported by Brazo and Liston (1979). Greatest numbers were caught at sunset and midnight in 1976 and at midnight and sunrise in 1977 (Tables 5 and 6), indicating increased nocturnal activity. CPE at the control site was greater than at the impact area during both years and all seasons except spring, 1977 (Tables 7 and 8). This may indicate avoidance of the power plant and associated water currents.

Nearly equal numbers of males and females were collected and, based on gonadal conditions (Appendix A, Tables 1 and 2), spawning may have taken place along the shoreline in June of 1976 when two partially spent males, and six spent females were collected. Each year one ripe male specimen was captured in April.

Yellow Perch

Shoreline collections of yellow perch were sparse compared to those at the 6-24-m depths reported by Brazo and Liston (1979). Only 231 specimens were collected in gill nets and nine in seines during 1976 and 1977. Greatest numbers were taken in July (Tables 3 and 4) during both years. Greater numbers of yellow perch were collected at sunrise and sunset than midday and midnight (Tables 5 and 6) reflecting their crepuscular feeding activity (Scott and Crossman 1973). During 1976, CPE was significantly higher at the control area for all seasons while in 1977 no significant differences were found (Tables 7 and 8). Most of the yellow

Table 23. Length - age frequencies of gizzard shad captured in gill nets during April - November, 1976.

Total length (mm)	I	II	III	IV	V	VI	Total
				Age			
160 - 179	1						1
180 - 199	1						1
200 - 219	3	2					5
220 - 239	5	8					13
240 - 259	1	5					6
260 - 279		3					3
280 - 299							
300 - 319				1	2		3
320 - 339			5	2			7
340 - 359			7	2	1		10
360 - 379			12	6	1		19
380 - 399			11	10	3		24
400 - 419			4	9			13
420 - 439			2	11	2		15
440 - 459			1		1		2
460 - 479					2	2	4
480 - 499				2	1		3
500 - 519					1		1
520 - 539					1		1
540 - 559					1		1
Totals	11	18	42	43	16	2	132
Percent	8.3	13.6	31.8	32.6	12.1	1.5	

Table 24. Length - age frequencies of gizzard shad captured in gill nets during April - November, 1977.

	Age						
Total length (mm)	0	I	II	III	IV	V	Total
80 - 99	29						29
100 - 119	2						2
200 - 219			2				2
220 - 239			1				1
240 - 259							
260 - 279							
280 - 299							
300 - 319				1			1
320 - 339							
340 - 359				9	2		11
360 - 379				1	3		4
380 - 399					3		3
400 - 419				5	13		18
420 - 439					7	1	8
440 - 459					2	4	6
460 - 479						3	3
Totals	31		3	16	30	8	88
Percent	35.2		3.4	18.2	34.1	9.1	

perch taken in July during 1976 were spent (Appendix A, Table 1), indicating spawning was over. In 1977, however, most yellow perch were partially spent in July, indicating spawning was still in progress (Appendix A, Table 2). Female yellow perch were over twice as abundant as males in these samples (Table 16).

Coho Salmon

Only 149 coho salmon were collected in gill nets during 1976 and 1977 along the shoreline. Most were taken during fall (Tables 3 and 4) and little difference in diel collections was noted (Tables 9 and 10). CPE was nearly equal at all stations for all seasons (Tables 7 and 8). Sex ratio was 2:1 males to females in 1976 and 1:1 in 1977. Ripe coho salmon were first noted in September during 1976 (Appendix A, Table 1) and October in 1977 (Appendix A, Table 2). The predominant age-length class along shore was age III and length class 600-649 mm in 1976 and age II and length class 550-599 mm in 1977 (Tables 25 and 26). Ages ranged from I to IV and lengths from 129-755 mm.

Chinook Salmon

Shoreline gill net collections of chinook salmon were dominated by age I, 75% and 69% in 1976 and 1977, respectively (Tables 27 and 28). Yearlings were mainly collected in June and July in gill nets and adults in September. No diel pattern was noted (Tables 5 and 6) and similar numbers were collected at each station (Tables 7 and 8). Most mature adults were males during both years though few were in spawning condition (Appendix A, Tables 1 and 2). Chinook salmon

Table 25. Length - age frequencies of coho salmon captured in gill nets during April - November, 1976.

	Age				
Total length (mm)	I	II	III	IV	Total
200 - 249	1				1
250 - 299	1	1			2
300 - 349	11	3			14
350 - 399	7	1			8
400 - 449		2			2
450 - 499		5	4		9
500 - 549		4	3		7
550 - 599		3	2		5
600 - 649		2	10		12
650 - 699			8	1	9
700 - 749			2		2
Totals	20	21	29	1	71
Percent	27.1	30.0	41.4	1.4	

Table 26. Length - age frequencies of coho salmon captured in gill nets during April - November, 1977.

Total length (mm)	Age I	II	III	IV	Total
100 - 149	1				1
150 - 199	1				1
200 - 249	1				1
250 - 299	2				2
300 - 349	2	3			5
350 - 399	4	2			6
400 - 449	2	3			5
450 - 499		2			2
500 - 549		4			4
550 - 599		9			9
600 - 649		5	7	1	13
650 - 699		2	3		5
700 - 749					
750 - 799			1		1
Totals	13	30	11	1	55
Percents	23.6	54.5	20.0	1.8	

Table 27. Length - age frequencies of chinook salmon captured in gill nets during April - November, 1976.

	Age				
Total length (mm)	I	II	III	IV	Total
100 - 149	47				47
150 - 199	1				1
200 - 249	1				1
250 - 299					
300 - 349		2			2
350 - 399					
400 - 449					
450 - 499		4			4
500 - 549		3			3
550 - 599					
600 - 649					
650 - 699			1		1
700 - 749			1		1
750 - 799			1		1
800 - 849				2	2
850 - 899					
900 - 949					
950 - 999				1	1
1000 -1049				1	1
1050 -1099					
1100 -1149					
Totals	49	9	3	4	65
Percent	75.4	13.8	4.6	6.1	

Table 28. Length - age frequencies of chinook salmon captured in gill nets during April - November, 1977.

	Age				
Total length (mm)	I	II	III	IV	Total
80 - 99	1				1
100 - 149	26				26
150 - 199					
200 - 249					
250 - 299					
300 - 349					
350 - 399					
400 - 449					
450 - 499					
500 - 549		5			5
550 - 599					
600 - 649					
650 - 699		1			1
700 - 749					
750 - 799			3		3
800 - 849				1	1
850 - 899			1	1	2
Totals	27	6	4	2	39
Percent	69.2	15.3	10.3	5.1	

collected in gill nets ranged up to age IV and 1,030 mm in length.

Seine Collections

During April through October, 1976 and 1977, 42 seine hauls were made at each station. Alewives and spottail shiners, mainly YOY, were the most abundant species collected (Table 29). Total catch per effort (CPE) was much higher in August and September than other months during both years (Tables 30 and 31). The high numbers in August and September mainly represent recruitment of YOY alewives and spottail shiners to seine collections. Diel collections (Tables 32 and 33) fluctuated greatly but generally catches were lower during darkness. CPE was greatest at the control site in 1976 but in 1977 larger catches occurred near the LPSPP (Tables 34 and 35).

The following comprises brief descriptions of seasonal and diel patterns, station differences, and biological characteristics for commonly occurring species.

Alewife

The alewife catch in shoreline seines was comprised mainly of YOY in 1976 and 1977. In 1976, adults dominated collections during June and July while exclusively YOY were collected during August and September (Table 30). A similar pattern was seen in 1977, however, some YOY were recruited to the seines as early as July (Table 31). The high number of YOY alewife collected in October, 1977, indicated they stay near shore even after the lake cools down in the fall. YOY alewives were most abundant in shoreline waters early in the morning and late in

Table 29. Total number (TN), catch per effort (CPE), standard error (SE), and total weight (TW) of each fish species captured in beach seines during April - November, 1976 and 1977.

	1976				1977			
Species	TN	CPE	(SE)	TW(g)	TN	CPE	(SE)	TW(g)
Alewife	4654	64.6	(21.6)	6286	60306	478.6	(150.4)	43209
Spottail shiner	398	5.5	(2.2)	3339	9852	74.6	(35.1)	3821
Rainbow smelt	358	5.0	(2.2)	1025	376	2.8	(1.9)	1771
Longnose dace	66	0.9	(0.5)	234	224	1.7	(0.5)	1320
Chinook salmon	83	1.1	(0.5)	615	87	0.7	(0.4)	1202
Steelhead	14	0.2	(0.2)	3325	16	0.1	(0.04)	6128
Emerald shiner	4	0.06	(0.04)	30	9	0.07	(0.03)	114
Trout-perch	3	0.04	(0.03)	33	24	0.2	(0.08)	244
Yellow perch	2	0.03	(0.02)	13	7	0.05	(0.03)	95
Brown trout	4	0.06	(0.04)	222	0	0.0	(0.0)	0
Johnny darter	1	0.01	(0.01)	1	65	0.5	(0.2)	70
9-spine stickleback	1	0.01	(0.01)	3	3	0.02	(0.01)	6
Longnose sucker	0	0.0	(0.0)	0	1	0.08	(0.07)	951
Lake trout	1	0.01	(0.01)	11	0	0.0	(0.0)	0
Mottled sculpin	3	0.04	(0.02)	7	7	0.05	(0.02)	55
Lake whitefish	0	0.0	(0.0)	0	246	1.9	(1.3)	149
Fathead minnow	0	0.0	(0.0)	0	5	0.04	(0.02)	7
White sucker	1	0.01	(0.01)	5	3	0.02	(0.01)	131
Sand shiner	0	0.0	(0.0)	0	4	0.03	(0.03)	5
Golden shiner	0	0.0	(0.0)	0	1	0.08	(0.07)	1
Coho salmon	0	0.0	(0.0)	0	5	0.04	(0.03)	194
Totals	5603	77.57	(27.4)	15131	71241	561.58	(190.2)	59473

Table 30. Monthly catch per effort (CPE) and standard error (SE) for beach seines from April - September, 1976.

	April		May		June		July		August		September	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Alewife	0.0	(0.0)	0.4	(0.3)	2.3	(1.3)	2.4	(1.2)	139.4[1]	(86.0)	266.5[1]	(81.5)
Spottail shiner	0.08	(0.08)	1.8	(1.4)	23.3	(11.3)	1.6	(1.1)	0.8	(0.6)	5.4	(3.7)
Rainbow smelt	2.0	(1.2)	3.2	(1.7)	0.0	(0.0)	0.7	(0.1)	7.0	(4.6)	2.4	(1.1)
Longnose dace	0.0	(0.0)	0.5	(0.3)	3.4	(2.7)	0.9	(0.4)	0.08	(0.08)	0.5	(0.2)
Chinook salmon	0.0	(0.0)	0.0	(0.0)	6.0	(2.3)	0.8	(0.4)	0.0	(0.0)	0.0	(0.0)
Rainbow trout	0.2	(0.1)	0.6	(0.4)	0.3	(0.3)	0.08	(0.08)	0.0	(0.0)	0.08	(0.08)
Emerald shiner	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.3	(0.3)
Trout-perch	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.2	(0.2)
Yellow perch	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.2	(0.1)	0.0	(0.0)	0.0	(0.0)
Brown trout	0.0	(0.0)	0.2	(0.1)	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Johnny darter	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)
9-spine stickleback	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mottled sculpin	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.2	(0.1)
White sucker	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)
Totals	2.28	(1.4)	6.86	(4.4)	35.66	(18.3)	6.76	(3.5)	147.28	(91.3)	275.66	(87.3)

1. All young-of-the-year.

Table 31. Monthly catch per effort (CPE) and standard error (SE) for beach seines from April - October, 1977.

	April		May		June		July	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Alewife	0.04	(0.04)	0.0	(0.0)	3.6	(1.8)	45.8	(21.8)
Spottail shiner	0.3	(0.1)	0.06	(0.06)	5.3	(3.6)	7.1	(3.5)
Rainbow smelt	1.9	(1.4)	2.4	(1.2)	14.2	(13.8)	0.3	(0.2)
Longnose dace	0.5	(0.5)	3.6	(2.9)	3.2	(2.3)	1.1	(0.5)
Chinook salmon	0.0	(0.0)	0.4	(0.3)	4.2	(2.5)	0.2	(0.1)
Rainbow trout	0.08	(0.06)	0.1	(0.08)	0.3	(0.2)	0.1	(0.08)
Emerald shiner	0.04	(0.04)	0.0	(0.0)	0.0	(0.0)	0.3	(0.2)
Trout-perch	0.04	(0.04)	0.1	(0.08)	0.1	(0.1)	0.4	(0.3)
Yellow perch	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.2	(0.2)
Johnny darter	0.0	(0.0)	0.0	(0.0)	0.2	(0.1)	0.4	(0.4)
9-spine stickleback	0.0	(0.0)	0.06	(0.06)	0.06	(0.06)	0.0	(0.0)
Longnose sucker	0.04	(0.04)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mottled sculpin	0.0	(0.0)	0.1	(0.08)	0.0	(0.0)	0.0	(0.0)
Lake whitefish	0.0	(0.0)	0.0	(0.0)	11.8	(9.5)	1.8	(1.7)
Fathead minnow	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.06	(0.06)
White sucker	0.04	(0.04)	0.0	(0.0)	0.0	(0.0)	0.06	(0.06)
Sand shiner	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Golden shiner	0.04	(0.04)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Coho salmon	0.0	(0.0)	0.0	(0.0)	0.06	(0.06)	0.2	(0.2)
Totals	3.02	(2.3)	6.82	(4.8)	43.02	(34.0)	58.02	(29.3)

Table 31.(cont'd.).

Species	August CPE	August (SE)	September CPE	September (SE)	October CPE	October (SE)
Alewife	695.0[1]	(167.8)	217.9[1]	(865.0)	685.4[1]	(302.6)
Spottail shiner	490.3[1]	(201.5)	28.1[1]	(13.2)	2.1[1]	(1.2)
Rainbow smelt	0.9	(0.5)	0.4	(0.2)	0.06	(0.06)
Longnose dace	2.9	(1.1)	0.4	(0.2)	0.4	(0.2)
Chinook salmon	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Steelhead	0.1	(0.1)	0.06	(0.06)	0.06	(0.06)
Emerald shiner	0.06	(0.06	0.1	(0.08)	0.0	(0.0)
Trout-perch	0.4	(0.4)	0.3	(0.3)	0.0	(0.0)
Yellow perch	0.2	(0.1)	0.0	(0.0)	0.0	(0.0)
Johnny darter	2.6	(1.5)	0.4	(0.2)	0.0	(0.0)
9-spine stickleback	0.06	(0.06)	0.0	(0.0)	0.0	(0.0)
Longnose sucker	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mottled sculpin	0.1	(0.1)	0.2	(0.1)	0.0	(0.0)
Lake whitefish	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Fathead minnow	0.0	(0.0)	0.0	(0.0)	0.2	(0.1)
White sucker	0.0	(0.0)	0.06	(0.06)	0.0	(0.0)
Sand shiner	0.0	(0.0)	0.0	(0.0)	0.2	(0.2)
Golden shiner	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Coho salmon	0.06	(0.06)	0.0	(0.0)	0.0	(0.0)
Totals	1192.68	(373.2)	2209.02	(879.4)	688.42	(304.4)

1. All young-of-the-year.

Table 32. Diurnal catch per effort (CPE) and standard error (SE) for beach seines from April - November, 1976.

	Hours											
	0000 - 0400		0400 - 0800		0800 - 1200		1200 - 1600		1600 - 2000		2000 - 2400	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Alewife	59.2	(30.7)	109.1	(56.7)	127.1	(103.2)	8.3	(7.7)	44.8	(40.4)	39.5	(26.3)
Spottail shiner	9.3	(7.6)	4.7	(3.7)	4.4	(3.7)	2.3	(1.5)	0.4	(0.2)	12.1	(9.2)
Rainbow smelt	9.2	(7.0)	5.4	(3.6)	0.2	(0.2)	0.7	(0.5)	3.0	(1.6)	11.4	(10.4)
Longnose dace	4.0	(2.7)	0.7	(0.5)	0.3	(0.2)	0.08	(0.08)	0.08	(0.08)	0.4	(0.3)
Chinook salmon	2.1	(1.8)	1.8	(1.4)	1.3	(1.3)	0.3	(0.3)	0.8	(0.6)	0.6	(0.4)
Rainbow trout	0.4	(0.2)	0.3	(0.2)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.4	(0.3)
Emerald shiner	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.3	(0.3)	0.0	(0.0)
Trout-perch	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.2	(0.2)
Yellow perch	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Brown trout	0.3	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)
Johnny darter	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)
9-spine stickleback	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Lake trout	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mottled sculpin	0.08	(0.08)	0.0	(0.0)	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
White sucker	0.0	(0.0)	0.0	(0.0)	0.08	(0.08)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Totals	84.94	(50.64)	122.08	(66.18)	133.66	(108.96)	11.76	(10.16)	49.54	(43.3)	64.6	(47.1)

Table 33. Diurnal catch per effort (CPE) and standard error (SE) for beach seines from April - November, 1977.

	0000 - 0400		0400 - 0800		0800 - 1200		1200 - 1600		1600 - 2000		2000 - 2400	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)	CPE	(SE)
Alewife	46.9	(19.3)	1886.8	(805.0)	2710.8	(2108.7)	840.7	(392.7)	13206.0	(8408.8)	210.0	(92.1)
Spottail shiner	4.2	(2.8)	1.0	(0.06)	380.2	(276.3)	1010.8	(988.7)	230.1	(151.3)	0.9	(0.6)
Rainbow smelt	3.7	(1.8)	0.5	(0.2)	0.5	(0.2)	0.5	(0.3)	0.2	(0.1)	11.7	(11.3)
Longnose dace	4.5	(1.9)	0.6	(0.3)	0.8	(0.4)	1.5	(0.8)	0.05	(0.05)	2.7	(2.3)
Chinook salmon	0.4	(0.2)	0.3	(0.3)	0.0	(0.0)	0.5	(0.3)	0.6	(0.5)	2.3	(2.1)
Rainbow trout	0.1	(0.1)	0.05	(0.05)	0.1	(0.1)	0.3	(0.1)	0.2	(0.1)	0.05	(0.05)
Emerald shiner	0.2	(0.1)	0.05	(0.05)	0.1	(0.06)	0.0	(0.0)	0.05	(0.05)	0.05	(0.05)
Trout-perch	1.0	(0.4)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.1	(0.1)
Yellow perch	0.1	(0.1)	0.05	(0.05)	0.1	(0.1)	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)
Johnny darter	1.3	(1.2)	0.5	(0.3)	0.8	(0.4)	0.2	(0.2)	0.2	(0.2)	0.0	(0.0)
9-spine stickleback	0.05	(0.05)	0.0	(0.0)	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)
Longnose sucker	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Mottled sculpin	0.3	(0.1)	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)
Lake whitefish	0.5	(0.4)	0.0	(0.0)	1.5	(1.4)	7.9	(7.8)	1.0	(1.0)	0.3	(0.3)
Fathead minnow	0.1	(0.1)	0.05	(0.05)	0.05	(0.05)	0.0	(0.0)	0.05	(0.05)	0.0	(0.0)
White sucker	0.05	(0.05)	0.05	(0.05)	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Sand shiner	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)
Golden shiner	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)
Coho salmon	0.1	(0.1)	0.05	(0.05)	0.0	(0.0)	0.0	(0.0)	0.0	(0.0)	0.05	(0.05)
Totals	63.75	(28.95)	1884.0	(806.46)	3095.05	(2387.81)	1862.5	(1391.0)	13438.45	(8562.15)	228.25	(109.05)

Table 34. Catch per effort (CPE) and standard error (SE) for beach seines at station 1 and station 8 (control) from April - October, 1976.

	Station 1		Station 8	
Species	CPE	(SE)	CPE	(SE)
Alewife	50.6	(22.5)	78.6	(37.2)
Spottail shiner	3.8	(3.1)	7.2	(3.0)
Rainbow smelt	0.7	(0.4)	9.2	(4.2)
Longnose dace	0.4	(0.1)	1.5	(0.9)
Chinook salmon	1.3	(0.8)	1.1	(0.5)
Rainbow trout	0.3	(0.1)	0.08	(0.04)
Emerald shiner	0.0	(0.0)	0.1	(0.09)
Trout-perch	0.03	(0.03)	0.06	(0.06)
Yellow perch	0.03	(0.03)	0.03	(0.03)
Brown trout	0.06	(0.06)	0.06	(0.04)
Johnny darter	0.0	(0.0)	0.03	(0.03)
9-spine stickleback	0.03	(0.03)	0.0	(0.0)
Longnose sucker				
Lake trout	0.03	(0.03)	0.0	(0.0)
Mottled sculpin	0.03	(0.03)	0.06	(0.04)
Lake whitefish				
Fathead minnow				
White sucker	0.0	(0.0)	0.03	(0.03)
Totals	57.31	(27.21)	98.05	(46.13)

Table 35. Catch per effort (CPE) and standard error (SE) for beach seines at station 1, station 5, and station 8 (control) from April - October, 1977.

	Station 1		Station 5		Station 8	
Species	CPE	(SE)	CPE	(SE)	CPE	(SE)
Alewife	6708.2	(3241.1)	1708.5	(778.4)	2001.7	(820.8)
Spottail shiner	730.2	(390.4)	50.6	(15.2)	805.2	(280.5)
Rainbow smelt	0.9	(0.5)	6.8	(5.9)	1.2	(0.8)
Longnose dace	1.0	(0.5)	0.7	(0.3)	3.6	(1.6)
Chinook salmon	0.05	(0.03)	1.4	(1.1)	0.7	(0.3)
Rainbow trout	0.1	(0.05)	0.0	(0.0)	0.3	(0.1)
Emerald shiner	0.05	(0.03)	0.05	(0.03)	0.1	(0.08)
Trout-perch	0.02	(0.02)	0.02	(0.02)	0.5	(0.2)
Yellow perch	0.02	(0.02)	0.1	(0.07)	0.02	(0.02)
Brown trout						
Johnny darter	0.1	(0.1)	1.2	(0.7)	0.2	(0.1)
9-spine stickleback	0.07	(0.04)	0.0	(0.0)	0.0	(0.0)
Longnose sucker	0.0	(0.0)	0.0	(0.0)	0.03	(0.03)
Lake trout						
Mottled sculpin	0.02	(0.02)	0.1	(0.06)	0.02	(0.02)
Lake whitefish	0.6	(0.5)	5.2	(4.1)	0.02	(0.02)
Fathead minnow	0.0	(0.0)	0.1	(0.06)	0.02	(0.02)
White sucker	0.0	(0.0)	0.05	(0.03)	0.02	(0.02)
Sand shiner	0.0	(0.0)	0.0	(0.0)	0.1	(0.06)
Golden shiner	0.0	(0.0)	0.0	(0.0)	0.02	(0.02)
Coho salmon	0.0	(0.0)	0.1	(0.08)	0.0	(0.0)
Totals	7441.33	(3633.3)	1774.92	(806.0)	2813.75	(1104.7)

the afternoon (Tables 32 and 33) prior to sunset. No significant difference between sites was noted in 1976 and 1977 (Tables 34 and 35).

Spottail Shiner

Seine collections of spottail shiners were much lower during 1976 than 1977 (Table 29). During 1976, the majority of spottail shiners collected were yearlings and older with peak numbers occurring in June (Table 30). In 1977, the number of yearling and older spottail shiners collected was similar to 1976; however, large numbers of YOY were collected in August and September (Table 31).

In 1976, adult spottail shiners were collected mainly after dark (Table 32), while in 1977, YOY were collected close to shore primarily during daylight hours (Table 33). Spottail shiners did not demonstrate a significant preference for the control site or the impact sites (Tables 34 and 35).

Rainbow Smelt

Rainbow smelt were the third most abundant species in seine collections. Adults were collected mainly in the spring during their spawning run while YOY were recruited to the seine in August and remained near shore through October (Tables 30 and 31). Rainbow smelt were caught mainly after dark with greatest numbers collected near midnight (Tables 32 and 33). During 1976 and 1977, significantly more rainbow smelt were collected at the control site than the impact site just south of the plant (Tables 34 and 35). During 1977, however, the impact station north of the plant yielded more rainbow smelt than the control site (Table 36). Nearly equal numbers of males and females were collected each year, however, the majority of the rainbow smelt collected were YOY.

Longnose Dace

Longnose dace was the fifth most abundant species collected in shoreline seine in 1976 and 1977. Peak numbers occurred in the spring during spawning (Tables 30 and 31). As with rainbow smelt, longnose dace were collected mainly after dark and were most abundant around midnight (Tables 32 and 33). A similar pattern of abundance between collections at the control site was significantly greater than the southern impact site (Tables 34 and 35). However, in 1977, more longnose dace were collected at the northern impact site than the other sites combined.

Chinook Salmon

Juvenile chinook salmon, the next most abundant species in shoreline seine collections, were collected in June shortly after being planted (Tables 30 and 31). Collections were greatest at night (Tables 32 and 33) and little difference between sites was noted (Tables 34 and 35).

Lake Whitefish

In 1977, a large number of YOY lake whitefish was collected in June and July at the impact site just north of the plant (Table 35) possibly indicating this area is a spawning site for this species.

Sieve Net Collections

Young-Of-The-Year Fish

Utilization of shoreline waters as a nursery area for larval and post larval stages of several fish species is demonstrated by sieve net collections (Table 36). Lake whitefish, the first species collected were seen exclusively in May. Yellow perch followed in mid-May through mid-June. Rainbow smelt were first noted in mid-May but were not seen again until mid-June and were collected in sieve nets until late August. Longnose dace were seen in one collection in August while spottail shiners and alewives were collected from mid-July through September.

Sufficiently consistent samples of alewife, spottail shiner, and rainbow smelt were collected to demonstrate mean growth of these YOY fish (Table 37). Each of these species reached nearly the same size (alewives 27 mm and spottail shiners 34.3 mm) by late August.

Greater numbers of alewife and spottail shiner were collected at the control site (station 8) than either of the impact sites (Table 38). Lake whitefish and yellow perch, however, were most abundant at the north impact site.

Macroinvertebrates

In an offshoot of this thesis research, the food habits of spottail shiner and longnose dace collected in Lake Michigan shoreline during 1975 were assessed (Anderson and Brazo 1978). The major food of both

Table 36. Density (number/m^3) of young-of-the-year fish at all stations combined on each sampling date during 1977.

Dates	Alewife Density (N)	Spottail Shiner Density (N)	Rainbow Smelt Density (N)	Lake Whitefish Density (N)	Yellow Perch Density (N)	Longnose Dace Density (N)	Unid. Catostomidae Density (N)	Unid. Larvae Density (N)
05/02	0.0	0.0	0.0	0.26 (23)	0.0	0.0	0.25 (18)	0.1 (2)
05/18	0.0	0.0	0.07 (1)	0.16 (10)	0.02 (1)	0.0	0.0	0.04 (4)
05/25	0.0	0.0	0.0	0.03 (3)	0.6 (56)	0.0	0.0	0.16 (10)
06/15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03 (1)
06/20	0.0	0.0	0.0	0.0	0.01 (1)	0.0	0.0	0.0
07/13	0.88 (125)	0.22 (33)	0.01 (1)	0.0	0.0	0.0	0.0	0.0
07/27	0.48 (83)	0.68 (112)	0.01 (1)	0.0	0.0	0.0	0.0	0.0
08/13	0.34 (65)	0.02 (3)	0.02 (4)	0.0	0.0	0.01 (2)	0.0	0.0
08/24	0.34 (59)	0.99 (188)	0.11 (19)	0.0	0.0	0.0	0.0	0.0
09/14	0.16 (29)	0.01 (1)	0.0	0.0	0.0	0.0	0.0	0.0
09/28	1.33 (226)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 37. Mean total length of young-of-the-year fish captured in sieve nets on each sampling date during 1977.

	Alewife			Spottail shiner			Rainbow smelt			Lake whitefish			Yellow perch			Longnose dace		
Dates	(n)	Length	Std. Dev.	(n)	Length	Std. Dev.	(n)	Length	Std. Dev.	(n)	Length	Std. Dev.	(n)	Length	Std. Dev.	(n)	Length	Std. Dev.
05/25										(51)	20.5	2.4	(50)	8.5	1.4			
06/15																		
06/20													(1)	7.9	-			
07/13	(123)	13.8	5.4	(30)	7.0	1.9	(1)	19.9	4.5									
07/27	(82)	19.6	3.4	(112)	8.2	2.9	(1)	20.2	-									
08/13	(52)	17.5	4.9	(3)	9.4	0.8	(4)	25.3	6.5				(2)	4.0	.28	-	19.9	-
08/24	(31)	27.6	4.0	(150)	34.3	6.1	(19)	31.3	1.8									
09/14	(24)	32.3	9.0	(1)	48.3	-												
09/28	(26)	31.3	4.6															

Table 38. Density (nr/m^3) of young-of-the-year captured in sieve nets by station during 1977.

	Station		
Species	8	1	5
Alewife	0.50	0.17	0.29
Spottail shiner	0.45	0.05	0.02
Rainbow smelt	0.02	0.01	0.02
Lake whitefish	0.01	0.02	0.04
Yellow perch	0.02	0.02	0.13
Longnose dace	0.002	0.0	0.0
Unid sucker	0.0	0.0	0.01
Unid larvae	0.05	0.03	0.11

species was terrestrial insects which had probably been blown into the lake and been entrained in the alongshore current. The diet overlap of these fish decreased significantly from spring to fall as did the diet breadth of the longnose dace. Anderson and Brazo (1978) attributed these results to decreased availability of common food types in the fall. In 1977, seasonal changes in composition and density of shoreline macroinvertebrates in the alongshore drift and benthos were assessed to determine if macroinvertebrate density decreased in the fall as predicted from but analysis.

Invertebrate species from nineteen orders were collected in shoreline waters. Terrestrial insects comprised nearly 90% of invertebrate drift (Table 39). Major taxa collected were terrestrial Diptera (24.0%), terrestrial Coleoptera (9.0%), and Chironomidae adults (7.6%). Terrestrial insect parts were partially decomposed and could not be further identified. Density of drifting invertebrates was similar during spring (2706/1000 m^3) and summer (2815/1000 m^3), but declined in fall (630/1000 m^3). Composition of drift fauna was similar throughout the year. During spring, terrestrial insect parts, Diptera, Hymenoptera, and Chironomidae comprised 96.3% of invertebrate drift. During summer, Coleoptera became important in the drift. Fall drift samples contained mainly terrestrial insect parts, Diptera, Homoptera, and Hymenoptera.

Assuming that 1977 macroinvertebrate densities and composition were representative of conditions in 1975, the prediction based on food habit analysis was correct, shoreline macroinvertebrates were less abundant during fall.

The source of terrestrial insects in drift in diets of shoreline fish was not directly traced. However, a phenomenon described for Swedish lakes by Norlin (1967) may apply to Lake Michigan. He found some

Table 39. Seasonal abundance (number/1000 m^3) of Lake Michigan's shoreline drift invertebrates near Ludington, Michigan during 1977.

	Spring (%) 5/2-6/15 n=36	Summer (%) 6/20-8/24 n=45	Fall (%) 9/14-11/8 n=36	Mean (%) Total
Aquatic Invertebrates				
*Chironomidae	147 (5.4)	303 (10.8)	- -	162 (7.6)
*Trichoptera	13 (0.5)	85 (3.1)	- -	37 (1.7)
Ephemeroptera larvae	- -	29 (1.0)	3 (0.5)	12 (0.6)
Hydracarina	8 (0.3)	3 (0.1)	- -	4 (0.2)
Amphipoda	7 (0.3)	53 (1.9)	21 (3.3)	29 (1.4)
Pelecypoda	2 (0.1)	1 (.1)	- -	1 (0.1)
**Diptera larvae	3 (0.1)	- -	2 (0.3)	2 (0.1)
Coleoptera larvae	4 (0.2)	- -	- -	1 (0.1)
Odonata	- -	1 (.1)	- -	1 (.1)
Terrestrial Invertebrates				
Terrestrial insect parts	1293 (47.8)	1351 (48.0)	407 (64.6)	1043 (49.1)
Diptera	1005 (37.1)	467 (16.6)	47 (10.6)	509 (24.0)
Coleoptera	37 (1.4)	416 (14.8)	24 (3.8)	192 (9.0)
Hymenoptera	161 (6.0)	25 (0.9)	47 (7.5)	74 (3.5)
Homoptera	12 (0.4)	39 (1.4)	54 (8.6)	35 (1.7)
Hemiptera	5 (0.2)	5 (0.2)	- -	4 (0.2)
Psocoptera	- -	6 (0.2)	- -	2 (0.1)
Neuroptera	- -	27 (1.0)	- -	10 (0.5)
Siphonoptera	4 (0.2)	- -	- -	1 (0.1)
Araneae	5 (0.2)	4 (0.1)	3 (0.5)	4 (0.2)
Orthoptera	- -	- -	2 (0.3)	1 (0.1)
Totals	2706	2815	630	2123

* Includes immature and mature life stages.
** Excluding Chironomidae

terrestrial insects in the alongshore drift were washed in from shore by waves; however, the majority were blown in from upland areas. These insects were entrained in warm air currents rising from fields then released into nearby lakes as the warm air cooled near the lake creating a downdraft. Insects were then concentrated along the windward shore and entrained in the alongshore current. Thus, when lake water temperature is significantly lower than the surrounding air temperature, the lake may act as a collecting basin for airborn insects. The "collection basin" phenomenon also explains the decrease in terrestrial insects in fall compared to spring and summer. In spring, air temperature increases faster than water temperature and the lake water is colder than surrounding air, resulting in downdrafts and insect deposition. This phenomenon is generally true in summer, but not to as great a degree. During fall, however, the reverse situation occurs and lake water is warmer than the surrounding air creating updrafts rather than downdrafts. In these situations, no insect deposition may occur. Terrestrial insect density in Lake Michigan shoreline waters was much lower in the fall than in spring and summer.

Zooplankton

Zooplankton catch was dominated by *Bosmina* and *Cyclops* (Table 40). *Bosmina* were most abundant in May, July, and November. *Cyclops* reached its highest density in November. *Diaptomus* density was greatest during September through November while *Daphnia* density peaked in May. *Chydorus*, *Alona*, and *Ceriodaphnia* were most abundant during July. Comparison of total zooplankton density among stations (Table 41) showed that similar densities occurred at each station.

Table 40. Monthly density (nr/m^3) of the major zooplankton species caught in sieve nets in shoreline waters during May through November, 1977.

Species	May	June	July	Aug	Sept	Oct	Nov	Total
Bosmina	1004	422	2552	335	21	85	1655	6074
Cyclops	220	48	125	85	52	62	1030	1621
Diaptomus	48	20	49	21	107	82	123	450
Daphnia	61	3	6	18	10	5	47	150
Chydorus	14	11	141	41	3	2	10	222
Alona	0	3	32	4	0	0	0	39
Ceriodaphnia	0	1	10	1	0	0	0	12
Nauplii	297	232	147	90	58	57	59	940
Totals	1644	740	3062	594	251	293	2924	9508

Table 41. Zooplankton density (nr/m^3) by station and date in shoreline waters during 1977.

Date	Station 8	Station 1	Station 5
05/18	267	636	190
05/25	374	953	970
06/15	250	156	192
06/20	296	196	410
07/13	1356	1788	1497
07/27	332	399	839
08/13	374	307	175
08/24	66	108	127
09/14	22	47	13
09/28	827	146	193
10/22	70	108	116
11/08	2058	302	566
Totals	5548	5146	5287

Ekman Dredge Collections

The major categories of invertebrates found in dredge samples (Table 42) were Oligocheata (37.8%), Chironomidae (33.4%), and terrestrial insect parts (13.5%). Invertebrate density decreased steadily from a spring high of $480.4/m^2$ to a low of $99.4/m^2$ in the fall. The composition of the benthic fauna changed from predominantly aquatic species in spring to terrestrial in the fall. Chironomidae and Oligocheata, the major aquatic invertebrates throughout the year, comprised 98.6% of spring, 42.9% of summer, and 16.3% of fall benthic invertebrates. The major terrestrial invertebrate groups, insect parts, and homoptera reached their greatest densities in the summer.

Food Habit Studies

Alewife and Spottail Shiner Young-Of-The-Year

Since young-of-the-year alewife and spottail shiner were the most abundant shoreline inhabitants, their food habits were studied to enhance our understanding of this zone. During 1977, in Lake Michigan shoreline waters near Ludington, Michigan, alewife YOY fed mainly on *Cyclops* in July, *Bosmina*, *Cyclops*, and *Diaptomus* in August and September. In October, *Cyclops*, *Bosmina*, and *Daphnia* were the major food items (Table 43). Spottail shiner consumed mainly *Chydorus*, *Alona*, and *Bosmina* in July, included *Chironimid* larvae in August, and fed almost exclusively on *Bosmina* during September and October (Table 44).

The degree to which alewife and spottail shiner ate similar food was determined through calculation of diet overlap and breadth indices

Table 42. Seasonal abundance (mean number/m^2) of Lake Michigan's shoreline benthic invertebrates near Ludington, Michigan, during 1977.

	Spring (%) 4/29, 5/19 n=18	Summer (%) 6/24, 8/12 n=18	Fall (%) 8/31, 9/30, 10/38 n=27	Mean (%) Total
Aquatic Invertebrates				
*Chironomidae	231.9 (48.3)	57.1 (24.1)	- -	82.6 (33.4)
Oligocheata	241.5 (50.3)	61.7 (26.0)	16.2 (16.3)	93.6 (37.8)
Hydracarina	- -	4.6 (2.0)	- -	1.3 (0.5)
Trichoptera larvae	- -	1.5 (0.7)	- -	0.4 (0.2)
Coleoptera larvae	2.3 (0.5)	- -	- -	0.7 (0.3)
Amphipoda	- -	1.5 (0.7)	- -	0.4 (0.2)
Ostracoda	- -	- -	9.3 (0.3)	4.0 (1.6)
Pelecypoda	- -	- -	2.3 (2.3)	1.0 (0.4)
Isopoda	- -	1.5 (0.7)	- -	0.4 (0.2)
Terrestrial Invertebrates				
Terrestrial insect parts	- -	81.8 (34.4)	23.1 (23.2)	33.3 (13.5)
**Diptera	- -	15.4 (6.5)	11.6 (11.6)	9.4 (3.8)
Coleoptera	- -	1.5 (0.7)	4.6 (4.7)	2.4 (1.0)
Homoptera	- -	4.6 (2.0)	23.1 (23.3)	11.2 (4.5)
Hymenoptera	2.3 (0.5)	1.5 (0.7)	6.9 (7.0)	4.0 (1.6)
Araneae	2.3 (0.5)	1.5 (0.7)	- -	1.1 (0.4)
Thysanoptera	- -	1.5 (0.7)	2.3 (2.3)	1.4 (0.6)
Neuroptera	- -	1.5 (0.7)	- -	0.4 (0.2)
Totals	480.3	237.2	99.4	247.6

* Includes immature and mature life stages
** Excluding Chironomidae

Table 43. Monthly frequency of occurrence (FO), percent total number (%TN), and percent total volume (%TV) of food consumed by young-of-the-year alewives during July - October, 1977.

	July			August		
Food organism	FO	%TN	%TV	FO	%TN	%TV
Bosmina	11.7	7.1	4.1	63.0	46.5	30.4
Chydorus	8.3	2.8	1.8	11.1	0.9	0.6
Alona	3.3	0.8	0.6	11.1	0.4	0.3
Cyclops	58.3	75.6	79.6	44.4	36.3	41.9
Chironomid lar.	0.0	0.0	0.0	11.1	0.4	1.2
Unid. Copepoda	11.7	9.1	8.9	11.1	2.7	2.9
Daphnia	1.7	0.8	2.1	18.5	1.2	3.5
Eubosmina	0.0	0.0	0.0	7.4	0.3	0.2
Polyphemus	5.0	1.2	0.6	7.4	0.2	0.1
Diaptomus	5.0	2.4	2.1	40.7	9.4	9.3
Unid. ter. insects	0.0	0.0	0.0	0.0	0.0	0.0
Herpacticoid	1.7	0.4	0.3	0.0	0.0	0.0
Copepoda nauplii	0.0	0.0	0.0	7.4	1.7	0.9
Leptodora	0.0	0.0	0.0	3.7	0.2	8.7
Total sample size	60	254	$3.38 mm^3$	27	1026	$12.4 mm^3$
Number of empty stomachs		17			5	

Table 43. (cont'd.).

Food organism	September FO	September %TN	September %TV	October FO	October %TN	October %TV
Bosmina	83.3	40.3	27.7	70.0	72.2	54.6
Chydorus	0.0	0.0	0.0	0.0	0.0	0.0
Alona	0.0	0.0	0.0	20.0	3.5	3.7
Cyclops	63.3	30.9	37.7	80.0	14.4	19.3
Chironomid lar.	0.0	0.0	0.0	0.0	0.0	0.0
Unid. Copepoda	13.3	1.0	1.2	0.0	0.0	0.0
Daphnia	10.0	2.3	7.3	40.0	4.9	17.3
Eubosmina	10.0	2.0	1.4	10.0	1.5	1.2
Polyphemus	0.0	0.0	0.0	20.0	0.2	0.1
Diaptomus	46.7	22.9	24.0	10.0	1.6	1.9
Unid. ter. insects	0.0	0.0	0.0	0.0	0.0	0.0
Herpacticoid	0.1	0.7	0.7	20.0	1.7	1.9
Copepoda nauplii	0.0	0.0	0.0	0.0	0.0	0.0
Leptodora	0.0	0.0	0.0	0.0	0.0	0.0
Total sample size	30	2305	26.43mm^3	10	1291	13.47mm^3
Number of empty stomachs		0			0	

Table 44. Monthly frequency of occurrence (FO), percent total number (%TN), and percent total volume (%TV) of food consumed by young-of-the-year spottail shiners during July - October, 1977.

	July			August		
Food organism	FO	%TN	%TV	FO	%TN	%TV
Bosmina	30.4	13.3	10.4	58.3	28.4	14.7
Chydorus	66.7	43.3	38.3	33.3	23.0	12.9
Alona	39.1	40.0	43.2	33.3	16.2	11.2
Cyclops	1.5	0.2	0.2	0.0	0.0	0.0
Chironomid lar.	10.1	1.4	5.4	50.0	24.3	58.6
Unid. Copepoda	7.2	1.3	1.6	0.0	0.0	0.0
Daphnia	1.5	0.2	0.6	0.0	0.0	0.0
Eubosmina	1.5	0.2	0.2	8.3	5.4	2.6
Polyphemus	1.5	0.2	0.2	0.0	0.0	0.0
Diaptomus	0.0	0.0	0.2	0.0	0.0	0.0
Unid. ter. insects	0.0	0.0	0.0	8.3	2.7	tr
Herpacticoid	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda nauplii	0.0	0.0	0.0	0.0	0.0	0.0
Leptodora	0.0	0.0	0.0	0.0	0.0	0.0
Total sample size	69	623	6.34mm^3	12	74	1.16mm^3
Number of empty stomachs		0			3	

Table 44. (cont'd.).

Food organism	September FO	September %TN	September %TV	October FO	October %TN	October %TV
Bosmina	100.0	94.1	89.5	100.0	80.0	75.0
Chydorus	0.0	0.0	0.0	0.0	0.0	0.0
Alona	0.0	0.0	0.0	0.0	0.0	0.0
Cyclops	100.0	1.0	1.2	100.0	20.0	25.0
Chironomid lar.	100.0	1.9	9.3	0.0	0.0	0.0
Unid. Copepoda	0.0	0.0	0.0	0.0	0.0	0.0
Daphnia	0.0	0.0	0.0	0.0	0.0	0.0
Eubosmina	0.0	0.0	0.0	0.0	0.0	0.0
Polyphemus	0.0	0.0	0.0	0.0	0.0	0.0
Diaptomus	0.0	0.0	0.0	0.0	0.0	0.0
Unid. ter. insects	100.0	2.9	tr	0.0	0.0	0.0
Herpacticoid	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda nauplii	0.0	0.0	0.0	0.0	0.0	0.0
Leptodora	0.0	0.0	0.0	0.0	0.0	0.0
Total sample size	1	103	$0.86mm^3$	1	5	$0.04mm^3$
Number of empty stomachs		0			0	

(Colwell and Futuyma 1971). Two overlap indices were calculated, one based on taxonomic categories of food consumed (Table 45) and another based on size of food items (Figure 5). Taxonomic overlap indices were relatively low, 0.1 through 0.34, (total possible range is 0 through 1) with higher values in August than July. Low overlap of food resulted from spottail shiners and alewife mainly consuming cladocerans and copepods, respectively (Figure 6). During August alewives ate more Bosmina than in July resulting in a greater degree of overlap. Diet overlap based on food size (0.61) was higher than diet overlap based on taxonomic category (0.1 through 0.34). There was still a marked degree of difference in food size consumed with alewives using a greater proportion of larger food items (Figure 6). Diet breadth of the spottail shiner increased faster than for alewives (Table 44) due to incorporation of benthic food items into their diet (Figure 6).

Changes in composition of major zooplankton species in the near-shore waters of Lake Michigan (Figure 7) seemed to have no impact on the composition of zooplankton species consumed by alewives or spottail shiners suggesting some degree of food selection. It is probable, however, that the decline in density of plankton late in August was partly responsible for increased overlap and diet breadth.

Adult Salmonid

Many fish which occur along shore are potential forage for large salmonids which move into shore mainly during spring and fall. Stomach contents of brown trout, lake trout, rainbow trout, and coho salmon collected in shoreline gill nets were examined seasonally to determine diet in this zone of Lake Michigan.

Table 45. Diet overlap and breadth, by taxonomic category, for young-of-the-year spottail shiner and alewife in Lake Michigan's shoreline waters.

	July 13	July 27	Aug 13	Aug 24
Diet overlap*	0.18	0.11	0.34	0.28
Diet breadth**				
Spottail shiner	1.58	2.36	3.70	4.81
Alewife	1.75	1.70	1.79	2.40
Mean length (mm)				
Spottail shiner	8.80	10.20	12.50	34.60
Alewife	13.60	20.90	20.80	26.80

$$* \text{ Diet overlap} = 1 - 1/2 \sum \left(\frac{\%TN_{AL} - \%TN_{SS}}{100} \right)$$

$$** \text{ Diet breadth} = 1/ \sum \left(\frac{\%TN}{100} \right)^2$$

Figure 5. Percent total number of food items arranged by size groups, consumed by young-of-the-year alewife and spottail shiner on July 27, 1977.

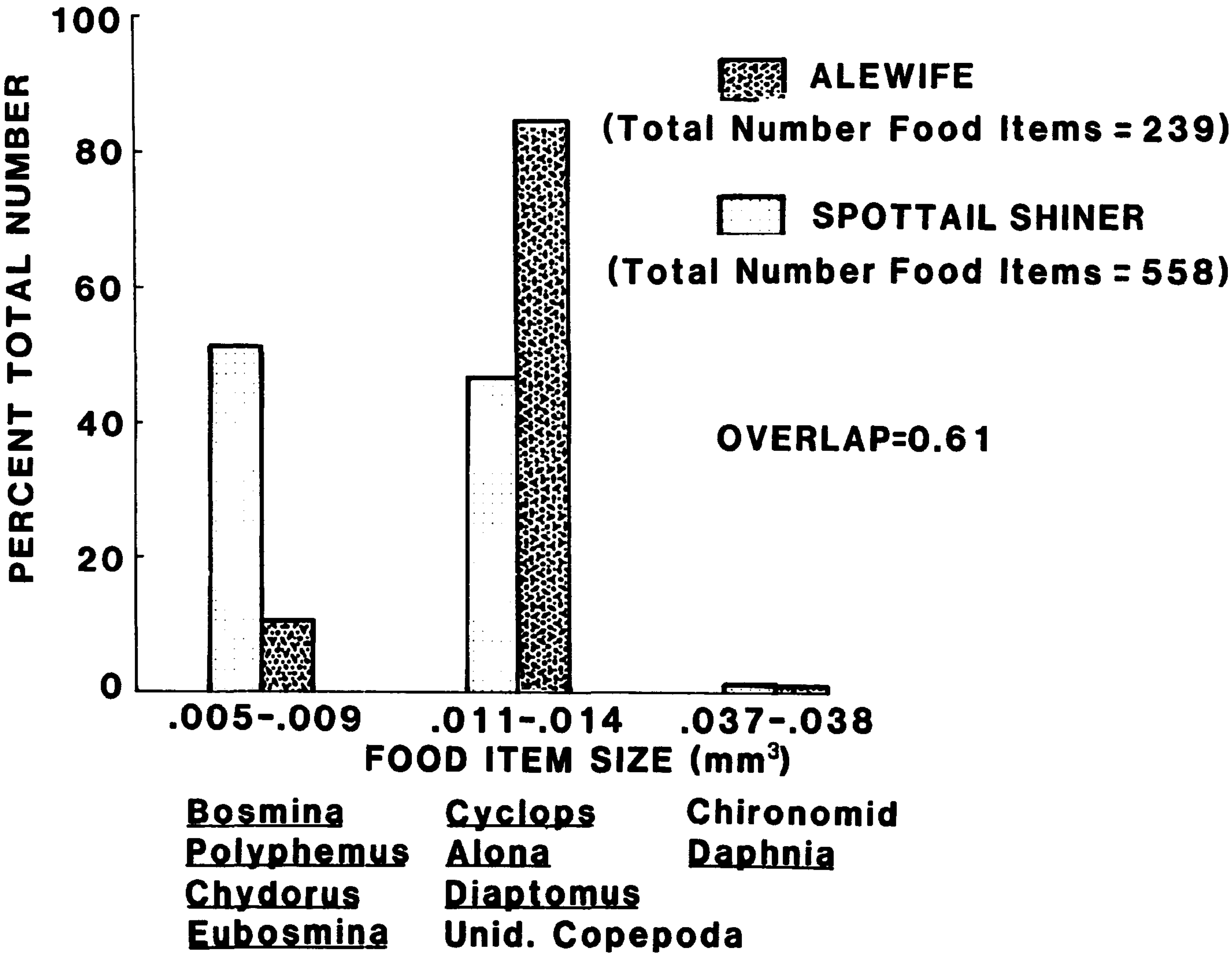

ALEWIFE
(Total Number Food Items = 239)
SPOTTAIL SHINER
(Total Number Food Items = 558)
OVERLAP=0.61
PERCENT TOTAL NUMBER
100
80
60
40
20
0
.005-.009
.011-.014
.037-.038
FOOD ITEM SIZE (mm³)
Bosmina
Polyphemus
Chydorus
Eubosmina
Cyclops
Alona
Diaptomus
Unid. Copepoda
Chironomid
Daphnia

Figure 6. Percent total number of food items consumed by spottail shiner (SS) and alewife (AL) on sample dates in July and August, 1977.

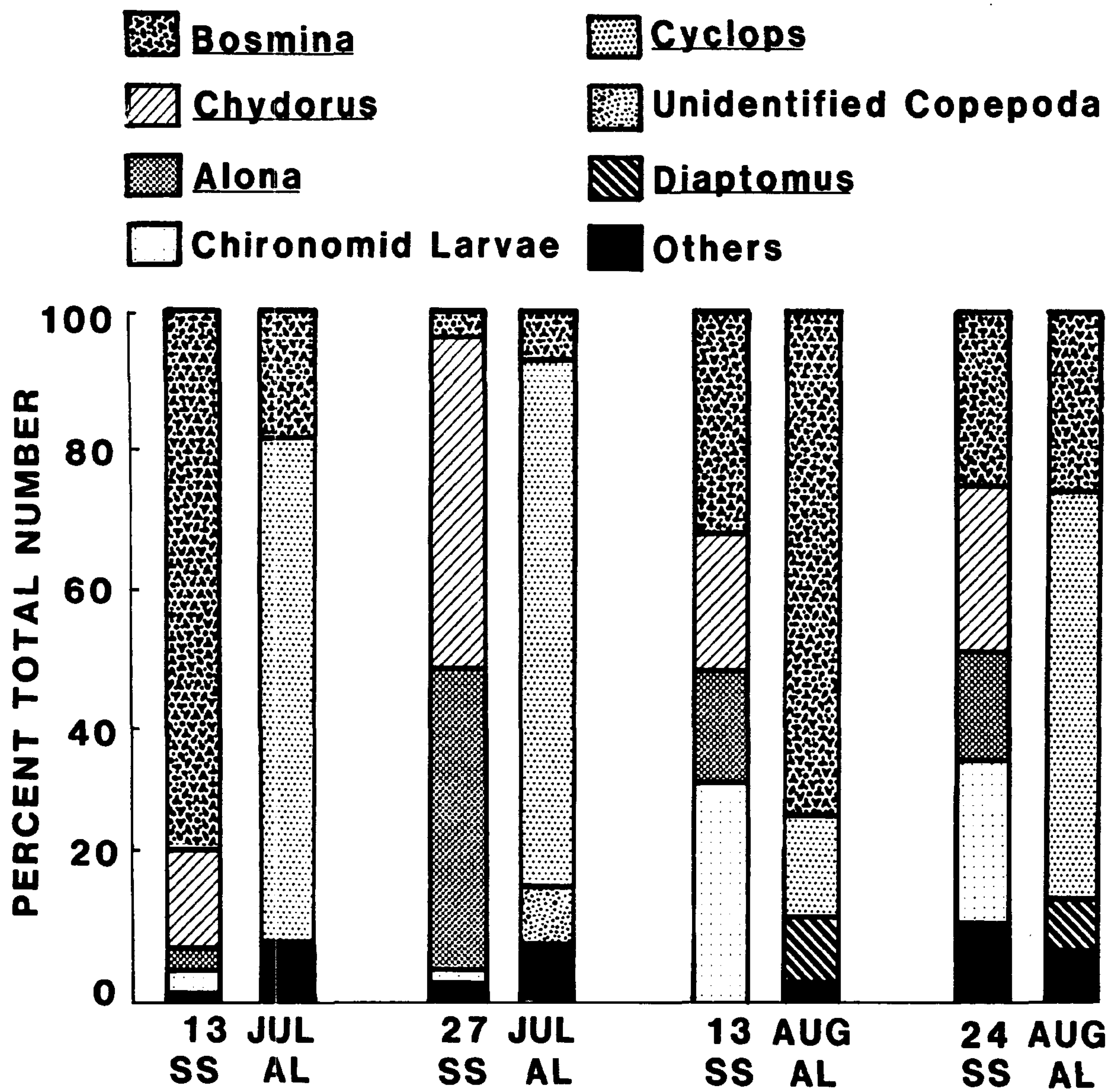
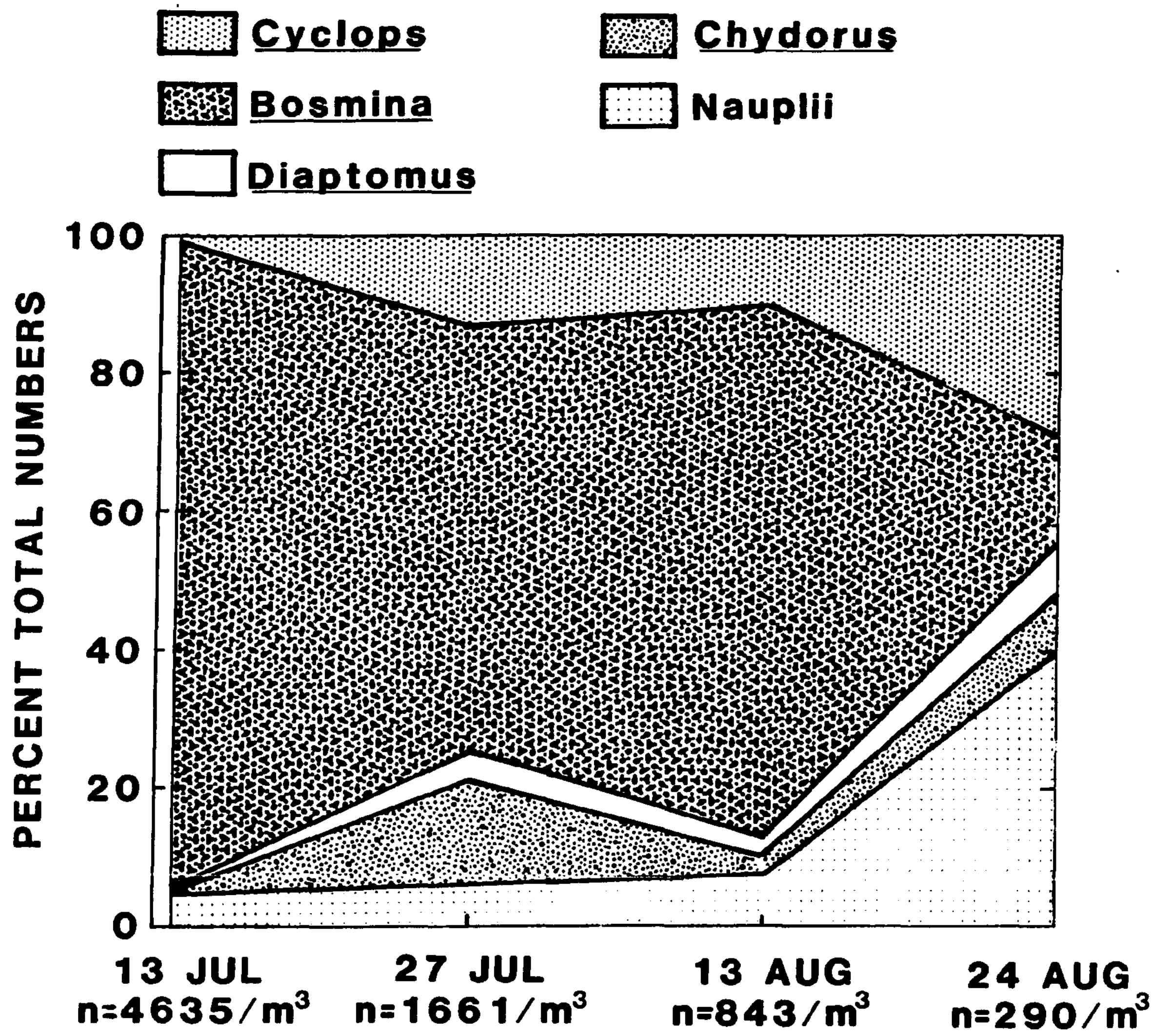

Bosmina
Chydorus
Alona
Chironomid Larvae
Cyclops
Unidentified Copepoda
Diaptomus
Others
PERCENT TOTAL NUMBER
0
20
40
60
80
100
13 JUL
SS AL
27 JUL
SS AL
13 AUG
SS AL
24 AUG
SS AL

Figure 7. Percent total number of major zooplankton species collected in shoreline waters on sample dates during July and August, 1977.


Cyclops
Chydorus
Bosmina
Nauplii
Diaptomus
PERCENT TOTAL NUMBERS
100
80
60
40
20
0
13 JUL
n=4635/m³
27 JUL
n=1661/m³
13 AUG
n=843/m³
24 AUG
n=290/m³

From the perspective of volume of food consumed, alewives represented the largest percentage of the identifiable food items found for all adult salmonids examined (Table 46). Rainbow smelt were found in brown trout and rainbow trout stomachs during spring and in lake trout stomachs during the fall. Sculpin appeared during spring in brown trout and rainbow trout stomachs and during summer in brown trout stomachs only. Terrestrial insects were noted mainly in brown trout and rainbow trout stomachs along with several aquatic invertebrates. It is surprising that no spottail shiners were found in the large salmonid stomachs examined since spottail shiner appear to be nearly as abundant as alewives near shore.

Table 46. Frequency of occurrence (FO), percent total number (%TN), and percent total volume (%TV) of food organisms consumed by large salmonids (>450 mm) captured in shoreline gill nets during 1976 through 1977.

Spring

	Brown trout			Rainbow trout			Lake trout			Coho salmon		
Food organism	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV
Alewife	42.9	56.5	84.7	15.4	74.2	79.2	28.5	70.0	95.0	66.7	100.0	100.0
Sculpin	8.6	9.8	2.1	3.8	16.1	1.9						
Smelt	8.6	5.4	7.5	3.8	3.2	9.7						
Unid. fish	28.6	18.5	5.6	7.7	6.4	1.9	28.5	30.0	5.0			
Terr. insects	5.7	9.8	tr									
Number of stomachs		35			26			7			3	
Number of empty stomachs		8			18			3			1	

Summer

Food organism	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV
Alewife	11.5	52.6	74.8	5.9	16.9	61.5	50.0	100.0	100.0			
Sculpin	3.8	15.8	12.2									
Unid. fish	3.8	21.0	12.2	5.9	1.5	15.4						
Terr. insects	7.7	10.5	0.8	17.6	81.5	23.0						
Number of stomachs		26			17			6				
Number of empty stomachs		19			12			3				

Table 46.(cont'd.).

	Fall											
	Brown trout			Rainbow trout			Lake trout			Coho salmon		
Food organism	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV	FO	%TN	%TV
Alewives	12.5	50.0	55.4	3.7	14.4	86.3	7.7	36.3		7.8	82.3	58.0
Smelt							3.8	9.0				
Unid. fish				6.5	0.2	0.6	19.2	54.5		2.6	5.9	2.0
Fish eggs				2.8	12.8	8.1				2.6	5.9	40.0
Decapoda				0.9	0.2	0.6						
Amphipoda				1.9	2.0	tr						
Terr. insects	18.7	50.0	44.6	10.2	66.7	4.1				2.6	5.9	tr
Chironamid lar.				2.8	0.7	tr						
Trichoptera lar.				2.8	2.9	tr						
Number of stomachs		16			108			26			38	
Number of empty stomachs		10			27			18			31	

DISCUSSION

The shoreline waters zone of Lake Michigan does not represent an isolated portion of Lake Michigan that harbors a unique community of fish. This zone is open to emigration and immigration of many fish species. Therefore, a sampling of this zone to determine fish species composition provides merely a snapshot of a constantly changing community. The results of this study provide a series of snapshots in time and space that reveal changes in the shoreline waters fish community by season, time of day, and sample site. Concurrent monitoring of physical parameters, investigation of food habits, sampling available food resources, and determination of age structure, maturity, sex ratios and gonadal condition together allow formulation of theories to explain major changes in shoreline waters fish species composition.

Seasonal changes in shoreline fish species composition seem to be mainly associated with spawning activity and subsequent hatching of the eggs. Most species moved near shore to spawn in a serial manner, i.e., rainbow trout and rainbow smelt in early spring, longnose dace in mid-spring, spottail shiner and alewife in late spring-summer, and lake trout, brown trout, and salmon during fall. Of these species, rainbow smelt, longnose dace, spottail shiner, alewife, and lake trout actually spawn in shoreline waters. The remaining species spawn in tributaries to the lake. Of the shoreline spawners, alewife and spottail shiner spawn at nearly the same time and their young coexist in this zone through late summer and early fall.

In some lakes the fish community has evolved such that YOY of each species using shoreline waters are at different developmental stages (Keast 1978). Since YOY fish tend to change food habits frequently as they grow, diet overlap is reduced. Thus, diet overlap and competition for food is reduced via temporal segregation. Spottail shiner and alewife caught in this study, however, seemed to have reduced competition for food through spatial segregation. Spottail shiner YOY tended to consume more benthic zooplankton and aquatic insect larvae while alewife YOY ate zooplankton found higher in the water column. A previously abundant shoreline species, emerald shiner, which spawned in the same time period but was more palagic in nature than spottail shiners, has declined drastically since alewives entered Lake Michigan. Thus, alewife and emerald shiner were probably in direct competition for food during early development stages. Alewives were probably able to outcompete emerald shiners because they are capable of filter feeding as well as making individual strikes (Janssen 1976). Predation by adult alewife on YOY emerald shiners and on the pelagic emerald shiner eggs (Crowder 1980) probably contributed to emerald shiner decline also.

Despite free access to deeper waters, the YOY alewives and spottail shiners remained in shoreline waters through summer and into fall. Particle size of the food resource may be a factor in YOY remaining near shore. Smaller zooplankton such as Bosmina and nauplii are predominant near shore in Lake Michigan while larger zooplankton such as Diaptomus predominate offshore (Evans and Hawkins 1977; Roth and Steward 1973). Zooplankton sampled during the present study were consistent with these findings as was zooplankton found in YOY alewife and spottail shiner gut analysis. It is possible, the mouth size of YOY alewife and spottail shiner prevent efficient feeding on the larger zooplankton. A second factor which may also cause most YOY to remain near shore is the warm shoreline water temperature during August and early September. This factor was substantiated by declines in YOY abundance when upwellings caused warm water masses to move away from shore.

Alewife and spottail shiner YOY fish did not, however, remain in shoreline waters after dark to the extent they did during daylight hours. Low CPE after dark indicated that many YOY moved to deeper water. Janssen (1976 and 1978) reported that adult alewives dispersed after dark in nearshore waters to feed. It is possible that their young followed the same pattern and dispersed throughout the nearshore zone at night resulting in a lower CPE in shoreline waters.

Keast (1978), Helfman (1978), and Werner et al. (1977) also found that YOY fish tend to remain in shallow water in temperate freshwater lakes. They hypothesized this behavior functioned in reducing predation and intraspecific competition. In Lake Michigan, as is discussed in the next paragraph, adult alewife and spottail shiner do not move offshore until fall; thus, the potential for intraspecific competition and predation still exists. Alewife age structure, however, did indicate that few age II individuals used shallow waters; thus, possibly reducing intraspecific competition somewhat.

Mid and late spring spawning adults remained abundant in shoreline waters through the summer probably for similar reasons as the YOY (food availability and preferred water temperature). Wells (1968) reported that spottail shiner and alewife moved shoreward in spring as water temperature near shore increased and remained near shore until nearshore water temperature declined in fall. Alewife adults were found to feed heavily on YOY fish in August and September (Webb and McComish 1974) while spottail shiner and longnose dace adults fed extensively on terrestrial insects which accummulated along shore during summer. The warm waters nearshore also may have provided a barrier to major shoreward movements of piscivores; thus, to some degree, protecting adult alewives, spottail shiners, and longnose dace from predation.

Lake trout was the only abundant fall shoreline spawner. These fish moved shoreward in September and October after the majority of alewives and spottail shiners had moved offshore. Most individuals were caught after sunset when wave action was minimal.

No consistent pattern was seen in comparing the control station to the impact stations. The dynamic nature of the fish community nearshore makes assessment of the impact of a facility such as the LPSPP by comparing stations very difficult. A better approach may be to use the general patterns of fish movements into the shoreline waters derived from this study to alter water intake periods. For example, fewer lake trout may be entrained in the LPSPP reservoir if water intake were curtailed on calm nights in September and October. Pumping could also be curtailed during peak rainbow trout spawning times in the spring to decrease entrainment of this species. During August, daytime pumping should be avoided to decrease entrainment of large numbers of YOY that are concentrated nearshore.

Further studies of the shoreline waters would allow better definition of behavior patterns and their relation to physical parameters. Predictive models could then be formulated to allow shoreline facilities such as the LPSPP to reduce entrainment of fish with minimal reduction in operating time.

SUMMARY

The shoreline waters (0-3 m) of Lake Michigan near Ludington, Michigan, were sampled with variable mesh gill nets, seines, and sieve nets to obtain a representation of the fish species composition during spring, summer, and fall. Food resources were sampled and gut analysis performed to understand how fish use this zone.

Thirty-five species of fish were caught during April through November, 1976 and 1977. Spottail shiner and alewife dominated the catch from late May through early September. Rainbow trout were the most abundant species caught in April and November while lake trout were the most abundant in October. Gonadal condition of these fish revealed that many adults of each species were in spawning condition. Alewife and spottail shiner young-of-the-year (YOY) were initially caught in sieve nets in mid-July and dominated seine collections in August and September.

Food habit studies of YOY alewife and spottail shiner indicated that spottail shiner ate epibenthic foods such as Chydorus, Alona, and Chironomidae larvae. Alewife ate more pelagic foods such as Bosmina and Cyclops. Adult alewife food habits were not studied; however, spottail shiner and longnose dace adults were both found to eat terrestrial insects which accummulate in the shoreline waters. Adult salmonid stomaches were examined to determine which shoreline species were most susceptible to predation. Alewives were by far the most frequently consumed prey by salmonids.

Comparison of fish catch near the Ludington Pumped Storage Power Plant and a control site 4.8 km to the south did not reveal any consistent patterns.

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APPENDIX A

Table 1. Monthly maturity and gonadal condition of each fish species captured in gill nets during 1976.

April

Species	Maturity		Gonadal Condition				
	Immature	Mature	Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	7	7	0	0	0	0
Alewife	2	16	18	0	0	0	0
Rainbow trout	20	77	40	50	3	4	0
Lake trout	0	2	2	0	0	0	0
White sucker	5	31	20	10	0	5	1
Redhorse	0	1	1	0	0	0	0
Brown trout	5	24	29	0	0	0	0
Rainbow smelt	0	37	3	33	0	1	0
Longnose sucker	1	13	7	1	0	6	0
Gizzard shad	0	31	30	1	0	0	0
Yellow perch	0	2	2	0	0	0	0
Longnose dace	0	1	1	0	0	0	0
Coho salmon	2	0	2	0	0	0	0
Carp	0	4	3	1	0	0	0
Chinook salmon	0	2	2	0	0	0	0
Trout-perch	0	2	2	0	0	0	0
Round whitefish	0	2	1	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	1	0	1	0	0	0
Pumpkinseed	0	1	1	0	0	0	0
Largemouth bass	0	1	1	0	0	0	0
Black crappie	0	1	1	0	0	0	0

Table 1. (cont'd.).

May

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	75	67	7	0	1	0
Alewife	14	10	24	0	0	0	0
Rainbow trout	6	12	9	1	0	8	0
Lake trout	0	19	19	0	0	0	0
White sucker	16	17	23	0	0	10	0
Redhorse	2	0	2	0	0	0	0
Brown trout	4	53	57	0	0	0	0
Rainbow smelt	0	51	0	22	1	28	0
Longnose sucker	6	8	8	0	0	6	0
Gizzard shad	0	16	16	0	0	0	0
Yellow perch	0	0	0	0	0	0	0
Longnose dace	0	15	15	0	0	0	0
Goho salmon	1	5	6	0	0	0	0
Carp	0	0	0	0	0	0	0
Chinook salmon	3	0	3	0	0	0	0
Trout-perch	0	12	7	5	0	0	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	5	3	2	0	0	0
Northern pike	0	1	0	1	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

June

Species	Maturity		Gonadal Condition				
	Immature	Mature	Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	270	94	57	43	76	0
Alewife	25	75	70	27	1	2	0
Rainbow trout	4	3	7	0	0	0	0
Lake trout	0	5	5	0	0	0	0
White sucker	12	12	16	0	0	8	0
Redhorse	1	5	5	0	0	1	0
Brown trout	2	18	20	0	0	0	0
Rainbow smelt	0	2	0	0	0	2	0
Longnose sucker	6	0	6	0	0	0	0
Gizzard shad	0	16	7	0	2	7	0
Yellow perch	1	16	1	0	1	15	0
Longnose dace	0	31	20	3	0	9	0
Coho salmon	0	3	3	0	0	0	0
Carp	0	16	3	13	0	0	0
Chinook salmon	10	0	10	0	0	0	0
Trout-perch	0	25	8	16	0	1	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	1	1	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

July

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	250	24	30	38	158	0
Alewife	34	28	37	17	3	5	0
Rainbow trout	2	1	2	0	0	0	0
Lake trout	0	24	24	0	0	0	0
White sucker	39	52	84	0	0	7	0
Redhorse	2	16	18	0	0	0	0
Brown trout	8	5	20	0	0	0	0
Rainbow smelt	0	1	1	0	0	0	0
Longnose sucker	17	23	37	0	0	3	0
Gizzard shad	2	12	14	0	0	0	0
Yellow perch	33	62	38	0	5	52	0
Longnose dace	0	29	4	3	12	10	0
Coho salmon	0	1	1	0	0	0	0
Carp	0	6	5	1	0	0	0
Chinook salmon	36	0	36	0	0	0	0
Trout-perch	0	4	0	2	1	1	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

August

Species	Maturity: Immature	Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	234	18	0	15	101	0
Alewife	33	2	33	0	0	2	0
Rainbow trout	4	0	4	0	0	0	0
Lake trout	0	59	59	0	0	0	0
White sucker	15	44	59	0	0	0	0
Redhorse	1	29	30	0	0	0	0
Brown trout	15	11	26	0	0	0	0
Rainbow smelt	0	10	10	0	0	0	0
Longnose sucker	12	7	19	0	0	0	0
Gizzard shad	17	18	35	0	0	0	0
Yellow perch	14	6	18	0	0	2	0
Longnose dace	0	8	0	0	1	7	0
Coho salmon	2	4	6	0	0	0	0
Carp	0	7	6	0	0	1	0
Chinook salmon	2	0	2	0	0	0	0
Trout-perch	0	2	0	0	2	0	0
Round whitefish	0	1	1	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

September

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	72	54	0	0	18	0
Alewife	0	11	7	0	0	4	0
Rainbow trout	6	14	19	0	1	0	0
Lake trout	0	79	79	0	0	0	0
White sucker	6	20	26	0	0	0	0
Redhorse	0	10	10	0	0	0	0
Brown trout	1	16	17	0	0	0	0
Rainbow smelt	0	19	19	0	0	0	0
Longnose sucker	3	1	4	0	0	0	0
Gizzard shad	7	7	14	0	0	0	0
Yellow perch	0	1	1	0	0	0	0
Longnose dace	0	2	2	0	0	0	0
Coho salmon	10	18	26	2	0	0	0
Carp	0	0	0	0	0	0	0
Chinook salmon	1	19	19	1	0	0	0
Trout-perch	0	5	3	2	0	0	0
Round whitefish	0	2	2	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

October

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	39	39	0	0	0	0
Alewife	0	2	2	0	0	0	0
Rainbow trout	1	13	14	0	0	0	0
Lake trout	0	131	96	35	0	0	0
White sucker	0	9	9	0	0	0	0
Redhorse	0	3	3	0	0	0	0
Brown trout	0	6	6	0	0	0	0
Rainbow smelt	0	16	16	0	0	0	0
Longnose sucker	0	4	4	0	0	0	0
Gizzard shad	2	6	8	0	0	0	0
Yellow perch	0	0	0	0	0	0	0
Longnose dace	0	7	7	0	0	0	0
Coho salmon	8	30	36	2	0	0	0
Carp	0	0	0	0	0	0	0
Chinook salmon	0	1	1	0	0	0	0
Trout-perch	0	1	1	0	0	0	0
Round whitefish	0	1	1	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 1. (cont'd.).

November

	Maturity		Gonadal Condition				
Species	Immature	Mature	Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0
Rainbow trout	0	10	8	2	0	0	0
Lake trout	0	0	0	0	0	0	0
White sucker	0	0	0	0	0	0	0
Redhorse	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0
Rainbow smelt	0	0	0	0	0	0	0
Longnose sucker	0	0	0	0	0	0	0
Gizzard shad	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0
Longnose dace	0	0	0	0	0	0	0
Coho salmon	0	0	0	0	0	0	0
Carp	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0	0
Trout-perch	0	0	0	0	0	0	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0

Table 2. Monthly maturity and gonadal condition of each fish species captured in gill nets during 1977.

April

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Gonadal Condition: Ripe	Gonadal Condition: Partly Spent	Gonadal Condition: Spent	Gonadal Condition: Abnormal
Spottail shiner	0	11	10	1	0	0	0
Alewife	0	0	0	0	0	0	0
Rainbow trout	2	118	30	74	3	13	0
Lake trout	0	2	2	0	0	0	0
White sucker	0	30	20	3	0	7	0
Redhorse	0	3	3	0	0	0	0
Brown trout	5	20	25	0	0	0	0
Rainbow smelt	0	19	1	18	0	0	0
Longnose sucker	1	27	13	6	1	8	0
Gizzard shad	0	4	3	1	0	0	0
Yellow perch	0	0	0	0	0	0	0
Longnose dace	0	0	0	0	0	0	0
Coho salmon	2	1	3	0	0	0	0
Carp	0	5	3	2	0	0	0
Chinook salmon	0	0	0	0	0	0	0
Trout-perch	0	1	0	1	0	0	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	3	2	0	0	1	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

May

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	181	108	71	0	2	0
Alewife	5	50	58	4	0	2	0
Rainbow trout	7	48	13	35	3	4	0
Lake trout	0	17	17	0	0	0	0
White sucker	13	26	24	0	0	15	0
Redhorse	2	14	8	0	0	8	0
Brown trout	9	16	25	0	0	0	0
Rainbow smelt	0	6	2	4	0	0	0
Longnose sucker	12	22	18	1	9	15	0
Gizzard shad	0	0	0	0	0	0	0
Yellow perch	1	0	1	0	0	0	0
Longnose dace	0	17	15	2	0	0	0
Coho salmon	1	0	1	0	0	0	0
Carp	0	18	5	13	0	0	0
Chinook salmon	0	0	0	0	0	0	0
Trout-perch	0	8	4	4	0	0	0
Round whitefish	2	1	3	0	0	0	0
Lake chub	0	3	0	3	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	1	1	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

June

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	306	187	100	0	19	0
Alewife	11	81	87	5	0	0	0
Rainbow trout	0	3	2	1	0	0	0
Lake trout	0	17	17	0	0	0	0
White sucker	14	33	41	0	0	6	0
Redhorse	3	16	17	1	0	1	0
Brown trout	2	13	15	0	0	0	0
Rainbow smelt	0	1	1	0	0	0	0
Longnose sucker	6	4	10	0	0	0	0
Gizzard shad	0	3	3	0	0	0	0
Yellow perch	0	4	4	0	0	0	0
Longnose dace	0	11	7	3	0	1	0
Coho salmon	0	1	1	0	0	0	0
Carp	0	19	5	14	0	0	0
Chinook salmon	15	0	15	0	0	0	0
Trout-perch	0	13	7	6	0	0	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	1	1	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

July

Species	Maturity		Gonadal Condition				
	Immature	Mature	Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	1	274	95	46	22	112	0
Alewife	24	85	70	35	2	2	0
Rainbow trout	0	0	0	0	0	0	0
Lake trout	0	20	20	0	0	0	0
White sucker	36	22	58	0	0	0	0
Redhorse							
Brown trout							
Rainbow smelt	0	0	0	0	0	0	0
Longnose sucker	19	1	20	0	0	0	0
Gizzard shad	0	17	17	0	0	0	0
Yellow perch	6	36	9	1	32	0	0
Longnose dace	0	5	2	0	1	2	0
Coho salmon	0	0	0	0	0	0	0
Carp	0	7	1	6	0	0	0
Chinook salmon	13	0	13	0	0	0	0
Trout-perch	0	5	1	3	1	0	0
Round whitefish	0	0	0	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	1	1	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	1	1	0	0	0	0
Bloater	0	1	1	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

August

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	214	13	2	49	150	0
Alewife	38	18	42	1	0	13	0
Rainbow trout	6	6	12	0	0	0	0
Lake trout	0	25	25	0	0	0	0
White sucker	9	9	17	0	0	1	0
Redhorse	9	33	42	0	0	0	0
Brown trout	3	7	10	0	0	0	0
Rainbow smelt	0	0	0	0	0	0	0
Longnose sucker	1	8	9	0	0	0	0
Gizzard shad	35	15	50	0	0	0	0
Yellow perch	3	10	11	0	0	2	0
Longnose dace	0	19	1	0	7	11	0
Coho salmon	2	2	4	0	0	0	0
Carp	0	4	4	0	0	0	0
Chinook salmon	1	0	1	0	0	0	0
Trout-perch	0	8	1	7	0	0	0
Round whitefish	0	1	1	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	1	1	0	0	0	0

Table 2. (cont'd.).

September

Species	Maturity: Immature	Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	100	93	0	2	5	0
Alewife	29	4	32	0	0	1	0
Rainbow trout	2	32	34	0	0	0	0
Lake trout	0	68	68	0	0	0	0
White sucker	17	22	39	0	0	0	0
Redhorse	2	41	43	0	0	0	0
Brown trout	2	19	21	0	0	0	0
Rainbow smelt	0	68	68	0	0	0	0
Longnose sucker	3	0	3	0	0	0	0
Gizzard shad	0	10	10	0	0	0	0
Yellow perch	3	7	10	0	0	0	0
Longnose dace	0	11	5	0	5	1	0
Coho salmon	3	7	10	0	0	0	0
Carp	0	2	2	0	0	0	0
Chinook salmon	0	16	16	0	0	0	0
Trout-perch	0	4	2	2	0	0	0
Round whitefish	1	3	4	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

October

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	13	13	0	0	0	0
Alewife	5	3	8	0	0	0	0
Rainbow trout	6	38	35	9	0	0	0
Lake trout	0	234	114	9	0	0	0
White sucker	4	8	12	0	0	0	0
Redhorse	2	5	7	0	0	0	0
Brown trout	0				0	0	0
Rainbow smelt	0	4	4	0	0	0	0
Longnose sucker	0	0	0	0	0	0	0
Gizzard shad	2	4	6	0	0	0	0
Yellow perch	3	0	3	0	0	0	0
Longnose dace	0	2	2	0	0	0	0
Coho salmon	6	18	15	9	0	0	0
Carp	0	0	0	0	0	0	0
Chinook salmon	0	6	5	1	0	0	0
Trout-perch	0	0	0	0	0	0	0
Round whitefish	1	1	2	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

Table 2. (cont'd.).

November

Species	Maturity: Immature	Maturity: Mature	Gonadal Condition: Green	Ripe	Partly Spent	Spent	Abnormal
Spottail shiner	0	5	5	0	0	0	0
Alewife	1	0	1	0	0	0	0
Rainbow trout	3	35	18	20	0	0	0
Lake trout	0	7	2	5	0	0	0
White sucker	3	2	5	0	0	0	0
Redhorse	0	3	3	0	0	0	0
Brown trout	0	9	3	5	0	1	0
Rainbow smelt	0	1	0	1	0	0	0
Longnose sucker	0	0	0	0	0	0	0
Gizzard shad	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0
Longnose dace	0	0	0	0	0	0	0
Coho salmon	2	18	9	11	0	0	0
Carp	0	1	0	1	0	0	0
Chinook salmon	0	0	0	0	0	0	0
Trout-perch	0	0	0	0	0	0	0
Round whitefish	1	0	1	0	0	0	0
Lake chub	0	0	0	0	0	0	0
Northern pike	0	0	0	0	0	0	0
Bowfin	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0
Bloater	0	0	0	0	0	0	0
Smallmouth bass	0	0	0	0	0	0	0

APPENDIX B

Table 1. Water condition parameters at stations 1 and 8 (control) and climatic parameters for the sample area on each sample date from April - November, 1976.

Station	Water Temp. (C) 1	Water Temp. (C) 8	Turb. 1	Turb. 8	Crnt. Dir. 1	Crnt. Dir. 8	Wave Ht. (cm) 1	Wave Ht. (cm) 8	Wind Dir.	24 Hr. W Dir.	Baro. Pres.
Date											
04/01	3.0	3.0	27.0	12.0	-	-	7	15	N	SW	29.60
04/06	6.4	6.8	57.0	25.0	N	N	15	15	SW	SW	29.79
04/07	6.1	6.0	4.0	38.0	S	S	7	15	N	SW	30.09
04/09	7.0	5.3	1.7	12.0	S	S	7	7	SW	SW	30.28
04/13	7.9	6.0	85.1	19.0	N	N	7	7	S	S	29.94
04/19	13.9	13.9	49.0	12.0	N	N	15	15	S	S	30.02
04/21	0.2	9.8	28.0	4.0	S	S	7	7	E	E	29.48
04/24	9.2	8.1	2.0	7.0	N	N	1	1	E	N	29.86
04/28	7.8	6.9	14.0	37.0	N	N	7	22	N	N	29.70
04/29	6.0	7.8	7.0	22.0	N	N	8	8	NW	NW	30.20
05/06	7.1	8.1	3.4	58.0	N	N	5	15	N	N	30.23
05/11	8.9	9.9	4.4	99.0	N	N	8	14	N	N	29.94
05/12	10.2	11.5	3.9	14.0	S	S	5	5	SW	N	29.98
05/14	9.0	9.0	4.1	5.8	S	S	13	15	SW	S	29.85
05/19	5.0	5.0	3.8	15.0	N	N	7	8	N	N	29.95
05/24	4.0	7.5	2.9	72.0	N	N	5	14	N	N	30.02
05/26	7.0	8.0	-	-	N	N	3	3	W	N	30.08
05/31	9.0	9.0	2.7	2.1	0	0	3	4	E	E	29.80
06/02	10.0	9.8	2.5	26.0	S	S	2	6	N	NE	30.16
06/09	15.0	15.5	74.0	15.0	N	N	12	18	SW	S	29.96
06/12	19.5	19.5	20.0	3.2	N	N	7	7	SE	S	29.84
06/20	18.7	19.0	9.4	70.0	N	N	8	10	SW	SW	30.04
06/21	17.0	6.5	-	-	S	S	2	1	S	NW	30.00
06/22	17.0	19.0	2.2	14.0	S	S	5	6	SW	NE	30.02
06/23	19.5	19.5	7.5	4.0	N	N	5	7	SW	SE	30.08
06/28	19.0	19.0	-	-	S	S	5	9	S	S	29.80
07/01	7.0	6.5	4.5	16.0	S	S	3	6	N	N	30.00

Table 1. (cont'd.).

Station	Water Temp. (C) 1	Water Temp. (C) 8	Turb. 1	Turb. 8	Crnt. Dir. 1	Crnt. Dir. 8	Wave Ht. (cm) 1	Wave Ht. (cm) 8	Wind Dir.	24 Hr. W Dir.	Baro. Pres.
Date											
07/06	18.5	19.0	54.0	6.7	N	N	13	13	SW	SW	29.96
07/09	13.0	14.0	4.6	5.0	N	N	3	4	N	S	29.98
07/12	12.0	9.0	-	16.0	S	S	6	7	N	NE	29.89
07/15	17.5	18.0	13.0	5.0	N	N	3	7	SW	SW	29.79
07/21	17.0	16.0	18.0	1.5	S	S	5	5	NE	NE	30.06
07/22	18.0	18.5	8.9	2.4	N	N	5	3	NW	NE	30.01
07/26	21.0	21.0	14.0	3.2	S	S	4	9	NW	SW	29.93
07/28	19.5	19.0	4.2	2.3	S	S	5	11	E	E	29.78
08/02	10.0	10.0	11.2	26.0	S	S	3	7	NW	N	30.20
08/06	13.0	14.0	13.2	7.8	S	S	5	6	NE	NE	30.10
08/14	17.0	16.0	1.8	9.3	S	S	3	10	N	NE	29.90
08/15	14.9	13.0	4.2	75.0	S	S	1	4	N	NE	30.08
08/16	13.0	12.0	4.4	4.9	S	S	1	8	SE	S	30.18
08/18	13.0	13.0	2.1	2.3	S	S	3	4	SE	S	30.20
08/31	14.0	13.5	37.0	6.8	N	N	17	14	SW	NE	30.15
09/08	18.0	18.5	74.0	5.3	N	N	14	9	SW	SW	30.13
09/16	13.0	14.0	2.8	2.5	S	S	3	10	N	NE	30.24
09/26	8.5	8.0	7.7	9.8	S	S	5	8	E	NE	30.02
09/30	16.0	16.0	20.0	4.9	N	N	9	8	S	N	30.78
10/04	16.0	16.0	57.0	4.5	N	N	18	22	S	SE	29.90
10/05	11.5	14.0	15.0	88.0	S	S	7	15	E	N	29.88
10/07	10.0	15.0	2.8	5.6	S	S	3	10	NE	NE	30.22
10/11	13.5	12.5	4.5	9.6	N	N	11	13	S	SE	30.08
10/18	9.0	9.5	4.3	6.5	S	S	3	6	E	N	30.38
10/26	6.5	8.0	4.5	2.0	S	S	4	10	NE	NE	30.17
11/10	4.0	-	3.0	-	S	-	8	-	NW	NW	29.92

Table 2. Water condition parameters at stations 1 and 8 (control) and climatic parameters for the sample area on each sample date from April - November, 1977.

Station	Water Temp. (C) 1	Water Temp. (C) 8	Turb. 1	Turb. 8	Crnt. Dir. 1	Crnt. Dir. 8	Wave Ht. (cm) 1	Wave Ht. (cm) 8	Wind Dir.	24 Hr. W Dir.	Baro. Pres.
Date											
04/01	2.0	1.0	6.0	19.0	0	0	0	0	C	N	30.17
04/03	3.0	3.0	2.8	35.0	N	N	2	3	NE	N	29.80
04/13	9.0	10.0	18.0	18.0	S	S	12	17	N	S	30.03
04/15	1.0	2.0	10.0	9.5	N	N	2	3	E	E	30.10
04/18	7.0	8.5	1.6	4.5	S	S	4	3	C	N	29.92
04/20	9.0	12.0	160.0	3.9	S	S	4	3	S	S	29.92
04/26	6.0	5.5	8.0	28.0	N	N	2	5	W	N	29.81
04/29	4.0	5.0	12.0	38.0	N	N	4	3	E	N	30.18
05/02	10.0	10.0	16.0	5.4	S	S	3	10	N	S	30.19
05/04	8.0	9.0	4.0	4.0	N	N	3	1	E	N	29.90
05/09	7.0	7.0	5.2	37.0	S	S	2	8	S	N	29.64
05/10	11.0	10.0	2.0	12.0	N	N	1	2	SW	N	30.04
05/15	15.0	15.0	4.6	2.6	N	N	5	5	S	S	29.92
05/16	15.0	13.0	74.0	4.6	N	N	8	10	S	S	30.00
05/24	16.0	16.0	13.0	7.5	N	N	2	3	SW	S	30.01
05/25	14.0	17.0	7.7	17.0	N	N	1	5	E	N	29.98
05/31	10.0	11.5	5.0	5.0	N	N	4	3	E	E	29.70
06/06	12.0	13.5	4.4	3.9	S	S	2	6	N	N	29.69
06/07	13.0	11.0	1.7	13.0	N	N	2	3	S	N	29.78
06/13	8.0	8.0	2.2	4.3	S	S	1	3	NW	N	30.11
06/17	20.0	20.0	4.3	7.3	N	N	5	1	S	S	29.74
06/20	16.0	15.0	13.0	7.5	S	S	5	15	NW	S	29.78
06/22	13.0	13.0	2.3	3.3	S	S	2	1	N	N	30.00
06/27	19.0	18.0	1.3	1.5	N	N	3	5	S	S	29.68
06/30	17.0	15.0	68.0	8.4	N	N	13	20	S	S	29.39
07/05	21.0	25.0	54.0	4.2	N	N	6	6	S	S	29.84
07/07	21.0	21.0	3.5	45.5	S	S	1	5	E	S	29.84

Table 2. (cont'd.).

Station	Water Temp. (C) 1	Water Temp. (C) 8	Turb. 1	Turb. 8	Crnt. Dir. 1	Crnt. Dir. 8	Wave Ht. (cm) 1	Wave Ht. (cm) 8	Wind Dir.	24 Hr. W Dir.	Baro. Pres.
Date											
07/13	17.0	17.0	3.2	5.0	N	N	3	2	W	W	30.05
07/17	20.0	20.0	26.0	6.0	N	N	3	5	SW	S	29.93
07/18	20.0	19.0	44.0	31.0	N	N	12	20	SW	S	29.88
07/21	24.0	23.0	8.1	6.3	S	S	3	2	N	S	30.07
07/26	12.0	10.0	3.1	3.4	S	S	3	15	NW	N	30.17
07/31	18.0	17.0	94.0	5.5	N	N	20	12	W	S	29.64
08/07	19.0	20.0	9.0	2.1	N	N	5	4	S	S	29.82
08/10	19.0	19.0	34.0	6.6	N	N	6	8	NW	W	29.86
08/13	18.0	18.0	16.0	3.1	N	N	10	18	W	SW	29.78
08/16	17.0	19.0	42.0	2.4	N	N	10	12	S	W	29.80
08/18	18.0	18.0	1.6	17.0	N	N	5	7	SW	NW	30.00
08/23	16.0	16.0	3.7	4.4	S	S	1	2	NE	N	29.90
08/25	8.0	8.0	1.2	1.6	S	S	1	2	E	N	30.18
08/29	17.0	18.0	2.2	37.0	S	S	1	4	SE	S	20.16
09/06	19.0	18.0	22.0	4.5	S	S	15	17	N	S	30.02
09/08	16.0	15.0	2.6	6.8	S	S	2	2	SE	N	30.02
09/13	15.0	16.0	2.7	6.9	S	S	4	12	NE	E	29.82
09/22	14.0	14.0	3.9	8.7	N	N	5	4	N	E	30.04
09/23	14.0	15.0	5.2	51.0	N	N	12	7	E	E	29.92
09/27	15.0	15.0	4.1	1.9	S	S	4	12	W	W	29.78
10/03	8.0	9.0	2.8	21.0	S	S	10	25	N	N	30.23
10/05	10.0	10.0	5.9	43.0	S	S	4	8	N	W	29.96
10/13	9.0	9.0	36.0	30.0	N	N	13	8	W	W	30.02
10/17	9.0	9.0	54.0	43.0	N	N	8	6	N	N	30.04
10/19	9.0	9.0	16.0	27.0	S	S	6	22	NW	N	29.96
10/20	9.0	9.0	17.0	25.0	N	N	12	8	S	NW	30.11
10/25	12.0	12.0	15.0	15.0	N	N	13	15	S	S	29.96
10/26	11.0	11.0	9.9	9.2	N	N	9	20	SW	S	30.00

Table 2. (cont'd.).

Station	Water Temp. (C) 1	8	Turb. 1	8	Crnt. Dir. 1	8	Wave Ht. (cm) 1	8	Wind Dir.	24 Hr. W Dir.	Baro. Pres.
Date											
11/01	12.0	12.0	52.0	4.2	N	N	10	12	NE	NE	29.78
11/02	12.0	12.0	47.0	7.9	N	N	10	12	NE	NE	30.08
11/07	10.0	10.0	8.0	5.5	S	S	2	5	N	E	30.35
11/08	11.0	11.0	3.0	3.1	N	N	3	2	W	S	29.30
11/30	3.0	3.0	30.0	7.9	N	N	3	2	S	S	30.14