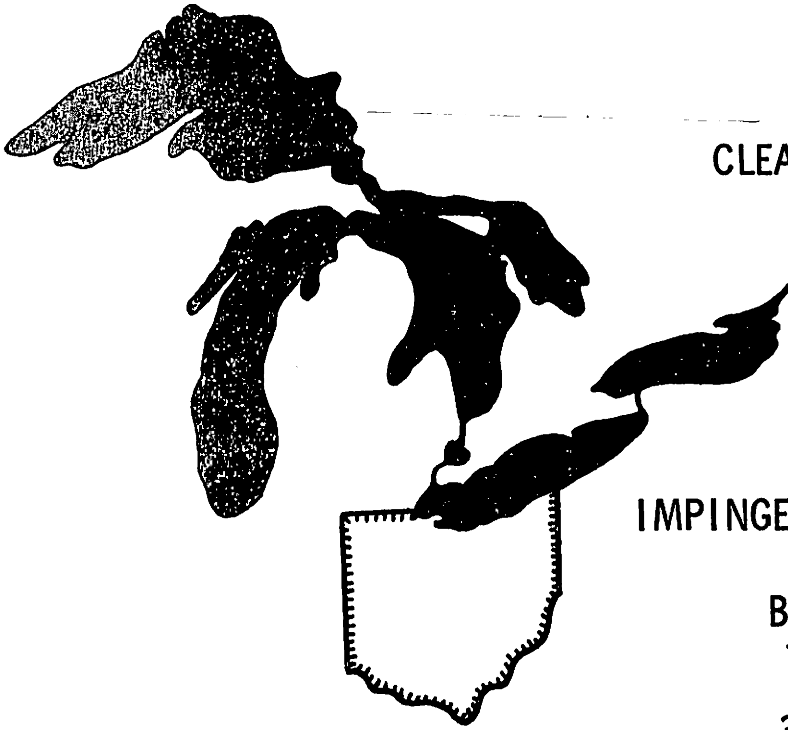
OHSU-S-78-003



CLEAR TECHNICAL REPORT NO. 78b

IMPINGEMENT AND ENTRAINMENT STUDIES AT THE BAY SHORE POWER STATION, TOLEDO EDISON COMPANY

316(B) PROGRAM, TASK II

Prepared by

Jeffrey M. Reutter
Charles E. Herdendorf
George W. Sturm

Submitted to

Toledo Edison Company
Toledo, Ohio

JUNE 1978

CENTER FOR LAKE ERIE AREA RESEARCH
THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO

TABLE OF CONTENTS

PROJECT STAFF

PRINCIPAL INVESTIGATORS

Dr. Charles E. Herdendorf
Dr. Jeffrey M. Reutter

TECHNICAL PERSONNEL

Michael L. Adams
Margarita Apanius
William C. Bartholomew - Entrainment Team Leader
Charles A. Bowen - Impingement Team Leader
Donald L. Breier
Richard Cherry
Dr. C. Lawrence Cooper - Field Team Leader
Donald H. Davis
Dr. Peter Fraleigh - University of Toledo Coordinator
John R. Hageman
John E. Hansley
Ralph E. Hubner Jr.
Theresa M. Karpinecz
Lynwood A. MacLean
Algimantas J. Pliodzinskas
Paul S. Roth
Ellen Russel
Harry A. Schutte III - Impingement Team Leader

STATISTICAL AND COMPUTER ANALYSIS

Margarita Apanius - Keypunching
Dr. Paul I. Feder
Laurie J. Fletcher - Keypunching
David W. Lowrey
George W. Sturm - Leader

TOLEDO EDISON LIAISON STAFF

Richard Crouse
David Domzal
Richard Jenne
Kenneth Mauer
James Sullivan

SECRETARIAL AND EDITORIAL STAFF

Dolores J. Adair
Margarita Apanius
Norma J. Darnell
Laurie J. Fletcher
JoAnn Franks
Pam Wertenbach

LIST OF TABLES

LIST OF TABLES (CON'T)

LIST OF TABLES (CON'T)

LIST OF FIGURES

LIST OF FIGURES (CON'T)

LIST OF FIGURES (CON'T)

LIST OF FIGURES (CON'T)

SUMMARY AND CONCLUSIONS

The Bay Shore Power Station of the Toledo Edison Company is located at the mouth of the Maumee River on the southern shore of Maumee Bay. At a net capacity of 623 MW_e the four coal-fired, steam electric units utilize 1149.3 cfs of water for once-through cooling at a calculated temperature rise of 9.6°F above ambient. The water is withdrawn from the Maumee River and discharged into Maumee Bay. The scope of the work performed for the following 316 (b) demonstration for this power station was in direct compliance with a study plan agreed upon by the U.S. Environmental Protection Agency (Region V), the Ohio Environmental Protection Agency, and the Toledo Edison Company in a meeting held on June 11, 1976 in Columbus, Ohio.

Studies of fish impinged on the intake traveling screens of the power station were conducted during the period September 15, 1976 to September 15, 1977. To summarize, impinged fish were collected during a 24-hour period once every seven days from September 15, 1976 to March 16, 1977 and from June 16 to September 15, 1977, and once every four days from March 16 to June 16, 1977. Each 24-hour collection was divided into a 12-hour "night" and a 12-hour "day" collection. Fish were collected by placing a basket (1/4 inch bar mesh) in the sluiceway leading from the traveling screens. This basket was monitored and emptied when full. The fish so collected during each 12-hour sampling period were sorted by species and then into size classes. Based on the coefficient of variation within each size class, the number of fish which had to be weighed and measured (standard length) individually to estimate the mean weight of the fish within that size class to within 10% of the true mean (95% confidence) was determined. The total weight of all fish impinged during each collection period was determined by actual field measurement. The total weight of each species or size class divided by the mean weight provided the estimate of the number of fish within that species. Data were keypunched, placed on magnetic tape, and then analyzed with an IBM 370-165 computer.

The volume of water pumped through the plant during each collection period was recorded and used to convert impingement numbers to a concentration (number/m^3). Concentrations from several sampling days were then averaged and used to estimate impingement on non-sampling days based on the volume of water pumped through the plant on the day in question. The above process was repeated for each species daily throughout the year except when there was a "fish run". Due to their erratic occurrence and duration, fish runs were treated as separate entities and not used for predictions of impingement on non-sampling days. However, the date and time of each run (including those which occurred on non-sampling days) and an estimate of the number of fish impinged during the run were added to the data set.

Studies of entrained fish eggs and larvae were conducted at the power station during the period September 1, 1976 to September 1, 1977. However, since the occurrence of ichthyoplankters is quite seasonal, the actual sampling for larvae was done from September 1 to September 15, 1976 and from March 16 to September 1, 1977. This period corresponds well with those of studies conducted by the USEPA in western Lake Erie. To summarize, two submersible pumps were placed in the intake canal in front of the trash racks (one meter below the surface and one meter above the bottom) and operated continuously for a 24-hour period once every seven days from September 1 to September 15, 1976 and June 16 to September 1, 1977 and once every four days from March 16 to June 16, 1977. Each 24-hour period was divided into a 12-hour "night" and a 12-hour "day" collection. The effluent from each pump emptied into a plankton net to capture ichthyoplankton. Larvae were identified and categorized by developmental stage. The ichthyoplankton concentration per unit volume of water was determined. The mean of surface and bottom ichthyoplankton concentrations from each period was multiplied by the total flow through the plant during that 12-hour period to obtain the number of larvae and eggs entrained with the cooling water. Mean ichthyoplankton concentrations from several sampling days were averaged and used to estimate entrainment losses on non-sampling days based on the flow through the plant on that day. All of the above data were keypunched and analyzed with an IBM 370-165 computer.

Ichthyoplankton collections were also made during the day at three locations in the Maumee River immediately upstream from the power station. Three 3-minute replicate tows were made at the surface and bottom of each location with a 0.75-meter diameter heavy duty oceanographic plankton net equipped with a calibrated flow meter. The number of larvae of each species and each developmental stage was then divided by the volume filtered to estimate larvae concentrations in the river. The river flow rates and corresponding ichthyoplankton concentrations permitted an estimation of ichthyoplankton populations in the Maumee River.

In addition to the above efforts, physical parameters including temperature, conductivity, and current direction and speed were measured at the river stations and in front of the trash racks. For correlative purposes these data were supplemented with water levels, river flow rates, and weather data.

Fifty-two species were collected in impingement samples during this study. No species listed on the "Federal Register of Endangered Species" were impinged, however, 4 species considered to be endangered in Ohio by the Ohio Division of

Wildlife were impinged. For the remainder of this section (Summary and Conclusions) all discussions and estimates for both entrainment and impingement pertain to the entire study period, including non-sampling days.

Only one fish run occurred and during this 12-hour run, it is estimated that 506,112 fish weighing 2,436 kg were impinged. It is estimated that during the remainder of the year, 17,810,633 fish weighing 170,708 kg were impinged. It is probably safe to assume that at least 10 percent of these fish survive when returned to the lake.

Sport fish make up a relatively small portion of those impinged at Bay Shore as impingement is primarily a seasonal gizzard shad problem subject to wide variability in daily number and volume. Approximately 75 percent of the total number and 85 percent of the total weight of fish impinged during the study were impinged between October 13 and February 2, and gizzard shad constituted 70 percent of the total number and 83 percent of the total weight of fish impinged during this 3.5-month period. Furthermore, the combination of gizzard shad, emerald shiner and alewife, 3 forage species, constituted 97 percent of the total number and 96 percent of the total weight of fish impinged during this 3.5-month period. The remaining 25 percent of the total number and 15 percent of the total weight of fish impinged during the entire year were distributed over the remaining 8.5-months. The weight of each species impinged was less than 1.0 percent of the total commercial harvest of that species from Lake Erie for all species of high economic value (channel catfish, walleye, white bass, yellow perch, etc). Furthermore, it was indicated that percent by weight is a more appropriate comparison than percent by number. Walleye impingement (12,187 individuals) amounted to less than 0.1 percent of the brood stock of western Lake Erie.

Correlations and multiple regressions developed for impingement on a yearly basis were of little value, however, on a quarterly basis, multiple regressions were occassionally useful in interpreting results or possibly predicting relative numbers of several species of fish impinged.

The volume of the Maumee River estuary is less than 2 percent of the volume of the Western Basin of Lake Erie. However, previous reports indicated the estuary was more productive on a fish per unit volume basis than the Western Basin for gizzard shad, freshwater drum, white bass, walleye, and logperch. These previous studies also indicated that the estimated abundance of larvae in the estuary was, at times, as great as the estimated abundance in the entire Ohio portion of the Western Basin.

Estimates indicate approximately 284,718,000 larval fishes and 426,150,000 fish eggs were entrained at the Bay

Shore Power Station from September 1, 1976 to September 1, 1977. The larvae of sport fish made up a relatively small portion of the entrainment as gizzard shad was the dominant species entrained representing 78.4 percent of the total. Furthermore, all significant entrainment of larval fishes occurred between May 15 and July 15.

Ichthyoplankton populations in the river were developed based on the mean ichthyoplankton concentration in the river and the flow down the river from April 9 to September 1, 1977. It was estimated that during this period 7,303,256,000 larvae passed the intake to the Bay Shore Power Station. The number entrained was estimated to be 3.9 percent of this total. However, based on the maximum temperature experienced by the larvae during condenser passage, it is estimated that only 1.3 percent of those passing the plant are killed. Furthermore, natural mortality for the remaining larvae is quite high. Yellow perch is the only species for which mortality estimates exist, and for this species it is estimated that the 2,426,431 larvae entrained could have produced 24,264 age 3 adults.

It should be noted that the above estimates of the number of larvae passing the power plant intake are based on river flow data which may fail to accurately account for larvae originating from the bay or lake. Due to the complexity of the hydrology of the river, estuary, bay and lake, these contributions can be significant. For example, emerald shiners and yellow perch were collected in greater numbers when the water mass at the intake was of bay origin. It is felt that the estuary and bay should really be viewed as one unit, a gradient between the river and lake water, rather than two separate entities.

Each year the Ohio Division of Wildlife develops estimates of year class strength for several fish species from the Western Basin of Lake Erie based on the number of young-of-the-year (YOY) caught per trawling hour. Based on these results, which ranked 1977 YOY populations of walleye and white bass as "extreme high" and YOY populations of yellow perch and freshwater drum as "excellent", one must conclude that entrainment and impingement losses at the Bay Shore Power Station are small in comparison to natural mortality and other factors governing the YOY populations of these species. Furthermore, and again based on the Ohio Division of Wildlife's YOY index, one can not demonstrate an adverse impact of the YOY populations of these species in the Western Basin of Lake Erie due to entrainment and impingement losses at the Bay Shore Power Station.

INTRODUCTION

Section 316(b) of Public Law 92-500 (Federal Water Pollution Control Act of 1972) requires that the location, design, construction, and capacity of cooling water, intake structures reflect the best technology available for minimizing adverse environmental impact. If it can be demonstrated that a power station, with its present design, is not having an adverse effect on the environment, the requirements of the above law have been met. It is the purpose of this report to define and evaluate fish impingement and entrainment at the Bay Shore Power Station of the Toledo Edison Company. This should allow determination of the significance of this impact on the fish communities of the Maumee River and Lake Erie. The scope of the work performed, as described in this report, was in direct compliance with a study plan agreed upon by the U.S. Environmental Protection Agency (Region V), the Ohio Environmental Protection Agency, and the Toledo Edison Company in a meeting held on 11 June 1976 in Columbus, Ohio. Three volumes of appendices accompany this report.

IMPINGEMENT

Impingement is the noun form of the verb impinge, arising from the Latin verb "impingere" meaning "to fasten". In the terminology of 316(b) discussions, impingement refers to fish which are impinged on the traveling screens at the cooling water intakes of power plants. The U.S. Fish and Wildlife Service (Edsall and Yocom, 1972) has concluded that the constant pressure exerted on the impinged organisms by the cooling water flow can prevent their escape from the intake screens and, as a result, may cause them to perish by suffocation. The number of fish impinged depends on both physical and biological factors. Some physical factors that may contribute to impingement include: (1) intake structure design and location, (2) the volume of water withdrawn, (3) the velocity of water approaching and flowing through the intake screens, (4) time of day, (5) meteorological conditions, (6) ice control procedures, (7) water levels and currents, and (8) water temperature and other water quality characteristics. Some biological factors affecting impingement include: (1) the species in question and their population densities, (2) their seasonal abundance, (3) size, (4) swimming ability (speed and endurance), (5) distribution in the water column, (6) diel activity, and (7) physiological condition of the organisms (presence or absence of stress, coefficient of condition, etc.). Quantitative predictions of fish impingement and correlations of impingement with individual biological or physical parameters are extremely difficult due to the complexity of the interactions between the physical and biological factors.

Recently, King *et al.* (1977) and Tatham *et al.* (1977) have shown that assuming 100 percent mortality of impinged fish is a conservative approach as actual mortality ranges from 10-93 percent depending on the species, season, and mode of traveling screen operation. Continuous operation of the traveling screens produced the highest survival. These results are to be expected if Edsall and Yocom's (1972) hypothesis of suffocation on the traveling screens is true, for when traveling screens are operated continuously, impinged fish have less time to suffocate.

ENTRAINMENT

Entrainment is the noun form of the verb entrain, meaning "to draw along with" and originates from the Middle French verb "entrainer," meaning "to drag". In the terminology of 316(b) discussions, entrainment refers to aquatic organisms, smaller than the mesh of the intake screens, which are "entrained" with the cooling water flow and drawn through the plant. The most-frequently entrained organisms are: (1) microscopic algal cells (phytoplankton), microcrustaceans, protozoans and rotifers (zooplankton), and (3) planktonic eggs and larvae of fish (ichthyoplankton). Only the ichthyoplankton segment is addressed in this report.

Nature has countered the extremely high natural mortality rates these early life stages suffer with high fecundities. Many species lay over 500,000 eggs yearly. However, entrainment of these early life stages still warrants scrutiny since future age classes must arise from this group.

Quantifying entrainment requires frequent monitoring due to the high variability in the densities of fish eggs and larvae. However, these forms are present for only a few months each year, and entrainment losses for any planktonic species can be estimated simply by multiplying densities observed in front of the intake screens by the flow through the plant. It should be noted that this technique yields the number which are entrained but does not address entrainment mortality. Recently, Cannon *et al.* (1977) found that mortality of entrained fish larvae generally ranges from 0-30 percent when the maximum temperature experienced by the larvae during condenser passage is less than 30°C.

STATION DESCRIPTION

The Bay Shore Power Station is located on the southern shore of Maumee Bay at approximately 41°41'00" N latitude and 83°26'00" W longitude, near the mouth of the Maumee River (Figure 1). This is a base load station with a net summer capacity of 623 megawatts (MW_e) and net winter capacity of 636 MW_e provided by four coal-fired, steam electric units. At a net capacity of 623 MW_e, this station utilizes 1149.3 cfs (32.55 cms) of water for once-through cooling at a calculated temperature rise of 9.6°F above ambient. Cooling water for the Bay Shore Power Station is obtained from the Maumee River and after traversing the condensers, is discharged to Maumee Bay (Figure 2). Cooling water enters through a 3,000-foot inlet canal and discharges through a short canal.

The 3,000-foot long intake canal is 250 feet wide and varies in depth from 15 to 20 feet, depending on silt accumulation and dredging frequency. The cooling water traverses a trash rack and one of nine 1/4 or 3/8-inch mesh traveling screens before entering the condenser (Figures 3 and 4). Material collected on the traveling screens is washed into a sluiceway and transported to the discharge canal.

Heated discharge water is recirculated into the intake area in winter when the intake temperature drops below 35°F. A gate between the intake and discharge canals is opened and remains open until spring (December to late March) when water temperatures rise. Approximately 10 percent of the total plant cooling water is recirculated at these times. Most of the recirculated water enters the unit number 1 condenser where the Maximum ΔT attributable to recirculated water is 2-3°F.

ANALYSIS OF FACTORS AFFECTING ENTRAINMENT/IMPINGEMENT AND ITS SIGNIFICANCE

OBJECTIVES OF ANALYSIS

A literature review of Maumee River and Bay hydrology and the biology and economic importance of fish species resident in the lower Maumee River and Maumee Bay of Lake Erie was conducted in an attempt to determine the reasons for the incidence of entrainment and impingement of those fish species and size classes collected, and to determine the significance of these losses to man. Factors included in this analysis were: (1) swimming speeds, (2) fecundity, (3) economic and trophic importance, (4) hydrology, (5) habitat preference, and (6) rare and endangered species status. The following sections discuss these factors and relate them to the impingement/entrainment potential for important species. These results will be related to the results of the monitoring program to place fish impingement and entrainment at the power station in perspective with fish population dynamics in the Maumee River and the Western Basin of Lake Erie.

Swimming Speeds

Ichthyoplankton, consisting of fish eggs and larvae, is the portion of the fish population which is susceptible to entrainment at the power station. Being planktonic, fish in these life stages are incapable of sustained swimming and, therefore, have virtually zero swimming speeds. Until the post-larval stages, these individuals are largely passive floaters and their primary mobility is due to water currents.

Adult swimming speeds are generally related to body form (morphology) and length. Burst speeds of 10 body lengths (BL) per second and cruising speeds of 3 BL/sec are generally accepted for fish (Bainbridge, 1958; Blaxter, 1969). Cruising speeds can be sustained for up to several hours (Bainbridge, 1960). Fry and Hart (1948) observed that swimming ability decreases rapidly when the temperature is extremely low or high.

Much work has been done over the past eighty years on fish swimming speeds. Comparison between investigators is difficult, however, because the differences in apparatus and in definition of various swimming responses. Apparatus has varied from a rotating annular chamber to photography of a fishes progress against a measured background. Therefore, various types of swimming speeds were measured. Burst speed is a quick, unsustainable response of only a few seconds. It is usually utilized to escape danger. Cruising (sustained) speed is used more in migratory studies when speeds are maintained over a long period of time.

Regnard (1893) concluded that the maximum burst speed of fishes was 10 times the body length per second. Bainbridge (1958), who later measured speed in relation to amplitude and size of tail beat arrived at the same conclusion. Blaxter (1969) concluded that the only fishes capable of burst speeds of 10 times the body length per second were Salmonids (trout, lake whitefish, and cisco), Scombriods (pelagic fishes of tropical, sub-tropical, and temperate open oceans), and some freshwater and a few marine species. He further states that the cruising speed for most fishes is between 2 to 3 body lengths per second.

Most of the work dealing with swimming speeds of fishes was performed with marine or western North American species. There are, however, some measurements of swimming speeds for fish species found in Lake Erie. Measurements for 19 of these species are given in Table 1. Table 2 contains the list of references used as data sources for fish swimming speeds in Table 1.

Intake velocities were measured at the trash racks in front of the traveling screens at the power station in September and December 1976 and in March and June 1977. Maximum, minimum, and mean velocities from each date are listed in Table 3. Under average conditions, fish greater than 8.5 cm in length, and under maximum velocity conditions, fish greater than 21.5 cm in length, should easily escape impingement. This assumption is based on a sustained swimming speed of 3 BL/sec.

Fecundity

Fecundity is the general term used to describe the number of eggs produced by fish (Lagler, *et al.*, 1962). The number of eggs that are produced by an individual female varies according to a great many different factors including age, size, conditions, and species. Some eggs are buoyant (pelagic) and have specific gravity about the same as fresh water, e.g., freshwater drum. Most stream and nearshore lake fish, on the contrary, have eggs that are heavier than fresh water, causing them to sink (demersal) and have an adhesive coating which keeps them from being swept away by currents.

The reproductive characteristics of 33 common Lake Erie species are listed in Table 4. This list was derived from a large number of sources; figuring most prominently were the following: Trautman (1957), Carlander (1953), and unpublished observations of fishery biologists with the Ohio Division of Wildlife and the U.S. Fish and Wildlife Service. The first column gives sexual maturity, listed either as age class, length, or weight at which maturity is normally reached. The second column is spawning temperature. The third and fourth columns are fecundity. Egg production is listed as eggs per female of a specific age, weight, or length. In some cases, more than one figure is given to indicate changes in reproductive capacity with age. Spawning season is column five. The season listed is for Lake Erie; however, if data were not available specifically for Lake Erie, data from a comparable latitude were used. This is also true for spawning temperature. Longevity is the final column in the reproductive portion of the table. Fish species are listed in phylogenic order, with scientific and common names in accord with those recommended by the American Fisheries Society in its Special Publication No. 6, A List of Common and Scientific Names of Fishes From the United States and Canada,1970. The information given under fecundity characteristics for each of the species has been obtained from one or more of the 50 numbered references (indicated in parenthesis following the data) which are listed in Table 5.

The reported fecundity of the most commonly entrained species ranged from a few thousand to nearly a million eggs per female. With the exception of yellow perch (44,000) and emerald shiners (500-1,500), all of the common species (gizzard shad, white bass, freshwater drum, and walleye) have a mean egg production between 300,000-600,000 per female. Therefore, because of similar fecundities, entrainment of a particular species appears to be related more to the number of gravid females in the area than to the relative egg production between species.

Economic and Trophic Importance

Commercial fishing has been an important industry for people living around western Lake Erie for over 100 years. Annual Lake Erie production (commercial catch) has varied between 15,000 to 35,000 tons (average 25,000 tons) which accounts for approximately 50 percent of the total annual production of the Great Lakes (Hartman, 1973). Presently yellow perch and rainbow smelt are the most important commercial species. The walleye population, which has been closed to commercial fishermen in Ohio and Michigan for the past five years, has recovered to a point where commercial catches may soon be permitted.

Sport fishing in the Ohio waters of Lake Erie is a popular sport. In 1977, approximately 1,175 tons of fish were taken in these waters (Table 6). Yellow perch, white bass, walleye, freshwater drum, and channel catfish, respectively, were the most common species taken. They accounted for over 97 percent of the total catch.

The economic and trophic importance of 17 of the common fish found in Maumee Bay is given in Table 7. The following discussion of related research in Maumee River and Bay will serve to highlight the trophic status and ecological niche of the important fish species impinged and entrained at the power station.

In conjunction with an environmental impact assessment of commercial sand and gravel dredging in the lower Maumee River and Maumee Bay of Lake Erie, the Center for Lake Erie Area Research (Herdendorf and Cooper, 1975 and 1976) conducted investigations of the adult and larval fish populations in these areas. Sampling stations (Figure 1) extended 15 km upstream beyond the power station and 15 km into Maumee Bay. Stations 43 and 44 were located near the water intake channels for the Bay Shore and Acme Power Stations, respectively. Adult nektonic fish populations were sampled with gill nets during the period May to October 1975, while larval fish populations were sampled with ichthyoplankton nets during the periods June-August, 1975, and April-June 1976. Gill nets were set bi-weekly at stations 9, 11, 15, 16, 43, and 44, while plankton net tows were made tri-weekly (1975) and every four days (1976) at stations 2, 16, 16A, 43, 44, 75, and 76, and every 10 days (1976) at stations 37, 30, 39, 40, 41, and 42 (Figure 1). The following discussions of important commercial, sport, and forage fish are based on the results of this study.

Maumee Bay and River adult fish catches were dominated by rough fish species (Table 8). The gizzard shad was the most abundant species captured. Other fish contributing significantly to the total catch were alewife, carp, and freshwater drum. Forage fish captured were spottail shiner and emerald shiner, with the former more abundant. Both species occurred more frequently and in greater numbers in the bay. Important game and sport fish captured were: walleye, yellow perch, white bass, and channel catfish. The largest catches of these species were made in the bay. The sauger, an important species recently stocked in Lake Erie, was captured in both the bay and the river; the majority were captured in the river.

Several generalizations can be made concerning the age structure of the fish populations. Walleyes mature between the ages of II and III. The data indicates mostly immature walleyes were captured. It is thought that walleyes moved through the study area prior to the first sampling period. Data collected by the Ohio Division of Wildlife in April of 1975 indicates that large numbers of walleyes were present above Perrysburg at that time (Figure 1). Over 900 walleyes were tagged by the Ohio Division of Wildlife during four 4-hour electro-shocking trips (personal communication, Russell Scholl, Ohio Division of Wildlife, Fish Management Section). The white bass captured were mostly immatures, below age class III. A mature population of yellow perch (age II and III) was indicated by 1975 captures. The majority of the mature yellow perch were taken in the bay. Channel catfish mature later, between the ages of IV and VI. Very few channel catfish were captured, and of these only a small percentage were mature. Mature channel catfish occurred mainly in the bay.

Fish catches in the bay averaged 245 fish per net set. The largest catch in the bay occurred in the month of August. River fish catches averaged 32 fish per net set with no month producing a substantially larger number of fish except when large numbers of alewife or gizzard shad were taken in a single net. Station 43 had the largest total catch of the four river stations. The peak month for this station was October. The peak month in the bay was controlled by a surge of gizzard shad, while the peak month at station 43 at the river mouth was caused by a surge of alewives.

The fish catch and larvae records indicate that the gizzard shad was the dominant species in the bay and river, using both as nursery grounds and adult habitat. Yellow perch adults and larvae were also numerous in the bay and, to a lesser extent, in the river. Although few adult white bass were captured, large numbers of larvae appeared in the bay during May and June. Walleyes did not appear to be numerous after the April spawning run.

Commercial and sport fish of major interest. Walleye larvae were encountered during a four-week period, April 7-May 7, 1976, in the Maumee River at Perrysburg and in the riffle zone above Perrysburg. Larvae were encountered sporadically during a five-week period, April 13-May 20, 1976, in the mid and lower reaches of the Maumee River estuary. Mean larval densities at the station in the Maumee River riffle zone did not exceed $9.5/100m^3$. Mean densities in the mid and lower Maumee River estuary did not exceed $3/100m^3$. The numbers of larvae estimated for the Maumee River estuary ranged from 7.02×10^6 to 4.21×10^7 during this period. Samples taken in Maumee Bay yielded larvae on two dates, April 21 and 30. The maximum mean density ($23.5/100m^3$) occurred at station 41, a sandy ridge at the outer end of the bay. The number of larvae in Maumee Bay and adjacent Lake Erie on April 21 was estimated at 3.275×10^6. The number on April 21 was estimated at 2.78×10^7. Larval densities recorded from the Maumee River riffle zone were considerably lower than anticipated, while those from Maumee Bay were higher. The rapid and early warming of the water in the riffle zone, due to record-setting high temperatures in early April, appeared to have limited spawning at this well-recognized spawning site. It can be argued that spawning activity was transferred to the cooler waters of Maumee Bay due to climatic conditions occurring in the 1976 season. Coincidentally, spawning habitat provided this species by completion of the U.S. Corps of Engineers Diked Disposal Area may have increased spawning in the bay, especially along the margins of the dike. Emery (1976) listed walleye as common commercial and sport fish in Lake Erie.

White bass larvae were encountered in samples during a seven-week period extending from April 27 to June 8. Larvae were least abundant in the Maumee River at Perrysburg and in the riffle zone above Perrysburg. Larvae were taken first and in greatest numbers in the mid and lower reaches of the Maumee River estuary. The maximum number encountered (mean density=499/100m^3) occurred in samples taken during the first week of June. Inspection of larval densities indicates considerable spawning occurred during a relatively short period of time. This study indicates that the shallows and island-dominated region of the upper Maumee River estuary are significant spawning areas for Lake Erie white bass. White bass larvae were encountered in Maumee Bay on a single date, June 6. The number of larvae in Maumee Bay and adjacent Lake Erie on June 6 was estimated at 2.116 x 10^6. Emery (1976) listed white bass as common commercial-sport-forage fish in Lake Erie.

Larvae of yellow perch were not encountered in samples taken in the Maumee River at Perrysburg, the riffle zone above Perrysburg, or in the mid reaches of the Maumee River estuary. Yellow perch were taken sporadically over a three-week period, April 30-May 22, in Maumee Bay. Larvae captured at the mouth of the estuary must be considered bay-spawned fish due to their absence further upstream. The maximum mean density (38/100m^3) occurred at station 39 in Maumee Bay, a shallow water inshore station relatively close to the U.S. Corps of Engineers Diked Disposal Area. Spawning habitat provided this species by the Disposal Area may have resulted in much higher numbers of larvae in the near vicinity of the dike than indicated by estimates based on sampling stations located some distance from the margin of the dike. The number of larvae in Maumee Bay and adjacent Lake Erie on April 30 was estimated at 1.805 x 10^6, on May 10 at 4.635 x 10^6, and on May 22 at 1.38 x 10^6. Emery (1976) listed yellow perch as common commercial-sport-forage fish in Lake Erie.

Commercial and sport fish of minor interest. Carp larvae were captured in the Maumee River estuary from April 23 to June 8. Larvae were most abundant in the Maumee River at Perrysburg and in the riffle zone above Perrysburg. Mean densities in the river at and above Perrysburg ranged from 0.5 to 582/100m^3. The abundance of larvae in the mid and lower reaches of the Maumee River estuary are much lower relative to the Maumee River proper. Mean densities in the estuary ranged from 0.5 to 18/100m^3. Larvae were not captured in Maumee Bay. Emery (1976) listed carp as common commercial-sport-forage fish in Lake Erie.

Freshwater drum were encountered in samples collected during the latter portion of this study, May 27-June 8. Larval drum were not captured in the Maumee River at Perrysburg.

Larval abundance at each station in the mid and lower Maumee River estuary and in Maumee Bay was low and represents the initiation of spawning by this species. The number of larvae in Maumee Bay and adjacent Lake Erie on June 7 was estimated at 6.59×10^5. Emery (1976) listed freshwater drum as commercial-sport-forage fish in Lake Erie.

Larvae of rainbow smelt were not encountered in samples taken in the Maumee River at Perrysburg, the riffle zone above Perrysburg, or in the mid reaches of the Maumee River estuary. Smelt larvae were captured on two dates, May 20 and 27, at the mouth of the Maumee River estuary, station 43, and on two dates, May 10 and 22, in Maumee Bay. Larval densities ranged from 0.5 to $4.5/100m^3$. Larvae captured at the mouth of the estuary must be considered bay-spawned fish due to their absence further upstream. The number of larval smelt in Maumee Bay and adjacent Lake Erie on May 10 was estimated at 5.29×10^6 and on May 22 at 1.183×10^7. Emery (1976) listed rainbow smelt as commercial-sport-forage fish in Lake Erie.

Gizzard shad larvae far exceeded those of any other species encountered during this study. Low densities (mean ranged from 1 to $7/100m^3$) were encountered from May 25 to June 8 in the Maumee River at Perrysburg. No larval shad were captured in the riffle zone above Perrysburg. Larvae were captured from May 18 to June 8 in the mid reaches of the Maumee River estuary. In the mid reach, densities in the main channel (station 2) were relatively high; mean densities ranged from 5 to 665 from May 18 to June 8, while the densities at stations outside the channel (16 and 16A) increased slowly, maximum mean density at the latter stations was $2,195/100m^3$. Shad larvae were encountered in samples from the lower reaches of the estuary (stations 43 and 44) during two intervals, April 23 to April 27 and May 10 to June 8. Densities during the first interval, a period of warm weather, were low, 0.5 to $8.5/100m^3$. From May 10 to June 8 densities in the lower reaches of the estuary were considerable; mean densities ranged from 30 to $1,202/100m^3$ at station 44, while a slow increse to high levels occurred, maximum of $1,100/100m^3$, at station 43 at the mouth of the estuary. These observations indicate spawning probably occurs in the mid reaches of the estuary and water movements result in increasing numbers at the mouth of the estuary. Larval shad were encountered in Maumee Bay on April 30, May 22, and June 6. Densities in the Maumee River estuary exceeded those in the Bay by 1-2 orders of magnitude. The number of larvae in Maumee Bay and adjacent Lake Erie on April 30 was estimated at 7.945×10^6, 0.0 on May 10, 3.03×10^6 on May 22, and 3.92×10^7 on June 7. Emery (1976) listed gizzard shad as commercial-forage fish in Lake Erie.

Other species. Larvae of crappie, logperch, spottail shiner, and white sucker occurred sporadically and in low densities; densities rarely exceeded $4/100m^3$. For Lake Erie, Emery (1976) listed crappies (black and white) as common sport fish; common shiner as an uncommon forage fish; logperch as an uncommon, although formerly common fish without assigned importance; spottail shiner as a common forage fish and white sucker as a common commercial-sport-forage fish.

Hydrology

Maumee River characteristics. The Maumee River is formed in Fort Wayne, Indiana by the merger of the St. Joseph River and the St. Marys River. The St. Joseph River originates in Hillsdale County, Michigan and flows southwest to Indiana. The St. Marys River originates in Shelby County, Ohio and flows northwest to Indiana. The Maumee flows from Fort Wayne through Defiance to Toledo and Lake Erie. The entire drainage basin is 6,586 square miles, 1,260 are in Indiana, 470 in Michigan and 4,856 in Ohio (Ohio Division of Water, 1960). The basin has a circular shape with a diameter of roughly 100 miles. The average gradient of the Maumee River is 1.3 ft/mile. The St. Marys averages 2.8 ft/mile and the St. Joseph 1.6 ft/mile. Some of the headwater tributaries have gradients as high as 10 ft/mile.

The main stem flows generally northeast from Ft. Wayne to Toledo, Ohio, about 135 miles distance. The Maumee River empties into Maumee Bay, a shallow basin at the southwestern tip of Lake Erie. The relatively flat basin yields a low gradient and a correspondingly sluggish flow. With a mean discharge of approximately 4,700 cfs (ranges from a high of 94,000 cfs to a low of 32 cfs), it is not a large river, but it is the largest tributary to the Great Lakes (Great Lakes Basin Commission, 1975). Mean flow for October 1974 through September 1975 was 5,420 cfs, with a maximum flow of 49,000 cfs in February 1975. The Maumee River accounts for only 3 percent of the flow into Lake Erie, but included in this discharge is 1.2 million tons of suspended solids annually, representing 37 percent of the total sediment load to the lake. Low relief, gentle gradient and fine-grained soils account for many of the rivers traits: its low velocity, muddiness and sediment-clogged bed (Horowitz, *et al.*, 1975). Floods occur annually during the early part of the year usually in February, March or April. The floods are caused by rainfall, frozen ground and melting snow. These factors are accentuated by the inability of the slow, sluggish Maumee to accept the increased load.

The lower 15 miles of the Maumee River can be considered a freshwater estuary. The formation of this estuary on Lake Erie is the result of a series of geologic events related to Pleistocene glaciation. The flow of the Maumee River was reversed from its southwest direction when the glacial lakes drained from the Erie Basin as the ice sheet melted exposing the Niagara River outlet. Base-level lowering accelerated river velocities and the Maumee valley was cut deeply into lacustrine deposits, glacial tills and bedrock. With the weight of the ice removed, the outlet eventually rebounded and produced a rise in water level. The lake encroached upon the valley forming the present drowned stream mouth which is analogous in many ways to a marine estuary. Virtually all of the tributaries entering Lake Erie on the Ohio shore have estuarine-type lower reaches where lake water masses affect water level and quality for several miles upstream from traditional mouths (Brant and Herdendorf, 1972).

The estuary of the river begins just above the Maumee-Perrysburg Bridge where the bedrock riffles end. As the water enters the estuary, its velocity abruptly diminishes, except during major run-off events, causing sedimentation of suspended particles. Within the estuary, currents are extremely unstable. Reversals of flow due to fluctuations in Lake Erie water levels have been measured by Herdendorf (1970a). The estuary is approximately a mile wide at Eagle Point and nearly 30 feet deep in the dredged navigation channel (Figure 1). Early maps and charts show that the estuary was frequently 25 feet deep even before the Corps of Engineers began to improve the harbor. Horowitz, *et al.*, (1975) considered the estuary a reservoir, a sloshing dilution basin where the river is progressively mixed with backflow from the lake, and a large settling basin where solids from upriver are sedimented and occasionally scoured during periods of major flushing. They also reported that the river water can be relatively stagnant for long intervals.

Miller (1968) observed that currents in Toledo Harbor exhibit some of the properties of tidal currents, in that they reverse when the water level changes from "flood" to "ebb" during wind tide and seiche activity. During the period May to November 1966 he found that 90 percent of the time the currents were less than 15 cm/sec (0.5 ft/sec), and that the maximum speeds, about 45 cm/sec (1.5 ft/sec), occurred during the greatest rate of change in water level, whereas the minimums are at times of high and low water. A comparison of simultaneous data obtained from current meters and drogues showed that current speeds in the mid-channel were up to 2.5 times greater than near the channel edge. Miller also made estimates of river discharge magnitude in relation to its effect on the currents during seiching. Below 7,000 cfs current maintains its reversing characteristics and the effect of river discharge on current speed is not easily recognized. Above this discharge value the current reverses from its down-channel direction only during periods of rapid rises in lake level. For discharge rates greater than 20,000 cfs, the up-channel current component usually disappears even with 40 cm (1.3 ft) seiche amplitudes. Periods with this rate of flow are infrequent and of short duration. Horowitz, *et al.* (1975) also studied the hydraulic complexities of the estuary. In May and September 1974 they demonstrated periods of stagnation, river flushing and reverse flow with stage recorders and drogues; as the water level rose, lake water was pushed into the estuary, as it fell, river water flowed into the bay.

They estimated that each one-foot change in water level causes the volume of water in the estuary to adjust by approximately 120 million cubic feet.

Maumee Bay characteristics. Maumee Bay lies at the western end of Lake Erie between 41°41'N and 41°45'N latitude and 83°20'W and 83°29'W longitude, mainly in Lucas County, Ohio. It is separated from Lake Erie by two spits: (1) Woodtick Peninsula, with North Cape at its southern tip, extends southerly from the Michigan shoreline and (2) Cedar Point projects northwesterly from the Ohio shore (Figure 5). Bathymetrically, Maumee Bay is a broad, shallow shelf sloping gently downward toward the northeast. The maximum depth is 10 feet below low water datum (LWD) and the mean depth is 5 feet (Benson, 1975). Relief of the bay floor is low except for the areas surrounding the navigation channel, which bisects the bay in a northeast-southwest direction. Adjacent to the channel, about 2000 feet from either side, are a series of linearly arranged islands and shoals, sandy at their surface (Charlesworth, 1974), that were formed from spoil banks when the channel was dredged to 25 feet in the 1930's. In the 1960's the channel was deepened to 28 feet. The navigation channel is now 500 feet wide and maintained to minimum depth of 28 feet below LWD. Dredging activities for the channel extend upstream 6 miles from the mouth of the river and lakeward for a distance of 17 miles. Presently, the dredged material from the inner five miles in the bay and all of the river is dumped in a diked disposal facility (Toledo Island) within the bay (a new disposal area on the east side of the river mouth was recently completed and will meet the dredged disposal needs for the next ten years). Lakeward from the five mile limit, the dredgings are dumped in designated areas in the open lake (U.S. Army, Corps of Engineers, 1974). At the entrance to the bay, Turtle Island on the north side of the channel and Cedar Point spit to the southeast also produce noticeable changes in the bottom topography. Maumee Bay and the adjacent portion of Lake Erie under consideration in this study covers approximately 30 square miles, seven square miles of which have sand deposits with the remainder composed of silt and clay.

Maumee Bay is characterized by a low clay shore, highly developed as a residential area on the west, and grading through a less intense development on the south to marsh on the northeast. Except for short reaches of sand on the bay side of Cedar Point, the Bay has practically no beaches. The material offshore is lacustrine clay with a thin overburden of recently deposited silt, except near Cedar Point where the overburden is a relatively thick layer of sand. The lacustrine clay, up to 30 feet thick, was laid down in the glacial lakes which once covered a large part of northwest Ohio and southeastern Michigan. The lake clay is in turn underlain by sandy glacial till approximately 80 feet thick with Silurian dolomite below (U.S. Army Corps of Engineers, 1945). Slopes in the Maumee Bay nearshore zone are gentle. Within 1000 feet of the bay shore depths are generally less than 5 feet below LWD. Benson (1975) found that within 100 feet of the shore slopes ranged from 185 to 370 ft/mile, but lakeward of 500 feet offshore, slopes were generally less than 10 ft/mile.

The Ohio Department of Natural Resources, Division of Shore Erosion (Verber, 1954 and Hartley, 1960) extensively studied Maumee Bay sediment deposits and concluded that none of the sand can come from the Maumee River because the river loses its sand carrying capacity upon reaching lake level, near Perrysburg, as evidenced by the fact that "muck" is found as the bottom material in the lower reach of the river, at its mouth, and all the way out to the sand spit in the bay. They also concluded that sand does not come from the shores of Maumee Bay because the banks are composed of clay containing a negligible amount of sand.

Walters and Herdendorf (1975) demonstrated that the Maumee River has produced a sediment plume that extends from Maumee Bay into western Lake Erie by measuring the concentration and distribution of mercury in the surficial sediments. This technique indicates that recent sedimentation in Maumee Bay ranges from 0.5 to 1.0 cm/year.

McBride (1975) lists seven sources of sediment supply to and within Maumee Bay: (1) Maumee and Ottawa Rivers which supply fine grained material to the western and southwestern part of the bay, (2) Lake Erie which may supplv additional fine grained material to the bay, (3) relatively coarse material transported into the bay from the north by the southeasterly flowing longshore current along the lakeward side of North Cape, (4) coarse grained material brought into the bay system by the longshore current flowing in a northwesterly direction along Cedar Point, (5) residual coarse material found in the southern bay as a result of the winnowing and removal of the fine-grained component of the underlying Pleistocene, pebbly till-clay, (6) lateral dispersal of coarse material from the spoil banks along the navigation channel probably supplies some coarse material to the southern bay, and (7) erosion of the rip-rap along the southern shore and Point Place may supply a minor amount of sediment to nearshore areas. He also divides the bay into three basic areas based on the prevalent energy conditions and subsequent sediment grain size characteristics: (1) wave and littoral current dominated, characterized by relatively high energy conditions and relatively coarse-grained, relatively well sorted sediments, (2) wave dominated, characterized by moderate energy conditions and relatively coarse-grained, relatively poorly sorted sediments, and (3) sheltered areas, characterized by low energy conditions and fine-grained, poorly sorted sediments. He points out that the man-made spoil banks, as well as the underwater extension of Cedar Point act as barriers, sheltering the western part of the bay and the area just southwest of Cedar Point, respectively from the intense wave activity generated by strong northwest winds. Throughout the bay, the turbulent forces resulting from wave activity are probably the major factor controlling the distribution of sediments once they have entered the bay.

The primary driving forces that produce current in the Maumee River estuary are wind tides, seiches and river discharge. The estuary and harbor area of Maumee Bay are not greatly affected by longshore currents because of the sheltering effect of man-made fills (Miller, 1968). The outer parts of the bay, in the vicinity of Cedar Point spit and North Cape, are more strongly affected by longshore currents. Wind tides are a direct result of wind stress which pushes water toward the leeward shore, increasing the water level at that shore while it is depressed on the windward shore. As the wind force diminishes, the stress cannot maintain the gradient, resulting in a free oscillation of the lake surface or seiche. The period for a longitudinal seiche (NE - SW) on Lake Erie is approximately 14 hours (Verber, 1960). Wind-produced fluctuation occurring in conjunction with prevailing low or high water have resulted in water levels ranging from 7.5 feet below (U.S. Army, Corps of Engineers, 1945) to 7.4 above (Carter, 1973) LWD.

The Maumee Bay shore is exposed to storm waves mainly from the east to northeast to north. The maximum fetch distance for the Maumee Bay shoreline is approximately 50 miles which restricts the development of large waves. The shallow nature of the bay causes "deep water" open lake waves to break, reform, and break again several times before they reach the shore, thus dissipating much of their energy (Benson, 1975). The maximum annual "deep water" wave height which could be developed in the western basin of Lake Erie had been calculated by the U.S. Army, Corps of Engineers (1953) to be approximately 8.1 feet at Monroe, Michigan during the ice free period of the year. The depth of water at which a wave breaks is approximately 1.3 times the wave height (U.S. Army, Corps of Engineers, 1961). No detailed analysis of wave characteristics is available for Maumee Bay but Benson (1975) stated the generalization that wave heights are lower in the bay than for the open lake due to: (1) predominately offshore winds which do not generate large nearshore waves in the bay, (2) low fetch distances when compared to other portions of the Lake Erie shoreline and (3) shallowness of the bay which precludes the formation or translation of large waves. In particular he concluded that the spoil islands adjacent to the navigation channel exert a "tremendous influence" on the wave characteristics of the bay. Waves crossing the spoil mounds interact with the bottom and break, thus acting as an offshore breakwater offering protection to the west shore of

Maumee Bay when waves are from the east or northeast and for the south shore when waves are from the north or northwest. Benson also stated that the subaqueous portion of the Cedar Point spit can influence wave activity within the bay by buffering large open lake waves from the north and northeast.

Waves approaching the shore obliquely generate littoral currents which flow parallel to the shoreline and may attain velocities capable of eroding and transporting particles as large as sand and gravel, particularly during storm periods. The material moved and redeposited by these currents, generally sand and gravel, is termed littoral or longshore drift. There is little or no littoral drift within Maumee Bay, but its low, clay banks are experiencing a shore recession rate up to 20 feet per year (Herdendorf, 1975) with an average of 5 feet per year or volumetrically, 1.2 cu. yds. per foot per year (Benson, 1975). The original U.S. Land Survey of the south shore of Maumee Bay in 1834 shows the shoreline to be between 1000 to 1400 feet lakeward of the present shore (U.S. Army, Corps of Engineers, 1961). However, littoral drift moving south along the Michigan shore is responsible for the formation of Woodtick Peninsula. Similarly, drift moving predominately northwest along the 15-mile stretch of Ohio shores of Lake Erie between Locust Point and Cedar Point has formed the Cedar Point - Turtle Island spit.

Water quality. The Maumee River estuary, for much of its 15-mile length is polluted. Despite its "gross" pollution designation, few of the numerical water quality standards are violated (Horowitz, *et al*, 1975). Dissolved oxygen and fecal coliform bacteria, particularly downstream from the Anthony Wayne Bridge, are the principal parameters which exceed the standards. Over one million tons of sediment flow down the river to the estuary annually. This produces continually turbid conditions in the lower reaches of the river. Also carried by the river are substantial quantities of fertilizers and pesticides. Approximately 160,000 tons of nitrogen, phosphorus and potassium and 16,000 tons of herbicides, fungicides, and insecticides are applied to farm lands within the basin annually. Turbidity in Maumee Bay decreases 130 percent from the river mouth to navigation light No.30 (five miles offshore) and reaches background concentrations approximately 15 miles into Lake Erie (Pinsak and Meyer, 1975). The general trend is for high concentrations of nutrients, chloride, silica, calcium, sodium, magnesium and potassium in the river to decrease northeastwardly across the bay. The Toledo Lucas County Port Authority (Fraleigh, *et al.*, 1975) conducted a comprehensive investigation in 1974 of water quality and biota of Maumee Bay with particular emphasis on the proposed diked disposal area adjacent to Harbor View. This study found that Lake Erie has a pronounced effect on the water quality of the bay; the dilution effect of the lake in summer tends to improve water quality in the bay. In general, good quality lake water enters the bay from the east and poor quality water enters from the south and west via the Maumee and Ottawa Rivers.

In mid-March 1975, a survey was conducted by the Center for Lake Erie Area Research (Herdendorf *et al.*, 1977a) in the lower Maumee River, Maumee Bay and the adjacent portions of western Lake Erie to determine the quality of water issuing from the river. The study was conducted during spring run-off in an attempt to quantify the effect of the river discharge. The sediment-ladened effluent from the river coupled with wave-resuspended sediments produced highly turbid water for approximately seven miles offshore at the outer terminus of the bay.

Figure 6 illustrates the composite surface temperature of the lower Maumee River, Maumee Bay and the adjacent part of western Lake Erie during the March 1975 cruise. Three zones of high temperatures were observed: (1) Maumee River mouth, (2) discharge from the Bay Shore Power Station immediately east of the river mouth and (3) discharge from Consumers Power Company generating plant at the base of Woodtick Peninsula. The temperature of Maumee Bay decreased progressively from the river mouth (6^{o}C) to 11 miles offshore at the Toledo Harbor Lighthouse (3^{o}C). Northeast of the lighthouse a wedge of colder (1^{o}C) Detroit River water appears to have been moving toward the bay. Water lakeward to the 3^{o} contour (seven miles) appears to be directly related to Maumee River outflow. Conductivity contours (Figure 7) show the Maumee River as a source of highly mineralized water flowing into Maumee Bay. The conductivity patterns are similar to those observed for temperature, except that the river seems to be the main source of highly conductive water. A definite flow of Maumee River water toward the east is indicated by a lobe in the contours projecting in that direction beyond the bay. Based on the decrease in conductivity across the bay (600 to 300 umhos/cm), the concentration of dissolved ions at the lighthouse is about half of that found at the river mouth indicating a rapid dispersion rate. A wedge of low conductance (200 umhos/cm) Detroit River water was noted moving toward the southwest.

Habitat Preference

The Western Basin of Lake Erie, including Maumee Bay, has long been considered important in the reproduction of many fish species, due to its shallow nature and many reefs and shoals (Hartman, 1970). Trautman (1957) and Scott and Crossman (1973) provide life history information on Lake Erie fish species and indicate that many lake-dwelling populations are migratory, utilizing tributary waters, such as the lower Maumee River and Maumee Bay, as spawning and nursery areas. This attraction of spawners to tributary waters results in the concentration of spawning activity and consequently fish eggs and larvae in relatively small areas.

Tables 7 and 9 contain summaries of the habitat preferences of common fish species in Lake Erie. The habitat requirements of the 33 species listed on Table 7 were derived from Trautman (1957), Scott and Crossman (1973), and direct observations by the authors. The first two columns indicate the preferred habitat for spawning. For the purpose of this table, tributaries are defined as the portions of Lake Erie tributaries that are above the estuarine or "lake effected" lower reaches of these streams. Nearshore includes the shallows (less than 10 meters) near the shore, offshore reefs and shoals, and estuarine lower courses of the tributaries. The remainder of the characteristics refer to the preferred habitats for mature individuals during non-spawning seasons. The demarcation of shallow and deep water has been taken at a depth of approximately 10 meters. Water clarity refers to the amount of suspended particulate material (largely inorganic) in the water. Turbid water can roughly be defined as that having a Secchi disk transparency of less than one meter. Bottom types have been subdivided primarily on the size of the sediment particles forming the bottom. Mud is defined as semi-fluid silt-and clay-sized particles (less than 62 microns). Sand includes sand-and gravel-sized particles which include pebbles and cobbles (62 microns to 256 mm). Rocky bottoms include boulders (256 mm to 4096 mm) and larger slabs of exposed bedrock. Organic bottoms are generally fine-grained in nature but contain high percentages of partially decomposed plant and animal parts. Rooted aquatic plants (macrophytes) are categorized on density of growth rather than type. Table 9 contains a similar listing for both spawning and nursery habitat preferences.

Maumee River habitat. The Maumee River is a large, warm-water, low gradient stream draining relatively flat farm land in northwestern Ohio. The soils in the drainage basin are formed primarily from glacial till and lacustrine deposits left from earlier stages of Lake Erie. The underlying bedrocks are mostly Silurian and Devonian dolomites and limestone; less prevalent bedrocks are sandstone and shale (Herdendorf and Cooper, 1975; Forsyth, 1975).

Miller (1968) stated that due to the sluggish flow and numerous wind-induced lake seiches, an outflow into the bay occurred only about 60 percent of the time. Planimeter measurements from a NOAA navigational chart (scale 1:15,000) indicate the area of the estuary to be approximately 14.0 square kilometers. The mean depth of the Maumee River estuary based upon 1,155 soundings appearing on the chart is 2.9 meters. A dredged navigational channel extending from the mouth of Maumee Bay to Rossford is maintained by the U.S. Army Corps of Engineers; about 12.9 kilometers of this channel with a mean depth of 6.8 meters lies within the estuary. In addition, lake levels during 1975-1977 were 1.0 meters higher than the depths appearing on the chart which represent levels referenced to Low Water Datum (568.6 ft., International Great Lakes Datum). From the area and average depth of the Maumee River estuary, the volume of the estuary was calculated to be approximately 5.80×10^7 cubic meters.

Maumee Bay habitat. Maumee Bay lies at the western end of Lake Erie, separated from the lake by two spits, Woodtick peninsula extending southerly from the Michigan shoreline and Cedar Point extending northwesterly from the Ohio shore. For the purposes of this study, the northeastern boundary of the bay includes the water at the mouth of Maumee Bay out to the 4-m depth contour. This yields an area of 88.3 km^2 and a water volume of $15.0 \times 10^7 m^3$. Maumee Bay is a productive spawning area because of its generally shallow nature and the various sand deposits located in the bay. The bay also acts as a catch basin for larvae produced upriver and, therefore, serves as a nursery ground.

Habitat preference in western Lake Erie. In conjunction with USEPA investigations of larval fish populations in western Lake Erie and the potential impact of power plants on these populations, the Center for Lake Erie Area Research (Heniken, 1977) conducted surveys designed to quantify fish larvae densities throughout the Western Basin during the spring spawning seasons of 1975-1977. The following discussion of habitat preferences for the major species in the Western Basin is derived from the results of these surveys.

Gizzard shad concentrations in western Lake Erie appear to be centered mainly in Maumee and Sandusky Bays; concentrations of larvae exceed $1000/100m^3$. These bays have the poorest water quality in the basin--Secchi disc readings seldom exceed 0.3m and specific conductance is approximately twice that of the open lake. To a lesser extent, the Ohio shoreline, which is influenced by plumes of turbid water from the Maumee River, is also a spawning area. Gizzard shad generally appear to utilize turbid water areas for lake spawning and nursery grounds.

Within the Western Basin, white bass larvae are also found exclusively in the bay areas. However, because of the large numbers of larvae found in the tributary rivers, the primary spawning grounds may not be the bays. The larvae found in the bays may originate in the rivers and flow downstream to the bays with river currents. The bays however, do serve as important nursery grounds.

Freshwater drum is another species found almost exclusively in the highly turbid areas. Drum eggs and pro-larvae contain a large oil globule which causes them to float near the surface. Eggs are often seen and collected on the surface. This characteristic permits them to survive in areas where oxygen tensions are low in the bottom water and also places the drum larvae in the surface waters where plankton is concentrated. The increase in drum populations in Lake Erie may be in part due to this characteristic.

Yellow perch larvae are found mostly in the nearshore areas and appear to be concentrated near the bottom. The tendency for perch to be near the bottom may be a reaction to light levels because in the more turbid areas of the lake stratification was not as obvious. Perch prefer to spawn in sandy areas with vegetation (Scott and Crossman, 1973). The inshore areas where the larvae were found are sandy to gravelly with Cladophora being the main vegetation.

Walleye larvae were not collected in large enough numbers in the lake to characterize their spawning areas; however, the walleye larvae were found in areas similarly to those preferred by the yellow perch. Walleye larvae were found inshore in sandy to rocky substrates. The presence of larvae inshore between Locust and Catawba Points could be a result of the southerly flow of the Detroit River across the reefs depositing larvae in this area (Figure 5). The fact that a large number of larvae were found on Niagara Reef (68/100m^3) indicates that the reefs are probably being utilized for spawning.

Emerald shiner larvae were found in highest numbers in the least-turbid and open water portions of the basin, especially in the deeper water adjacent to rocky reefs. Larvae were generally captured in the larger size ranges (late postlarvae to juvenile stages). These larvae either do not sense the collection net or are unable to avoid the net. If the latter situation is the case, then emerald shiner larvae are probably incapable of moving off the reefs under their own locomotion, but are swept off the reef by the same strong currents which are responsible for sweeping the reefs clean of sediments (Herdendorf, 1970b). The other alternative situation is that this species does spawn in deeper waters.

Neither spottail shiners nor carp larvae were ever collected in large numbers. Both species appeared centered in the Bass and Kelleys Islands areas. These species apparently favor the rocky areas around the islands. At times, Cladophora was scraped loose during bottom tows over the reefs and carp eggs were often found in this green, filamentous algae.

Rainbow smelt favor gravelly areas for spawning (Scott and Crossman, 1973). Distribution patterns for larvae in the Western Basin indicate that spawning probably takes place on the clean gravel bottoms in Canadian waters and that the larvae are carried southward by Detroit River flow. Smelt larvae are seldom collected nearshore or in bays where turbidity is high.

Habitat preferences in Maumee River. In conjunction with USEPA investigations of larval fish populations in western Lake Erie, the Center for Lake Erie Area Research (Snyder, 1978) studied the contribution of the Maumee and Sandusky Rivers to fish populations of western Lake Erie during 1975 and 1976. Sampling stations in the Maumee River extended from the riffle area at the head of the estuarine portion of the river to Maumee Bay. The following discussion of habitat preferences for the major species in the Maumee River is derived from the results of this study.

During the two years of the study, 19 species of larval fishes were recorded; another 4 taxa were identified to the genus or family level. Over 98 percent of the total catch was composed of 4 species: gizzard shad, freshwater drum, white bass, and carp. Four other species could be considered temporarily abundant; emerald shiners, log-perch, walleye, and white suckers each were the dominant species in the catch during the peaks of their populations.

The most abundant of all species found in the Maumee River was the gizzard shad, which comprised 67.4 percent of the total catch. Concentrations of these larvae in the Maumee River frequently exceeded 1000 per 100 m^3 in 1975 and 2000 per 100 m^3 in 1976. Gizzard shad were well-distributed and abundant at all sampling stations. Studies in western Lake Erie show that gizzard shad larvae are most abundant in areas where turbidity is high. Secchi disc readings in the river were often as low as 20 cm. This level of turbidity is fairly constant in the Maumee River throughout most of the year. Analysis of 1976 data showed that gizzard shad were randomly scattered in the water column until 29 May, after which a preference for the surface was seen. At the end of May, most gizzard shad were in the 8-10 mm length range, giving some indication of the size at which larvae may exhibit the ability to maintain a preferred depth. This preference for surface waters probably indicates a response to the phototropic movement of planktonic algae upon which the young shad feed. A preference for the lee of an island over the main channel or a sheltered backwater was implied by analysis of the data. This apparent attraction may be partially caused by the fact that the water depth at this station was only 1.5 meters, causing both the surface and bottom tows to be taken relatively near the surface.

Walleye larvae collected at riffle stations were found to be randomly distributed, indicating that newly hatched walleye pro-larvae are at the mercy of the river currents for their movements. Thus, early pro-larval walleye must remain in the main river current to survive; those which are carried into areas without currents could perish if their yolk sacs are absorbed before they are carried downstream into areas of zooplankton abundance. Walleye eggs collected at riffle stations exhibited a patchy distribution. Walleye eggs are demersal and nonadhesive after water hardening, usually being deposited in areas having clean gravel where they generally slip into crevices among the stones. Although many undeveloped eggs were seen that could have been recently spawned and not yet lodged into crevices, a large percentage were also seen in various advanced stages of embryonic development. This suggests that the eggs had been relatively stable for some period of time before being disturbed and carried by the current. Disturbances could be hydrological to some extent, such as increases in flow rate, or could be due to the activity of other organisms, including man. Walleye spawning areas in both rivers receive intense fishing pressure during spawning migrations with fishermen wading just feet apart in some locations where spawning walleye congregate. Walleye are not territorial during spawning and nests are not established. Most spawning occurs at night as spawners enter shallow areas from deeper sections downstream (Priegel, 1970). This allows some possibility that courtship and spawning behavior could disturb some previously deposited eggs. During 1976 walleye larvae did not exceed 3/100 m^3 in the Maumee River although peak densities on the riffles reached 9/100 m^3.

A species commonly encountered during May and June by sport fishermen around the riffle stations was the white bass. Sport fishing success for this species appeared rather high on most sampling dates; many times white bass were actually hooked in front of the net as samples were being taken. During the 1976 segment of this study in which riffle areas were sampled, no white bass larvae were captured at the Maumee River riffle stations. During this same period, white bass larvae in the estuary reached densities as high as 499/100 m^3 (June 8). This may indicate that white bass utilized spawning areas within the estuaries to a greater extent than riffle areas. White bass demonstrated a preference for sheltered backwater areas having reduced current rather than the main river channel or the lee of an island, and for bottom rather than surface waters. On almost all sampling dates during which freshwater drum eggs were collected the eggs were found to be more abundant in the main river channel than in the lee of an island or in a sheltered backwater area. Drum eggs are non-motile and at the mercy of river currents for their movements. Since white bass larvae were most abundant in the backwater areas which held the fewest drum eggs, this provides strong evidence that the larvae actively sought the quieter waters rather than being concentrated there by currents. This trend was seen best when larval densities were highest. During that period most white bass were in the post-larval stage, providing them with sufficient physical development to allow lateral movements.

Freshwater drum were also found to be abundant at all river stations. Although adult drum may be found in the estuary throughout the year, large numbers of adults ascend the tributaries in May and June to spawn. The eggs of freshwater drum contain a large, distinct oil globule which makes them the only species in Lake Erie with buoyant eggs. This buoyancy carries through to the pro-larvae causing them to float at the surface along with the eggs. Both the eggs and larvae of freshwater drum were found to be in the greatest abundance in the downstream areas near the river mouths. Since spawning occurs throughout the estuary, as evidenced by the presence of eggs, this downstream tendency quite likely represented the effect of eggs and larvae being carried down by currents and concentrated at the river mouths. Drum larvae, as with walleye and white bass, exhibited a preference for the bottom.

Carp larvae usually first appeared in mid-May and were encountered on most sampling dates thereafter. This species was found in far greater abundance at riffle stations rather than estuarine stations. Densities as high as 582/100 m^3 were observed in the riffles whereas estuarine densities did not exceed 20 per 100 m^3. Populations of larval carp were estimated to be higher in 1976 than in 1975 for the Maumee River estuary. However, the abundance of carp larvae in the shallow riffle zones and the high level of shoreline spawning activity witnessed during sampling suggest that limnetic sampling as performed in this study may not reveal the extent of larval carp production in the littoral areas of these estuaries. Carp appear to be one of the most cautious and evasive of all larval species encountered. A single specimen, 10.0 mm in length was captured in 1975; otherwise no specimens in excess of 8.5 mm were taken.

Emerald shiners were captured in all life stages from 6 mm pro-larvae to 41 mm juveniles. Like gizzard shad, emerald shiners display little net avoidance and large juveniles were common in late-summer collections; adults were also frequently captured in the plankton net. In 1975, the earliest appearance of emerald shiners was on June 25 in the Maumee River. This species, as with many shiners, has a prolonged spawning period; eggs are deposited and fertilized periodically throughout most of the summer (Scott and Crossman, 1973). Therefore, between June and August, young-of-year emerald shiners may be collected in all stages of development.

Logperch and white sucker larvae were found to share several similarities. Both species spawn at water temperatures of 9-12°C, closely following the walleye which spawns at 5-11°C (Scott and Crossman, 1973). Both larval species may appear during the same week. In 1976, the white sucker became the dominant species at the end of April, but was succeeded by the logperch in even higher numbers by mid-May. Rapid growth was displayed by both the logperch and white sucker; lengths in excess of 10 mm are often attained by the beginning of June.

The yellow perch and rainbow smelt are common species in Lake Erie (Emery, 1976), but apparently do not use the estuaries to a significant degree. Larvae of both species were often found to be common at river mouth stations in the Maumee River but no larvae of either species were found at any upstream stations during the two years of the study. The U.S. Army Corps of Engineers has constructed a diked disposal area at the mouth of the Maumee River using limestone riprap. New spawning habitat provided by this disposal area may have resulted in the increased presence of perch and smelt larvae at the mouth of the Maumee since neither species was collected at the mouth of the Sandusky River.

Certain species which one might expect to encounter in the estuaries were not collected, at least in large numbers. Alewives were not encountered in the estuaries during this study despite the abundance of the species in Lake Erie. Great Lakes alewives usually spawn on beaches and in ponds having outlets to the lakes, throughout the spring and early summer rather than in tributaries (Scott and Crossman, 1973). Gill netting efforts in the Maumee River conducted throughout 1975 yielded no adult alewives within the estuary on any collection date, except at the river mouth (Herdendorf and Cooper, 1975).

Sunfish and crappie larvae were very rarely encountered during the study, yet streamside observations and informal interviews with fishermen indicate that both taxa are common to the estuaries. Ictalurids were also infrequently encountered in the samples although several species are common to the estuaries (Trautman, 1957). Faber (1967) surveyed larval fishes in two northern Wisconsin lakes and found that certain species exhibited a preference for littoral areas and seldom ventured into limnetic regions. This tendency may be based upon avoidance of predators, a need to maintain visual contact with the shore or bottom, or other reasons. In any case, it must be recognized that the limnetic sampling performed in this and most other ichthyoplankton studies may not adequately sample all of the larval species inhabiting a given body of water.

The volume of the Maumee River estuary is less than 2 percent of the volume of the Western Basin of Lake Erie. Using data from a companion study to this investigation which surveyed the larval fishes found in a portion of the Western Basin (Heniken, 1977), the Maumee River estuary was found to be more productive on a fish per volume basis than the Western Basin for gizzard shad, freshwater drum, white bass, walleye, and logperch. The estimated abundance of larvae in the estuary was at times, as great as the estimated abundance in the entire Ohio portion of the Western Basin.

Rare and Endangered Species

No fish species listed as endangered on the Federal Register of Endangered Species were collected during this study. However, the Ohio Division of Wildlife (ODW) issued, effective 1 May 1976, a revised list of 40 endangered fish species in Ohio. These species are listed in "Endangered Wild Animals in Ohio," publication 316(R576) of the ODW. Of the 40 species listed, four were taken in impingement samples at the Bay Shore Power Plant.

Species	Number Sampled	Projected Annual Impingement Estimate
silver Lamprey (*Ichthyomyzon unicuspis*)	38	184
mooneye (*Hiodon tergisus*)	1	5
silver chub (*Hybopsis storeriana*)	27	123
channel darter (*Percina copelandi*)	1	1

No endangered species were taken in entrainment samples. Herdendorf and Cooper (1975) reported mooneye larvae in samples collected in May 1975 on a submerged sand bar at the entrance to Maumee Bay. No other endangered species have been reported from ichthyoplankton studies of the lower Maumee River or Maumee Bay within the past three years.

Although not on the endangered list, one rare species was collected in impingement samples, the threespine stickleback (*Gasterosteus aculeatus*). This species has not previously been reported for Lake Erie or the Maumee River. A total of 7 individuals were collected at the power station. It is suspected that the impinged fish of this species were released bait. This species is a common bait item sold by dealers along the Michigan shore of Lake Erie (personal communication, Dr. Andrew White, John Carroll University). Due to current reversals in the estuarine portion of the Maumee River, the origin of any of the rare and endangered species is not necessarily upstream from the power station.

The Ohio Division of Wildlife has based its list of endangered species on the state-wide status of a particular species. Consequently, the status of a species on a regional basis within the state or within a particular body of water is not necessarily endangered. The number of silver lampreys and silver chubs collected in the impingement samples suggests that these species are fairly abundant in western Lake Erie, and therefore, represent "healthier" or more stable populations than found at inland areas of the state.

Identification of rare and endangered species was confirmed by Dr. T.M. Cavender of The Ohio State University Museum of Zoology.

METHODS

IMPINGEMENT

Studies of fish impinged on the intake traveling screens of the power station were conducted during the period September 15, 1976 to September 15, 1977 (Table 10). Detailed collection methods (Herdendorf, 1976) and data analysis procedures (Feder *et al.*, 1976) are presented in Appendix A. To summarize, impinged fish were collected during a 24-hour period once every seven days from September 15, 1976 to March 16, 1977 and from June 16 to September 15, 1977, and once every four days from March 16 to June 16, 1977. Each 24-hour collection was divided into a 12-hour "night" and a 12-hour "day" collection. Fish were collected by placing a basket (1/4 inch bar mesh) in the sluiceway leading from the traveling screens. This basket was monitored and emptied when full. The percentage of time that the basket was out (being emptied) while the screens were running was recorded. Estimates of the total number of fish impinged were adjusted accordingly. The fish so collected during each 12-hour sampling period were sorted by species and then into size classes or "strata" within each species. This was done to reduce the coefficient of variation of the weights of each species or size class of fish. Based on the coefficient of variation within each size class, the number of fish which had to be weighed and measured (standard length) individually to estimate the mean weight of the fish within that size class to within 10% of the true mean (95% confidence) was determined. This method was initiated on October 6, 1976. Prior to that time, 30 individuals or 10% of the total number impinged for each species, whichever was greater, were weighed and measured. In either case (before or after October 6), the total weight of all fish impinged was determined by actual field measurement. The total weight of each species or size class divided by the mean weight provided the estimate of the number of fish within that species. Data were keypunched, placed on magnetic tape, and then analyzed with an IBM 370-165 computer utilizing the "Statistical Analysis System: SAS" (Service, 1972 and Barr *et al.*, 1976) software program.

The above method provided a reliable estimate of the number of fish impinged on actual sampling days. However, to estimate impingement losses on non-sampling days, it is necessary to obtain the average number of fish impinged per day using the results from several sampling days, which can be quite variable. This variability is largely due to changes in fish concentrations, physical factors, and variability in the volume of cooling water pumped through the station each day. Simply multiplying the mean impingement per day by the number of non-sampling days assumes that these parameters are constant, from day to day, which is not the case. To eliminate variable flow rates as a source of error, the flow of cooling water through the plant 24 hours per day throughout the sampling period was added to the data set. The cooling water flow was determined by multiplying the flow rate of each circulating pump in the station by its hours of operation. This permitted fish impingement on sampling days to be converted to a concentration (number of fish impinged per cubic meter of cooling water for both day and night samples). These concentrations were developed for total fish impingement and fish impingement per species. Values from several sampling days were then averaged and used to estimate impingement on non-sampling days based on the volume of water pumped through the power station on a particular day. Example: the mean concentration of yellow perch impinged on January 5, 12, and 19 (Collection periods 19, 20, and 21) during the "day" (days and nights were separated at 05:00 and 17:00) was multiplied by the flow through the plant on January 7 during the day to obtain the number of yellow perch impinged on January 7 during the day. The "night" results were treated similarly and added to the day results to obtain the total number of yellow perch impinged on January 7. The above process was repeated for each species daily throughout the year except when there was a "fish run". Fish runs are herein defined as a heavy accumulation of fish which causes traveling screens to turn on automatically and necessitates continuous operation of these screens. Due to their erratic occurrance and duration, fish runs were treated as separate entities and not used for predictions of impingement on non-sampling days. The duration of fish runs occurring on non-sampling days was recorded and used to predict impingement losses at these times based on rates of impingement obtained by actual measurement from runs which occurred on sampling days. Variability due to changes in the concentration of fish in the intake canals and other factors can never be totally eliminated and, consequently, remains as the major source of error in the estimates.

One specimen of each impinged species from each 12-hour sampling period was preserved for reference. This voucher collection is maintained at The Ohio State University. The Fishes of Ohio (Trautman, 1957) was used for identification. The identification of rare and endangered species was verified by Professor T.M. Cavender, curator of the fish collection at The Ohio State University Museum of Zoology.

ENTRAINMENT

Studies of entrained fish eggs and larvae were conducted at the power station during the period September 1 to September 15, 1976, and March 16 to September 1, 1977 (Table 10). Detailed collection methods (Herdendorf, 1977) and data analysis procedures (Feder *et al.*, 1976) are presented in Appendix A. To summarize, two submersible pumps (Kenco model no. 139) were placed in the intake canal in front of the trash racks (one meter below the surface and one meter above the bottom) and operated continuously for a 24-hour period once every seven days from September 1 to September 15, 1976 and June 16 to September 1, 1977 and once every four days from March 16 to June 16, 1977. Each 24-hour period was divided into a 12-hour "night" and a 12-hour "day" collection. The effluent from each pump emptied into a plankton net (50 cm diameter, 0.571 mm mesh) to capture ichthyoplankton. Larvae were identified and categorized by developmental stage (pro-larva, early post-larva, and late post-larva). The ichthyoplankton concentration per unit volume of water was determined by dividing the number of each species and each developmental stage in each collection by the volume of water pumped through the net during that 12-hour collection. The flow rate of each pump was recalculated on each sampling day. The mean of surface and bottom ichthyoplankton concentrations from each period was multiplied by the total flow through the plant during that 12-hour period to obtain the number of larvae and eggs entrained with the cooling water. All of the above data were keypunched and then analyzed with an IBM 370-165 computer utilizing the "Statistical Analysis System: SAS" (Barr *et al.*, 1976) software program.

The above method provided an estimate of entrainment on sampling days. Mean ichthyoplankton concentrations from several sampling days were averaged and used to estimate entrainment losses on non-sampling days based on the flow through the plant on that day. Example: the mean concentration of yellow perch pro-larvae from samples collected on May 15, 19, and 23 (Collection Periods 44, 45, and 46) during the "day" was multiplied by the flow through the plant on May 20 during the day (days and nights were separated at 05:00 and 17:00) to obtain the number of yellow perch pro-larvae entrained on May 20 during the day. "Night" results were treated similarly and added to the day results to obtain the total number of yellow perch pro-larvae entrained on May 20. Variability in these estimates as evidenced by the confidence intervals is due to variability in the ichthyoplankton concentrations between sampling periods.

In addition to the above intake-canal studies, ichthyoplankton collections were made during the day at three locations in the Maumee River immediately upstream from the power station (Figure 2). Three 3-minute replicate tows were made at the surface and bottom of each location with a 0.75-meter diameter heavy duty oceanographic plankton net (0.571 mm mesh) equipped with a calibrated flow meter for calculation of the water volume filtered. The number of larvae of each species and each developmental stage was then divided by the volume filtered to estimate larvae concentrations in the river. These results were keypunched as were the daily flow rates for the Maumee River as recorded by the U.S.Geological Survey gage at Waterville, Ohio. The river flow rates and corresponding ichthyoplankton concentrations permitted an estimation of ichthyoplankton populations in the Maumee River.

Taxonomic keys developed by Fish (1932), Norden (1961 a and b), and Nelson and Cole (1975) were used to identify larvae. Following preservation in 5% formalin and identification, specimens were transferred to glycerin and alcohol and stored. This voucher collection of specimens collected from each location on each sampling date is maintained at The Ohio State University, Columbus, Ohio.

PHYSICAL MEASUREMENTS

Temperature and conductivity profiles were made at 1-ft depth intervals from surface to bottom directly in front of trash racks 3, 5, and 8 and at 3-ft depth intervals at each river station during each collection period with a Beckman RB 3-3341 solubridge temperature-compensated meter. Current direction and velocity was measured at the same locations and depths in the river, and quarterly in front of each trash rack with a Hydro Products Model 960-S Profiling Current Meter System. The operating status of the deicing system was also monitored during each collection period. All of these data were keypunched for correlation testing with numbers and species of impinged fish.

In addition to the daily river flow rates and power plant intake rates mentioned earlier, weather data from the U.S. Weather Service at the Toledo Express Airport and hourly water level data from the U.S.Department of Commerce, NOAA Lake Survey Center, which measures lake levels adjacent to the U.S. Coast Guard Station in Toledo, directly opposite the Bay Shore intake, were keypunched. Weather data included temperature, wind speed, and wind direction at 3-hour intervals throughout the year and barometric pressure daily throughout the year. All these parameters and several of their derivatives were tested for correlation with impingement results. The derivatives included: (1) change in water level from 12 hours earlier and from 24 hours earlier, (2) change in air temperature from 12 hours earlier and from 24 hours earlier, (3) change in barometric pressure from the previous day, (4) change in river flow from the previous day, (5) change in wind speed from the previous 12 hours and from the previous 24 hours, (6) difference in conductivity between that observed in the intake canal at the Acme Power Station and that observed at the Bay Shore Power Station, and (7) difference in conductivity between the intake canal and the river.

Due to the frequency of current reversals as described in the "Hydrology" section of this report, the derivatives concerning change in water level and difference in conductivity were added to help identify the source water of the impinged fish. For example: (1) increasing water level generally indicates a current reversal and water entering the estuary from the bay, (2) since lake water has a lower conductivity than river water, a large difference between the conductivities observed at the two power stations indicates bay water entering the estuary, and (3) since the stations at which conductivity is measured in the river are slightly upstream from the plant intake, a higher value recorded in the river would indicate the plant is drawing water from downstream, whereas a higher value recorded in the intake should only occur during a sudden and rapid current reversal. A species with a high positive correlation with increasing water level would be a "lake species" which entered the estuary during a current reversal.

IMPINGEMENT

RESULTS

Scientific and common names of fish species collected in impingement samples are presented in Table 11. A total of 17,810,633 fish weighing 170,708 kg and representing 52 species were impinged at the Bay Shore Power Station from September 15, 1976 to September 15, 1977 (Table 12). These estimates were based on fish concentrations (no./m^3) observed on sampling dates and flow rates through the plant throughout the year (Figure 8). The above impingement estimates do not include fish runs. However, only 1 fish run occurred at Bay Shore during the monitoring program. This run occurred during the night collection on December 15 (collection period 16). During this 12-hour period 506,112 fish weighing 2,436 kg were impinged (Appendix B, Table B-10). Of this total, 143,723 fish (28%) weighing 1,522 kg (62%) were gizzard shad, 339,660 fish (67%) weighing 695 kg (29%) were emerald shiners, and 21,630 fish (4%) weighing 181 kg (7%) were alewives. Consequently, these three forage species constituted 99.8% by number and 98.4% by weight of all fish impinged during this run. For the remainder of this report, all discussions will refer to impingement during "normal" times (no fish runs) unless otherwise specified.

Gizzard shad was the dominant species impinged during the year, representing 63.7% by number and 71.8% by weight of total fish impingement (Table 13). The combination of three forage species, gizzard shad, emerald shiner, and alewife, represented approximately 90% of the number of fish impinged and 82% of the weight. Furthermore, although 52 species were impinged, only 7, gizzard shad, emerald shiner, alewife, white bass, yellow perch, freshwater drum, and spottail shiner (in that order), constituted 1.0% or more of the total number and weight of fish impinged, and there were only ten species which constituted at least 0.1% of the total number impinged and 0.2% of the total weight impinged.

Total fish impingement showed definite seasonal patterns being the highest in both numbers and weight during the late fall and early winter, October 13, 1976 - February 2, 1977 (Figures 9 and 10 and Tables 14 and 15). Approximately 75% of the total number and 85% of the weight of fish impinged occurred during this 3.5 month interval. However, these values were strongly biased by impingement of the three dominant species, gizzard shad, emerald shiner, and alewife, which was also the greatest at this time (Figures 11-16). The remaining seven species from Table 13 occurred in lesser numbers and, with the exceptions of rainbow smelt and spottail shiner, were most common at other times of the year (Figures 17-30). Channel catfish were most abundant in late July and August (Figure 21). However, these were primarily YOY fish (light weight) as the impinged weight was relatively constant from early April to early August (Figure 22). Impingement of freshwater drum showed a preliminary small peak in October, but maximum numbers were observed in late July and early August and maximum weight in May (Figures 23 and 24). Walleyes were impinged in greatest numbers from late June through August (Figure 25). These were primarily YOY fish. The greatest weights were impinged during late March and April when adults migrated up the Maumee River to spawn (Figure 26). White bass impingement was highest in number and weight during July and August (Figures 27 and 28). Yellow perch impingement was highest from mid-April through August (Figures 29 and 30).

Impingement throughout the year was divided into 8-day (March 16-June 12, 1977), 11-day (June 12-June 23, 1977), and 14-day (September 15, 1976-March 16,1977 and June 23- September 15, 1977) intervals each of which contained 3 collection periods to allow the construction of confidence intervals for the estimates. Table 14 presents the impingement estimates for 11 prominant species during each of the 32 intervals described above. Table 15 is similar to Table 14 but bases impingement estimates on weight rather than number. Table 15 lists the 12 species which constituted at least 2% of the weight impinged during at least one of the 32 intervals.

In an effort to better describe and understand the reasons for the variability, as described above, in the number of fish impinged, correlations of impingement with ambient temperature, the volume of intake water, conductivity in front of the trash racks, and deicing status (on or off) were developed (Table 16). If one assumes that a correlation coefficient of 0.710 is highly biologically significant (personal communication, Dr. Bernard Griswold, Leader, Ohio Cooperative Fishery Unit, U.S. Fish and Wildlife Service), then, although several of the coefficients in Table 16 are statistically significant at the 0.05 level, none carry a high biological significance. The value of 0.710 converts to a regression coefficient (r^2) of 0.5 and indicates that 50% of the variability in a given population is associated with the variability of the parameter in question. Further correlation efforts for total impingement with several other physical parameters are presented in Table 17. Individual values for each parameter in Table 17 are contained in Appendix B (Table B-16 and Figures B-1 to B-5).

The best correlations for impingement of an individual species occurred for yellow perch (Table 16). Total fish impingement was significantly (0.05 level) correlated with ambient water temperature, deicing, water level, water level change from 12 and 24 hours earlier, air temperature, and river flow (Tables 16 and 17). Although intake volume (the volume of water drawn through the plant) was not significantly correlated with total impingement (0.05 level), there were significant positive correlations with the impingement of several economically important species: carp, channel catfish, walleye, white bass, and yellow perch. Plots of impingement versus each of these parameters are contained in Appendix B and illustrate the generally poor correlations vividly (Figures B-6 to B-30). In addition, multiple regressions using these parameters never produced coefficients (r^2) which could explain the majority of the variability in annual fish impingement.

Much of the difficulty in obtaining good correlations and regressions is due to the fact that less than 100 individuals were actually collected during the 62 collection periods for 32 of the 52 species impinged. Furthermore, all of the above correlations were based on results from the entire year. This creates confusion and discrepancies which will be discussed in the "Discussion" section which follows.

In an effort to develop more significant correlations and regressions, the year was divided into four quarters based upon visual inspection of impingement results. Collection periods 3 through 21 (September 15, 1976 to January 19, 1977) were designated season 1, collection periods 22 through 37 (January 26 - April 17, 1977) were designated season 2, collection periods 38 through 52 (April 21 - June 16, 1977) were designated season 3, and collection periods 53 through 65 (June 23 - September 15, 1977) were designated season 4. Correlation coefficients were then developed each season for the impingement of eight select species with the 23 parameters defined in Table 18 (Tables 19-22). The eight species for which correlation coefficients were developed, alewife, channel catfish, freshwater drum, gizzard shad, rainbow smelt, walleye, white bass, and yellow perch, were selected based primarily upon their significance to man and their abundance in the collections. Correlation coefficients were developed using only numbers impinged since the overall correlation coefficient between number impinged and weight impinged was greater than 0.9.

Separating impingement into 4 seasons significantly increased correlative capability as coefficients greater than 0.6 occurred each season. During season 1, walleye impingement and change in water level from 24 hours earlier produced a correlation coefficient greater than 0.6 (Table 19). White bass impingement yielded coefficients greater than 0.6 when correlated with water level (positive), ambient water temperature (positive), intake volume (positive), conductivity (negative), deicing status (negative), and intake temperature (positive). At the 0.05 level, none of the parameters tested was significantly correlated with the impingement of alewife, channel catfish, or gizzard shad.

During season 2, highly biologically significant correlation coefficients (greater than 0.7) were developed for the impingement of freshwater drum with the difference between conductivity of the river and the intake (positive), walleye with deicing status (negative), and yellow perch with the difference between the conductivity of the river and the intake canal and river temperature (both positive) (Table 20). Other coefficients greater than 0.6 were observed for the impingement of alewife and the difference between river and intake canal conductivity (positive); channel catfish and deicing status (negative), the difference between river and intake canal conductivity (positive), and river temperature (positive); freshwater drum and river temperature; rainbow smelt and the difference between river and intake canal conductivity (positive); walleye and water level change from 12 and 24 hours earlier (both positive); and yellow perch and air temperature (positive), ambient water temperature (positive), and intake temperature (positive). At the 0.05 level, none of the parameters tested was significantly correlated with the impingement of gizzard shad or white bass.

During season 3, the largest coefficient observed during this study, 0.814, was found when gizzard shad impingement was correlated with river flow (Table 21). Other correlation coefficients greater than 0.6 occurred for freshwater drum with ambient temperature and intake temperature (both positive), gizzard shad and change in river flow from the previous day (positive), and white bass with intake conductivity and difference in conductivity between the Acme and Bay Shore Power Station intake canals. At the 0.05 level, none of the 22 parameters listed in Table 21 was significantly correlated with alewife or channel catfish impingement.

During season 4, gizzard shad impingement and change in river flow from the previous day (negative) was the only coefficient produced which was greater than 0.6 (Table 22). However, the freshwater drum was the only species for which significant coefficients (0.05 level) were not observed.

To further define the impingement during each season, a series of multiple regressions were tested. First, to select the parameters to use in the regressions, correlation coefficients were developed for all the parameters listed in Table 18 with each other. This allowed the elimination of parameters which were highly correlated and, consequently, duplicating each other. The first set of regressions was developed for each of the eight species listed above during each of the four seasons using 12 parameters (Table 18): (1) river flow, (2) temp I, (3) water level, (4) level Δ12 hrs, (5) ambient temp, (6) mean conductivity recorded in the intake canal in front of the trash racks, (7) barometric pres., (8) level Δ 24 hrs, (9) air temp, (10) wind speed, (11) intake volume, and (12) condif A-B. These regressions were analyzed and parameters which were contributing little or nothing to the regressions were removed. A second set of regressions was then developed for each of the eight species using the remaining parameters. However, the parameters used varied from season to season. Seven parameters were used in the regressions for season 1 (Table 18): (1) temp I, (2) mean intake canal conductivity, (3) water level, (4) level Δ24 hrs, (5) barometric pres., (6) air temp, and (7) intake volume. Nine parameters were used in the season 2 regressions: (1) temp I, (2) mean intake canal conductivity, (3) water level, (4) level Δ12 hrs, (5) barometric pres, (6) river flow,(7) air temp, (8) intake volume, and (9) condif A-B. Seven parameters were used in the season 3 regressions: (1) temp I, (2) mean intake conductivity, (3) water level, (4) level Δ12 hrs, (5) barometric pres, (6) river flow, and (7) air temp. During season 4, seven parameters were used in the regressions: (1) temp I, (2) mean intake canal conductivity, (3) water level, (4) level Δ24 hrs, (5) barometric pres, (6) river flow, and (7) condif A-B.

Regressions which were significant (0.05 level) are presented in Table 23. The best regression developed was that for walleye during season 4 when 76.1% of the impingement variability was explained by the regression model. The regression for gizzard shad during season 3 produced a coefficient of 0.707 but could not be considered because the statistical assumptions of the model were violated (increasing residuals).

Additional data are contained in Appendix B. Raw data are on file at The Ohio State University's Center for Lake Erie Area Research.

DISCUSSION

Assuming impingement at the Bay Shore Power Station from September 15, 1976-September 15, 1977 was representative of a "normal year", then annual impingement at this station should be considered in two segments: 1) October 13-February 2 , and 2) the remainder of the year. This division is based on the number and weight impinged and the species impinged.

Approximately 75% of the total number and 85% of the total weight of fish impinged at the Bay Shore Power Station from September 15, 1976 to September 15, 1977 occurred from October 13-February 2. Gizzard shad constituted 70% of the total number and 83% of the total weight of fish impinged during this 3.5 month period. The combination of gizzard shad, emerald shiner, and alewife, three forage species, constituted 97% of the total number and 96% of the total weight of fish impinged from October 13- February 2. The remaining 25% of the total number of fish impinged for the year and the remaining 15% of the total weight impinged for the year were distributed over the remaining 8.5 months. It was during this period that species of greater economic importance, primarily, freshwater drum, walleye, white bass, and yellow perch, became more significant components of the impingement. These were primarily YOY fish and their increased prominence in the collections was due more to a reduction in gizzard shad and emerald shiner impingement than to real increases in their numbers. Furthermore, even during this eight month period, either gizzard shad or emerald shiner was the dominant species by number more than 50% of the time. By number, yellow perch and white bass were the only other species to dominate an interval. Yellow perch was the dominant species entrained during intervals 25-27, and white bass was the dominant species from interval 28-30 (Table 14). By weight, yellow perch and freshwater drum were the only species other than gizzard shad and emerald shiner to dominate an interval. Yellow perch was dominant during intervals 2, 19, 20, and 25-32 (early June to late September), and freshwater drum was dominant during intervals 22 and 23 (Table 15).

The correlations and regressions presented in the "Results" section (Tables 16-23) were done in an effort to better understand the reasons or causes of the impingement. Much was gained by this undertaking for we now know that to increase the accuracy of regressions, the year must be viewed in segments. In essence, by dividing the year into segments we are attempting to add some of our knowledge of fisheries biology to the model in addition to eliminating spring and fall overlaps in the values of parameters such as temperature. Consider the following biological factors which can confound the results when the entire year is viewed as a whole: (1) fish spawn during spring and summer creating vast numbers of small individuals at these times, (2) fish grow rapidly increasing in weight, but mortality reduces their numbers, (3) several species, of which the walleye is the most notable, enter the Maumee River to spawn during the spring, (4) YOY gizzard shad are recruited into the adult population in the fall of their first year and migrate shoreward to tributaries (Bodola, 1965), and (5) fish swimming ability is greatly reduced at the low ambient temperatures which occur during the late fall and winter. Consequently, the biology of the species can cause environmental variables to appear to have opposite effects during different seasons. White bass impingement is a good example of this phenomenon as it was negatively correlated with intake conductivity during season 1 and positively correlated during season 3 (Table 23). In this case more fish were impinged during the fall when the conductivity was lower indicating that they were being impinged with lake water which has a lower conductivity than river water (Figure 7). During season 3, one possible explanation for the positive correlation between mean intake conductivity and white bass impingement was that it was due to the spawning migration up the Maumee River. Then, on days when the flow passing the plant was primarily of river origin, more white bass were being carried back to the lake.

Although several of the multiple regressions which were developed were significant (0.05 level), none, with the possible exception of walleye during season 4, explained enough of the variability to make it a useful tool for accurately predicting impingement numbers. However, on a relative basis the regressions can be quite useful. For example, during season 3, white bass impingement can be expected to increase when intake conductivity increases and intake temperature decreases.

Based on the results of this study, the results of a similar study conducted at the Acme Power Station of the Toledo Edison Company, the correlations and multiple regressions developed in both studies, and commercial fishing records, it is possible to hypothesize on the habitat selection of the more abundant species--lake or river. Alewife, emerald shiners, rainbow smelt, spottail shiners, white bass and yellow perch appear to be "lake species" as they are impinged in greater proportions at Bay Shore (downstream) and generally tend to be impinged when conductivity is lower (lake water has a lower conductivity than river water). Channel catfish, freshwater drum, gizzard shad (possibly "lake") and walleye appeared to exhibit no significant trend of "lake" or "river" origin. These hypotheses are based on the results from the entire year and could vary from season to season. Walleye and white bass are the most notable examples of this variability for both would have to be considered river species during the spring when they enter the river and swim to the Perrysburg riffles to spawn.

The previous discussions have described fish impingement at the Bay Shore Power Station but have not shown the significance of this impingement in relation to Lake Erie or Maumee River fish populations. This is impossible for most species as population estimates for the lake and river do not exist. However, the "First Technical Report of the GLFC Scientific Protocol Committee on Interagency Management of the Walleye Resource of Western Lake Erie" lists brood stocks (all males age 2 and older; all females age 3 and older) for walleye in the Western Basin during 1975, 1976, and 1977 as 3,086,600 fish, 5,119,000 fish, and 8,611,900 fish, respectively (personal communication, Allan VanVooren, Ohio Division of Wildlife, Lake Erie Research Unit). The estimate of total walleye impingement at the Bay Shore Power Station, 12,187 (Table 13), is approximately 0.1% of the 1977 Western Basin brood stock estimate. In addition, this percentage is a high estimate as many of the 12,187 walleyes impinged were YOY and not yet brood stock (Table B-10, Appendix B). Estimated Maumee River brood stocks for 1975, 1976, and 1977 were 177,700 fish, 337,600 fish, and 540,800 fish, respectively (Scholl, 1977 and personal communication, Allan VanVooren, Ohio Division of Wildlife, Lake Erie Research Unit). In this case, the 12,187 walleyes impinged were 2.2% of the 1977 brood stock. Again, this is a high estimate since mortality from YOY to age 2 and 3 is not considered.

As stated earlier, direct comparisons of impingement with lake and river populations for other species is impossible since these lake and river population estimates only exist for walleye. However, comparisons of impingement with sport and commercial harvests could be of assistance in determining the significance of the impingement. Table 6 lists sport and commercial harvests from the Ohio waters of Lake Erie for several sport species. Tables 24 and 25 present commercial fish landings from the Ohio waters of Lake Erie and all of Lake Erie, respectively. Tables 26 and 27 compare impingement numbers and weights to sport and commercial harvests. In Table 26, the differences observed between the percentage by number and the percentage by weight for each species are caused by the large numbers of YOY and sub-legal adults which are impinged, but too small to be taken commercially or by sport fishermen. The "real" percentage of the sport and commercial harvests is probably somewhere between the percentage by number and the percentage by weight, as natural mortality would deplete the numbers of YOY before they were large enough and heavy enough to be harvested by sport or commercial fishermen.

For yellow perch, it is possible, using survival rates from Patterson (1976) (see entrainment discussion), to convert impingement losses during the study to the number of age class III adults that could have been produced if the impingement had not occurred. Since, during this study, individual lengths and weights were recorded for every collection period, it is possible to estimate the number of fish within each age class. The catch of yellow perch was divided into 3 groups: YOY, age class III and older adults, and those sub-adults in between. Each group was defined as follows based on length and time of year: for collection periods 3-39 (September 15, 1976 to April 25, 1977), YOY perch were less than 90 mm long; no YOY for periods 40-52 (April 29 to June 16, 1977); for periods 53-65 (June 23 to September 15, 1977), YOY perch were less than 66 mm long; age class III (and older) adults were greater than 150 mm long; and sub-adults were all those in between. The results of this effort indicated that of the 437,260 yellow perch impinged, 29,373 were adults, 116,826 were YOY, and 291,061 were sub-adults. Then, using Patterson's mortality estimates, the 116,826 YOY perch impinged could have produced 2,024-5,567 age class III adults and the sub-adults could have produced 42,029-110,603 adults. Consequently, the 437,260 yellow perch impinged at Bay Shore represent a loss of 73,426 to 145,543 mature adults. This is approximately 17 to 33% of the total number impinged and 44 to 87% of the weight impinged. If one assumes that this same number and weight relationship will hold true for the other species, then comparisons of impingement losses with sport and commercial harvests are more accurate if based on weight rather than number.

The large percentage (18,188.5%) of the sport harvest for the species designation "others" is due to the large numbers of forage species (primarily gizzard shad) which are impinged but not collected by anglers. It should be noted that it is incorrect to assume that sport or commercial fishing harvests would increase by the percentages in Tables 26 and 27 if the plant were not operating, for that assumption implies that all fish which are impinged would be caught by sport or commercial fishermen if they were not impinged.

One final point should be made. Based on the results of the Ohio Division of Wildlife's trawling effort for YOY fish, the number captured in 1977 was classified as "extremely high" or "excellent" for walleye, yellow perch, white bass, and freshwater drum (Scholl, 1978). Consequently, one can not say that impingement losses of YOY fish at the Bay Shore Power Station had an adverse impact on these populations of YOY fish in Lake Erie.

ENTRAINMENT

RESULTS

Scientific and common names of fish species and groupings collected in entrainment samples at the Bay Shore Power Station from September 1 - September 15, 1976 and March 16 - September 1, 1977 are presented in Table 28. It is estimated that 284,717,618 larval fish representing 19 taxa and 426,150,109 fish eggs were entrained at the Bay Shore Power Station during the sampling period (Table 29). Drum eggs were separated from other fish eggs by the presence of the large oil globule and constituted 99.9% of the total number of eggs entrained. Gizzard shad and white bass were the dominant larval species, representing 78.4% and 11.6% of the total, respectively. All significant entrainment of larvae occurred between May 15 and July 15 (Figure 31). The first egg was collected from the river on April 25 (collection period #39), while the first larvae were collected on April 21 (collection period #38) from the river and intake canal. These were walleye larvae.

Of the 19 taxa of larval fishes, only four, carp, freshwater drum, gizzard shad, and white bass, represented more than 1% of the total (Table 29). The number entrained versus collection period and date was plotted for each of the four species mentioned above, plus walleye and yellow perch due to the significance placed on them by sport and commercial fishermen (Figures 32-37). Illustrations of the same type were also developed for freshwater drum eggs and other eggs (Figures 38 and 39).

Carp larvae were entrained from the end of April to the end of August with maximum entrainment occurring on May 23 (Figure 32). Freshwater drum larvae were entrained from the end of May to mid-August with maximum entrainment occurring on June 4 (Figure 33). Gizzard shad larvae were entrained from mid-May to early August with maximum entrainment occurring on May 31 (Figure 34). Walleye larvae were entrained from mid-April to mid-May with maximum entrainment occurring on May 11 (Figure 35). White bass were entrained from mid-May to early August with maximum entrainment occurring on May 19 (Figure 36). Yellow perch larvae were entrained from the end of April to mid-July with maximum entrainment occurring on May 15 (Figure 37). Freshwater drum eggs were entrained from mid-May to late August with maximum entrainment occurring on July 7 (Figure 38). Non-drum eggs occurred in early and mid-May with maximum entrainment occurring on May 19 (Figure 39).

Night entrainment of carp larvae was 3.16 times greater than entrainment during the day. This difference was significant at the 0.05 level (Table 30). Day/night differences for the other 5 species mentioned above were not significant. Table 31 presents surface and bottom differences and horizontal differences between stations for the six larval species discussed above from samples collected at stations 4-6 in the Maumee River directly upstream from the Bay Shore intake (Figure 2). Differences between stations were not significant (0.05 level). However, freshwater drum were found in significantly (0.002 level) greater numbers at the bottom, while gizzard shad occurred in significantly (0.03 level) greater numbers at the surface. The surface/bottom ratios are also provided in Table 31, since many times a difference may be biologically significant and not statistically significant. Walleye is a good example of this, for it was approximately twice as abundant at the bottom as at the surface, yet the difference was not statistically significant (0.05 level). Problems of this type occur frequently in statistics when the assumptions, upon which testing procedures are based, are violated. In the case above, the surface and bottom variances were not equal. This is an assumption which must be met for both parametric and non-parametric testing. When it is violated the tests can become overly conservative, as undoubtedly occurred with the walleye. Consequently, visual interpretation, in some cases, can be more reliable than a statistical test.

Appendix C contains a thorough analysis of entrainment results and larval densities in the Maumee River.

DISCUSSION

The previous discussion, tables, and illustrations have adequately described ichthyoplankton entrainment at the Bay Shore Power Station; however, the significance of this entrainment in relation to ichthyoplankton populations in the Maumee River has not been shown. Fecundity estimates are of little value in estimating river populations without accurate estimates of the number of spawners (brood stock) and of the mortality from eggs to larvae. These values are not available. In a classical river situation, the number of larvae passing a particular point could be estimated at any point in time from river flow and larvae densities. However, although daily flow rates for the Maumee River are available from the U.S. Geological Survey Station in Waterville, Ohio (approximately 20 miles above Bay Shore), the intake of the Bay Shore Power Station is located on an estuarine portion of the Maumee River in which the flow has been estimated to be in a downstream direction only 60% of the time (Miller, 1968). In an effort to avoid this problem, ichthyoplankton concentrations from stations 4-6 in the Maumee River were averaged from all collection periods between April 9, the day that the first ichthyoplankter was collected (during the 316 (b) study near the

Acme Power Station), and September 1, 1977, the end of the study. These concentrations are presented in column two of Table 32. The total flow down the Maumee River during this period was also determined by adding the daily flows based on the daily flow rates recorded at Waterville, Ohio. Although the direction of the flow in the estuary during this 5.7-month period obviously reversed itself many times, the water flowing downstream eventually must go to the lake, and by looking at a 5.7-month period, effects of the short-term variations in direction can be reduced. Furthermore, although an individual larva could be susceptible to entrainment more than once due to flow reversals, that larva has an equal opportunity to rush past the plant very rapidly with little or no chance of being entrained during a water level decrease following a flow reversal. The above procedure averages these 2 cases. Consequently, this 5.7-month flow down the river (1,402,479,596m^3) multiplied by the 5.7-month mean larvae concentrations gives an estimate of the number of larvae and eggs passing the power station (Table 32). The significance of entrainment can then be determined by comparing it to the above estimate for the river population.

One must bear in mind that the above technique does not account for lake larvae which move upstream during current reversals and which may be a significant portion of the entrainment. Furthermore, because of the complex hydrological interactions of Maumee River water and Maumee Bay water in the vicinity of the plant intake, it is difficult to differentiate the origin of a water mass entering the cooling system of the plant. However, due to the potential significance of this information, an attempt to determine the source of the intake water was made based on 1) water level changes, 2) current flow direction and velocity in the river adjacent to the intake, and 3) specific conductivity of the water adjacent to the intake. The results of this analysis are presented in Table 33. The "dominant current", designated as "out" of the river or "in" (upstream or backwards) was determined by adding the velocities in an "out" direction recorded at 1-meter depth intervals at each station in the river and comparing it to the total of the "in" velocities during each collection period--it was common to obtain currents moving in both directions during one collection period at one station. The direction, in or out, with the larger total value was termed the dominant current. Water level changes were determined from values recorded at the NOAA Lake Survey Center, Toledo, Ohio.

Of the three parameters used to differentiate the source of the intake water (lake or river), conductivity was felt to be the most reliable for the following reasons: (1) immediately following a period of downstream flow, a flow reversal determined from current measurements and increasing water level would indicate that lake water was passing the plant, when in actuality it was still river water, but it was passing the plant in the opposite direction, and (2) immediately following a long period of reverse flow and increasing water levels, a return to a downstream flow, as determined by current direction and decreasing water level, would indicate that river water was passing the intake, when in actuality it was lake water which had "backed up" into the river. Conductivity measurements were not affected by these phenomena.

Because the normal conductivity of western Lake Erie is ≤300 umhos/cm, (Figure 7) it appears that "lake" water never completely displaced "river" water in Maumee Bay or the estuarine portion of Maumee River (Table 33). Although, with the exception of collection period 54, the lowest conductivity values measured were well in excess of 300 umhos/cm, conductivities reached the normal range for the river (500-700 umhos/cm) only 40% of the time (Table 33). Therefore, it appears that Maumee Bay and the lower reach of the Maumee River is a mixing zone for river and lake water masses, and although it appears that the river dominates the water masses in the vicinity of the water intake, Table 33 indicates that Maumee Bay water, which is a mixture of lake and river water masses, has a significant influence on the water masses present at the water intake. Consequently, a more realistic way to consider this unusual environment is to view the estuarine portion of the Maumee River and Maumee Bay as one unit, which is a gradient between river and lake water, rather than two separate entities which are little more than artificial designations.

In an effort to further explain entrainment, the results of Table 33 were compared to larvae occurrence records from the river and intake canal (Tables 34 and 35) and inspected to see if the source of the intake water (river or bay) had a significant effect on the species impinged. This was done primarily for taxa which were suspected to be of either river or bay origin.

Impingement results indicated that alewife, emerald shiner, rainbow smelt, spottail shiner, white bass, and yellow perch were species of probable bay or lake origin. This hypothesis could not be tested for alewife using entrainment results, as any alewife larvae which may have occurred in the samples were not differentiated from gizzard shad larvae. However, Snyder (1978) did not find any alewife larvae in the river during his study.

Emerald shiner entrainment results agree with the impingement results, in that this species appears to be of lake or bay origin. This species was entrained on 4 sampling dates during the study (Table 34) and all 4 were on days when the source water was considered to be of bay origin (Table 33). In addition, 67 percent of its occurrences in river samples were also on days when the water was suspected to be of bay origin (Table 35). It should also be noted that the concentration of this species observed in the river near Bay Shore was 26 times greater than the concentration observed upstream during 316 (b) studies at the Acme Power Station.

The occurrence of rainbow smelt in the river and in the intake canal does not appear to be correlated with bay or river source water. However, the species was not collected during the 316 (b) study at Acme, upstream from Bay Shore, and, therefore must be considered a "bay or lake" species.

Spottail shiners occurred only once in intake canal samples and on 6 occasions in the river. It must be considered a "bay or lake" species since the occurrence in the intake canal and 5 of the 6 occurrences in the river were on days when the source water was considered to be of bay origin.

The white bass is generally considered a river spawner, however, the results did not substantiate this. Only 21 percent of its occurrences in the river were on days with a river water flow and only 25 percent of its occurrences in the intake canal were on days when the source water was considered to be of river origin. However, Snyder (1978) felt that this species may spawn in the estuary itself which would explain its occurrence on days when the dominant source water was of bay or lake origin.

Walleye, which, in the vicinity of the Maumee River spawn primarily in the river, occurred on 5 occasions in the intake canal and 5 in the river. Four occurrences in the river and 3 of those in the intake canal were on days when the water source was of river origin.

Yellow perch must be considered a lake or bay species as 65 percent of its occurrences in the river and 83 percent of its occurrences in the intake canal were on days when the source water was suspected to be of bay or lake origin. Furthermore, concentrations observed in the river at Bay Shore were 6.5 times greater than concentrations observed farther upstream during 316 (b) studies at the Acme Power Station.

In general, the above discussion indicates that the Bay Shore Power Station does not entrain everything flowing down the Maumee River. In fact, although the intake volume is equal to approximately 25 percent of the mean river flow, most of the cooling water is definitely a mixture of river and lake water, and many of the entrained larvae appear to be of bay or lake origin.

In an effort to further explain entrainment at the Bay Shore Power Station, correlation coefficients were developed for the concentrations, both in the river and in the intake canal, of carp, channel catfish, freshwater drum, emerald shiner, gizzard shad, walleye, white bass, and yellow perch with all the parameters listed in Table 18. This was done only for the period of occurrence of each species and was all but fruitless due to few observations for several species

(Table 34 and 35) and the fact that the presence of larvae is a very seasonal phenomenon that will generally occur at the prescribed time relatively independent of most environmental factors.

The major causes of unusually high or low values for the percentage of the river population entrained (Table 32) is due to behavioral characteristics or preferences of the species in question and the sampling techniques employed (limnetic or open water).

The channel catfish and the carp are good examples of this. Table 32 indicates that channel catfish were not in the river but were entrained at the power plant. Similar results were observed for troutperch and white suckers and could be indicative of spawning in the intake canal. However, it is more likely that our limnetic sampling procedures did not adequately sample these populations in the river for Snyder (1978) considered larvae of the ictalurids to prefer littoral areas.

Carp occurred during thirteen collection periods in the intake canal and twelve in the river (Tables 34 and 35). Table 33 indicates that 77 percent of the occurrences from the intake canal and 75 percent of those from the river were on days when the flow was considered to be of bay origin. This indicates that most of the carp entrained were of bay origin. This is contradictory to the results of Snyder (1978) who found the greatest concentrations of carp larvae in the riffle areas and littoral zone. However, Snyder (1978) also found the carp to be very evasive and this along with its preference for the littoral zones may account for the relatively high percentage found in the intake canal as our limnetic river sampling may have missed them.

The significance of entrainment losses may be increased or decreased depending on the validity of the entrainment estimate and the validity of assuming 100 percent mortality for entrained fish larvae. Cannon *et al.*, (1977) found that entrainment mortality was dependent upon the maximum temperature experienced by the larvae during condenser passage. When the maximum temperature experienced by the larvae was less than 30°C, mortality was generally 0-30 percent. Above 30°C, mortality increased rapidly to 100 percent. However, these results would appear to be somewhat dependent upon the residence time of the larvae at the elevated temperatures. Cannon's work is based on tests of 30-40 minutes duration. Residence times in hot water at Bay Shore range from 10-12 minutes, so Cannon's results would appear applicable. In any event, Cannon's results definitely reduce the impact of entrainment on larval fish populations. Using Cannon's techniques, it appears that of the 284,717,618 larvae entrained, 96,124,175 were killed (Table 32). This was computed by adding 10.8°F (maximum ΔT across condensers observed during 316 (a) thermal discharge studies at the Bay Shore Power Station) to ambient water temperature (Figure 40) and noting the date on which the total reached 30°C. Using this technique, larvae mortality was considered to be 30 percent prior to June 12, 100 percent after June 23, and 65 percent in the interim. Sixty-five percent was used for the period June 12-23 because entrainment estimates were made at designated intervals, and 30°C was reached midway through the interval of June 12-23. Consequently, the mean of 30 percent and 100 percent mortality, 65 percent was used.

Whereas Cannon's results tend to decrease the impact of entrainment on ichthyoplankton populations in the river, estimating entrainment based on the concentration of larvae observed at sampling stations in the river would raise the entrainment estimates. For example, column 4 of Table 32 lists concentrations for selected species from pump samples in the intake canal. Those concentrations were computed in the same manner as the river concentrations, from net samples, column 2. Comparing the two, shows the larval fish concentration in the river to be 6.0 times greater than the concentration in the intake canal. It is possible that this is a real difference caused by larvae avoiding the turbulence in and around the intake canal or lower larvae concentrations in the vicinity of the intake. Both hypotheses are quite probable. Some species such as white bass do appear to prefer quieter waters (Snyder, 1978) which would tend to make them avoid the intake of the power plant. The second hypothesis, lower concentrations near the intake, is substantiated by Table 31, for although differences in larval concentrations were not significantly different (0.05 level) between stations, station 5 (mid-channel) and station 6 (northwest bank) had larval concentrations 1.14 and 1.52, respectively, times as great as station 4 at the intake.

The above arguments have attempted to substantiate the belief that the observed differences in larvae concentrations between the intake canal and the river are real. It is also possible that this is an artificial difference due to differences in the efficiencies of the sampling methods--nets in the river and pumps in the intake canal. Since the ratio of the river concentration to the intake concentration is 6.0, this argument gains most of its credence from the fact that multiplying total larval entrainment by 6.0 would increase the "% of number passing the plant" (column 6) to 23.4 percent which is approximately the portion of the Maumee River used by the Bay Shore Power Station. At the present time, the state-of-the-art of ichthyoplankton sampling has not evolved to a point where this argument can be satisfactorily resolved.

The above discussions have attempted to relate ichthyoplankton entrainment at the Bay Shore Power Station to ichthyoplankton populations in the Maumee River. Patterson (1976), as cited by the U.S. Nuclear Regulatory Commission (1977), has attempted to put larvae mortality for yellow perch (an important commercial species) into perspective by converting the loss of larvae through entrainment to the potential loss of adult perch. Several assumptions are involved in this conversion.

I. All entrained larvae are killed.

II. All larvae lost by entrainment are in their late larval stage. This provides a conservative or high estimate because it does not account for early larval mortality which may range from 83-96 percent (Patterson, 1976).

III. Yellow perch become vulnerable to commercial capture, but reach sexual maturity at age class III.

IV. A one percent survival rate from late larvae to age III adults is assumed. Again, this is conservative since survival rates from:

late larvae to YOY = 4 to 17 percent;
YOY to age class I = 12 to 33 percent;
age class I to age class II = 38 percent;
age class II to age class III = 38 percent
(Patterson, 1976, and Brazo, *et al.*, (1975).

This trend translates to a survivorship ranging from 0.1 percent to one percent over the period from the late larval stage to age class III.

Based on the above assumptions, the 2,426,431 yellow perch larvae entrained at Bay Shore would convert to 24,264 age class III adults.

In closing, several points should be mentioned regarding the significance of the entrainment of ichthyoplankton at the Bay Shore Power Station and the value of ichthyoplankton estimates in general. Each year the Ohio Division of Wildlife produces a report entitled "Status of Ohio's Lake Erie Fisheries". This report summarizes the size of the YOY population for several species and ranks them with similar results from previous years. The report covering 1977 (Scholl, 1978) (YOY populations from this year would be those entrained as larvae during this study) lists 1977 Western Basin YOY populations of walleye and white bass as "extreme high", and YOY populations of yellow perch and freshwater drum as "excellent". Consequently, one can not demonstrate an adverse impact on these YOY populations due to entrainment of larvae at the Bay Shore Power Station. The obvious conclusion to be drawn from this is that in comparison to natural mortality and other factors affecting survival from larvae to YOY in western Lake Erie, entrainment losses at the Bay Shore Power Station are small. It should also be noted that the YOY index of year class strength was selected by the Ohio Division of Wildlife because large variability in larvae mortality rates made larvae populations poor indicators of year class strength.

LITERATURE CITED

Bailey, R.M., J.E. Fitch, E.S. Herald, E.A. Lachner, C.C. Lindsey, R.C. Robins, and W.B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. Third ed. Amer. Fish. Soc. Spec. Pub. No. 6. 150 pp.

Bainbridge, R. 1958. The speed of swimming fish as related to size and to the frequency of the tail beat. J. Exp. Biol., 35 (1):109-33.

Bainbridge, R. 1960. Speed and stamina in three fish. J. Exp. Biol. 37:129-153.

Barr, J., J.H. Goodnight, J.P. Sall and Jane T. Helwig. 1976. A user's guide to SAS 76. SAS Institute, Inc., Raleigh, N.C. 329 pp.

Bell, M.C. 1973. Fisheries handbook of engineering requirements and biological criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Div., Portland, Oregon.

Benson, D.J. 1975. Maumee Bay erosion and sedimentation. U.S. Army, Corps of Eng., Draft Rept. Contract DACW 35-75-C-0038. 214 pp.

Blaxter, J.H.S. 1969. Swimming speeds of fishes. F.A.D. Fish Rep. 62(2):69-100.

Bodola, A. 1965. Life history of the gizzard shad, Dorosoma cepedianum (Le suer), in western Lake Erie. Fishery Bull. 65(2): 391-425.

Brant, R.A. and C.E. Herdendorf. 1972. Delineation of Great Lakes estuaries. Proc. 15th Conf. Great Lakes Res., Internal. Assoc. Great Lakes Res. 1972:710-718.

Brazo, D.C., P.I. Tack and C.R. Liston. 1975. Age, growth and fecundity of yellow perch, Perca flavascens, in Lake Michigan near Ludington, Michigan. Proc. Am. Fish. Soc. 104:727.

Cannon, T.C., S.M. Jinks, L.R. King and G.J. Lauer. 1977. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. (Abstract). Fourth National Workshop on entrainment and impingement. Ecological Analysts, Inc.

Carlander, K.D. 1953. Handbook of freshwater fishery biology with the first supplement. Wm. C. Brown Co., Dubuque, Iowa. 429 pp.

Carter, C.H. 1973. The November 1972 storm on Lake Erie. Ohio Dept. Nat. Res., Div. Geol. Surv. Infor. Circ. 39. 12 pp.

Charlesworth, L.J. 1974. Maumee Bay dike impact study, phase I: initial bottom sediment sampling. U.S. Army, Corps of Eng. Contract DACW 35-75-M-0189. 309 pp.

Edsall, T.A. and T.G. Yokom. 1972. Review of recent technical information concerning the adverse effects of once-through cooling on Lake Michigan. U.S. Fish and Wildlife Service, paper prepared for Lake Michigan Enforcement Conference.

Emery, L. 1976. Fish inhabiting U.S. waters of the Great Lakes, with indications of their relative abundance and of their importance as commercial, sport, or forage species, pp. 201-206. in J. Boreman (ed.) Great Lakes fish egg and larvae identification (Proc. of a workshop). U.S. Fish and Wildlife Serv., OBS Natl. Power Plant Team (Ann Arbor, Mich.), FWS/OBS-76/23: 220 pp.

Faber, D.J. 1967. Limnetic larval fishes in northern Wisconsin lakes. J. Fish. Res. Bd. Canada. 24(5): 927-937.

Feder, P.I., G.W. Sturm and J.M. Reutter. 1976. Data collection and storage for impingement and entrainment studies at two Toledo Edison power stations on the Maumee River, Toledo, Ohio. The Ohio State Univ., Columbus, Ohio. CLEAR Proc. Man. No. 3. 32 pp.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U.S. Bur. Fish. 47:293-398.

Forsyth, J.L. 1975. The Geological setting of the Sandusky River Basin, Ohio. Proc. Sandusky River Basin Symposium, May 2-3, 1975, Tiffin, Ohio. Co-sponsored by Heidelberg College and Bowling Green State University, Ohio: 13-60.

Fraleigh, P.C., J.C. Burnham, G.H. Gronau, T. Kovacik and E.J. Tramer. 1975. Maumee Bay environmental quality study. Draft Final Report, Toledo Lucas County Port Authority.

Fry, F.E.J. and J.S. Hart. 1948. Cruising speed of goldfish in relation to water temperature. J. Fish. Res. Bd. Can. 7:169-175.

Great Lakes Basin Commission. 1975. Surface water hydrology. Great Lakes Basin Framework Study, Appendix 2, Great Lakes Basin Comm., Ann Arbor, Michigan. 133 pp.

Hartley, R.P. 1960. Sand dredging area in Lake Erie. Ohio Dept. Nat. Res., Div. Shore Erosion Tech. Rept. 5. 79 pp.

Hartley, S.M. and C. E. Herdendorf. 1977. Spawning ecology of Lake Erie fishes. The Ohio State Univ., Columbus, Ohio. CLEAR Tech. Rept. No. 62. 10 pp.

Hartley, S.M. and A.R. Van Vooren. 1977. The fishing potentials, special management areas, and their interaction with dredge spoil sites in Lake Erie. Ohio Division of Wildlife. 328 pp.

Hartman, W.L. 1970. Resource crises in Lake Erie: The Explorer. 12(1):6-11.

Hartman, W.L. 1973. Effects of exploitation, environmental changes and new species on the fish habitats and resources of Lake Erie. Great Lakes Fish. Comm. Tech. Rept. No. 22. 43 pp.

Heniken, M.R. 1977. Distribution and abundance of larval fish in a portion of the western basin of Lake Erie. Masters Thesis. Ohio State Univ., Columbus. 95 pp.

Herdendorf, C.E. 1970a. Sand and gravel resources of the Maumee River estuary, Toledo to Perrysburg, Ohio. Ohio Dept. Nat. Res., Div. Geol. Surv. Rept, Invest. 76. 19 pp.

Herdendorf, C.E. 1970b. Limnological investigations of the spawning reefs and adjacent areas of western Lake Erie with special attention to their physical characteristics. Dissertation. The Ohio State University. 203 pp.

Herdendorf, C.E. 1975. Shoreline changes of Lakes Erie and Ontario. Bull. Buffalo Soc. Nat. Sci. 25(3): 43-76.

Herdendorf, C.E. 1976. Operating manual for fish impingement studies at the Acme and Bay Shore power stations. The Ohio State Univ., Columbus, Oh. CLEAR Procedures Manual No. 2. 18 pp.

Herdendorf, C.E. 1977. Operating manual for fish entrainment studies at the Acme and Bay Shore power stations. The Ohio State Univ., Columbus, Ohio. CLEAR Procedures Manual No. 4. 16 pp.

Herdendorf, C.E. and C.L. Cooper. 1975. Environmental impact assessment of commercial sand and gravel dredging in Maumee River and Maumee Bay of Lake Erie. The Ohio State University, Columbus, Ohio. CLEAR Tech. Rept. No. 41. 380 pp.

Herdendorf, C.E. and C.L. Cooper. 1976. Investigations of larval fish populations in Maumee River estuary and Maumee Bay and assessment of the impact of commercial sand and gravel dredging on these populations. The Ohio State Univ., Columbus, Ohio. CLEAR Tech. Rept. No. 49. 86 pp.

Herdendorf, C.E., D.E. Rathke, D.D. Larson, and L.A. Fay. 1977a. Suspended sediment and plankton relationships in Maumee River and Maumee Bay of Lake Erie. Plenum Pub. Co., Geobotany, pp 247-282.

Herdendorf, C.E., C.L. Cooper, M.R. Heniken and F.L. Snyder. 1977b. Western Lake Erie fish larvae study: 1975 preliminary data report. The Ohio State University, Columbus, Ohio. CLEAR Tech. Rept. No. 47 (revised). 75 pp.

Herdendorf, C.E., C.L. Cooper, M.R. Heniken, and F.L. Snyder. 1977C. Western Lake Erie Fish Larvae Study: 1976 Preliminary Data Report. The Ohio State Univ., Columbus, Ohio. CLEAR Tech. Rept. No. 63.

Horowitz, J., J.R. Adams and L.A. Bazel. 1975. Water pollution investigation: Maumee River and Toledo area. U.S. Environ. Protect. Agency EPA-90519-74-018. 170 pp.

King. L.R., J.B. Hutchison Jr., T. Huggins. 1977. Impingement survival studies for white perch, striped bass, and Atlantic tomeod at Three Hudson River Power Plants. (Abstract). Fourth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc.

Lagler, K.F., J.E. Bardach and R.R. Miller. 1962. Ichthyology. John Wiley and Sons, Inc., New York. 545 pp.

McBride, R.T. 1975. Distribution of recent sediment in Maumee Bay, western Lake Erie. M.S. Thesis, Dept. Geol. Univ. of Toledo. 155 pp.

Miller, G.S. 1968. Currents at Toledo Harbor. Proc. 11th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res. 1968:437-453.

Nelson, D.D. and R.A. Cole. 1975. The distribution and abundance of larval fishes along the western shore of Lake Erie at Monroe, Michigan. Michigan State Univ., East Lansing, Michigan. Institute of Water Research Tech. Rept. No. 32.4. 66 pp.

Norden, C.R. 1961a. A key to larval fishes from Lake Erie. University of Southwestern Louisiana, Lafayette. Mimeo. Rept. 4 pp.

Norden, C.R. 1961b. The identification of larval perch, Perca flavescens, and walleye, Stizostedion v. vitreum. Copeia 61:282-288.

Ohio Division of Water. 1960. Water inventory of the Maumee River basin. Ohio Dept. Nat. Res., Div. Water, Water Plan Inven. Rept. 11. 112 pp.

Patterson, R.L. 1976. Analysis of losses in standing crop and fishery yields of yellow perch in the western basin of Lake Erie due to entrainment and impingement mortality at the Detroit Edison Monroe Power Plant, Large Lakes Research Station. U.S. Environmental Protection Agency, Grosse Ile, Mich.

Pinsak, A.P. and T.L. Meyer. 1975. Baseline reference for Maumee Bay, Maumee River basin level B study, interim report. Gt. Lakes Basin Comm. 40 pp.

Priegel, G.R. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Tech. Bull. Wis. Dep. Natur. Res. 45: 105 pp.

Regnard, M.P. 1893. Sur un dispositif qui permet de mesurer la vitesse de translation d'un poisson se mouvant dans l'eau. C.R. Hebd. Sean. Acad. Sci., Paris. 9(5):81-3.

Reutter, J.M. and C.E. Herdendorf. 1976. Thermal discharge from a nuclear power plant; predicted effects on Lake Erie fish. Ohio J. Sci. 76:39-45.

Scholl, R.L. 1977. Status of Ohio's Lake Erie Fisheries: January 1, 1977. Ohio Dept. of Nat. Res. Div. of Wildlife. 17 pp.

Scholl, R.L. 1978. Status of Ohio's Lake Erie Fisheries: January 1, 1978. Ohio Dept. of Nat. Res. Div. of Wildlife. 20 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 pp.

Service, J. 1972. A user's guide to the statistical analysis system, SAS. Student Supply Stores. North Carolina State University, Raleigh, N.C. 260 pp.

Snyder, F.L. 1978. Ichthyoplankton studies in two Lake Erie estuaries. Masters Thesis. The Ohio State Univ., Columbus, Ohio. 150 pp.

Tatham, T.R., D.L. Thomas, and G.J. Miller. 1977. Survival of fishes and macroinvertebrates impinged at the Oyster Creek Generating Station, Forked River, New Jersey. (Abstract) Fourth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc.

Trautman, Milton B. 1957. The Fishes of Ohio. The Ohio State Univ. Press, Columbus, Ohio 683 pp.

U.S. Army, Corps of Engineers. 1945. Beach erosion study, Ohio shore line of Lake Erie from Ohio-Michigan state line to Marblehead, Ohio. 79th Congr., 1st Sess., U.S. House Doc. 177. 27 pp.

U.S. Army, Corps of Engineers. 1953. Wave and lake level statistics for Lake Erie. Beach Erosion Board Tech. Memo. 37. 14 pp.

U.S. Army, Corps of Engineers. 1961. Lake Erie shore line from the Michigan-Ohio state line to Marblehead, Ohio, beach erosion control study. 87th Congr., 1st Sess., U.S. House Doc. 63. 153 pp.

U.S. Army, Corps of Engineers. 1974. Confined disposal facility for Toledo Harbor, Ohio. Final Environ. Impact Statement. Detroit Dist. 85 pp.

U.S. Nuclear Regulatory Commission. 1977. Draft environmental impact statement related to construction of Erie Nuclear Plant, Units 1 and 2, Ohio Edison Company, et al. U.S. NRC. Office of Nuclear Reactor Regulation. Docket Nos. STN 50-580 and STN 50-581.

Verber, J.L. 1954. Maumee Bay sand survey. Ohio Dept. Nat. Res., Div. Shore Erosion. 15 pp.

Verber, J.L. 1960. Long and short period oscillations in Lake Erie. Ohio Dept. Nat. Res., Div. Shore Erosion. 80 pp.

Walters, L.J. and C.E. Herdendorf. 1975. Influence of the Detroit and Maumee Rivers on sediment supply and dispersal in western Lake Erie. Abst. 18 Conf. Gt. Lakes Res., Internat. Assoc. Gt. Lakes Res.

TABLES

TABLE 1

SWIMMING SPEEDS OF FISH FOUND IN LAKE ERIE

SPECIES	SIZE (cm)	SWIMMING SPEED Sustained Speed cm/sec	BL/sec	Burst Speed cm/sec	BL/sec	DATA SOURCE
Alewife	7.1	18.6	2.6	-	-	Kothas (1970)
Alewife	7.9	56.1	7.1	-	-	Kothas (1970)
Alewife	-	-	-	-	13.8	Bell (1973)
Bluegill	3.5	15.7	4.0	-	-	King (1969)
Bluegill	4.5	14.3	3.2	-	-	King (1969)
Carp	-	-	-	-	12.6	Bainbridge (1958)
Carp	-	-	-	36.6	-	Kreitmann (1933)
Channel catfish	-	-	-	-	4.2	Hocutt (1973)
Channel catfish	3.0	27.5	9.2	-	-	King (1969)
Channel catfish	10.0	38.3	3.8	-	-	King (1969)
Coho salmon	fry	30.0	-	-	-	Brett et. al. (1958)
Coho salmon	36.0	216.0	6.0	-	-	Weaver (1963)
Coho salmon	61.0	549.0	9.0	-	-	Weaver (1963)
Goldfish	-	-	6.4	-	-	Fry and Hart (1948)
Goldfish	21.3	-	-	200	9.4	Bainbridge (1958)
Goldfish	-	-	-	-	10.0	Blaxter and Dickson (1959)
Lamprey	-	-	-	189.0	-	Sakowicz and Zarnecki (1954)
Largemouth bass	-	-	-	-	8.1	Hocutt (1973)
Largemouth bass	27.0	65	2.4	-	-	Morgan and Moore (1972)
Northern pike	-	-	-	42.7	-	Sakowicz and Zarnecki (1954)
Northern pike	-	-	-	-	10.0	Gray (1953)
Quillback	2.4	21.7	9.0	-	-	King (1969)
Pumpkinseed	7.5	17.0	2.3	-	-	King (1969)

TABLE 1 CON'T.

SWIMMING SPEEDS OF FISH FOUND IN LAKE ERIE

SPECIES	SIZE (cm)	SWIMMING SPEED				DATA SOURCE
		Sustained Speed		Burst Speed		
		cm/sec	BL/sec	cm/sec	BL/sec	
Smallmouth bass	fry	-	6.8	-	-	Larimore and Duever (1968)
Spotfin shiner	-	-	-	-	8.6	Hocutt (1973)
Spottail shiner	5.4	10.7	2.0	-	-	Schuler (1968)
Sucker	-	-	-	-	9.8	Wales (1950)
Walleye	1.5	4.7	3.1	-	-	Houde (1969)
White crappie	6.0	11.7	2.0	-	-	King (1969)
White crappie	8.1	21.7	2.7	-	-	King (1969)
White sucker	-	-	-	-	8.0	Bell (1973)
Yellow perch	1.3	4.2	3.2	-	-	Houde (1969)

TABLE 2

FISH SWIMMING SPEED LITERATURE CITED IN TABLE 1

Bainbridge, R. 1958. The speed of swimming of fish as related to size and to the frequency of the tail beat. J. Exp. Biol., 35(1):109-33.

Bainbridge, R. 1960. Speed and stamina in three fish. J. Exp. Biol. 37:129-153.

Bell, M.C. 1973. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fisheries-Engineering Research Program, Corps of Engineers, North Pacific Division, Portland, Oregon.

Blaxter, J.H.S. 1969. Swimming speeds of fishes. F.A.D. Fish.Rep. 62(2):69-100.

Blaxter, J.H.S. and W. Dickson. 1959. Observations on the swimming speeds of fish. J. Cons. perm. int. Explor. Mer. 24(3):472-7.

Brett, J.R., M. Hollands, and D.F. Alderice. 1958. The effect of temperature on cruising speed of young Sockeye and Coho Salmon. F. Fish. Res. Bd. Can. 15:587-605.

Fry, F.E.J. and J.S. Hart. 1948. Cruising speed of goldfish in relation to water temperature. J. Fish. Res. Bd. Can. 7:169-175.

Gray, J. 1953. The locomotion of fishes. Essays in Marine Biology (Richard Elmhiray Nem.) London, Oliver and Boyd. pp. 1-16.

Hocutt, C.H. 1973. Swimming performance of three warm water fishes exposed to a rapid temperature change. Chesapeake Science. 14(1):11-16.

Houde, E.D. 1969. Sustained swimming ability of larvae of walleye and yellow perch. Fish. Res. Board Can. 26:1647-1659.

King, L.R. 1969. Swimming speed of the channel catfish, white crappie and other warm water fishes from Conowingo Reservoir, Susquehanna River, PA. M.S. Thesis, Cornell University. 83 p.

Kothas, E. 1970. Study of the swimming speed of some anadromous fishes found below Conowingo Dam , Susquehanna River, MD. Ichthyological Assoc., Progress Rept.

Kreitmann, . 1933. Les barrages et al circulation des poissons. Bull. Soc. Centr. d'Agriculture et de Peche. 40 (4-6).

Larimore, W. and M.J. Duever. 1968. Effects of temperature acclimation on the swimming ability of Smallmouth Bass Fry. Trans. American Fish. Soc. 97:175-184.

TABLE 2 CONT'D.

Morgan, P.V. and R.E. Moore. 1972. Survey of large volume water intake system velocities and fish swimming speeds in the Great Lakes. Cyrus M. Rice Div., NUS Corp., Pittsburgh, PA. 27 p.

Regnard, M.P. 1893. Sur un dispositif qui permet de mesurer la vitesse de translation d'un poisson se mouvant dans l'eau. C.R. Hebd. Sean. Acad. Sci., Paris 9(5):81-3.

Sakowicz, S. and S. Zarnecki. 1954. Pool passes: biological aspects in their construction. Polish Agricultural Annual, 69(D):5-171.

Schuler, V.F. 1968. Progress report of swim speed study conducted on fish of the Conowingo Reservoir. Ichthyological Assoc., Progress Rept.

Wales, J.H. 1950. Swimming speed of the western sucker Catostomus occidentalis Ayres. Calif. Fish Game, 36(4):433-4.

Weaver, C.R. 1963. Influence of water velocity upon orientation and performance of adult migratory Salmonids. Fishery Bull. Fish Wildl. Serv. U.S. 63(1): 97-121.

TABLE 3

INTAKE VELOCITIES AT THE BAY SHORE POWER STATION

Date	VELOCITY (knots)			VELOCITY (cm/sec)		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1 September 1976	0.50	0.05	1.10	25.72	2.57	56.58
1 December 1976	0.56	0.03	1.25	28.81	1.54	64.30
20 March 1977	0.39	0.00	0.93	20.06	0.00	47.84
16 June 1977	0.42	0.01	1.20	21.60	0.51	61.73
MEAN	0.47	0.02	1.12	24.18	1.16	57.61

TABLE 4

SPAWNING AND HABITAT CHARACTERISTICS OF COMMON LAKE ERIE FISH

TAXON	REPRODUCTIVE CHARACTERISTICS						HABITAT CHARACTERISTICS (42,45)												
	Maturity	Spawning	Fecundity		Spawning	Longevity	Spawning Location		Water Depth		Water Clarity		Bottom Type				Rooted Aquatic Plants		
Family and Species	Age Class	Temperature (°C)	Female Age or Size	Egg Production/Female	Season	Years	Tributaries	Nearshore	Shallow	Deep	Clear	Turbid	Mud	Sand	Rocky	Organic	Absent	Moderate	Abundant
ACIPENSERIDAE																			
Acipenser fulvescens Lake sturgeon	XX(38)	12-19°C(22)	13,608-17,690g 48,535-52,617g	181,720-188,800(50) 652,904-682,640(50)	May-June(45)	80+(38)	X		X		X			X	X		X		
CLUPEIDAE																			
Alosa pseudoharengus Alewife	M-II F-III(26)	22°C(13)	178 mm	10,000-12,000(26)	June-July(45)	9+(26)	X	X	X	X	X		X	X	X	X			
Dorosoma cepedianum Gizzard shad	II(24)	19.5°C(6)	282-297 mm 434-452 mm	23,405-96,560(24) 267,216-350,288(24)	June-July(6)	9+(24)	X	X	X	X	X	X	X	X	X	X			
SALMONIDAE																			
Coregonus artedii Cisco	II-III(24)	1.1-5.0°C(16)	II III	16,000-42,500 (24) 14,000-38,600(24)	Nov.-Dec.(16)	13(24)		X	X	X	X		X		X		X		
Salvelinus namaycush Lake trout	XIII-XVII(24)			6,000 (24)	Sept.-Nov.(19)	41(24)		X	X	X	X		X		X		X		
OSMERIDAE																			
Osmerus mordax Rainbow smelt	II-III(24)	10°C(13)	241 mm 185-195 mm	57,910 (33) 25,102 (30)	May (13)	6(24)	X	X		X	X		X		X		X		
ESOCIDAE																			
Esox lucius Northern pike	M-II-III F-II(12)	8°C(1)	431-480 mm 597 mm	22,000 (49) 48,950 (31)	Feb.-March(45)	24(24)	X	X	X	X	X			X	X	X			X
Esox masquinongy Muskellunge	M-III F-III-IV(24)	4.5-10°C(45)	900-1170 mm	22,092-164,112 (25)	April(45)	30(24)	X	X	X	X	X		X			X			X
CYPRINIDAE																			
Carassius auratus Goldfish	100-185 mm(32)			1400(28)		4(24)	X	X	X		X	X	X	X	X	X			X
Cyprinus carpio Carp	M-II-IV F-III-V(5)	25.2°C(40)	1225-1905g	72,000-347,000(44)	April June(24)	16(24)	X	X	X		X	X	X	X	X	X		X	
Notemigonus crysoleucas Golden shiner	I-II(8)	16-27°C(8)			May-August(14)	8(15)	X		X		X			X		X			X
Notropis atherinoides Emerald shiner	M-II-III F-III-IV(48)	23°C(47)	III-IV(48)	500-1,500(est.)	June-August(24)	5(48)		X	X		X		X	X	X	X	X		
Notropis hudsonius Spottail shiner	59-84 mm(48)	20°C(13)	87-127 mm	1769-4380(48)	June (13)	5(48)		X	X	X	X			X	X				
Notropis spilopterus Spotfin shiner	I-II(43)		61-82 mm	316-1,155(43)	June-late August (43)	5(43)	X		X			X	X					X	
Pimephales promelas Fathead minnow	<I(10)	15.6°C(10)		800,1,000(10)	May-August(10)	1(10)	X		X			X	X				X	X	
Pimephales notatus Bluntnose minnow	<I(10)	>21°C(10)		200-500 (10)	April-Sept.(10)	3(10)	X		X		X	X	X	X	X	X			
CATOSTOMIDAE																			
Carpiodes cyprinus Quillback	1800-2700g(42)			4,000-15,000(45)	April-May(45)	3(24)	X	X	X	X	X			X	X				
Catostomus commersoni White sucker	M-III-VII(17) F-III-IX	10°C(47)	406-510 mm	56,000-139,000(49)	March-April(24)	12(24)	X		X	X	X	X	X	X	X	X	X	X	X

TABLE 4 (Con't.)

SPAWNING AND HABITAT CHARACTERISTICS OF COMMON LAKE ERIE FISH

TAXON Family and Species	REPRODUCTIVE CHARACTERISTICS Maturity Age Class	Spawning Temperature(°C)	Fecundity Female Age or Size	Fecundity Egg Production/Female	Spawning Season	Longevity Years
ICTALURIDAE						
Ictalurus melas Black bullhead	III(3)	15.6–23.9°C(45)	183–224 mm	168–6,820(11)	May–June(45)	9(35)
Ictalurus natalis Yellow bullhead	II–III(42)	15.6–23.9°C(45)	170–680g	1,652–6,660(46)	May–June(45)	5(41)
Ictalurus nebulosus Brown bullhead	F–III(42)	15.6–23.9°C(45)	203–330 mm	2,400–13,800(18,34,49)	May–June(45)	6(37)
Ictalurus punctatus Channel catfish	IV–VI(29)	27°C(47)	406–508 mm	4,200–106,000(34)	April–August(45)	8(36)
PERCICHTHYIDAE						
Morone chrysops White bass	III(36)	19°C(47)		242,000–933,000(42)	April–May(45)	7(36)
CENTRARCHIDAE						
Lepomis gibbosus Pumpkinseed	II(23)	18–21°C(8)	61–92 mm	600–2,923(46)	April–May(45)	8–10(42)
Lepomis macrochirus Bluegill	II–III(32)	19–27°C(8)		2,360–47,400(8)	May–August(4)	8–10(42)
Pomoxis annularis White crappie	II–III(21)	18°C(47)		5,000–30,000(45)	May–June(45)	8(21)
Pomoxis nigromaculatus Black crappie	II–III(27)	14–18°C(2)		11,000–188,000(8)	March–May(2)	8–10(42)
Micropterus dolomieui Smallmouth bass	III–VI(32)	13–18°C(8)		2,000–10,000(2)	May–July(42)	15(42)
Micropterus salmoides Largemouth bass	II(4)	18–22°C(4)		2,000–25,000(10)	May–July(4)	15(42)
PERCIDAE						
Perca flavescens Yellow perch	M–II F–III(48)	16°C(40)	246 mm	44,000(48)	Mid–April–May(45)	8(48)
Stizostedion canadense Sauger	M–23.7mm F–26.2mm(9)	8.2°C(45)	305–311 mm	43,000–48,500(9)	April–May(45)	10(9)
Stizostedion v. vitreum Walleye	M–II–III F–III–V(48)	4.5–11.1°C(45)		48,000–614,000(48)	March–May(45)	13(39)
SCIAENIDAE						
Aplodinotus grunniens Freshwater drum	M–III–VII F–V–VI(7)	21.0°C(47)		100,000–500,000(45)	Spring(45)	9(7)

TAXON Family and Species	HABITAT CHARACTERISTICS (42,45) Spawning Location: Tributaries	Spawning Location: Nearshore	Water Depth: Shallow	Water Depth: Deep	Water Clarity: Clear	Water Clarity: Turbid	Bottom Type: Mud	Bottom Type: Sand	Bottom Type: Rocky	Bottom Type: Organic	Rooted Aquatic Plants: Absent	Rooted Aquatic Plants: Moderate	Rooted Aquatic Plants: Abundant
ICTALURIDAE													
Ictalurus melas Black bullhead	X	X	X			X	X					X	
Ictalurus natalis Yellow bullhead	X	X	X		X			X	X	X			X
Ictalurus nebulosus Brown bullhead	X	X		X	X			X	X	X		X	
Ictalurus punctatus Channel catfish	X		X	X	X			X	X		X		
PERCICHTHYIDAE													
Morone chrysops White bass	X		X		X			X	X				
CENTRARCHIDAE													
Lepomis gibbosus Pumpkinseed		X	X		X			X		X			X
Lepomis macrochirus Bluegill		X	X		X			X	X	X		X	
Pomoxis annularis White crappie		X	X		X	X	X	X	X	X		X	
Pomoxis nigromaculatus Black crappie		X	X		X			X		X			X
Micropterus dolomieui Smallmouth bass		X	X		X				X			X	
Micropterus salmoides Largemouth bass	X	X	X		X			X	X	X			X
PERCIDAE													
Perca flavescens Yellow perch		X	X	X	X			X		X			X
Stizostedion canadense Sauger	X	X	X			X	X				X	X	
Stizostedion v. vitreum Walleye	X	X	X		X			X	X		X		
SCIAENIDAE													
Aplodinotus grunniens Freshwater drum		X	X	X	X				X				

Data Source: Hartley and Herdendorf (1977)

TABLE 5

FISH FECUNDITY LITERATURE CITED IN TABLE 4

1) Adams, C.C. and T.L. Hankinson. 1928. The ecology and economics of Oneida Lake fish. Roosevelt Wild. Ann. 1(3+4):241-358.

2) Allison, D. and J. Gallant. 1971. Spawning characteristics of certain game and panfishes in Ohio. ODNR, Div. of Wildlife, Fish Mgnt. Sec. 7 p.

3) Barnickol, P.G. and W.C. Starrett. 1951. Commercial and sport fishery of the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa. Bull. Ill. Nat. Hist. Surv. 25(5):267-350.

4) Bennett, G.W. 1971. Management of lakes and ponds. Van Nostrand Reinhold Co., Cincinnati, Ohio. 375 p.

5) Black, V.S. 1951. Osmotic regulations in teleost fishes. Pub. Ont. Fish. Res. Lab. 71:53-89.

6) Bodula, A. 1964. Life history of the Gizzard shad, Dorosoma cepedianum (Le Seur) in western Lake Erie. Fisheries Bull. 65(2):391-425.

7) Butler, R.L. and L.L. Smith, Jr. 1949. The age and rate of growth of the sheephead, Aplodinotus grunniens Rafinesque in the Upper Mississippi River nagivation pools. Trans. Amer. Fish. Soc. 79:43-54.

8) Calhoun, A. 1966. Inland fisheries management. California Dept. of Fish and Game. 546 p.

9) Carlander, K.D. 1949. Growth rate studies of saugers, Stizostedion canadense canadense (Smith) and yellow perch, Perca flavescens (Mitchell) from Lake of the Woods, Minn. Trans. Amer. Fish. Soc. 79:30-42.

10) Carlander, K.D. 1953. Handbook of freshwater fishery biology with the first supplement. Wm. C. Brown Co., Dubuque, Iowa. 429 p.

11) Carlander, K.D. and G. Sprugel. 1950. Project 42. Bullhead management Quart. Rept. Iowa Coop. Wildl. Fish. Res. Units 15(4):44-45.

12) Clark, C.F. 1958. Northern pike, Exos luscius Linnaeus. Data for Handbook of Biological Data. 10 p.

TABLE 5 CONT'D.

13) Commercial Fisheries Review 1961. Lake Erie fish population survey for 1961 season. Commer. Fish. Rev. 23(6):23-24.

14) Cooper, G.P. 1936. Age and growth of the golden shiner (Notemigonus chrysoleucas auratus) and its suitability for propagation. Mich. Acad. Sci., Arts and Let. 21:587-597.

15) Dobie, J.R., O.L. Meehean, S.F. Snieszko and G.N. Washburn. 1956. Raising bait fish. U.S. Fish and Wildl. Service, Circ. 35. 113 p.

16) Dryer, W.R. and J. Beil. 1964. Life history of lake herring in Lake Superior. Fish. Bull. U.S. 63(3):493-530.

17) Eddy, S. and K.D. Carlander. 1940. The effect of environmental factors upon the growth rates of Minnesota fishes. Proc. Minn. Acad. Sci. 8:14-19.

18) Eddy, S. and T. Surber. 1947. Northern Fishes; Ref. Ed., Univ. Minn. Press. 276 p.

19) Eschmeyer, P.H. 1957. Life history and ecology of the lake trout of the Great Lakes. Data for Handbook of Biological Data.

20) Fraser, J.M. 1955. The smallmouth bass fishery of South Bay, Lake Huron. J. Fish. Res. Bd. Can. 12(1):147-177.

21) Hansen, D.F. 1951. Biology of the white crappie in Illinois. Bull. Ill. Nat. Hist. Surv. Vol. 25, Art. 4:211-265.

22) Harkness, W.J.K. 1958. Lake sturgeon, Acipenser fulvescens Rafinesque. Data for Handbook of Biological Data. 4 p.

23) Harlan, J.R. and E.B. Speaker. 1956. Iowa fish and fishing; 3rd ed. Iowa St. Cons. Comm. 377 p.

24) Hartman, W.L. 1973. Effects of exploitation, environmental changes, and new species on the fish habitats and resources of Lake Erie. Great Lakes Fish. Comm. Tech. Rept. No. 22. 43 p.

25) Hasler, A.D., R.K. Meyer and H.M. Field. 1940. The use of hormones for the conservation of the Muskellunge, Esox masquinongy immaculatus Girard. Copeia 1940(1): 43-46.

TABLE 5 CONT'D.

23) Hildebrand, S.F. 1963. Family Clupeidae. Pages 257-454 in Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. 1(3): 630 p.

27) Huish, M.T. 1954. Life history of the black crappie of Lake George, Florida. Trans. Amer. Fish. Soc. 83:176-194.

28) Indian Council of Agricultural Research. 1951. Madras rural pisci-cultural scheme. Progress Rept. Govt. Press, Madras. 75 p.

29) Katz, M. 1954. Reproduction of fish. Data for Handbook of Biological Data. 22 p.

30) Lagler, K.F. 1935. Notes on the spawning habits of the Atlantic smelt. Copeia 1953(3):141-142.

31) Lagler, K.F. 1939. Ohio fish management progress report. Ohio Conserv. Bull. 3(1):16-19.

32) Lagler, K.F. 1956. Freshwater fishery biology. Wm. C. Brown Co., Dubuque, Iowa. 421 p.

33) Langlois, T.H. 1945. Ohio's fish program. Ohio Div. Conserv., Dept. Nat. Res. 40 p.

34) Menzel, R.W. 1945. The catfish fishery of Virginia. Trans. Amer. Fish. Soc. 73:364-372.

35) Moen, T.E. 1959. Notes on the growth of bullheads. Ind. State Conserv. Comm. Quart. Biol. Rept. 11(3):29-31.

36) Ohio Dept. of Natural Resources, Division of Wildlife. Personal Communication-Carl Baker.

37) Oregon State Game Comm. 1952. Annual Report, Fishery Division 1951. 283 p.

38) Probst, R.T. and E.L. Cooper. 1954. Age, growth and production of the lake sturgeon (Acipenser fulvescens) in the Lake Winnebago Region Wisconsin. Trans. Amer. Fish. Soc. 84:207-227.

39) Rawson, D.S. 1956. The life history and ecology of the yellow walleye Stizostedion vitreum in Lac La Ronge, Saskatchewan. Trans. Amer. Fish. Soc. 86:15-37.

TABLE 5 CONT'D.

40) Reutter, J.M. and C.E. Herdendorf. 1974. Laboratory predictions of direct effects of the thermal discharge from the Davis-Besse nuclear power station on the Lake Erie fisheries resource. The Ohio State University, CLEAR Tech. Rept. No. 15. 26 p.

41) Schoffman, R.J. 1955. Age and rate of growth of the yellow bullhead in Reelfoot Lake, Tenn. J. Tenn. Acad. Sci. 30(1):4-7.

42) Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada.

43) Stone, U.B. 1940. Studies on the biology of the satinfin minnows, Notropis analostanus and Notropis spilopterus. Thesis Cornell University 98 p.

44) Swee, U.B. and H.R. McCrimmion. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc. 95(4):372-380.

45) Trautman, M.B. 1957. The Fishes of Ohio. The Ohio State University Press, Columbus. 683 p.

46) Ulrey, L., C. Risk, and W. Scott. 1938. The number of eggs produced by some of our common freshwater fishes. Invest. Ind. Lakes Streams 1(6):73-78.

47) United States Environmental Protection Agency. 1973. Proposed criteria for water quality. U.S. EPA, Washington, D.C. Vol. 1. 425 p.

48) U.S. Fish and Wildlife Service, Sandusky, Ohio. Personal Communication.

49) Vessesl, M.F. and S. Eddy. 1941. A preliminary study of the egg production of certain Minnesota fishes. Minn. Bur. Fish. Res. Invest. Rep. 26. 26 p.

50) Wallurg, C.H. 1957. Observations on the food and growth of juvenile American shad, Alosa sapidissima. Trans. Amer. Fish. Soc. 86:302-306.

TABLE 6

ESTIMATED 1977 SPORT AND COMMERCIAL FISH HARVEST FROM THE OHIO WATERS OF LAKE ERIE[a]

SPECIES	SPORT HARVEST		COMMERCIAL HARVEST		TOTAL HARVEST	
	No. of Individuals	Weight (Kilograms)	No. of Individuals	Weight (Kilograms)	No. of Individuals	Weight (Kilograms)
Yellow Perch	2,964,764	270,881	11,688,277[b]	1,051,945	14,653,041	1,322,826
Walleye	476,078	473,085	0[b]	0	476,078	473,085
White Bass	818,831	169,275	2,505,525[b]	501,105	3,324,356	670,380
Freshwater Drum	233,783	124,504	723,550[b]	361,775	957,333	486,279
Channel Catfish	63,311	25,549	288,460[b]	115,384	351,771	140,933
Smallmouth Bass	8,872	4,563	0[b]	0	8,872	4,563
Others	89,893	[c]	—	1,834,337[d]	—	1,834,337[e]
Total	4,655,532	1,067,857	—	3,864,546	—	4,932,403

[a] Scholl (1978)
[b] Estimated based on mean weight of sport fish.
[c] Data not available.
[d] Sixty-eight % carp.
[e] Excludes weight of "Others" caught by sport anglers.

TABLE 7

ECOLOGICAL AND ECONOMIC IMPORTANCE OF FISHES CAUGHT IN MAUMEE BAY DURING 1974 AND 1975

Fish	Spawning Habitat	Spawning Time	Adult Feeding Niche	Importance to Man
Walleye Stizostedion vitreum (Mitchill)	rocky shoals in lakes and rivers	Spring (6-11°C) pre-spawn migration 1.1°C	fish predator	perhaps the most important commercial and sport fish in Lake Erie
White bass Morone chrysops (Rafinesque)	rocky shoals in lakes and rivers	Spring (12-20°C)	fish predator	important commercial and sport fish
Yellow perch Perca flavescens (Mitchill)	weedy shallows or sand and gravel	Spring (8-13°C)	fish and bottom	important commercial fish and a food fish for Walleye
Freshwater drum Aplodinotus grunniens Rafinesque	over mud or sand bottom in shallow water	Summer (20+)	bottom and some fish	commercial fish and a food fish for Walleye
Carp Cyprinus carpio Linnaeus	weedy or grassy shallows	Spring (17-26°C)	benthic omnivore	environmentally a destructive pest species but also a commercial fish
Goldfish Carassius auratus (Linnaeus)	warm, weedy shallows	Late Spring	benthic omnivore	little to no value
Channel catfish Ictalurus punctatus (Rafinesque)	in dark nests in holes, log jams in shallow area of turbid waters	Summer (24-30°C)	bottom	commercial fish
White sucker Catostomus commersoni (Lacepede)	quiet, gravel shallows of lakes and rivers	Spring (10°C)	benthic omnivore	minor commercial; fish when abundant a major food item for predatory fish
Quillback Carpiodes cyprinus (Lesueur)	shallow quiet, mud or sand areas of lakes and rivers	Late Spring	benthic omnivore	of little value either directly to man or in the food chain to important species

TABLE 7--continued

ECOLOGICAL AND ECONOMIC IMPORTANCE OF FISHES CAUGHT IN MAUMEE BAY DURING 1974 AND 1975

Fish	Spawning Habitat	Spawning Time	Adult Feeding Niche	Importance to Man
Gizzard shad Dorosoma cepedianum (Lesueur)	probably over sand or gravel bottom	Late spring to summer	phytoplankton feeders	Small gizzard shad are an important forage fish for game and commercial species.
Alewife Alosa pseudoharengus (Wilson)	shallow beaches, ponds and quiet rivers	Spring	zooplankton feeders	Generally considered a nuisance due to annual die-offs but can be an important forage fish for game and commercial species.
Rainbow trout Salmo gairdneri Richardson	fine gravel in a riffle above a pool, in a small stream or outlet of such a stream	Spring	predator on fish	one of the top five sport fish in North America
Northern pike Esox lucius Linnaeus	in weedy flood plains of rivers and in marshes and weedy bays	Early Spring	fish predator	important but rare commercial and sport fish
Mooneye Hiodon tergisus Lesueur	pools in turbid rivers, backwater lakes and ponds	Late spring to early summer	omnivore	minor commercial and sport fish
Emerald shiner Notropis atherinoides Rafinesque	midwater	Late spring to summer	plankton	major food item for several sport fish; used as bait minnow by man
Spottail shiner Notropis hudsonius (Clinton)	over sandy shoals	Spring and early summer	omnivore	an important forage fish; used as bait minnow by man
Logperch Percina caprodes (Rafinesque)	sandy inshore shallows	Late spring	benthic carnivore	unknown importance as forage fish for game and commercial species

Data Source: Fraleigh, et al. (1975); Scott and Crossman (1973).

TABLE 8
SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY
Scientific and Common Names

Lepisosteidae
- *Lepisosteus osseus*
  - Longnose gar

Clupeidae
- *Alosa pseudoharengus*
  - Alewife
- *Dorosoma cepedianum*
  - Gizzard shad

Hiodontidae
- *Hiodon tergisus*
  - Mooneye

Osmeridae
- *Osmerus mordax*
  - Rainbow smelt

Cyprinidae
- *Carassius auratus*
  - Goldfish
- *Cyprinus carpio*
  - Carp
- *Hybopsis storeriana*
  - Silver chub
- *Notropis atherinoides*
  - Emerald shiner
- *Notropis hudsonius*
  - Spottail shiner

Catostomidae
- *Carpoides cyprinus*
  - Quillback
- *Catostomus commersoni*
  - White sucker
- *Moxostoma macrolepidotum*
  - Shorthead redhorse

Ictaluridae
- *Ictalurus melas*
  - Black bullhead
- *Ictalurus punctatus*
  - Channel catfish
- *Noturus gyrinus*
  - Tadpole madtom

Percopsidae
- *Percopsis omiscomaycus*
  - Trout-perch

Percichthyidae
- *Morone chrysops*
  - White bass

Centrarchidae
- *Pomoxis* sp.
  - Crappie
- *Pomoxis annularis*
  - White crappie
- *Lepomis* sp.
  - Sunfish

Percidae
- *Perca flavescens*
  - Yellow perch
- *Percina caprodes*
  - Logperch
- *Stizostedion canadense*
  - Sauger
- *Stizostedion v. vitreum*
  - Walleye

Scianenidae
- *Aplodinotus grunniens*
  - Freshwater drum

TABLE 8--continued
SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY
MAY - OCTOBER, 1975
Station 9

Species	5-16		6-5		7-10		8-26		9-7		9-21		10-4		Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	
Alewife	156-192	129	154-212	136	142-160	8					103-135	27			300
Black bullhead															
Carp	357	1	360	1	264-420	15	302-413	17	307-422	11	327-605	4	95-171	110	159
Channel catfish			178-350	4	160-217	3	296-322	2	224-370	4			166-414	3	16
Emerald shiner	116-120	7	104-120	21	117-120	3									31
Freshwater drum	237-281	2	117-350	13			87-165	6	89	2	89-258	4	293	1	28
Gizzard shad	323-405	6	305-443	7	260-340	6	76-392	394	90-174	92	134-193	15	107-182	127	647
Goldfish					245-380	2									2
Log perch	110-115	2													2
Longnose gar															
Quillback															
Sauger							335	1	341	1			381	1	3
Shorthead redhorse											352	1			1
Silver chub			175-190	2	189-190	2									4
Smelt													181-194	3	3
Spottail shiner	99-132	77	100-135	35	95-130	16	92-129	26	94-130	27	105-138	22	102-137	47	250
Trout perch	99-128	4	110	1											5
Walleye	208-490	19	192-398	8	233-285	10	304	1					193-364	5	43
White bass	244-340	5	155-290	4	170-260	4	367	1	91-107	2			89	1	17
White crappie															
White sucker	209	1							345	1					2
Yellow perch	146-202	18	145-220	61	112-202	25	145-214	26	128-206	70	147-212	70	146-207	36	306
Total		271		293		94		474		210		143		334	1819

TABLE 8--continued

SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY

MAY - OCTOBER, 1975

Station 11

Species	5-16		6-5		7-10		8-26		9-7		9-21		10-4		Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	
Alewife	181	1	163-187	3	152-156	2			103-115	5	98-194	59	94-197	218	288
Black bullhead							243	1							1
Carp					280-446	8									8
Channel catfish			261	1	310-315	2	372	1			141	1			5
Emerald shiner					105-115	5									5
Freshwater drum	223-331	10	93-333	9	125-201	5	86-151	4	76-84	2	94	1			31
Gizzard shad			400	1	266-383	5	77-398	392	101-326	75	121-164	31	100-328	214	718
Goldfish					331	1	245	1							2
Log perch															
Longnose gar															
Quillback															
Sauger					275	1							379	1	2
Shorthead redhorse															
Silver chub			167-190	3											3
Smelt					155	1									1
Spottail shiner	104-122	7	110-115	2	93-115	9	95-128	16	95-126	51	104-132	36	108-137	35	96
Trout perch															
Walleye	193-460	23	245	1	225-260	8	181	1			185-348	3	209-360	4	40
White bass	482	1			165-185	3							100-310	2	6
White crappie															
White sucker					167	1							440-446	2	3
Yellow perch	66-86	2	99-208	21	73-210	102	164-214	47	132-205	47	142-211	90	155-231	31	340
Total		44		42		153		463		180		221		507	1607

TABLE 8--continued
SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY
MAY - OCTOBER, 1975
Station 15

Species	6-5		7-8		8-26		9-6		9-21		10-5		10-18		Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No	
Alewife															
Black bullhead															
Carp	315-445	4	253-513	8	336	1	358-363	2	443-483	2					17
Channel catfish					342	1							235	1	2
Emerald shiner															
Freshwater drum	84-255	4	93-95	2					169-224	2	177	1	159	1	10
Gizzard shad	137-400	16	280-380	8	235-351	6	242	1					319	1	32
Goldfish	108-213	4	125	1											5
Log perch															
Longnose gar															
Quillback															
Sauger			271	1											1
Shorthead redhorse															
Silver chub															
Smelt															
Spottail shiner															
Trout perch															
Walleye															
White bass	145	1	263	1											2
White crappie															
White sucker															
Yellow perch															
Total		29		21		8		3		4		1		3	69

TABLE 8 -continued
SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY
MAY - OCTOBER, 1975
Station 16

Species	8-26		9-6		9-21		10-5		10-18						Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	
Alewife															
Black bullhead															
Carp	338-376	2	348-367	3	363	1	624	1							5
Channel catfish					226	1	290	1	156	1					3
Emerald shiner															
Freshwater drum	154	1													1
Gizzard shad	83-248	25	71-258	21	341	1	332-379	3	133-396	8					58
Goldfish	140-194	2	234	1	346	1									4
Log perch															
Longnose gar	658	1			434	1									2
Quillback															
Sauger					365	1	384	1	363-364	2					58
Shorthead redhorse															
Silver chub															
Smelt															
Spottail shiner															
Trout perch															
Walleye	407	1													1
White bass	90-359	3	241-258	2					243-268	4					9
White crappie	167	1													1
White sucker															
Yellow perch	193	1													1
Total		37		27		6		6		15					89

TABLE 8 -continued
SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY
MAY - OCTOBER, 1975
Station 43

Species	6-25		7-8		8-26		9-6		9-20		10-4		10-18		Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	
Alewife											111-131	229			229
Black bullhead															
Carp	253-422	9	397-475	2	230-505	22	229-352	9			352	1			43
Channel catfish															
Emerald shiner															
Freshwater drum	120-365	44	260	1	85-229	11	89	1			86-98	5	99-101	2	64
Gizzard shad	315-375	3	410	1	122-170	42	147	1			94-320	54	130-347	2	103
Goldfish	234-345	4			229-320	3	225-368	12	239-352	2	264-371	11	286-360	5	37
Log perch															
Longnose gar															
Quillback															
Sauger															
Shorthead redhorse															
Silver chub															
Smelt											186	1	168-180	2	3
Spottail shiner					102-122	2			115	1	105-128	38	110-121	5	46
Trout perch															
Walleye													191-197	2	2
White bass					86	1					95-149	2			3
White crappie															
White sucker															
Yellow perch					149-228	10	179-202	2			97-212	23	120-191	6	41
Total		60		4		91		25		3		364		24	571

TABLE 8[illegible]-continued

SPECIES COMPOSITION OF FISHES TAKEN FROM MAUMEE RIVER AND BAY

MAY - OCTOBER, 1975

Station 44

Species	7-8		8-8		8-26		9-7		9-20		10-5		10-18		Total
	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	Range (mm)	No.	
Alewife															
Black bullhead															
Carp	370-523	11	250-507	13	285-475	7	340	1	370-587	2	342-429	6	306	1	41
Channel catfish	153-202	4							249	1	163-195	2			7
Emerald shiner															
Freshwater drum	90	1	170-235	3	149-245	3					153-174	2			9
Gizzard shad	310-405	2	270-307	2	80-169	10			101-151	2	315-333	2			18
Goldfish	258-279	3					174-363	5	331-355	2	289	1	287-336	2	13
Log perch															
Longnose gar									370	1					1
Quillback	385	1	180-380	2							236	1	320	1	5
Sauger			335	1					361-364	2	353-377	4	342-376	4	11
Shorthead redhorse	373	1									192	1	380	1	3
Silver chub															
Smelt															
Spottail shiner															
Trout perch															
Walleye	237	1													1
White bass	267-282	2	95-250	3	87-134	7					149-351	3	240-265	6	21
White crappie															
White sucker															
Yellow perch															
Total		28		24		27		6		10		22		15	130

TABLE 9

SPAWNING AND NURSERY HABITAT PREFERENCE OF COMMON LAKE ERIE FISH SPECIES

Common and Scientific Name	SPAWNING AREAS - HABITAT TYPE							NURSERY AREAS - HABITAT TYPE									
		Shallow protected Sand or Mud Bottom		Shallow exposed		Gravel or Rubble with Current			Shallow protected Sand or mud bottom		Shallow exposed		Medium Depth Mud Bottom	Gravel or Rubble with Current		Deep	
	Tributary	Vegetation	Without Vegetation	Sand or Gravel Bottom	Rock or Rubble Bottom		Mid-Water	Tributary	Vegetation	Without Vegetation	Sand or Gravel Bottom	Rock or Rubble Bottom			Mid-Water	Mud Bottom	Sand or Gravel Bottom
Silver lamprey (Ichthyomyzon unicuspis)	X							X									
Sea lamprey (Petromyzon marinus)	X							X									
Lake sturgeon (Acipenser fulvescens)	X											X	X				
Spotted gar (Lepisosteus oculatus)			X						X								
Longnose gar (Lepisosteus osseus)			X						X								
Bowfin (Amia calva)		X	X						X								
Alewife (Alosa pseudoharengus)				X							X						
Gizzard shad (Dorosoma cepedianum)				X					X	X	X		X				
Coho salmon (Oncorhynchus kisutch)	X							X									
Lake whitefish (Coregonus clupeaformis)					X	X						X		X			
Rainbow smelt (Osmerus mordax)					X	X									X		X
Mooneye (Hiodon tergisus)	X							X									
Central mudminnow (Umbra limi)		X							X								
Grass pickerel (Esox americanus vermiculatus)		X							X								
Northern pike (Esox lucius)		X							X								
Muskellunge (Esox masquinongy)		X							X								
Carp (Cyrinus carpio)		X	X						X	X			X				
Goldfish (Carassius auratus)		X	X						X	X			X				
Silver chub (Hybopsis storeriana)							X								X		
Golden shiner (Notemigonus crysoleucas)		X							X								
Emerald shiner (Notropis atherinoides)							X								X		
Spottail shiner (Notropis hudsonius)				X							X						
Spotfin shiner (Notropis spilopterus)		X	X						X	X	X	X					
Bluntnose minnow (Pimephales notatus)		X	X						X	X							
Fathead minnow (Pimephales promelas)		X	X						X	X							
Quillback (Carpiodes cyprinus)		X							X								
White sucker (Catostomus commersoni)	X							X									
Bigmouth buffalo (Ictiobus cyprinellus)		X											X				
Silver redhorse (Moxostoma anisurum)	X							X									
Golden redhorse (Moxostoma erythrurum)	X							X									
Black bullhead (Ictalurus melas)		X	X						X	X							
Yellow bullhead (Ictalurus natalis)		X	X						X	X							
Brown bullhead (Ictalurus nebulosus)		X	X						X	X							
Channel catfish (Ictalurus punctatus)					X				X	X	X	X	X				
Stonecat (Noturus flavus)					X							X		X			
Tadpole madtom (Noturus gyrinus)		X							X								

TABLE 9-CON'T.

SPAWNING AND NURSERY HABITAT PREFERENCE
OF COMMON LAKE ERIE FISH SPECIES

Common and Scientific Name	SPAWNING AREAS - HABITAT TYPE							NURSERY AREAS - HABITAT TYPE									
		Shallow protected Sand or Mud Bottom		Shallow exposed					Shallow protected Sand or Mud Bottom		Shallow exposed					Deep	
	Tributary	Vegetation	Without Vegetation	Sand or Gravel Bottom	Rock or Rubble Bottom	Gravel or Rubble with Current	Mid-Water	Tributary	Vegetation	Without Vegetation	Sand or Gravel Bottom	Rock or Rubble Bottom	Medium Depth Mud Bottom	Gravel or Rubble with Current	Mid-Water	Mud Bottom	Sand or Gravel Bottom
Banded killifish (Fundulus diaphanus)		X							X								
Burbot (Lota lota)					X	X						X					
Troutperch (Percopsis omiscomaycus)				X							X	X				X	X
White bass (Morone chrysops)					X	X					X	X	X				
Rock bass (Ambloplites rupestris)					X							X					
Pumpkinseed (Lepomis gibbosus)		X	X						X	X							
Bluegill (Lepomis macrochirus)		X	X						X	X							
Smallmouth bass (Micropterus dolomieui)					X					X							
Largemouth bass (Micropterus salmoides)		X	X						X	X							
White crappie (Pomoxis annularis)			X	X						X			X				
Black crappie (Pomoxis nigromaculatus)		X							X								
Yellow perch (Perca flavescens)				X	X	X					X	X					
Sauger (Stizostedion canadense)					X	X					X						
Walleye (Stizostedion v. vitreum)					X	X					X						
Johnny darter (Etheostoma nigrum)					X						X						
Logperch (Percina caprodes)				X					X		X						
Freshwater drum (Aplodinotus grunniens)				X	X	X	X				X		X			X	X
Mottled sculpin (Cottus bairdi)			X								X						
Brook silverside (Labidesthes sicculus)		X	X						X	X							

Data sources: Hartley and VanVooren (1977) Herdendorf, et al. (1977b and c).

TABLE 10

FIELD MONITORING SCHEDULE AT THE BAY SHORE POWER STATION

Collection Period	Month	Day	Julian Date	Impingement	Entrainment
1	Sept.	1	245		X
2	1976	8	252		X
3		15	259		X
4		22	266	X	
5		29	273	X	
6	Oct.	6	280	X	
7		13	287	X	
8		20	294	X	
9		27	301	X	
10	Nov.	3	308	X	
11		10	315	X	
12		17	322	X	
13		24	329	X	
14	Dec.	1	336	X	
15		8	343	X	
16		15	350	X	
17		22	357	X	
18		29	364	X	
19	Jan.	5	005	X	
20	1977	12	012	X	
21		19	019	X	
22		26	026	X	
23	Feb.	2	033	X	
24		9	040	X	
25		16	047	X	
26		23	054	X	
27	March	2	061	X	
28		9	068	X	
29		16	075	X	X
30		20	079	X	X
31		24	083	X	X
32		28	087	X	X
33	April	1	091	X	X
34		5	095	X	X
35		9	099	X	X
36		13	103	X	X
37		17	107	X	X
38		21	111	X	X
39		25	115	X	X
40		29	119	X	X
41	May	3	123	X	X
42		7	127	X	X
43		11	131	X	X
44		15	135	X	X
45		19	139	X	X
46		23	143	X	X

TABLE 10 CONT'D.

FIELD MONITORING SCHEDULE AT THE BAY SHORE POWER STATION

Collection Period	Month	Day	Julian Date	Impingement	Entrainment
47	(May)	27	147	X	X
48		31	151	X	X
49	June	4	155	X	X
50		8	159	X	X
51		12	163	X	X
52		16	167	X	X
53		23	174	X	X
54		30	181	X	X
55	July	7	188	X	X
56		14	195	X	X
57		21	202	X	X
58		28	209	X	X
59	Aug.	4	216	X	X
60		11	223	X	X
61		18	230	X	X
62		25	237	X	X
63	Sept.	1	244	X	X
64		8	251	X	
65		15	258	X	

TABLE 11

COMMON AND SCIENTIFIC NAMES OF FISH IMPINGED
AT THE BAY SHORE POWER STATION

COMMON NAME	SCIENTIFIC NAME
Alewife	*Alosa pseudoharengus*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Black Bullhead	*Ictalurus melas*
Black Crappie	*Pomoxis nigromaculatus*
Bluegill Sunfish	*Lepomis macrochirus*
Bluntnose Minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brindled Madtom	*Noturus miurus*
Brook Silversides	*Labidesthes sicculus*
Brown Bullhead	*Ictalurus nebulosus*
Carp	*Cyprinus carpio*
Channel Catfish	*Ictalurus punctatus*
Channel Darter	*Percina copelandi*
Chinook Salmon	*Oncorhynchus tschawytscha*
Coho Salmon	*O. kisutch*
Emerald Shiner	*Notropis atherinoides*
Fathead Minnow	*Pimephales promelas*
Freshwater Drum	*Aplodinotus grunniens*
Gizzard Shad	*Dorosoma cepedianum*
Golden Shiner	*Notemigonus crysoleucas*
Goldfish	*Carassuis auratus*
Green Sunfish	*Lepomis cyanellus*
Johnny Darter	*Etheostoma nigrum*
Logperch Darter	*Percina caprodes*

TABLE 11 CONT'D.

Long-nosed Gar	*Lepisosteus osseus*
Mooneye	*Hiodon tergisus*
Mottled Sculpin	*Cottus bairdi*
Northern Hog Sucker	*Hypentelium nigricans*
Northern Pike	*Esox lucius*
Orangespotted Sunfish	*Lepomis humilis*
Pumpkinseed Sunfish	*L. gibbosus*
Quillback Carpsucker	*Carpiodes cyprinus*
Rainbow Smelt	*Osmerus mordax*
Rockbass	*Ambloplites rupestris*
Sauger	*Stizostedion canadense*
Sea Lamprey	*Petromyzon marinus*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Silver Chub	*Hybopsis storeriana*
Silver Lamprey	*Ichthyomyzon unicuspis*
Smallmouth Bass	*Micropterus dolomieui*
Spotfin Shiner	*Notropis spilopterus*
Spottail Shiner	*N. hudsonius*
Stonecat Madtom	*Noturus flavus*
Tadpole Madtom	*N. gyrinus*
Threespine Stickleback	*Gasterosteus aculeatus*
Troutperch	*Percopsis omiscomaycus*
Walleye	*Stizostedion v. vitreum*
White Bass	*Morone chrysops*
White Crappie	*Pomoxis annularis*
White Sucker	*Catostomus commersoni*
Yellow Bullhead	*Ictalurus natalis*
Yellow Perch	*Perca flavescens*

*Bailey, et al (1970).

TABLE 12

FISH IMPINGEMENT ESTIMATES AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977 *

SPECIES	NUMBER IMPINGED			WEIGHT IMPINGED		
	Number of Individuals	95% Confidence Limits		Grams	95% Confidence Limits	
		Lower	Upper		Lower	Upper
Alewife	1,375,911	786,515	2,406,986	10,740,831	6,139,805	18,789,757
Bigmouth Buffalo	10	2	44	2,555	583	11,196
Black Bullhead	119	77	184	5,835	3,769	9,034
Black Crappie	146	51	414	6,663	2,344	18,939
Bluegill	468	332	659	2,209	1,569	3,111
Bluntnose Minnow	422	229	777	651	354	1,199
Bowfin	6	2	20	2,877	907	9,131
Brindled Madtom	9	2	47	201	39	1,029
Brook Silversides	3	1	16	1	0	6
Brown Bullhead	244	189	315	26,240	20,323	33,881
Carp	1,953	1,512	2,522	216,658	167,762	279,804
Channel Catfish	20,995	16,214	27,186	1,036,760	800,659	1,342,484
Channel Darter	5	1	31	2	0	10
Chinook Salmon	10	2	39	785	193	3,201
Coho Salmon	152	105	221	15.034	10,375	21,784
Emerald Shiner	3,282,597	2,147,664	5,017,285	8,097,820	5,298,060	12,377,113
Fathead Minnow	626	464	843	1,243	922	1,674
Freshwater Drum	365,779	271,584	492,697	5,806,658	4,311,101	7,821,037
Gizzard Shad	11,347,255	8,698,622	14,802,368	122,357,850	93,797,543	159,614,453
Golden Shiner	38	19	74	94	48	182
Goldfish	4,471	3,292	6,073	588,267	433,104	799,018
Green Sunfish	2,227	1,369	3,624	7,717	4,743	12,556
Johnny Darter	26	4	162	7	1	42
Logperch Darter	4,647	2,940	7,345	19,298	12,209	30,505
Long-nosed Gar	64	35	117	3,129	1,716	5,707
Mooneye	5	1	20	18	4	70
Mottled Sculpin	7	2	31	7	2	31
Northern Hog Sucker	3	1	16	162	32	829
Northern Pike	132	71	248	8,195	4,371	15,365
Orange-spotted Sunfish	942	553	1,603	3,328	1,955	5,665
Pumpkinseed Sunfish	242	172	340	4,555	3,237	6,410
Quillback Carpsucker	452	245	834	18,251	9,898	33,654
Rainbow Smelt	87,374	62,615	121,923	351,679	252,025	490,739
Rockbass	95	23	398	3,897	931	16,312
Sauger	194	41	921	31,446	6,638	148,968
Sea Lamprey	10	2	39	1,114	273	4,543
Shorthead Redhorse	290	148	568	36,513	18,607	71,648
Silver Chub	123	83	183	1,847	1,247	2,736
Silver Lamprey	184	114	297	6,222	3,854	10,044
Smallmouth Bass	180	55	597	15,574	4,707	51,528
Spotfin Shiner	15	6	37	18	7	43
Spottail Shiner	212,515	164,608	274,365	1,661,339	1,286,823	2,144,854
Stonecat Madtom	78	42	145	703	377	1,309
Tadpole Madtom	653	384	1,109	3,596	2,118	6,108
Threespine Stickleback	32	19	52	56	34	93
Troutperch	23,308	19,315	28,127	150,166	124,439	181,212
Walleye	12,187	9,466	15,690	1,220,100	947,716	1,570,770
White Bass	624,078	467,610	832,902	2,766,071	2,072,565	3,691,632
White Crappie	1,297	930	1,809	59,197	42,446	82,558
White Sucker	780	497	1,223	113,751	72,477	178,530
Yellow Bullhead	14	6	36	330	131	830
Yellow Perch	437,260	347,626	550,007	15,310,639	12,172,095	19,258,448
TOTAL	17,810,633			170,708,159		

* Excluding fish runs.

TABLE 13

SUMMARY OF FISH IMPINGEMENT BY NUMBER AND WEIGHT
AT THE BAY SHORE POWER STATION FROM 15 SEPTEMBER 1976
TO 15 SEPTEMBER 1977

SPECIES *	NO. OF INDIVIDUALS		WEIGHT	
	Number	% of Total	Kilograms	% of Total
Gizzard Shad	11,347,255	63.7	122,358	71.8
Emerald Shiner	3,282,597	18.4	8,098	4.7
Alewife	1,375,911	7.7	10,741	6.3
White Bass	624,078	3.5	2,766	1.6
Yellow Perch	437,260	2.4	15,311	8.9
Freshwater Drum	365,779	2.1	5,807	3.4
Spottail Shiner	212,515	1.2	1,661	1.0
Rainbow Smelt	87,374	0.5	352	0.2
Walleye	12,187	0.1	1,220	0.7
Channel Catfish	20,995	0.1	1,037	0.6
Others	44,682	0.3	1,357	0.8
Total	17,810,663	100.0	170,708	100.0

* Ten most prominent species. To be listed a species represented at least 0.1% of the total number and 0.2% of the total weight. These are estimates. See Table 12 for confidence intervals.

TABLE 14

FISH IMPINGEMENT * AT THE BAY SHORE POWER STATION FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	1		2		3		4		5		6		7		8	
Dates	9/1-9/15/76		9/15-9/29/76		9/29-10/13/76		10/13-10/27/76		10/27-11/10/76		11/10-11/24/76		11/24-12/8/76		12/8-12/22/76	
Species	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT
Alewife	**		1287	1.8	3839	1.9	19470	2.1	113645	5.3	122163	8.2	45485	1.4	713126	27.8
Channel Catfish	**		30	0.0	172	0.1	183	0.0	72	0.0	225	0.0	512	0.0	203	0.0
Emerald Shiner	**		5301	7.2	12452	6.2	245785	26.2	142135	6.7	342096	22.9	1186490	37.3	803365	31.4
Freshwater Drum	**		2646	3.6	19239	9.5	33345	3.5	11217	0.5	3855	0.3	3432	0.1	2739	0.1
Gizzard Shad	**		57012	77.9	155132	76.6	625187	66.6	1833779	86.2	943102	63.2	1861561	58.5	997729	39.0
Rainbow Smelt	**		270	0.4	167	0.1	1223	0.1	16300	0.8	40806	2.7	19888	0.6	3854	0.2
Spottail Shiner	**		330	0.5	916	0.5	1380	0.1	3303	0.2	31492	2.1	50370	1.6	34869	1.4
Troutperch	**		38	0.1	95	0.0	108	0.0	105	0.0	202	0.0	144	0.0	95	0.0
Walleye	**		30	0.0	17	0.0	7	0.0	7	0.0	38	0.0	521	0.0	0	0.0
White Bass	**		3967	5.4	6496	3.2	6912	0.7	4412	0.2	2924	0.2	2329	0.1	708	0.0
Yellow Perch	**		2206	3.0	3445	1.7	5276	0.6	2875	0.1	4222	0.3	7827	0.2	1451	0.1
Others	**		52	0.1	357	0.2	586	0.1	700	0.0	956	0.1	1299	0.1	261	0.0
TOTAL	**		73169	100	202327	100	939462	100	2128550	100	1492081	100	3179858	100	2558400	100

* Data presented as numbers of individuals. All species listed except Walleye constituted at least 2% of the total number from at least one reporting interval.

** No samples collected.

TABLE 14 CONT'D.

FISH IMPINGEMENT * AT THE BAY SHORE POWER STATION FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	9		10		11		12		13		14		15		16	
Dates	12/22-1/5/77		1/5-1/19/77		1/19-2/2/77		2/2-2/16/77		2/16-3/2/77		3/2-3/16/77		3/16-3/24/77		3/24-4/1/77	
Species	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT
Alewife	371278	22.3	32880	1.4	10471	1.4	686	1.0	76	0.0	0	0.0	10	0.0	6	0.0
Channel Catfish	317	0.0	68	0.0	240	0.0	127	0.2	152	0.1	208	0.1	161	0.2	158	0.3
Emerald Shiner	37081	2.2	7833	0.3	1644	0.2	363	0.6	41395	21.8	79472	30.4	44150	55.6	41273	66.8
Freshwater Drum	5060	0.3	6646	0.3	9932	1.3	1086	1.6	3620	1.9	5104	2.0	1635	2.1	1983	3.2
Gizzard Shad	1238313	74.4	2372064	97.9	740109	96.5	62130	94.3	140057	73.6	163816	62.7	25140	31.7	9803	15.9
Rainbow Smelt	5117	0.3	1134	0.0	302	0.0	133	0.2	116	0.1	7	0.0	9	0.0	12	0.0
Spottail Shiner	4968	0.3	2238	0.1	1908	0.2	305	0.5	1100	0.6	4610	1.8	3916	4.9	4789	7.8
Troutperch	114	0.0	50	0.0	84	0.0	92	0.1	91	0.0	307	0.1	389	0.5	695	1.1
Walleye	0	0.0	0	0.0	0	0.0	41	0.1	56	0.0	44	0.0	125	0.2	66	0.1
White Bass	356	0.0	229	0.0	398	0.1	128	0.2	2092	1.1	2572	1.0	266	0.3	173	0.3
Yellow Perch	1288	0.1	269	0.0	1182	0.2	341	0.5	899	0.5	2251	0.9	1631	2.1	1978	3.2
Others	351	0.0	98	0.0	476	0.1	425	0.7	483	0.3	2547	1.0	1852	2.4	811	1.3
TOTAL	1664243	100	2423509	100	766746	100	65857	100	190137	100	260938	100	79284	100	61747	100

* Data presented as numbers of individuals. All species listed except Walleye constituted at least 2% of the total number from at least one reporting interval.

** No samples collected.

TABLE 14 CONT'D.

FISH IMPINGEMENT * AT THE BAY SHORE POWER STATION FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	17		18		19		20		21		22		23		24	
Dates	4/1-4/9/77		4/9-4/17/77		4/17-4/25/77		4/25-5/3/77		5/3-5/11/77		5/11-5/19/77		5/19-5/27/77		5/27-6/4/77	
Species	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT
Alewife	16	0.0	43	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	0.0	0	0.0
Channel Catfish	371	0.4	931	0.9	823	0.5	234	0.3	382	0.7	601	1.2	414	0.9	530	1.1
Emerald Shiner	71721	75.4	75730	72.0	124031	72.6	37550	50.0	33421	61.5	35029	68.4	24904	51.8	17984	37.3
Freshwater Drum	2230	2.3	3364	3.2	2331	1.4	1341	1.8	2433	4.5	5753	11.2	7187	15.0	8040	16.6
Gizzard Shad	9326	9.8	9832	9.4	13986	8.2	16180	21.6	10647	19.6	3266	6.4	509	1.1	2349	4.9
Rainbow Smelt	31	0.0	74	0.1	16	0.0	15	0.0	15	0.0	9	0.0	6	0.0	3	0.0
Spottail Shiner	6990	7.3	6868	6.5	8491	5.0	5307	7.1	4844	8.9	3356	6.6	3394	7.1	2729	5.6
Troutperch	732	0.8	948	0.9	1415	0.8	439	0.6	320	0.6	1656	3.2	6268	13.0	3399	7.0
Walleye	412	0.4	428	0.4	470	0.3	156	0.2	68	0.1	80	0.2	67	0.1	9	0.0
White Bass	238	0.3	216	0.2	213	0.1	156	0.2	202	0.4	288	0.6	147	0.3	46	0.1
Yellow Perch	1991	2.1	5647	5.4	17846	10.4	12586	16.8	1401	2.6	662	1.3	4716	9.8	12802	26.5
Others	1086	1.2	1002	1.0	1133	0.7	1025	1.4	605	1.1	450	0.9	445	0.9	440	0.9
TOTAL	95144	100	105083	100	170755	100	74989	100	54338	100	51150	100	48066	100	48331	100

* Data presented as numbers of individuals. All species listed except Walleye constituted at least 2% of the total number from at least one reporting interval.

** No samples collected.

TABLE 14 CONT'D.

FISH IMPINGEMENT * AT THE BAY SHORE POWER STATION FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	25		26		27		28		29		30		31		32	
Dates	6/4-6/12/77		6/12-6/23/77		6/23-7/7/77		7/7-7/21/77		7/21-8/4/77		8/4-8/18/77		8/18 9/1/77		9/1-9/15/77	
Species	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT	Number	% of TOT
Alewife	9	0.0	16	0.0	0	0.0	0	0.0	0	0.0	10	0.0	5891	1.7	9262	1.3
Channel Catfish	727	1.4	433	0.8	241	0.2	909	0.3	3832	0.9	6151	2.4	1894	0.5	1157	0.2
Emerald Shiner	16435	32.6	11937	23.0	1414	1.0	1347	0.4	1403	0.3	6090	2.4	41612	12.0	58666	8.1
Freshwater Drum	5554	11.0	2912	5.6	1833	1.3	2809	0.9	78212	19.0	50411	20.0	58645	17.0	46074	6.4
Gizzard Shad	1500	3.0	269	0.5	27721	20.1	53463	17.1	30873	7.5	66197	26.2	115340	33.3	487959	67.6
Rainbow Smelt	18	0.0	33	0.1	651	0.5	694	0.2	804	0.2	649	0.3	319	0.1	555	0.1
Spottail Shiner	1451	2.9	1366	2.6	2024	1.5	5184	1.7	8447	2.1	5986	2.4	7709	2.2	10830	1.5
Troutperch	291	0.6	1372	2.6	3117	2.3	1780	0.6	745	0.2	145	0.1	269	0.1	263	0.0
Walleye	61	0.1	526	1.0	1678	1.2	1513	0.5	2739	0.7	1538	0.6	960	0.3	1475	0.2
White Bass	52	0.1	53	0.1	37833	27.4	175924	56.1	220549	53.5	76345	30.2	63098	18.2	60933	8.5
Yellow Perch	24092	47.8	32866	63.3	61047	44.1	68850	21.9	64067	15.5	36367	14.4	49670	14.4	42905	6.0
Others	242	0.5	229	0.4	597	0.4	806	0.3	391	0.1	2558	1.0	737	0.2	369	0.1
TOTAL	50432	100	52012	100	138156	100	313279	100	412062	100	252447	100	346144	100	720448	100

* Data presented as numbers of individuals. All species listed except Walleye constituted at least 2% of the total number from at least one reporting interval.

** No samples collected.

TABLE 15

FISH IMPINGEMENT BY WEIGHT* AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	1		2		3		4		5		6		7		8	
Dates	9/1-9/15/76		9/15-9/29/76		9/29-10/13/76		10/13-10/27/76		10/27-11/10/76		11/10-11/24/76		11/24-12/8/76		12/8-12/22/76	
Species / Weight	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT	Kilo-grams	% of TOT
Alewife	**		7	1.8	18	2.3	120	3.1	741	5.7	792	9.4	352	1.8	5409	27.2
Carp	**		<0.5	0.1	1	0.1	4	0.1	4	0.1	5	0.1	0	0.0	0	0.0
Channel Catfish	**		<0.5	0.0	4	0.5	6	0.1	1	0.0	55	0.6	115	0.6	5	0.0
Emerald Shiner	**		16	3.9	20	2.5	516	13.5	368	2.8	738	8.6	2709	13.7	1896	9.6
Freshwater Drum	**		62	15.0	211	26.4	325	8.5	115	0.9	75	0.9	75	0.4	45	0.2
Gizzard Shad	**		150	36.3	271	33.9	2392	62.3	11447	87.9	5952	70.6	15327	77.5	12172	61.2
Goldfish	**		0	0.0	0	0.0	0	0.0	2	0.0	11	0.1	40	0.2	0	0.0
Spottail Shiner	**		3	0.7	7	0.9	12	0.3	31	0.2	286	3.4	376	1.9	226	1.2
Troutperch	**		<0.5	0.0	<0.5	0.1	1	0.0	<0.5	0.0	1	0.0	<0.5	0.0	<0.5	0.0
Walleye	**		1	0.4	3	0.4	1	0.0	1	0.0	4	0.1	65	0.3	0	0.0
White Bass	**		22	5.3	50	6.2	55	1.4	39	0.3	39	0.5	37	0.2	18	0.1
Yellow Perch	**		150	36.3	211	26.4	393	10.2	193	1.5	328	3.9	564	2.9	79	0.4
Others	**		1	0.2	3	0.3	19	0.5	82	0.6	147	1.8	106	0.5	23	0.1
TOTAL	**		413	100	800	100	3844	100	13025	100	8433	100	19767	100	19873	100

* Species representing 2% or more of the weight of fish impinged during at least one of the 32 intervals

** No samples collected

TABLE 15 CONT'D.

FISH IMPINGEMENT BY WEIGHT* AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	9		10		11		12		13		14		15		16	
Dates	12/22-1/5/77		1/5-1/19/77		1/19-2/2/77		2/2-2/16/77		2/16-3/2/77		3/2-3/16/77		3/16-3/24/77		3/24-4/1/77	
Species / Weight	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT
Alewife	2892	14.8	268	0.8	78	0.7	5	0.4	<0.5	0.0	0	0.0	<0.5	0.0	<0.5	0.0
Carp	<0.5	0.0	0	0.0	0	0.0	3	0.2	<0.5	0.0	2	0.0	11	0.8	3	0.3
Channel Catfish	5	0.0	<0.5	0.0	1	0.0	1	0.1	3	0.1	8	0.2	6	0.4	4	0.4
Emerald Shiner	90	0.5	26	0.1	5	0.0	1	0.1	126	4.0	188	4.5	119	8.5	108	10.8
Freshwater Drum	45	0.2	78	0.2	153	1.3	37	2.9	118	3.7	111	2.7	57	4.1	58	5.8
Gizzard Shad	16343	83.9	32803	98.8	11540	97.3	1169	92.3	2626	83.0	3609	86.7	885	63.3	549	54.9
Goldfish	<0.5	0.0	<0.5	0.0	3	0.0	2	0.1	2	0.1	25	0.6	88	6.3	62	6.2
Spottail Shiner	38	0.2	15	0.1	15	0.1	2	0.2	6	0.2	35	0.8	33	2.4	43	4.3
Troutperch	1	0.0	<0.5	0.0	1	0.0	<0.5	0.0	<0.5	0.0	1	0.0	3	0.2	6	0.6
Walleye	0	0.0	0	0.0	0	0.0	7	0.5	8	0.3	17	0.4	67	4.8	18	1.8
White Bass	6	0.0	2	0.0	9	0.1	14	1.1	236	7.5	96	2.3	17	1.2	13	1.3
Yellow Perch	65	0.3	10	0.0	33	0.3	13	1.0	26	0.8	49	1.2	77	5.5	122	12.2
Others	24	0.1	6	0.0	17	0.2	13	1.1	10	0.3	27	0.6	34	2.5	16	1.4
TOTAL	19509	100	33208	100	11855	100	1267	100	3163	100	4168	100	1398	100	1002	100

* Species representing 2% or more of the weight of fish impinged during at least one of the 32 intervals

** No samples collected

TABLE 15 CONT'D.

FISH IMPINGEMENT BY WEIGHT* AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	17		18		19		20		21		22		23		24	
Dates	4/1-4/9/77		4/9-4/17/77		4/17-4/25/77		4/25-5/3/77		5/3-5/11/77		5/11-5/19/77		5/19-5/27/77		5/27-6/4/77	
Species / Weight	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT
Alewife	<0.5	0.0	1	0.0	0	0.0	0	0.0	0	0.0	0	0.0	<0.5	0.0	0	0.0
Carp	25	1.8	19	1.3	34	1.4	21	1.5	8	1.1	6	0.6	4	0.5	7	0.6
Channel Catfish	11	0.8	36	2.5	41	1.7	8	0.5	16	2.2	50	4.9	40	4.6	42	4.0
Emerald Shiner	149	10.9	133	9.2	207	8.7	70	5.0	54	7.4	78	7.7	60	7.0	42	4.0
Freshwater Drum	73	5.4	119	8.3	114	4.8	61	4.3	124	17.0	360	35.5	426	49.4	333	31.7
Gizzard Shad	556	40.6	391	27.1	612	25.6	406	28.8	336	46.0	340	33.6	84	9.7	219	20.9
Goldfish	122	8.9	78	5.4	61	2.5	32	2.3	8	1.1	1	0.1	8	0.9	4	0.4
Spottail Shiner	61	4.5	64	4.4	61	2.5	38	2.7	39	5.4	30	3.0	29	3.4	18	1.7
Troutperch	6	0.4	8	0.5	10	0.4	3	0.2	3	0.3	12	1.2	37	4.3	14	1.4
Walleye	219	16.0	242	16.7	212	8.9	70	4.9	39	5.3	27	2.7	13	1.5	1	0.1
White Bass	12	0.9	15	1.0	16	0.7	8	0.6	18	2.5	58	5.7	30	3.4	5	0.5
Yellow Perch	113	8.2	307	21.2	986	41.2	681	48.3	69	9.5	28	2.8	120	13.9	355	33.8
Others	21	1.6	33	2.3	37	1.6	13	0.9	16	2.2	23	2.2	12	1.4	9	0.9
TOTAL	1369	100	1446	100	2391	100	1411	100	730	100	1013	100	863	100	1049	100

* Species representing 2% or more of the weight of fish impinged during at least one of the 32 intervals

** No samples collected

TABLE 15 CONT'D.

FISH IMPINGEMENT BY WEIGHT* AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 TO 15 SEPTEMBER 1977

Interval	25		26		27		28		29		30		31		32	
Dates	6/4-6/12/77		6/12-6/23/77		6/23-7/7/77		7/7-7/21/77		7/21-8/4/77		8/4-8/18/77		8/18-9/1/77		9/1-9/15/77	
Species / Weight	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT	Kilograms	% of TOT
Alewife	<0.5	0.0	<0.5	0.0	0	0.0	0	0.0	0	0.0	<0.5	0.0	9	0.4	48	1.3
Carp	5	0.4	2	0.1	1	0.0	2	0.1	6	0.2	39	2.1	10	0.5	4	0.1
Channel Catfish	50	3.6	26	1.7	24	0.9	142	5.4	242	7.8	80	4.4	9	0.4	10	0.3
Emerald Shiner	50	3.6	28	1.8	4	0.1	4	0.1	4	0.1	16	0.9	117	5.6	155	4.4
Freshwater Drum	258	18.7	183	11.8	120	4.5	162	6.2	1107	35.6	401	22.1	145	7.0	258	7.3
Gizzard Shad	103	7.5	29	1.9	264	9.9	71	2.7	80	2.6	221	12.2	323	15.6	1088	30.6
Goldfish	2	0.1	1	0.1	2	0.1	3	0.1	3	0.1	14	0.8	7	0.3	10	0.3
Spottail Shiner	10	0.7	9	0.6	15	0.6	26	1.0	21	0.7	25	1.4	31	1.5	52	1.4
Troutperch	1	0.1	8	0.5	18	0.7	9	0.4	4	0.1	<0.5	0.0	1	0.0	1	0.0
Walleye	6	0.5	4	0.3	5	0.2	9	0.3	41	1.3	47	2.6	34	1.6	70	2.0
White Bass	4	0.3	4	0.3	317	11.9	254	9.7	426	13.6	310	17.1	308	14.9	331	9.3
Yellow Perch	873	63.2	1246	80.6	1883	70.6	1922	73.2	1169	37.6	651	35.8	1079	51.9	1519	42.8
Others	28	1.3	4	0.3	13	0.5	22	0.8	10	0.3	11	0.6	6	0.3	6	0.2
TOTAL	1382	100	1545	100	2666	100	2626	100	3113	100	1816	100	2079	100	3552	100

* Species representing 2% or more of the weight of fish impinged during at least one of the 32 intervals

** No samples collected

TABLE 16

CORRELATION COEFFICIENTS[a] FOR IMPINGEMENT VS. AMBIENT WATER TEMPERATURE, INTAKE WATER VOLUME, CONDUCTIVITY, AND DEICING: BAY SHORE

SPECIES	NO. of FISH COLLECTED[b]	CORRELATION COEFFICIENT/PROBABILITY			
		AMBIENT TEMPERATURE	INTAKE VOLUME[c]	CONDUCTIVITY	DEICING[d]
Alewife	203,162	-0.247/0.013	-0.166/0.059	-0.145/0.250	0.236/0.008
Bigmouth Buffalo	2	-0.089/0.375	-0.157/0.074	0.000/1.000	0.139/0.119
Black Bullhead	25	0.079/0.434	-0.002/0.981	0.101/0.422	-0.027/0.760
Black Crappie	25	-0.166/0.097	-0.045/0.612	0.103/0.412	0.101/0.256
Bluegill	85	0.104/0.303	0.093/0.294	0.122/0.332	-0.095/0.288
Bluntnose Minnow	59	0.033/0.745	-0.084/0.344	0.056/0.657	-0.078/0.382
Bowfin	2	0.003/0.978	0.073/0.409	0.000/1.000	-0.081/0.365
Brindled Madtom	3	0.076/0.448	0.051/0.561	0.000/1.000	-0.057/0.524
Brook Silversides	1	-0.034/0.735	0.051/0.561	0.000/1.000	-0.057/0.524
Brown Bullhead	53	0.087/0.386	0.145/0.100	0.162/0.198	-0.184/0.039
Carp	314	0.279/0.005	0.228/0.009	0.176/0.161	-0.227/0.010
Channel Catfish	3,746	0.311/0.002	0.190/0.030	0.061/0.630	-0.196/0.027
Channel Darter	1	0.126/0.209	0.051/0.561	0.000/1.000	-0.057/0.523
Chinook Salmon	1	0.000/1.0000	0.051/0.561	-0.165/0.189	-0.057/0.524
Coho Salmon	34	0.223/0.025	0.165/0.060	-0.163/0.194	-0.183/0.039
Emerald Shiner	494,843	-0.214/0.031	0.026/0.772	-0.038/0.764	0.152/0.088
Fathead Minnow	119	0.101/0.316	0.043/0.630	0.036/0.778	-0.033/0.710
Freshwater Drum	57,925	0.269/0.007	0.141/0.110	0.155/0.217	-0.165/0.063
Gizzard Shad	1,635,682	-0.418/0.0001	-0.193/0.028	-0.047/0.713	0.221/0.012
Golden Shiner	7	-0.040/0.691	-0.020/0.819	0.236/0.058	-0.002/0.983
Goldfish	861	-0.200/0.045	-0.152/0.085	0.108/0.391	0.231/0.009
Green Sunfish	386	-0.079/0.432	-0.119/0.177	-0.023/0.854	-0.418/0.000
Johnny Darter	2	-0.133/0.184	-0.157/0.074	0.000/1.000	0.139/0.119
Logperch	832	0.129/0.197	0.092/0.300	-0.052/0.681	-0.086/0.338
Long-nosed Gar	9	0.018/0.858	0.143/0.103	-0.116/0.357	-0.098/0.272
Mooneye	1	-0.062/0.540	0.051/0.561	0.000/1.000	-0.057/0.524
Mottled Sculpin	1	-0.056/0.577	-0.157/0.074	0.000/1.000	0.139/0.119
Northern Hog Sucker	1	-0.027/0.791	0.051/0.561	0.085/0.499	-0.057/0.524
Northern Pike	18	0.272/0.006	0.117/0.183	-0.031/0.807	-0.131/0.144
Orangespotted Sunfish	174	-0.051/0.613	-0.128/0.147	0.095/0.452	0.130/0.145
Pumpkinseed Sunfish	52	0.047/0.641	0.158/0.072	-0.067/0.595	-0.154/0.085
Quillback Carp-sucker	74	-0.130/0.196	0.024/0.784	0.143/0.257	0.074/0.410
Rainbow Smelt	12,625	-0.224/0.024	0.086/0.330	-0.330/0.007	-0.006/0.946

TABLE 16 CONT'D.

SPECIES	NO. of FISH COLLECTED[b]	CORRELATION COEFFICIENT/PROBABILITY AMBIENT TEMPERATURE	INTAKE VOLUME[c]	CONDUCTIVITY	DEICING[d]
Rockbass	14	0.084/0.405	0.088/0.319	0.079/0.533	-0.098/0.273
Sauger	40	-0.121/0.227	0.080/0.365	-0.139/0.269	0.105/0.242
Sea Lamprey	1	0.000/1.000	0.051/0.561	-0.165/0.189	-0.057/0.524
Shorthead Redhorse	44	-0.163/0.103	0.049/0.577	-0.098/0.439	-0.077/0.390
Silver Chub	27	0.301/0.002	0.218/0.013	0.191/0.127	-0.242/0.006
Silver Lamprey	38	-0.126/0.208	-0.003/0.970	0.180/0.151	0.032/0.721
Smallmouth Bass	31	-0.161/0.107	0.062/0.486	-0.146/0.246	0.105/0.241
Spotfin Shiner	3	-0.025/0.805	-0.033/0.711	-0.123/0.328	0.015/0.863
Spottail Shiner	33,206	-0.127/0.206	0.088/0.322	-0.078/0.535	0.069/0.443
Stonecat Madtom	21	-0.028/0.778	0.122/0.168	0.206/0.100	-0.135/0.130
Tadpole Madtom	140	-0.100/0.321	0.145/0.099	-0.145/0.250	0.072/0.424
Threespine Stickleback	7	-0.010/0.925	0.122/0.167	0.030/0.815	-0.136/0.128
Troutperch	4,966	0.288/0.004	0.212/0.015	0.008/0.951	-0.208/0.019
Walleye	1,963	0.447/0.0001	0.259/0.003	-0.148/0.239	-0.239/0.007
White Bass	87,675	0.472/0.0001	0.187/0.033	-0.118/0.351	-0.210/0.018
White Crappie	216	-0.275/0.005	-0.278/0.001	0.209/0.096	0.198/0.026
White Sucker	147	0.165/0.100	0.086/0.332	0.093/0.460	-0.092/0.302
Yellow Bullhead	4	0.039/0.696	0.085/0.338	0.147/0.243	-0.094/0.293
Yellow Perch	70,279	0.560/0.0001	0.290/0.001	-0.249/0.046	-0.298/0.001
TOTAL	2,609,949	-0.415/0.0001	-0.154/0.089	-0.100/0.428	0.255/0.003

a Data presented as the correlation coefficient/probability. Probabilities of 0.05 or less are generally considered significant. The square of the correlation coefficient=the r^2value which represents the portion of the impingement variability explained by that parameter.

b Estimate of the number collected during the 61.5 collection periods.

c Little significance should be placed on this parameter as the intake flow was generally constant at Bay Shore.

d A negative correlation coefficient indicates that more fish were impinged when deicing was not occurring while a positive value indicates that more fish were impinged when deicing was occurring.

TABLE 17

CORRELATION COEFFICIENTS FOR FISH IMPINGEMENT AT THE BAY SHORE POWER STATION WITH SEVERAL PHYSICAL PARAMETERS

PARAMETER	CORRELATION COEFFICIENTS (r)	PROBABILITY OF A LARGER |r| *
1. Water Level	-0.348	0.0001
2. Water Level Change from 12 hours earlier **	-0.189	0.0372
3. Water Level Change from 24 hours earlier **	-0.266	0.0031
4. Air Temperature	-0.457	0.0001
5. Temperature Change from 12 hours earlier **	0.074	0.4182
6. Temperature Change from 24 hours earlier **	0.146	0.1081
7. Barometric Pressure	0.056	0.5426
8. Barometric Pressure Change from previous day**	-0.046	0.6173
9. River Flow (m^3/sec)	-0.187	0.0387
10. River Flow Change from preceeding day **	-0.069	0.4480
11. Wind Speed (knots)	0.061	0.5072
12. Wind Speed Change from previous 12 hours **	0.032	0.7272
13. Wind Speed Change from previous 24 hours **	0.146	0.1093

* A value of 0.05 or less indicates the correlation is significant.

** Calculated by subtracting present value from previous value. Therefore, a positive correlation indicates impingement increased with decreasing water level, temperature, barometric pressure, etc. and a negative correlation indicates that impingement increased when the above parameters increased.

TABLE 18

LEGEND FOR TABLES 19-22

Water Level -	Water level in feet above sea level as recorded near the U.S. Coast Guard, Toledo, Ohio, during the fish collection.
Level Δ12 hrs.*-	Change in the water level from that recorded 12 hours prior to the fish collection.
Level Δ24 hrs.*-	Change in water level from that recorded 24 hours prior to the fish collection.
Air Temp.-	Air temperature (^{o}F) as recorded by the National Weather Service at the Toledo Express Airport during the fish collection.
Temp. Δ12 hrs.*-	Change in air temperature from that recorded 12 hours prior to the collection.
Temp. Δ24 hrs.*-	Change in air temperature from that recorded 24 hours prior to the collection.
Barometric Pres.-	Barometric pressure (inches) as recorded by the National Weather Service at the Toledo Express Airport during the fish collection.
BPΔ24 hrs.*-	Change in barometric pressure from that recorded the day prior to the collection.
River Flow-	Flow of the Maumee River (m^3/sec) as recorded at the U.S. Geological Survey Gage, Waterville, Ohio, on the day of the fish collection.
Flow Δ24 hrs.*-	Change in Maumee River flow from that observed the day prior to the fish collection.
Wind Speed-	Wind speed (knots) as recorded during the fish collection by the National Weather Service, Toledo Express Airport.
Speed Δ12 hrs.*-	Change in wind speed from that recorded 12 hours prior to the fish collection.
Speed Δ24 hrs.*-	Change in wind speed from that recorded 24 hours prior to the fish collection.

Ambient Temp.-	Water temperature as recorded near mouth of intake canal.
Intake Volume-	Volume of water (m^3) pumped through the plant during the fish collection.
Conductivity I-	Conductivity as recorded in the intake canal in front of the trash rack nearest the point where warm water is recirculated during the winter.
Conductivity II-	Conductivity as recorded in the intake canal in front of the trash rack furthest from the point where warm water is recirculated during the winter.
On/Off-	Status of recirculation for deicing. A negative correlation coefficient indicates more fish were impinged when deicing was not occuring while a positive value indicates that more fish were impinged when deicing was occurring.
Condif A-B-	Difference in mean conductivities observed in front of the trash racks in the Acme and Bay Shore intake canals.
Condif I-R-	Difference in mean conductivities observed in the intake canal and at the river stations in front of the power plant.
Temp I-	Mean Temperature recorded in intake canal in front of the trash racks.
Temp R-	Mean Temperature recorded at the 3 river stations in front of the power station.
Weight-	Total weight (g) of the designated species.

* Calculated by subtracting present value from previous value. Therefore, a positive correlation indicates impingement increased with decreasing water level, temperature, barometric pressure, etc. and a negative correlation indicates that impingement decreased when the above parameters increased.

TABLE 19

CORRELATION COEFFICIENTS FOR NUMBER OF FISH IMPINGED
DURING SEASON 1: September 15, 1976 to January 19, 1977*

PARAMETER ** / SPECIES	Alewife	Channel Catfish	Freshwater Drum	Gizzard Shad	Rainbow Smelt	Walleye	White Bass	Yellow Perch
Water Level	-0.186/0.316	-0.268/0.145	0.438/0.014	-0.241/0.191	-0.159/0.392	-0.138/0.460	0.662/0.000	0.086/0.646
Level Δ12 hrs.*	-0.283/0.122	0.067/0.718	0.217/0.241	-0.142/0.447	-0.318/0.082	-0.200/0.281	-0.086/0.646	-0.132/0.480
Level Δ24 hrs.*	-0.222/0.230	-0.342/0.060	0.326/0.073	-0.323/0.077	-0.152/0.414	-0.601/0.000	0.072/0.702	-0.499/0.004
Air Temp.	-0.047/0.801	-0.169/0.364	0.373/0.039	-0.322/0.078	-0.056/0.763	-0.079/0.671	0.558/0.001	0.138/0.460
Temp. Δ12 hrs.*	0.005/0.978	-0.156/0.402	0.144/0.439	0.045/0.812	0.142/0.446	-0.236/0.202	0.188/0.312	-0.198/0.286
Temp. Δ24 hrs.*	0.062/0.742	-0.037/0.841	0.049/0.792	0.206/0.267	-0.173/0.351	-0.207/0.264	0.128/0.493	-0.186/0.316
Barometric Pres.	-0.219/0.237	-0.153/0.412	0.068/0.718	0.230/0.213	-0.083/0.657	0.141/0.448	0.137/0.462	0.178/0.337
BP Δ24 hrs.*	0.059/0.753	0.022/0.905	0.142/0.447	-0.217/0.242	0.174/0.348	0.047/0.802	0.148/0.426	0.208/0.262
River Flow	0.066/0.724	0.124/0.508	0.219/0.237	-0.171/0.358	-0.289/0.115	-0.181/0.330	-0.064/0.734	-0.158/0.395
Flow Δ24 hrs.*	-0.056/0.764	0.205/0.268	-0.321/0.078	0.263/0.153	0.228/0.217	0.201/0.279	-0.163/0.380	0.074/0.693
Wind Speed	-0.052/0.781	0.141/0.449	-0.088/0.638	-0.032/0.864	-0.257/0.162	-0.123/0.509	-0.008/0.968	-0.219/0.238
Speed Δ12 hrs.*	0.233/0.207	-0.197/0.288	-0.041/0.825	0.002/0.990	0.343/0.059	-0.061/0.745	-0.000/0.999	-0.399/0.831
Speed Δ24 hrs.*	0.292/0.112	-0.119/0.525	-0.031/0.868	0.255/0.167	0.065/0.728	0.237/0.200	-0.099/0.598	0.212/0.252
Ambient Temp.	-0.257/0.163	-0.199/0.282	0.527/0.002	-0.228/0.217	-0.275/0.135	-0.164/0.380	0.621/0.0002	0.026/0.889
Intake Volume	-0.218/0.240	0.033/0.858	0.286/0.119	-0.159/0.392	0.335/0.065	0.199/0.284	0.667/0.0001	0.457/0.010
Conductivity I	-0.010/0.957	-0.030/0.873	-0.284/0.121	0.334/0.066	-0.370/0.040	-0.132/0.479	-0.654/0.0001	-0.434/0.015
Conductivity II	-0.046/0.805	-0.235/0.203	-0.235/0.203	0.353/0.051	-0.392/0.295	-0.176/0.345	-0.553/0.001	-0.446/0.012
On/Off	0.301/0.100	0.219/0.236	-0.384/0.033	0.158/0.396	-0.229/0.216	0.206/0.266	-0.655/0.0001	-0.093/0.618
Condif A-B	0.197/0.287	0.331/0.069	-0.030/0.873	-0.134/0.472	0.516/0.003	0.259/0.160	0.168/0.365	0.402/0.025
Condif I-R	0	0	0 River Data Unavailable	0	0	0	0	0
Temp I	-0.293/0.110	-0.183/0.323	0.520/0.003	-0.205/0.270	-0.285/0.121	-0.103/0.581	0.614/0.0002	0.069/0.714
Temp R	0	0	0 River Data Unavailable	0	0	0	0	0
Total Weight	0.998/0.0001	0.308/0.081	0.914/0.0001	0.853/0.0001	0.971/0.0001	0.990/0.0001	0.608/0.0001	0.987/0.0001

* Data presented as correlation coefficient /probability. Probabilities of 0.05 or less are generally considered significant. The square of the correlation coefficient = the r^2 value which represents the portion of the impingement variability explained by that parameter.

** See Table 18 for descriptions of each parameter.

TABLE 20

CORRELATION COEFFICIENTS FOR NUMBER OF FISH IMPINGED DURING SEASON 2: January 26 to April 17, 1977*

SPECIES / PARAMETER **	Alewife	Channel Catfish	Freshwater Drum	Gizzard Shad	Rainbow Smelt	Walleye	White Bass	Yellow Perch
Water Level	-0.134/0.464	0.340/0.057	-0.057/0.758	-0.239/0.187	-0.180/0.326	-0.042/0.819	-0.215/0.237	0.356/0.046
Level Δ12 hrs.*	-0.048/0.795	0.054/0.769	-0.029/0.877	-0.043/0.816	-0.036/0.844	0.613/0.0001	-0.000/0.998	0.045/0.806
Level Δ24 hrs.*	-0.022/0.903	0.061/0.740	-0.007/0.971	-0.028/0.881	0.007/0.969	0.653/0.0001	-0.014/0.939	0.051/0.781
Air Temp.	-0.209/0.251	0.411/0.020	-0.068/0.711	-0.303/0.092	-0.127/0.489	0.222/0.223	-0.188/0.303	0.662/0.0001
Temp. Δ12 hrs.*	0.176/0.335	0.330/0.066	0.230/0.205	0.163/0.372	0.102/0.578	0.207/0.255	0.105/0.569	0.113/0.540
Temp. Δ24 hrs.*	0.152/0.407	0.212/0.244	0.235/0.196	0.156/0.393	0.026/0.888	0.237/0.192	0.104/0.572	0.162/0.376
Barometric Pres.	-0.247/0.172	0.190/0.297	-0.149/0.415	-0.210/0.249	-0.210/0.250	-0.067/0.715	0.130/0.478	0.051/0.783
BP Δ24 hrs.*	0.134/0.463	0.038/0.837	0.105/0.568	0.103/0.574	0.222/0.222	0.098/0.594	-0.167/0.360	0.164/0.368
River Flow	-0.233/0.199	-0.233/0.199	-0.145/0.428	-0.186/0.309	-0.389/0.028	0.061/0.741	0.163/0.373	-0.132/0.471
Flow Δ24 hrs.*	-0.031/0.866	0.068/0.711	0.060/0.746	0.019/0.916	-0.026/0.888	0.095/0.604	0.220/0.225	0.036/0.845
Wind Speed	-0.099/0.588	-0.227/0.212	-0.073/0.690	-0.077/0.676	-0.123/0.501	0.143/0.434	-0.024/0.896	0.159/0.386
Speed Δ12 hrs.*	0.172/0.348	0.346/0.052	0.199/0.276	0.176/0.335	0.218/0.231	-0.045/0.808	0.138/0.452	-0.036/0.847
Speed Δ24 hrs.*	0.014/0.939	0.115/0.532	-0.030/0.871	-0.035/0.849	0.053/0.773	-0.140/0.444	-0.069/0.709	-0.050/0.787
Ambient Temp.	-0.212/0.245	0.523/0.002	-0.051/0.780	-0.327/0.068	-0.227/0.211	0.491/0.004	-0.214/0.240	0.620/0.0001
Intake Volume	-0.158/0.388	0.498/0.004	-0.017/0.929	-0.263/0.146	-0.135/0.461	0.525/0.002	-0.187/0.305	0.520/0.002
Conductivity I	0.051/0.788	-0.061/0.749	-0.094/0.622	-0.017/0.928	0.203/0.282	-0.112/0.557	-0.228/0.225	-0.148/0.434
Conductivity II	-0.108/0.556	0.044/0.811	-0.180/0.324	-0.168/0.359	0.061/0.741	0.017/0.925	-0.186/0.308	-0.030/0.869
On/Off	0.126/0.507	-0.629/0.0002	-0.043/0.823	0.165/0.384	0.054/0.779	-0.751/0.0001	0.047/0.804	-0.527/0.003
Condif A-B	0.287/0.124	-0.278/0.137	0.034/0.859	0.219/0.245	0.399/0.029	-0.282/0.131	-0.270/0.148	-0.361/0.050
Condif I-R	0.618/0.019	0.602/0.023	0.784/0.001	0.006/0.985	0.682/0.007	-0.075/0.799	-0.125/0.670	0.776/0.001
Temp I	-0.208/0.253	0.534/0.002	-0.071/0.698	-0.345/0.053	-0.174/0.341	0.518/0.002	-0.279/0.122	0.623/0.0001
Temp R	0.321/0.225	0.663/0.005	0.690/0.003	-0.255/0.340	0.497/0.050	0.223/0.407	-0.007/0.981	0.775/0.0001
Total Weight	0.999/0.0001	0.944/0.0001	0.934/0.0001	0.994/0.0001	0.787/0.0001	0.989/0.0001	0.972/0.0001	0.973/0.0001

* Data presented as correlation coefficient /probability. Probabilities of 0.05 or less are generally considered significant. The square of the correlation coefficient = the r^2 value which represents the portion of the impingement variability explained by that parameter.

** See Table 18 for descriptions of each parameter.

TABLE 21

CORRELATION COEFFICIENTS FOR NUMBER OF FISH IMPINGED
DURING SEASON 3: April 21 to June 16, 1977*

PARAMETER ** \ SPECIES	Alewife	Channel Catfish	Freshwater Drum	Gizzard Shad	Rainbow Smelt	Walleye	White Bass	Yellow Perch
Water Level	-0.131/0.489	-0.207/0.273	-0.162/0.394	0.342/0.064	-0.038/0.840	-0.402/0.028	-0.027/0.888	-0.257/0.170
Level Δ12 hrs.*	0.308/0.098	-0.031/0.870	0.108/0.571	-0.321/0.084	-0.338/0.068	-0.049/0.799	-0.047/0.807	-0.099/0.602
Level Δ24 hrs.*	0.137/0.471	0.086/0.651	0.356/0.054	-0.224/0.233	-0.432/0.017	-0.072/0.704	-0.0001/0.999	0.072/0.707
Air Temp.	0.191/0.312	-0.118/0.535	0.439/0.015	-0.414/0.023	-0.102/0.593	0.066/0.728	-0.168/0.374	-0.182/0.336
Temp. Δ12 hrs.*	0.068/0.721	-0.161/0.397	-0.159/0.402	0.085/0.657	0.057/0.765	0.037/0.846	0.101/0.596	0.279/0.135
Temp. Δ24 hrs.*	-0.022/0.908	-0.096/0.615	-0.422/0.020	0.208/0.270	0.105/0.582	-0.096/0.615	0.039/0.838	-0.191/0.313
Barometric Pres.	0.122/0.520	0.102/0.593	-0.251/0.182	-0.306/0.100	0.029/0.878	0.041/0.830	0.240/0.201	-0.157/0.407
BP Δ24 hrs.*	0.053/0.779	-0.178/0.347	0.375/0.041	-0.031/0.872	-0.027/0.886	0.126/0.506	-0.282/0.131	0.218/0.246
River Flow	-0.191/0.312	-0.018/0.925	-0.338/0.068	0.814/0.0001	0.140/0.460	0.259/0.167	0.141/0.456	0.281/0.133
Flow Δ24 hrs.*	-0.164/0.387	0.027/0.887	-0.253/0.178	0.625/0.0002	0.059/0.756	0.140/0.461	0.196/0.300	0.155/0.412
Wind Speed	-0.209/0.267	0.297/0.111	0.044/0.818	0.320/0.084	-0.031/0.872	0.358/0.052	0.207/0.273	-0.022/0.909
Speed Δ12 hrs.*	0.011/0.954	-0.215/0.255	0.044/0.817	-0.012/0.951	-0.053/0.782	-0.192/0.309	0.024/0.899	-0.128/0.502
Speed Δ24 hrs.*	0.021/0.914	-0.202/0.283	-0.100/0.598	-0.308/0.098	-0.167/0.376	-0.454/0.012	-0.066/0.728	-0.374/0.042
Ambient Temp.	0.324/0.081	-0.270/0.149	0.614/0.0003	-0.564/0.001	-0.154/0.416	-0.229/0.223	-0.456/0.011	0.032/0.868
Intake Volume	0.000/1.000	0.226/0.230	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000
Conductivity I	-0.239/0.203	-0.082/0.668	-0.150/0.429	-0.014/0.943	0.143/0.452	0.237/0.208	0.695/0.0001	-0.377/0.040
Conductivity II	-0.287/0.124	-0.075/0.694	-0.045/0.812	-0.040/0.834	0.118/0.535	0.091/0.633	0.667/0.0001	-0.419/0.021
On/Off	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000
Condif A-B	0.173/0.362	0.194/0.303	0.004/0.984	-0.037/0.848	-0.199/0.291	0.076/0.692	-0.616/0.0003	0.374/0.042
Condif I-R	0.183/0.393	-0.209/0.328	0.173/0.420	0.117/0.586	0.039/0.855	0.085/0.694	0.268/0.206	-0.138/0.522
Temp I	0.303/0.104	-0.276/0.140	0.638/0.0001	-0.555/0.002	-0.175/0.356	-0.254/0.175	-0.441/0.015	0.021/0.913
Temp R	-0.001/0.996	-0.288/0.173	0.570/0.004	-0.481/0.017	-0.242/0.255	-0.070/0.747	-0.502/0.012	0.105/0.625
Total Weight	0.989/0.0001	0.360/0.051	0.875/0.0001	0.939/0.0001	0.844/0.0001	0.909/0.0001	0.851/0.0001	0.915/0.0001

* Data presented as correlation coefficient /probability. Probabilities of 0.05 or less are generally considered significant. The square of the correlation coefficient = the r^2 value which represents the portion of the impingement variability explained by that parameter.

** See Table 18 for descriptions of each parameter.

TABLE 22

CORRELATION COEFFICIENTS FOR NUMBER OF FISH IMPINGED
DURING SEASON 4: June 23 to September 15, 1977 *

PARAMETER ** / SPECIES	Alewife	Channel Catfish	Freshwater Drum	Gizzard Shad	Rainbow Smelt	Walleye	White Bass	Yellow Perch
Water Level	-0.347/0.083	0.350/0.080	-0.101/0.623	0.269/0.184	-0.273/0.177	-0.252/0.215	-0.081/0.695	0.018/0.929
Level Δ12 hrs.*	0.095/0.646	-0.312/0.120	0.070/0.734	-0.120/0.560	0.095/0.643	-0.264/0.193	0.072/0.727	-0.212/0.298
Level Δ24 hrs.*	0.256/0.208	0.022/0.917	0.165/0.420	-0.190/0.352	0.141/0.494	-0.136/0.507	0.121/0.556	-0.234/0.249
Air Temp.	0.064/0.756	-0.042/0.839	-0.321/0.110	-0.361/0.070	0.374/0.060	0.053/0.799	0.192/0.347	0.256/0.207
Temp. Δ12 hrs.*	-0.029/0.890	0.094/0.646	0.211/0.300	-0.058/0.780	-0.053/0.796	0.189/0.354	0.304/0.131	0.192/0.348
Temp. Δ24 hrs.*	-0.297/0.141	-0.067/0.747	-0.150/0.466	0.099/0.630	-0.210/0.304	0.028/0.891	-0.008/0.968	0.019/0.925
Barometric Pres.	0.324/0.107	-0.039/0.851	0.273/0.177	0.270/0.182	-0.296/0.141	-0.290/0.151	0.076/0.712	-0.254/0.210
BP Δ24 hrs.*	-0.037/0.857	-0.035/0.865	0.091/0.660	-0.184/0.367	0.280/0.166	0.070/0.736	0.185/0.366	0.235/0.247
River Flow	0.089/0.665	0.054/0.794	-0.060/0.773	0.543/0.004	0.185/0.366	-0.158/0.441	-0.326/0.104	-0.258/0.203
Flow Δ24 hrs.*	-0.295/0.143	-0.041/0.843	-0.041/0.843	-0.663/0.0002	-0.028/0.893	-0.127/0.536	0.055/0.788	0.163/0.426
Wind Speed	0.074/0.718	-0.133/0.518	-0.157/0.443	0.170/0.408	0.439/0.025	0.048/0.818	-0.157/0.444	0.022/0.917
Speed Δ12 hrs.*	-0.152/0.458	0.161/0.432	-0.027/0.895	-0.295/0.143	-0.196/0.338	0.165/0.420	0.093/0.652	0.179/0.380
Speed Δ24 hrs.*	-0.272/0.178	-0.127/0.536	-0.140/0.494	-0.180/0.380	-0.295/0.144	-0.024/0.906	-0.022/0.914	0.070/0.732
Ambient Temp.	-0.042/0.840	-0.270/0.182	-0.291/0.149	-0.409/0.038	-0.032/0.876	0.103/0.617	0.386/0.051	0.454/0.020
Intake Volume	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000
Conductivity I	0.144/0.501	0.024/0.911	0.392/0.058	0.254/0.232	-0.273/0.196	-0.275/0.194	-0.087/0.685	-0.302/0.152
Conductivity II	0.196/0.337	0.088/0.670	0.342/0.087	0.332/0.098	-0.155/0.450	-0.403/0.041	-0.318/0.114	-0.420/0.033
On/Off	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000	0.000/1.000
Condif A-B	0.419/0.042	0.130/0.544	0.146/0.496	0.416/0.044	0.319/0.129	0.379/0.067	0.152/0.477	0.015/0.944
Condif I-R	0.402/0.079	-0.450/0.047	-0.093/0.697	0.451/0.046	0.026/0.913	0.380/0.099	0.022/0.926	0.089/0.709
Temp I	-0.009/0.966	-0.268/0.185	-0.292/0.148	-0.422/0.032	-0.093/0.650	0.122/0.554	0.391/0.049	0.467/0.016
Temp R	0.202/0.368	-0.063/0.780	-0.352/0.108	0.096/0.671	0.104/0.645	0.087/0.700	0.417/0.053	0.430/0.046
Total Weight	0.996/0.0001	0.125/0.542	0.566/0.003	0.938/0.0001	0.813/0.0001	0.371/0.062	0.841/0.0001	0.839/0.0001

* Data presented as correlation coefficient /probability. Probabilities of 0.05 or less are generally considered significant. The square of the correlation coefficient = the r^2 value which represents the portion of the impingement variability explained by that parameter.

** See Table 18 for descriptions of each parameter.

TABLE 23

SUMMARY OF SIGNIFICANT * MULTIPLE REGRESSIONS FOR FISH IMPINGEMENT AT THE BAY SHORE POWER STATION

SEASON	SPECIES	REGRESSION COEFFICIENT (r^2) **	SIGNIFICANT PARAMETERS ***
1 (9/15/76-1/19/77)	Rainbow Smelt	0.522	intake conductivity (-)
	White Bass	0.598	temp I (+), intake conductivity (-)
	Yellow Perch	0.492	intake conductivity (-) level Δ24 hrs (-)
2 (1/26-4/17/77)	Walleye	0.687	temp I (+), water level (-), level Δ12 hrs (+), intake volume (+)
	White Bass	0.538	condif A-B (-)
	Yellow Perch	0.602	temp I (+), air temp (+)
3 (4/21-6/16/77)	Channel Catfish	0.470	water level (-)
	Freshwater Drum	0.443	temp I (+)
	Walleye	0.494	water level (-), river flow (+)
	White Bass	0.604	intake conductivity (+), temp I (-)
	Yellow Perch	0.612	intake conductivity (-), river flow (+), level Δ12 hrs (-), air temp (-), water level (-)
4 (6/23-9/15/77)	Gizzard Shad	0.639	condif A-B (+), temp I (+), river flow (+)
	Walleye	0.761	water level (-), intake conductivity (-), river flow (-), temp I (-)

* Only regressions which were significant at the 0.05 level are presented.

** The portion of the variability in the number impinged which was explained by the regression.

*** Only parameters which contributed significantly (0.05 level) to the regression are listed. They are listed in order of decreasing significance (most significant first) followed by the sign of the relation (+ or -).

TABLE 24

COMMERCIAL FISH LANDINGS FROM THE OHIO WATERS OF LAKE ERIE: 1974-1977*

SPECIES	1974	1975	1976	1977
Buffalo	14,528	14,982	13,620	15,890
Bullhead	12,258	14,074	19,522	29,056
Carp	1,284,366	1,265,298	1,196,290	1,249,408
Channel Catfish	136,200	117,586	101,242	115,316
Freshwater Drum	307,812	340,500	432,208	361,838
Goldfish	29,510	23,608	60,836	250,154
Quillback/Shad**	28,148	60,382	331,874	274,670
Rainbow Smelt	2,270	4,086	15,890	454
Sucker	39,952	24,516	28,602	14,982
White Bass	1,314,330	760,450	680,546	501,216
Yellow Perch	797,678	675,552	652,852	1,051,918
Total	3,962,512	3,301,488	3,533,482	3,864,902

* Scholl (1977). Data presented in kilograms.
** This is primarily the quillback carpsucker (Carpiodes cyprinus), but occasionally some fishermen include gizzard shad (Dorosoma cepedianum).

TABLE 25

COMMERCIAL FISH LANDINGS FROM LAKE ERIE:
1975 AND 1976*

SPECIES	WEIGHT (Kilograms)		
	1975	1976	MEAN
Buffalo	30,000	43,000	37,000
Bullhead	69,000	64,000	67,000
Carp	1,491,000	1,444,000	1,468,000
Channel Catfish	197,000	155,000	176,000
Freshwater Drum	538,000	619,000	579,000
Gizzard Shad	1,000	301,000	151,000
Goldfish	26,000	61,000	44,000
Quillback Carpsucker	60,000	58,000	59,000
Rainbow Smelt	7,688,000	7,845,000	7,767,000
Sucker	52,000	48,000	50,000
Walleye**	114,000	138,000	126,000
White Bass	1,932,000	1,162,000	1,547,000
Yellow Perch	4,597,000	2,903,000	3,750,000
Others	927,000	833,000	880,000
TOTAL	17,722,000	15,674,000	16,698,000

* Personal communication, Dr. David Wolfert, USFWS, Sandusky, Ohio.

** Not taken commercially in Ohio and Michigan waters.

TABLE 26

COMPARISON OF IMPINGEMENT LOSSES AT THE BAY SHORE POWER STATION WITH SPORT AND COMMERCIAL HARVESTS FROM THE OHIO WATERS OF LAKE ERIE[a]

SPECIES	NUMBER IMPINGED				WEIGHT IMPINGED			
	No. of Individuals	% of Sport Harvest	% of Comm. Harvest	% of Total Harvest[c]	Kilograms	% of Sport Harvest	% of Comm. Harvest	% of Total Harvest[c]
White Bass	624,078	76.2	24.9	1.9	2,766	1.6	0.6	0.4
Yellow Perch	437,260	14.8	3.7	3.0	15,311	5.7	1.5	1.2
Freshwater Drum	365,779	156.5	50.6	38.2	5,807	4.7	1.6	1.2
Walleye	12,187	2.6	—[d]	2.6	1,220	0.3	—[d]	0.3
Channel Catfish	20,995	33.2	7.3	6.0	1,037	4.1	0.9	0.7
Smallmouth Bass	180	2.1	0.0	2.0	16	0.4	0.0	0.4
Others	16,350,153[e]	18,188.5	—[f]	—[f]	144,551	—[g]	7.9	7.9
Total[h]	17,810,633	382.6	—[f]	—[f]	170,708	16.0	4.4	3.5

[a] Sport and commercial harvests during 1977. Impingement from 15 September 1976 to 15 September 1977.
[b] Number in commercial catch was estimated by dividing the weight of the commercial harvest by the average weight from the sport harvest.
[c] Total harvest = sport + commercial harvests.
[d] Not taken commercially.
[e] 82.1% of total number was gizzard shad and emerald shiners.
[f] Reliable estimates of the number collected commercially are not available.
[g] Data not available.
[h] Excluding fish runs.

TABLE 27

COMPARISON OF IMPINGEMENT LOSSES AT THE BAY SHORE POWER STATION WITH COMMERCIAL HARVESTS FROM LAKE ERIE

SPECIES	Kilograms Impinged	% of Ohio Commercial Harvest[a]	% of Total Lake Erie Comm. Harvest[b]
Buffalo	3	<0.05	<0.05
Bullhead	32[c]	0.1	<0.05
Carp	217	<0.05	<0.05
Channel Catfish	1,037	0.9	0.6
Freshwater Drum	5,807	1.6	1.0
Gizzard Shad	122,358	—	81.0
Goldfish	588	0.2	1.3
Quillback Carpsucker	18	—	<0.05
Quillback/Shad[d]	122,376	44.6	—
Rainbow Smelt	352	77.5	<0.05
Sucker	150	1.0	0.3
Walleye	1,220	—[e]	0.9
White Bass	2,766	0.6	0.2
Yellow Perch	15,311	1.5	0.4
Others	20,849	—	2.5
TOTAL[f]	170,708	4.4	1.0

[a] Ohio harvest from 1977.

[b] Mean of Lake harvests from 1975 and 1976.

[c] Black, brown, and yellow bullheads.

[d] In Ohio, the quillback carpsucker (<u>Carpiodes cyprinus</u>) and the gizzard shad (<u>Dorosoma cepedianum</u>) are lumped together.

[e] Not taken commercially in Ohio.

[f] Excluding fish runs. Also, this does not include "Quillback/shad" as the quillback and the shad are both added separately.

TABLE 28

COMMON AND SCIENTIFIC NAMES OF FISH ENTRAINED AT THE BAY SHORE POWER STATION

COMMON NAME	SCIENTIFIC NAME*
Bluegill Sunfish	*Lepomis macrochirus*
Carp	*Cyprinus carpio*
Channel Catfish	*Ictalurus punctatus*
Emerald Shiner	*Notropis atherinoides*
Freshwater Drum	*Aplodinotus grunniens*
Gizzard Shad	*Dorosoma cepedianum*
Logperch Darter	*Percina caprodes*
Rainbow Smelt	*Osmerus mordax*
Spottail Shiner	*Notropis hudsonius*
Troutperch	*Percopsis omiscomaycus*
Unidentified	
Unidentified Crappie	*Pomoxis* sp.
Unidentified Shiner	*Notropis* sp.
Unidentified Sucker	*Catostomidae*
Unidentified Sunfish	*Lepomis* sp.
Walleye	*Stizostedion v. vitreum*
White Bass	*Morone chrysops*
White Sucker	*Catostomus commersoni*
Yellow Perch	*Perca flavescens*

* Bailey, et al (1970).

TABLE 29

TOTAL ICHTHYOPLANKTON ENTRAINMENT AT THE BAY SHORE POWER STATION:
1 SEPTEMBER 1976 TO 1 SEPTEMBER 1977

SPECIES	No. per 100 m^3	LOWCONC[a]	UPCONC[b]	TOTAL	% of TOTAL	LOWTOT[c]	UPTOT[d]
Bluegill Sunfish	0.002	0.0003	0.011	28201	0.01	4678	169998
Carp	0.537	0.2709	1.066	8251539	2.90	4159814	16368014
Channel Catfish	0.037	0.0107	0.126	564532	0.20	164699	1935025
Emerald Shiner	0.009	0.0022	0.039	142572	0.05	34151	595207
Freshwater Drum	0.878	0.4801	1.605	13479134	4.73	7372574	24643639
Gizzard Shad	14.541	8.7750	24.095	223290406	78.43	134749933	370008388
Logperch Darter	0.002	0.0003	0.011	28778	0.01	4774	173487
Rainbow Smelt	0.058	0.0253	0.135	897099	0.32	387843	2075032
Spottail Shiner	0.016	0.0029	0.084	238132	0.08	44203	1282868
Troutperch	0.001	0.0001	0.011	12747	<0.01	981	165631
Unidentified	0.006	0.0019	0.018	88078	0.03	28585	271388
Unidentified Crappie	0.002	0.0003	0.011	28778	0.01	4774	173487
Unidentified Shiner	0.011	0.0011	0.103	166784	0.06	17593	1581135
Unidentified Sucker	0.023	0.0086	0.063	357889	0.13	132394	967447
Unidentified Sunfish	0.032	0.0053	0.193	493434	0.17	82108	2965329
Walleye	0.029	0.0135	0.061	441614	0.16	206873	942721
White Bass	2.156	0.8789	5.289	33107856	11.63	13496529	81215709
White Sucker	0.044	0.0162	0.119	673614	0.24	249356	1819709
Yellow Perch	0.158	0.0570	0.438	2426431	0.85	875124	6727696
TOTAL LARVAE	18.542			284717618	100.00		
Drum Eggs	83.186	46.6755	148.254	425804075	99.92	238919134	758872292
Other Eggs	0.067			346034	0.08		
TOTAL EGGS	83.253	46.7353	148.305	426150109	100.00	239225361	759133204

a Lower bound of 95% confidence interval for No./100 m^3.
b Upper bound of 95% confidence interval for No./100 m^3.
c Lower bound of 95% confidence interval for number entrained.
d Upper bound of 95% confidence interval for number entrained.

TABLE 30

A COMPARISON OF DAY AND NIGHT ENTRAINMENT

AT THE BAY SHORE POWER STATION [a]

SPECIES	Day [b]	Night [c]	Night/Day	Significance [d]
Carp	21,792	68,760	3.16	0.015
Freshwater Drum	105,675	78,125	0.74	0.595
Gizzard Shad	1,569,210	1,679,648	1.07	0.914
Walleye	6,330	8,134	1.28	0.692
White Bass	386,418	365,345	0.95	0.915
Yellow Perch	22,088	31,890	1.44	0.562 [d]
TOTAL	1,340,530	1,437,400	1.07	0.899

a Estimates of the mean number entrained on sampling dates. Only sampling dates when the designated species was present were used to generate these means. Therefore, the sum of the individuals will not equal the total, and comparisons of the means from different species are not valid.

b Approximately 5:00 AM to 5:00 PM

c Approximately 5:00 PM to 5:00 AM

d This represents the probability of obtaining a Day/Night difference this large or larger by chance alone. A value of 0.05 or less is generally considered significant and means that a difference that large or larger would occur by chance only 5% of the time. Consequently, Carp were entrained in significantly greater numbers during the night.

TABLE 31

A COMPARISON OF SURFACE AND BOTTOM ICHTHYOPLANKTON CONCENTRATIONS*
IN THE MAUMEE RIVER ABOVE THE BAY SHORE POWER STATION

STATION	DEPTH	CARP	FRESHWATER DRUM	GIZZARD SHAD	WALLEYE	WHITE BASS	YELLOW PERCH	OTHERS	TOTAL
4 (Southeast River Bank)	Surface	0.01396	0.08610	7.46788	0.00096	0.35027	0.03595	5.03000	12.98512
	Bottom	0.01073	0.31674	0.94889	0.00483	0.62840	0.02939	6.08144	8.02042
	Surf/Bot	1.30103	0.27183	7.87012	0.19876	0.55740	1.22321	0.82711	1.61901
5 (Mid-channel)	Surface	0.00899	0.05369	10.12341	0.00163	0.71847	0.01941	6.83566	17.76126
	Bottom	0.06827	0.31528	2.03844	0.00324	0.16582	0.02824	3.82585	6.44514
	Surf/Bot	0.13168	0.17029	4.96625	0.50309	4.33283	0.68732	1.78670	2.75576
6 (Northwest River Bank)	Surface	0.00541	0.01676	13.82053	0.00779	0.81017	0.02226	5.25273	19.93565
	Bottom	0.00114	0.14799	6.12672	0.01654	0.80254	0.05207	5.17940	12.32640
	Surf/Bot	4.74561	0.11325	2.25578	0.47098	1.00951	0.42750	1.01416	1.61731
Grand Mean	Surface	0.00945	0.05218	10.47061	0.00346	0.62630	0.02587	5.70613	16.89401
	Bottom	0.02814	0.26000	3.03802	0.00820	0.53225	0.03657	5.02890	8.93065
	Surf/Bot	0.33582	0.20069	3.44652	0.42195	1.17670	0.70741	1.13467	1.89169

* No./100 m^3

TABLE 32

COMPARISON OF ENTRAINMENT ESTIMATES, ENTRAINMENT MORTALITY ESTIMATES, AND ICHTHYOPLANKTON POPULATIONS IN THE MAUMEE RIVER NEAR THE BAY SHORE POWER STATION

SPECIES	RIVER POPULATIONS		TOTAL ENTRAINMENT			ENTRAINMENT MORTALITY	
	No./100m^3[a]	Total Number Passing Plant[b]	No./100m^3[c]	Number Entrained[d]	% of Number Passing Plant	Number Killed[e]	% of Number Passing Plant
Bluegill Sunfish	0.000	0[g]		28,201	[g]	28,201	
Carp	0.898	12,590,973[g]	1.855	8,251,539	65.5[g]	5,008,231	39.8
Channel Catfish	0.000	0[g]		564,532	[g]	564,532	
Emerald Shiner	0.369	5,172,246[g]		142,572	2.8[g]	83,282	1.6
Freshwater Drum	9.958	139,656,878	3.410	13,479,134	9.7	7,221,230	5.2
Gizzard Shad	465.037	6,522,042,437	65.890	223,290,406	3.4	69,812,545	1.1
Green Sunfish	0.002	27,771		0	0.0	0	0.0
Logperch Darter	0.020	286,804		28,778	10.0	28,778	10.0
Quillback Carpsucker	0.002	28,358		0	0.0	0	0.0
Rainbow Smelt	0.044	618,790[g]		897,099	145.0[g]	897,099	145.0
Spottail Shiner	0.138	1,937,219[g]		238,132	12.3[g]	71,440	3.7
Troutperch	0.000	0[g]		12,747	[g]	3,824	
Unidentified	0.186	2,610,012		88,078	3.4	68,410	2.6
Unidentified Crappie	0.216	3,027,329		28,778	1.0	28,778	1.0
Unidentified Shiner	0.020	276,446[g]		166,784	60.3[g]	50,035	18.1
Unidentified Sucker	0.025	357,167[g]		357,889	100.5[g]	107,367	30.0
Unidentified Sunfish	1.179	16,540,804		493,434	3.0	417,800	2.5
Walleye	0.431	6,049,074	0.102	441,614	7.3	132,484	2.2
White Bass	39.966	560,518,850	13.362	33,107,856	5.9	10,646,042	1.9
White Crappie	0.002	27,771		0	0.0	0	0.0
White Sucker	0.132	1,857,758[g]		637,614	36.3[g]	202,084	10.9
Yellow Perch	2.113	29,630,704[g]	0.696	2,426,431	8.2[g]	752,013	2.5
TOTAL LARVAE	520.738	7,303,256,391	86.214[f]	284,717,618	3.9	96,124,175	1.3
Drum Eggs	175.658	2,463,574,487		425,804,075	17.3		
Other Eggs	0.011	153,818[g]		346,034	225.0[g]		
TOTAL EGGS	175.669	2,463,728,305		426,150,109	17.3		

[a]Mean ichthyoplankton concentration from all samples collected from stations 4-6 in the Maumee River from 9 April to 1 September 1977.

[b]Total number of ichthyoplankters passing the plant, i.e., the number available for entrainment. This was computed by multiplying the mean inchtyoplankton concentration by the 1977 (1,402,479,595m^3) as measured at the USGS guage at Waterville, Ohio.

[c]Mean ichthyoplankton concentration from pump samples collected in the intake canal of the Bay Shore power station from 9 April 1977 to 1 September 1977.

[d]Estimate of the number of ichthyoplankters entrained at the Bay Shore power station from 1 September 1976 to 1 September 1977.

[e]Estimate of the number of entrained larvae which die during condenser passage. Cannon et al (1977) found that when the maximum temperature experienced by larvae during condenser passage was less than 30^{o}C, mortality generally ranged from 0-30%. For these estimates, mortality was considered to be 100% after June 23, 30% prior to June 12, and 65% in the interim.

[f]Only concentrations of the more prominent species are listed. This total includes all the very rare species, the concentrations of which are not listed.

[g]These estimates are based on river flow rates which may not be appropriate for all species, as several species were shown to be more prevalent when the intake water was of lake or bay origin. This estimate does not account for this phenomenon. Several other species may not be adequately sampled by limnetic techniques. See pages 48-51 for a discussion of these factors.

TABLE 33

INFERRED WATER MASSES IN THE VICINITY OF
THE BAY SHORE INTAKE FOR EACH COLLECTION PERIOD

Collection Period	Dominant Current		Water Level		Conductivity (umohs/cm)	Inferred Water Mass[5]	
	Out[1]	In[2]	Rising[3]	Falling[4]		River	Bay
29	X		X		450		X
30	X		X		536	X	
31	X			X	500	X	
32	X		X		568	X	
33	X			X	500	X	
34	X		X		588	X	
35	X		X		513	X	
36	X		X		440		X
37	X			X	563	X	
38	X		X		508	X	
39		X		X	397[6]		X
40	X		X		443[6]		X
41		X		X	521	X	
42	X		X		464	X	
43	X		X		500	X	
44		X		X	532	X	
45				X	658	X	
46			X		375		X
47				X	377		X
48				X	370		X
49	X		X		380		X
50	X			X	380		X
51	X			X	385		X
52		X		X	427	X	
53	X			X	350		X
54	X			X	313		X
55		X	X		362		X
56		X	X		378		X
57	X		X		350		X
58		X	X		497	X	
59		X		X	346		X
60	X		X		470	X	
61		X		X	527	X	
62	X		X		533	X	
63	X		X		403		X

[1]Dominant current flowing out of Maumee River (≥330° to ≤149°).

[2]Dominant current flowing into Maumee River (≥150° to ≤329°).

[3]Rising water level reference to 12 hours earlier.

[4]Falling water level reference to 12 hours earlier.

[5]Percent of influence: River 51%; Bay , 49%.

[6]Low conductance may be the result of low mineralization in the river (USGS Waterville Station) due to rainfall on 4/23-24.

TABLE 34

OCCURRENCE OF ICHTHYOPLANKTON TAXA IN ENTRAINMENT SAMPLES AT THE BAY SHORE POWER STATION

SPECIES \ COLLECTION PERIOD #	1	2	3	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Bluegill																														x								
Carp														x		x					x	x	x	x		x		x	x	x	x		x				x	
Channel Catfish																														x	x			x	x			
Emerald Shiner																									x				x		x			x				
Freshwater Drum																					x		x	x	x	x	x	x	x	x	x	x	x	x	x			x
Gizzard Shad																			x		x	x	x	x	x	x	x	x	x	x		x	x	x				
Green Sunfish																																						
Logperch Darter																														x								
Quillback Carpsucker																																						
Rainbow Smelt																			x											x		x	x					
Spottail Shiner																								x														
Troutperch																			x																			
Unidentified																		x											x		x							
Unid. Crappie																														x								
Unid. Shiner																							x															
Unid. Sucker																		x	x																			
Unid. Sunfish																												x										
Walleye													x	x	x			x	x																			
White Bass																			x		x	x	x	x	x	x	x	x		x			x	x				
White Crappie																																						
White Sucker														x			x	x																				
Yellow Perch														x					x		x	x		x		x						x						
Drum Eggs																			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	
Other Eggs																x	x	x	x	x																		

"x" indicates the presence of that taxon

TABLE 35

OCCURRENCE OF ICHTHYOPLANKTON TAXA IN RIVER SAMPLES NEAR THE BAY SHORE POWER STATION

SPECIES \ COLLECTION PERIOD #	1	2	3	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Bluegill																				NO SAMPLE COLLECTED - BOAT TROUBLE																		
Carp														x							x		x	x			x		x	x	x	x	x	x			x	
Channel Catfish																																						
Emerald Shiner																								x			x	x	x	x	x		x	x	x			
Freshwater Drum																		x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Gizzard Shad																		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Green Sunfish																														x								
Logperch Darter														x			x		x										x	x								
Quillback Carpsucker																	x																					
Rainbow Smelt																	x													x		x	x					x
Spottail Shiner																					x		x	x						x			x	x				
Troutperch																																						
Unidentified													x				x					x	x			x	x	x	x	x	x							
Unid. Crappie																							x							x					x			
Unid. Shiner																	x	x	x																			
Unid. Sucker																	x	x															x					
Unid. Sunfish																					x		x					x		x	x		x					
Walleye													x	x			x	x	x																			
White Bass																			x		x	x	x	x	x	x	x	x	x	x	x	x	x					
White Crappie																														x								
White Sucker														x																								
Yellow Perch														x	x	x		x	x		x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	
Drum Eggs																			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Other Eggs														x			x																					

"x" indicates the presence of that taxon

FIGURES

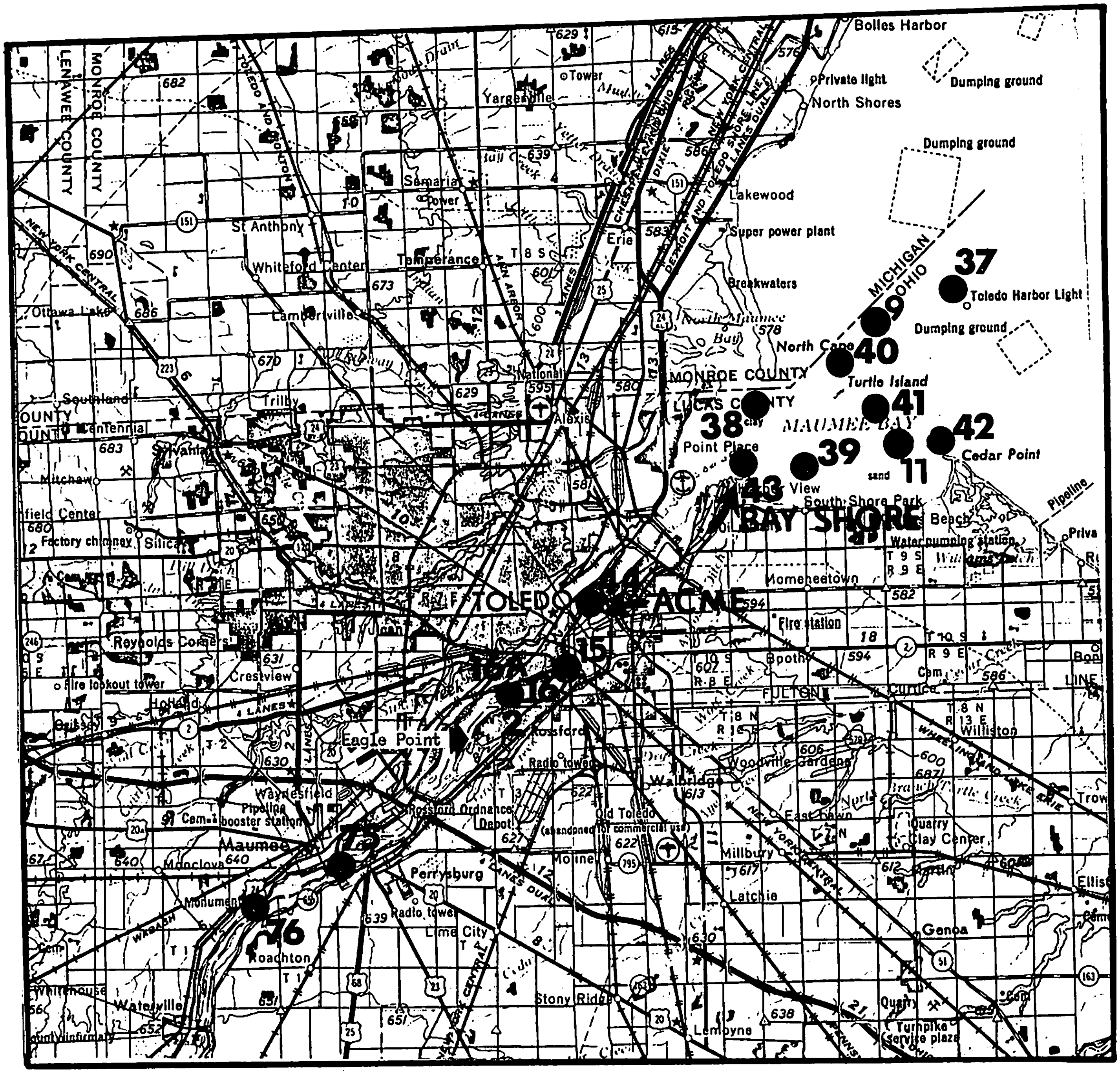


FIGURE 1. FISH AND ICHTHYOPLANKTON SAMPLING STATIONS (Herdendorf and Cooper, 1975 and 1976).

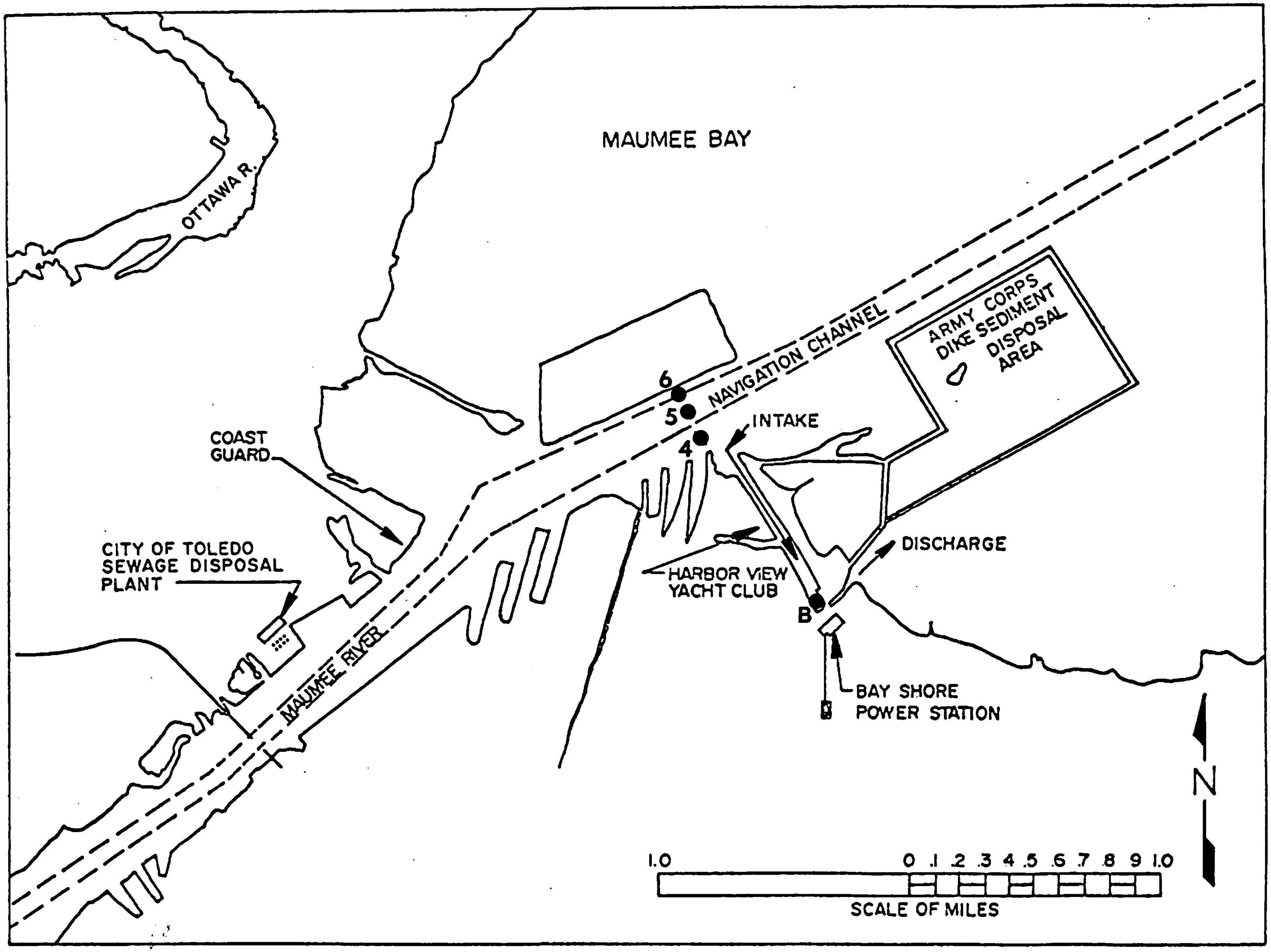
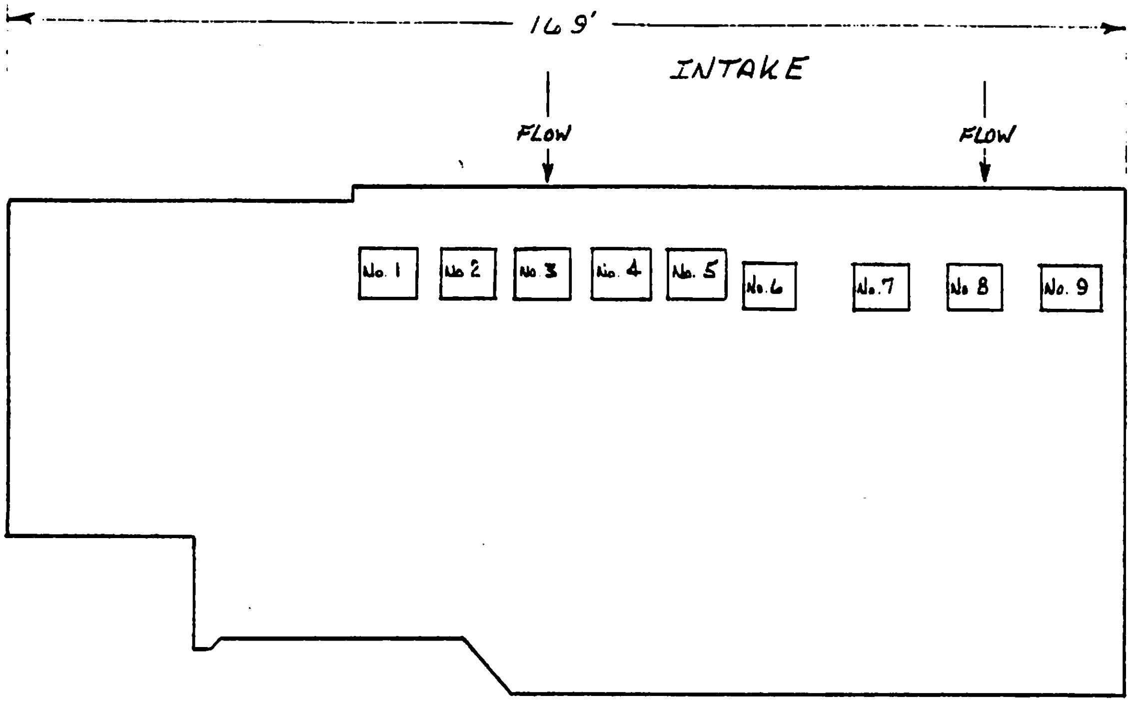
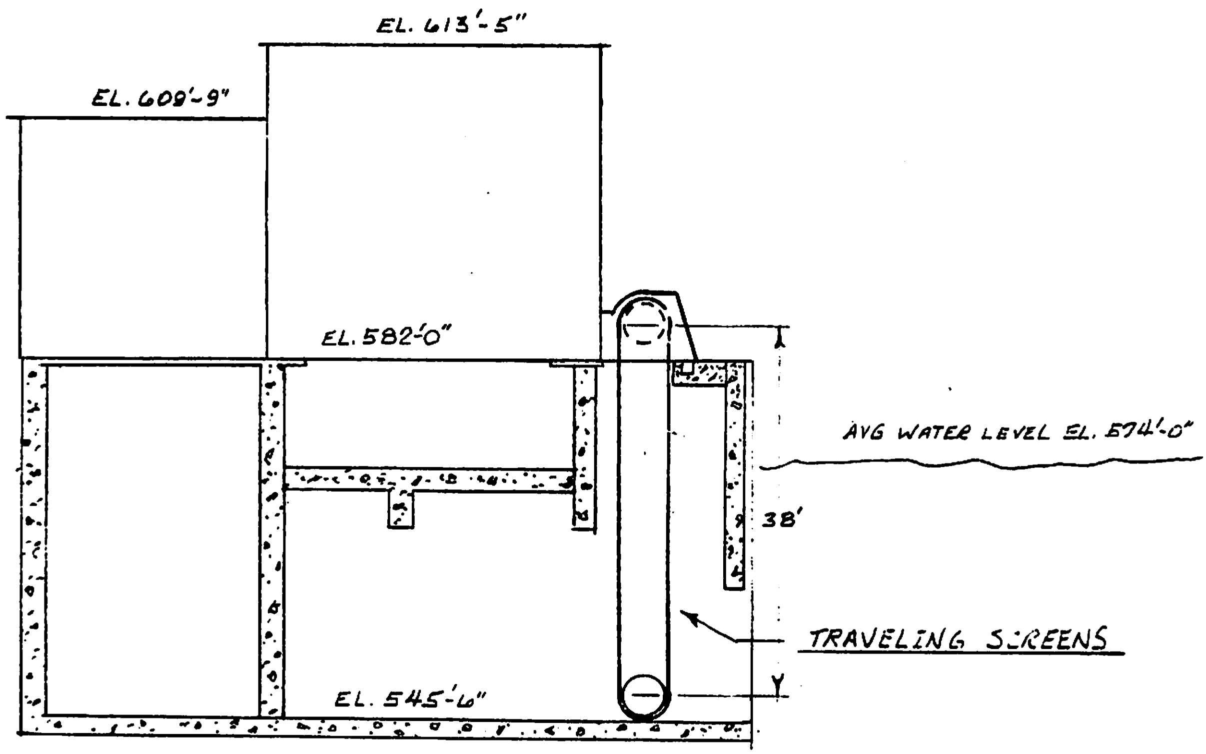


FIGURE 2
GENERAL AREA NEAR BAY SHORE POWER STATION
SHOWING COLLECTION STATIONS



PLAN VIEW



LATERAL VIEW

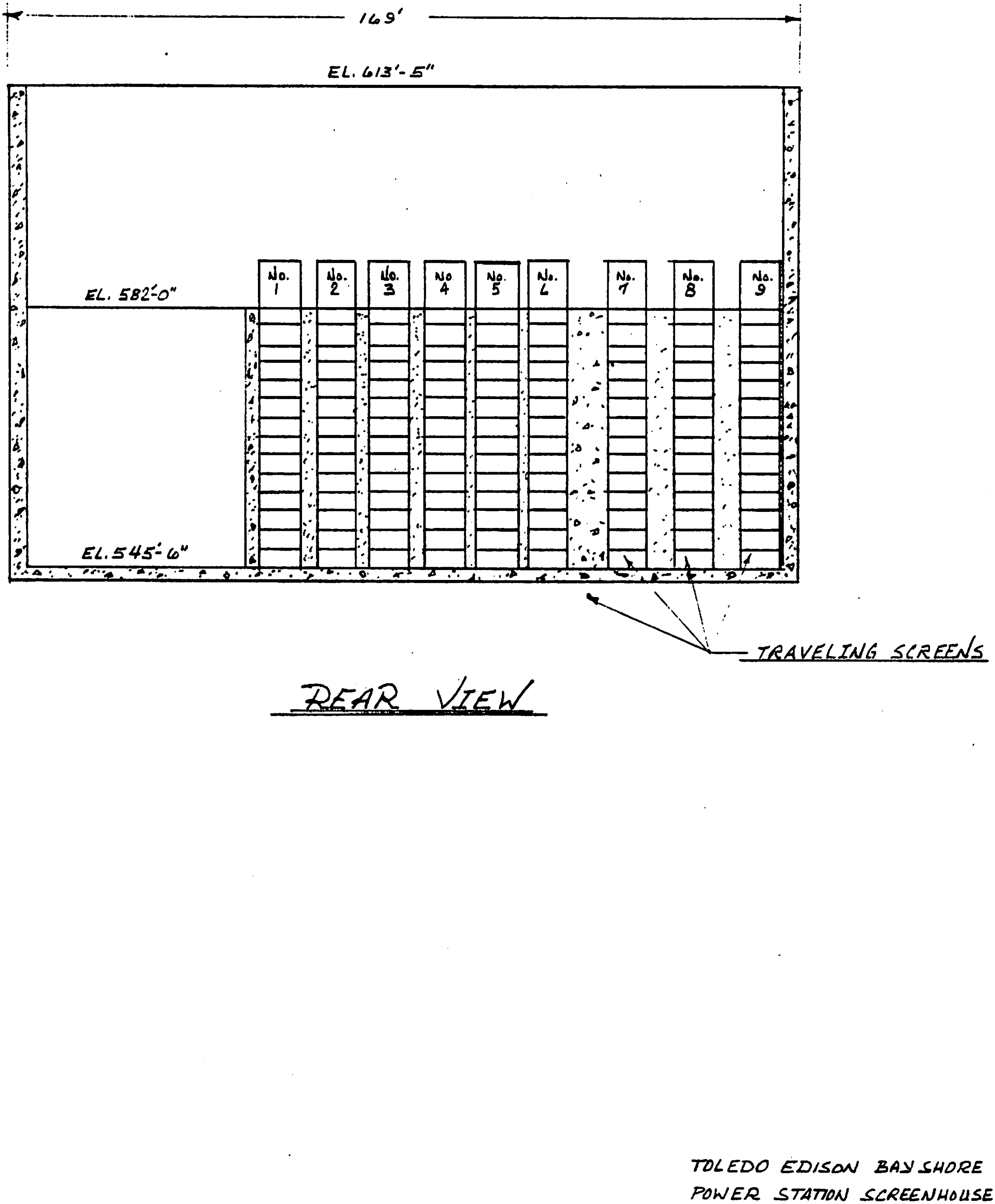
FIGURE 3

OVERVIEW AND LATERAL VIEW OF TRAVELING SCREENS
AT THE BAY SHORE POWER STATION

TOLEDO EDISON BAY SHORE
POWER STATION SCREENHOUSE

FIGURE 4

REAR VIEW OF TRAVELING SCREENS
AT THE BAY SHORE POWER STATION



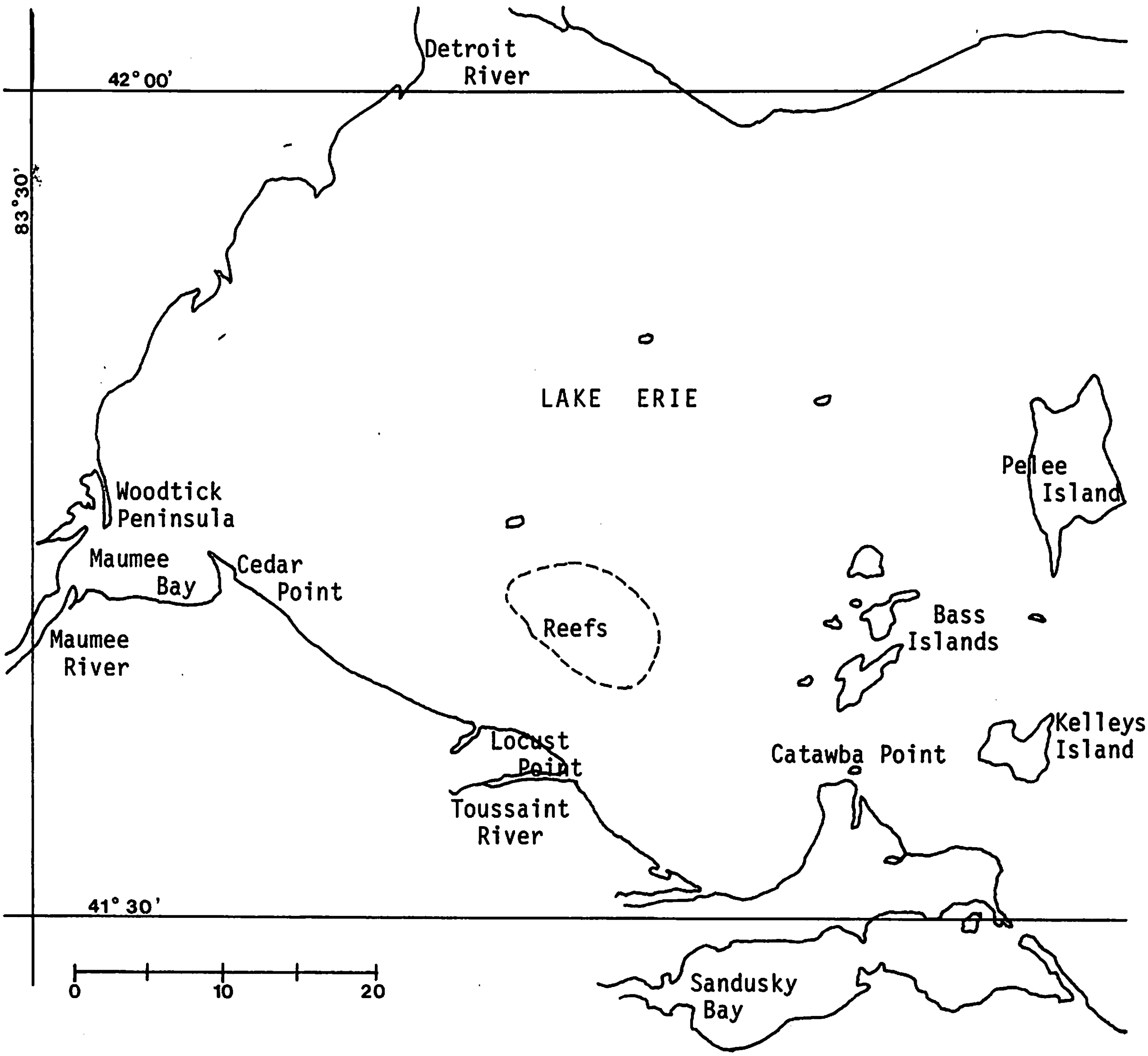
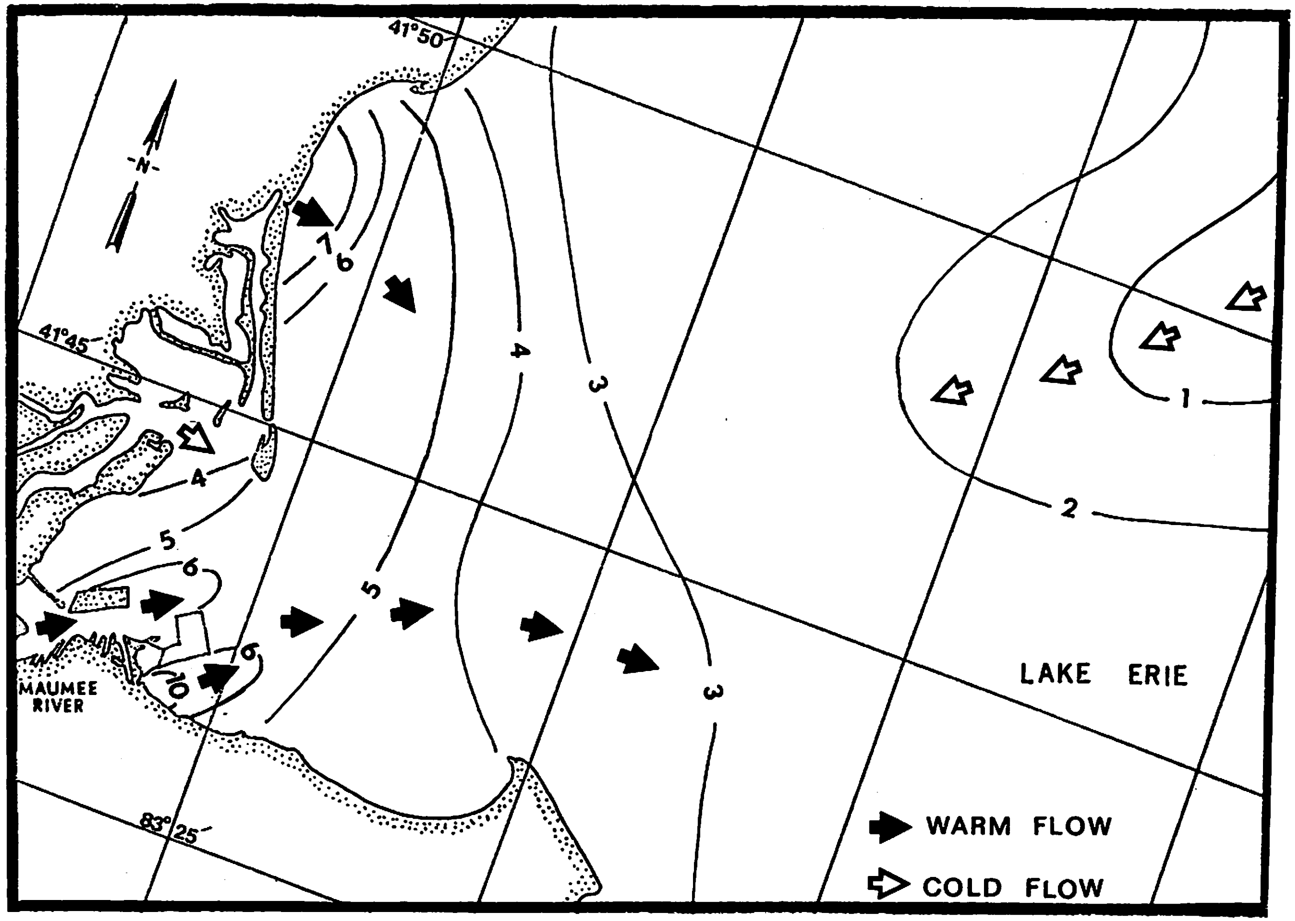


FIGURE 5

WESTERN LAKE ERIE

FIGURE 6

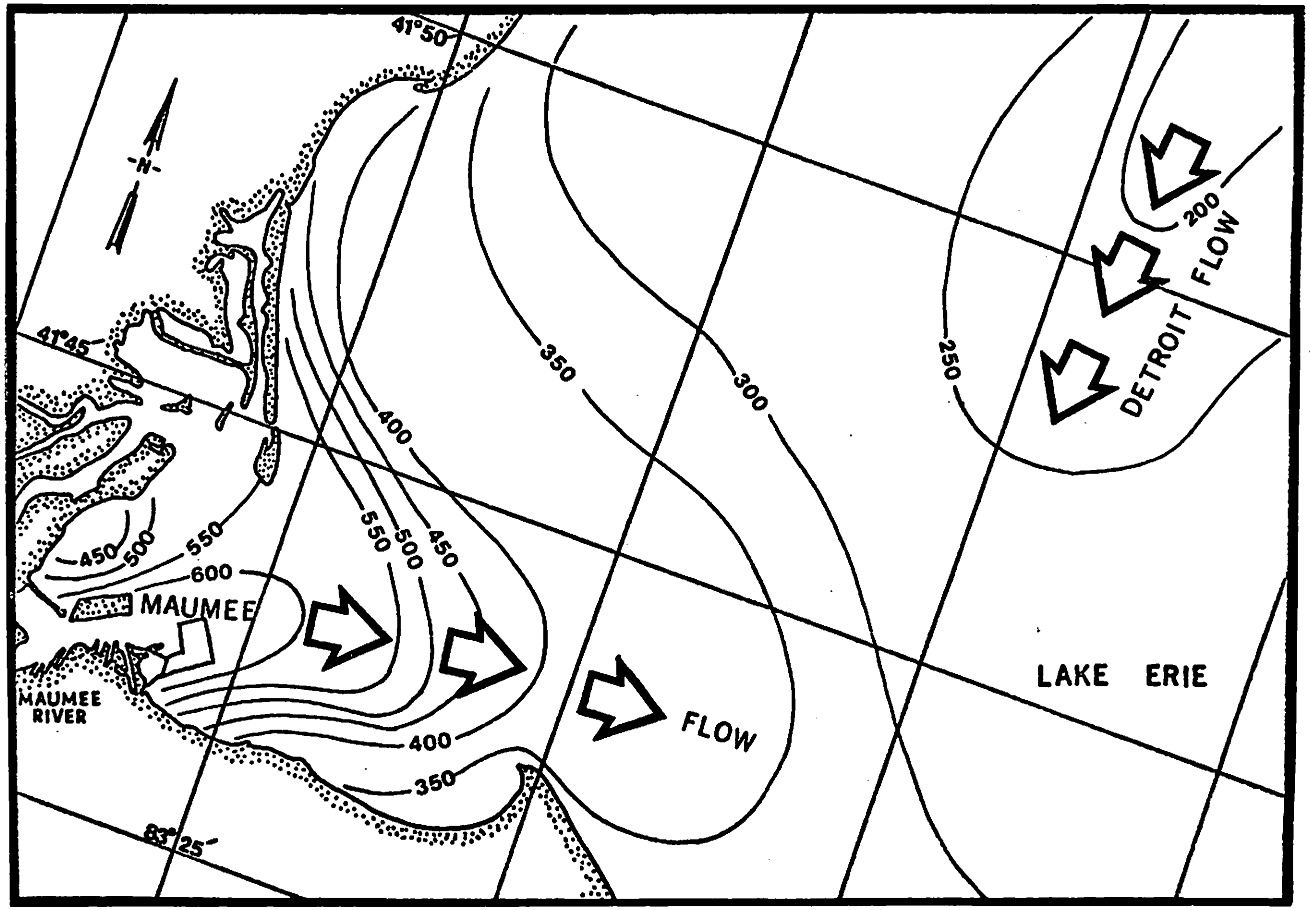
TEMPERATURE OF SURFACE WATER IN MAUMEE BAY ON 19-20 MARCH 1975 (contour interval: 1°C)



From Herdendorf et al. (1977a)

FIGURE 7

CONDUCTIVITY OF SURFACE WATER IN MAUMEE BAY ON 19-20 MARCH 1975 (contour interval: 50 umhos/cm)



From Herdendorf et al. (1977a)

FIGURE 8

VOLUME OF COOLING WATER USED DAILY AT THE BAY SHORE POWER STATION
FROM 1 SEPTEMBER 1976 - 15 SEPTEMBER 1977

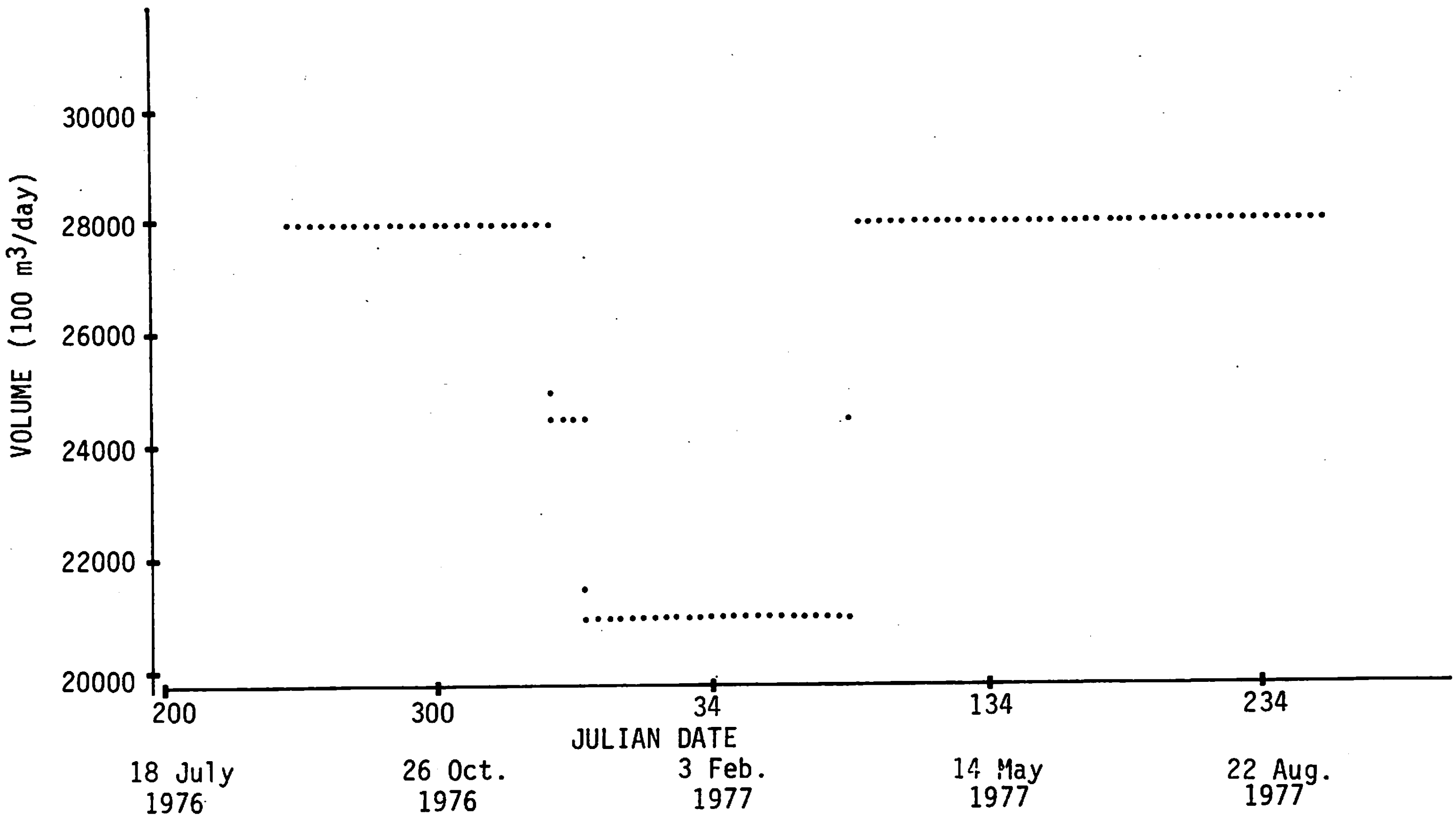
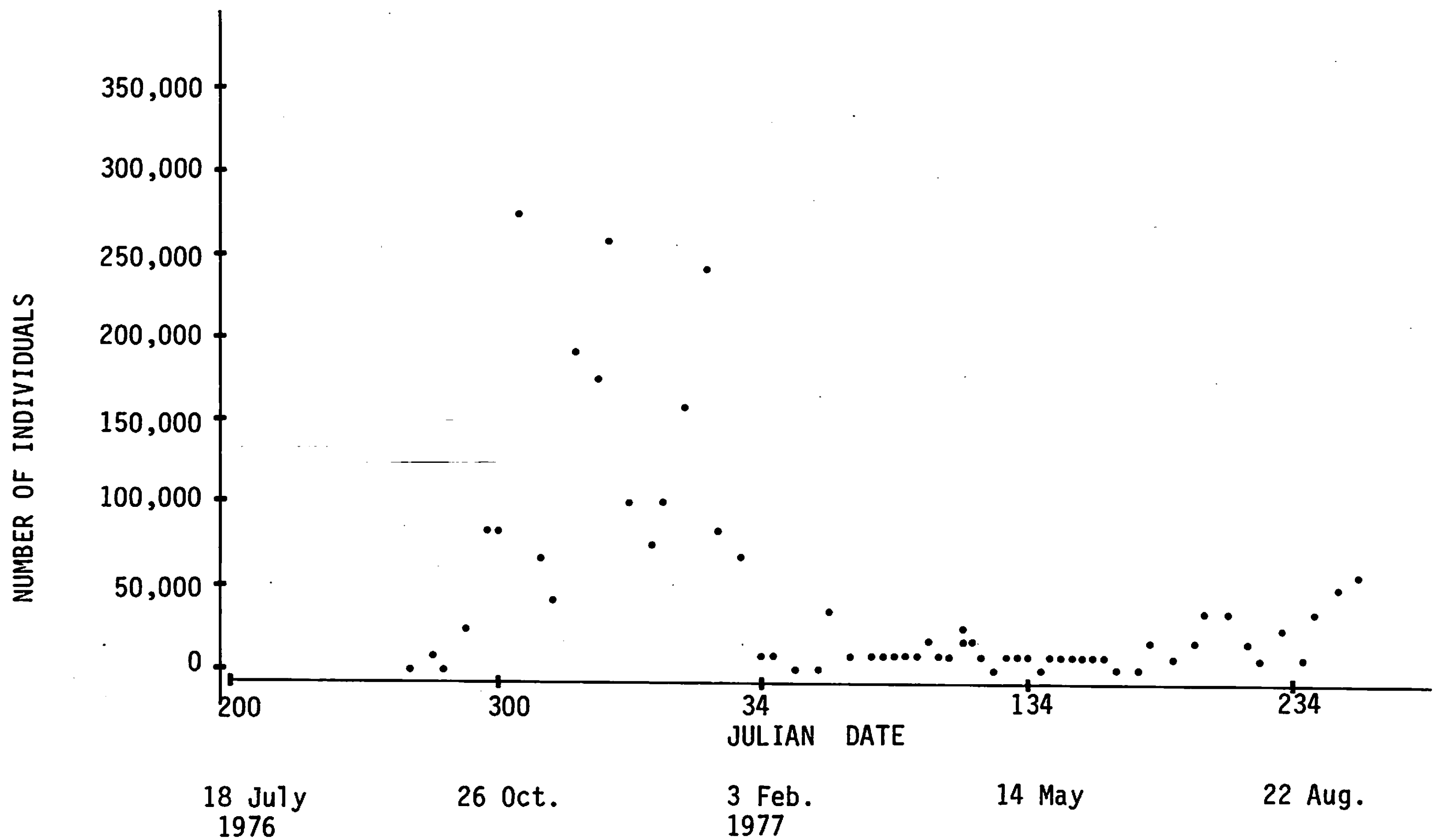


FIGURE 9

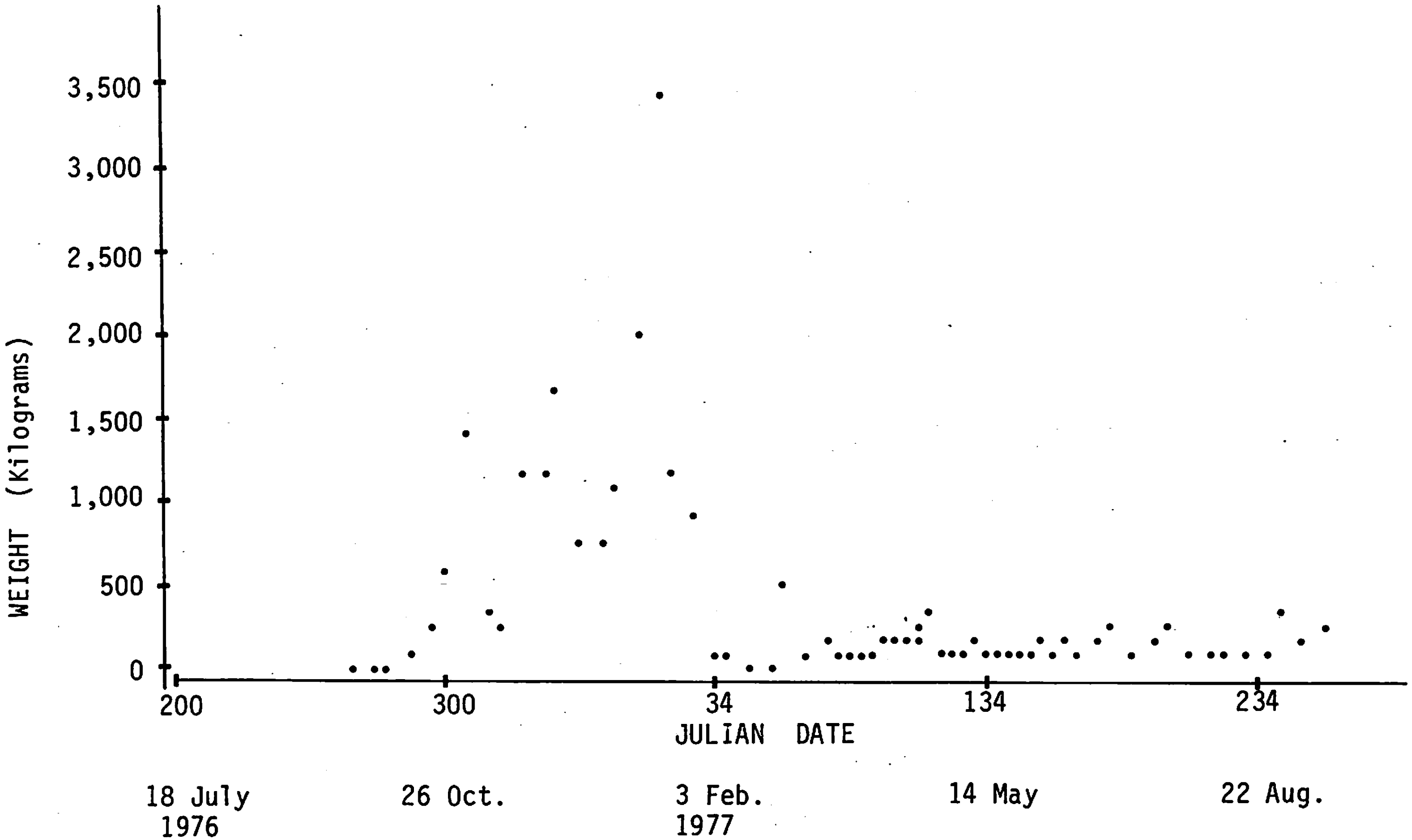
NUMBER OF FISH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 10

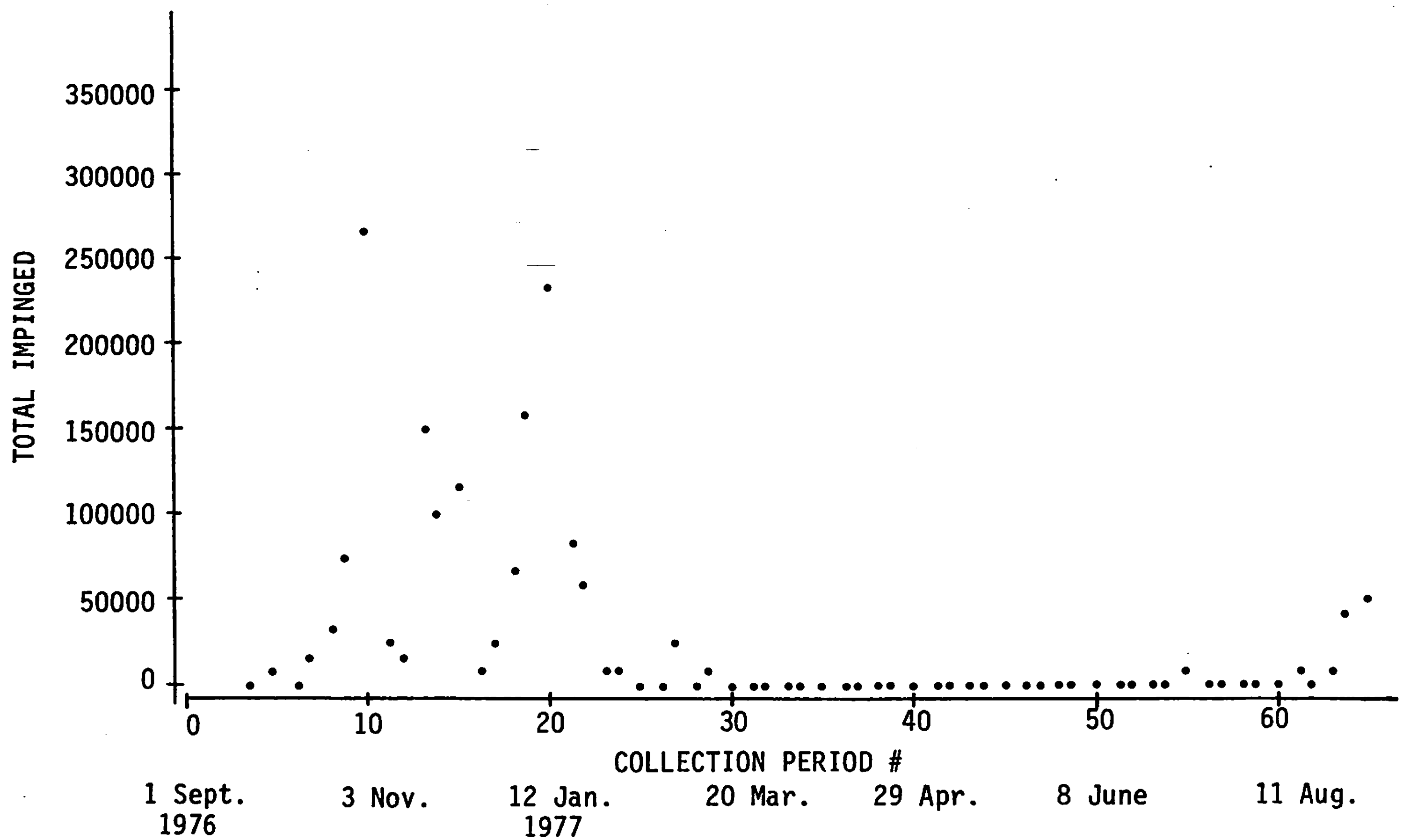
WEIGHT OF FISH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977*



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 11

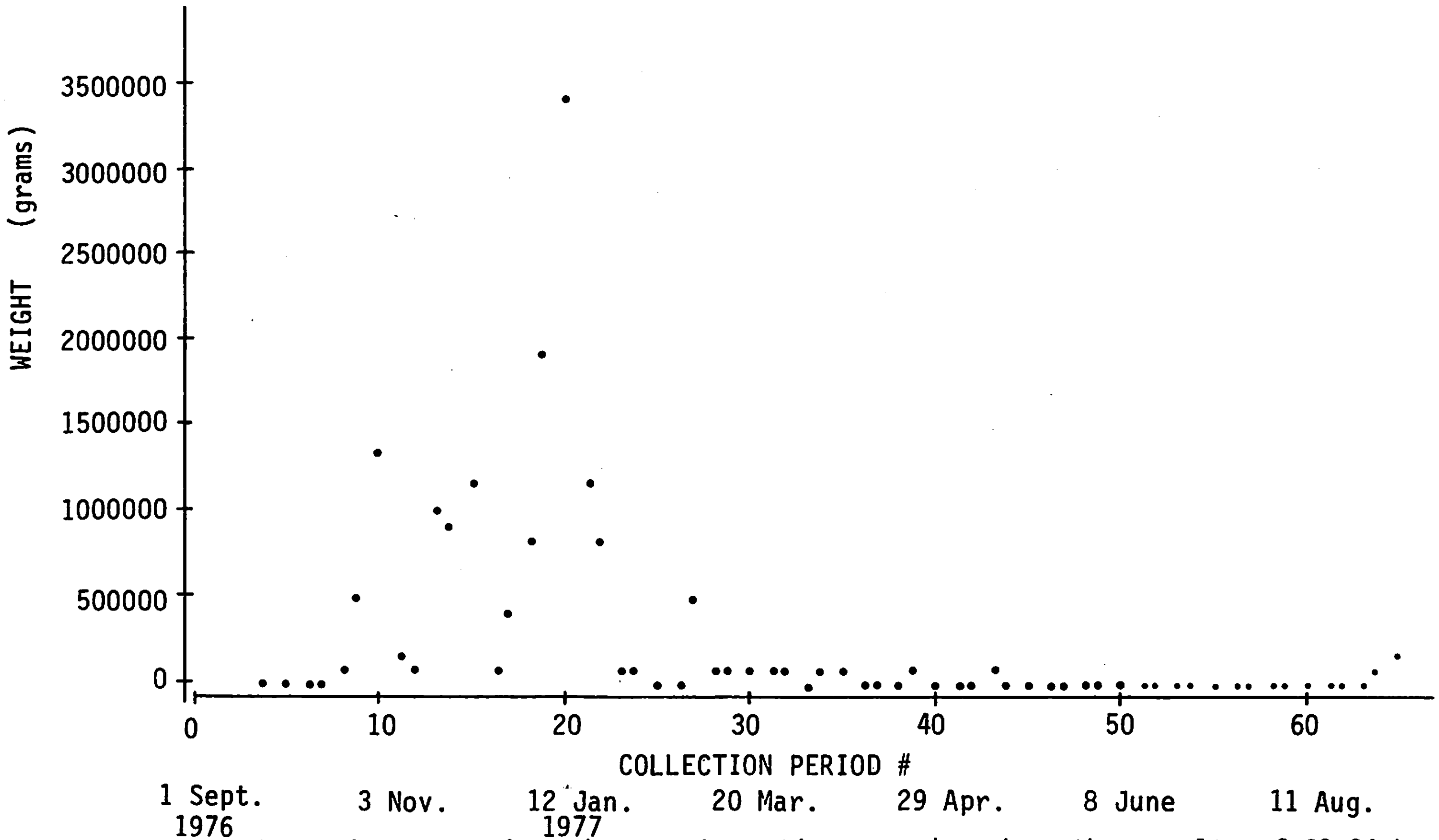
NUMBER OF GIZZARD SHAD IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977*



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 12

WEIGHT OF GIZZARD SHAD IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *

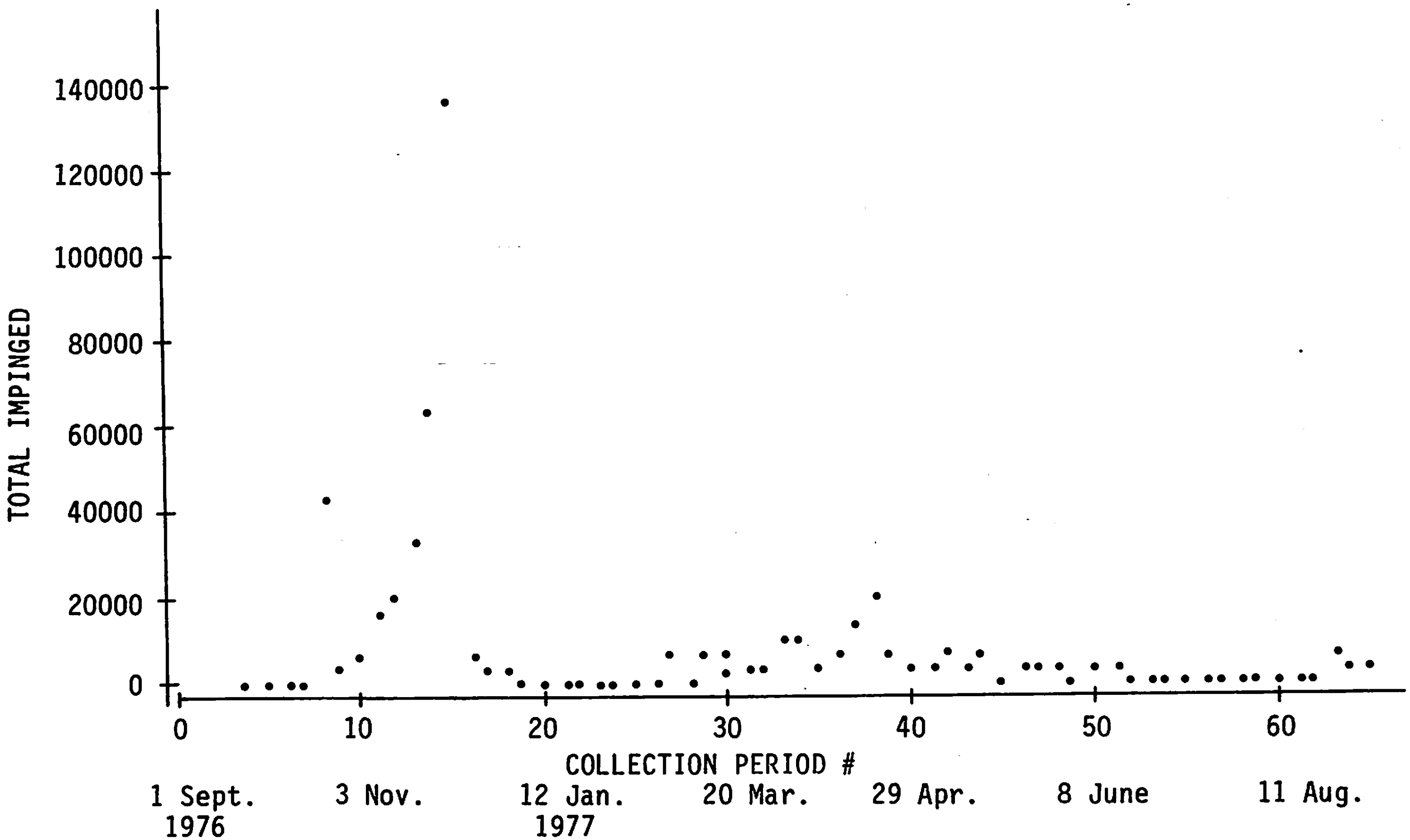


* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 13

NUMBER OF EMERALD SHINERS IMPINGED AT THE BAY SHORE POWER STATION

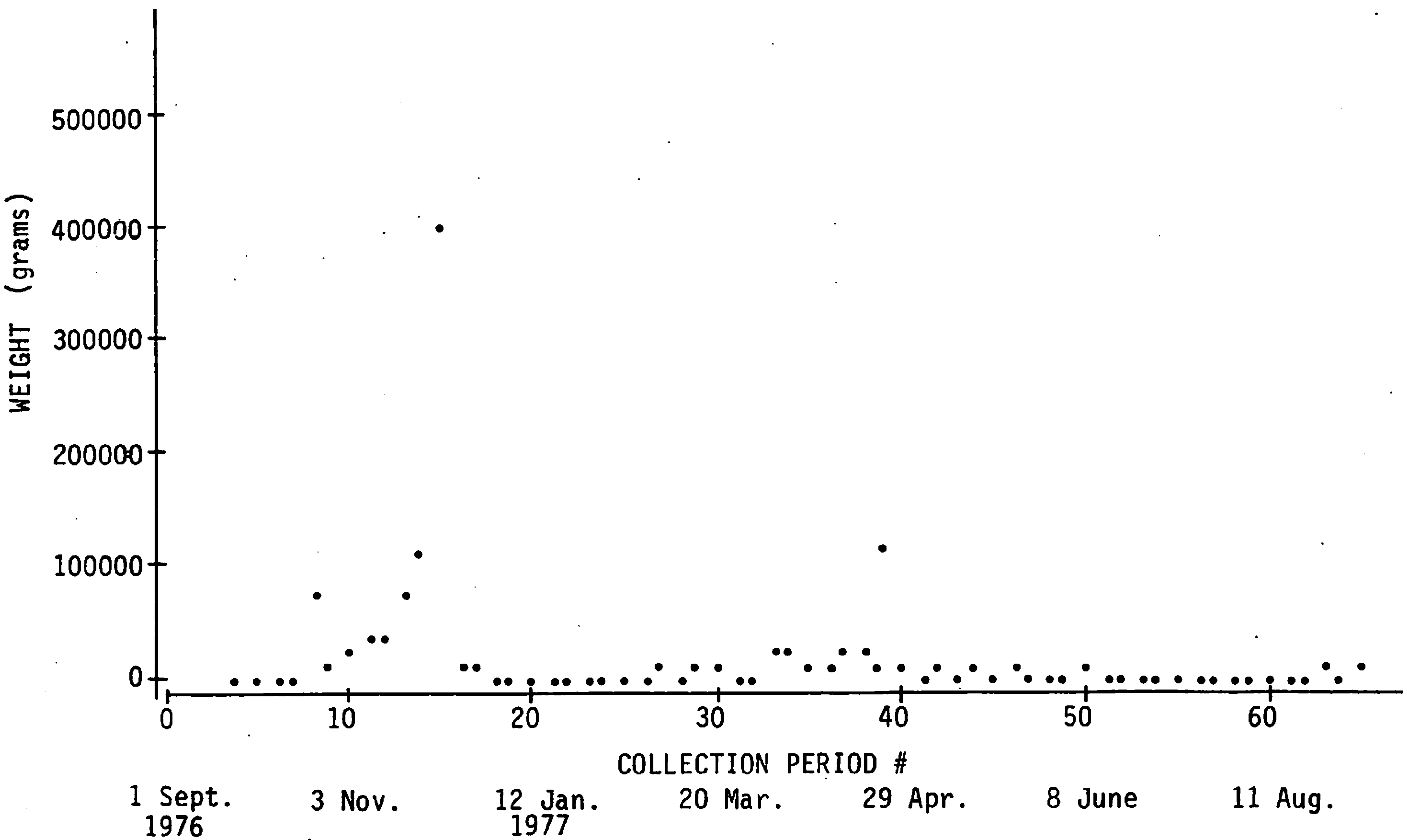
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 14

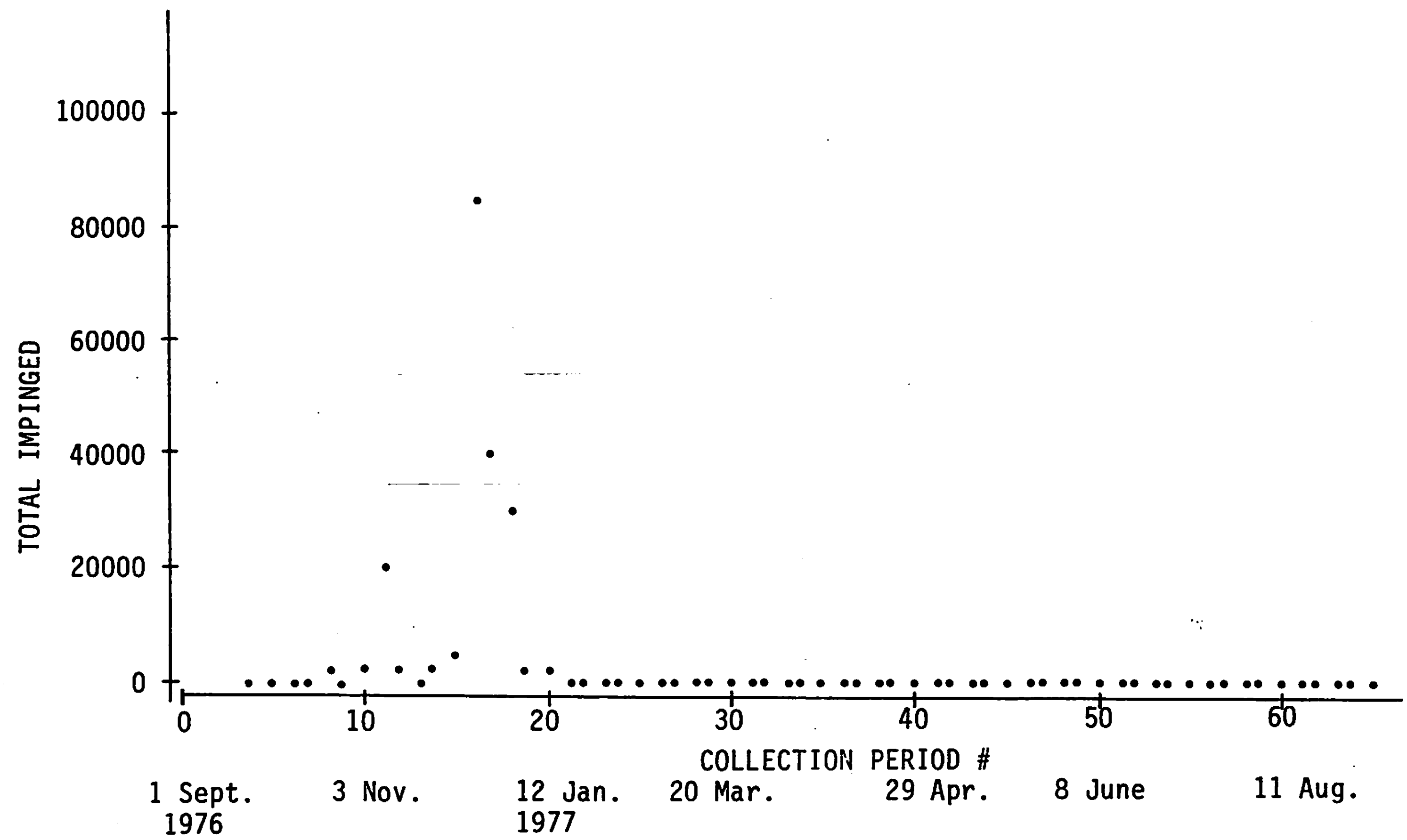
WEIGHT OF EMERALD SHINERS IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 15

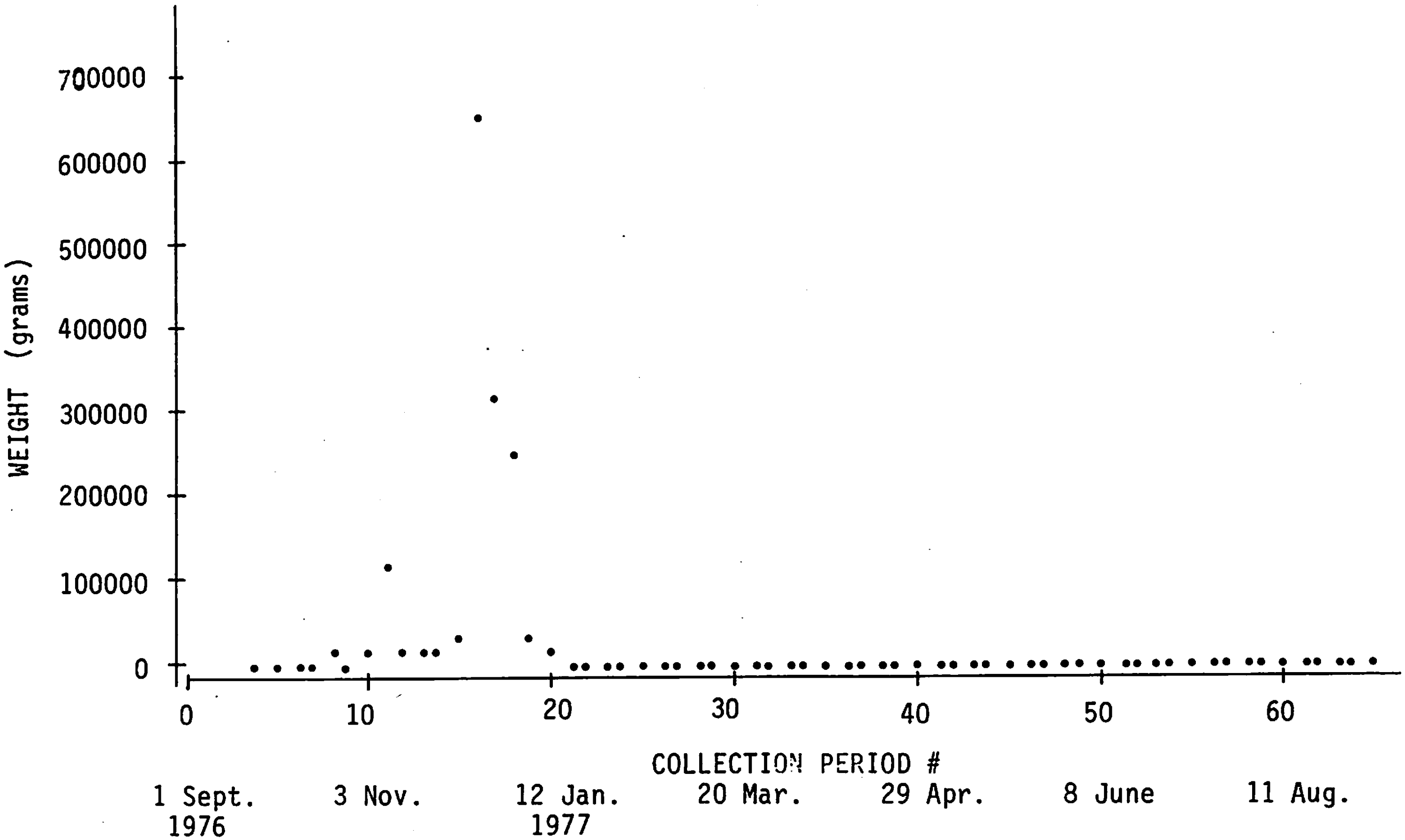
NUMBER OF ALEWIVES IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977*



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 16

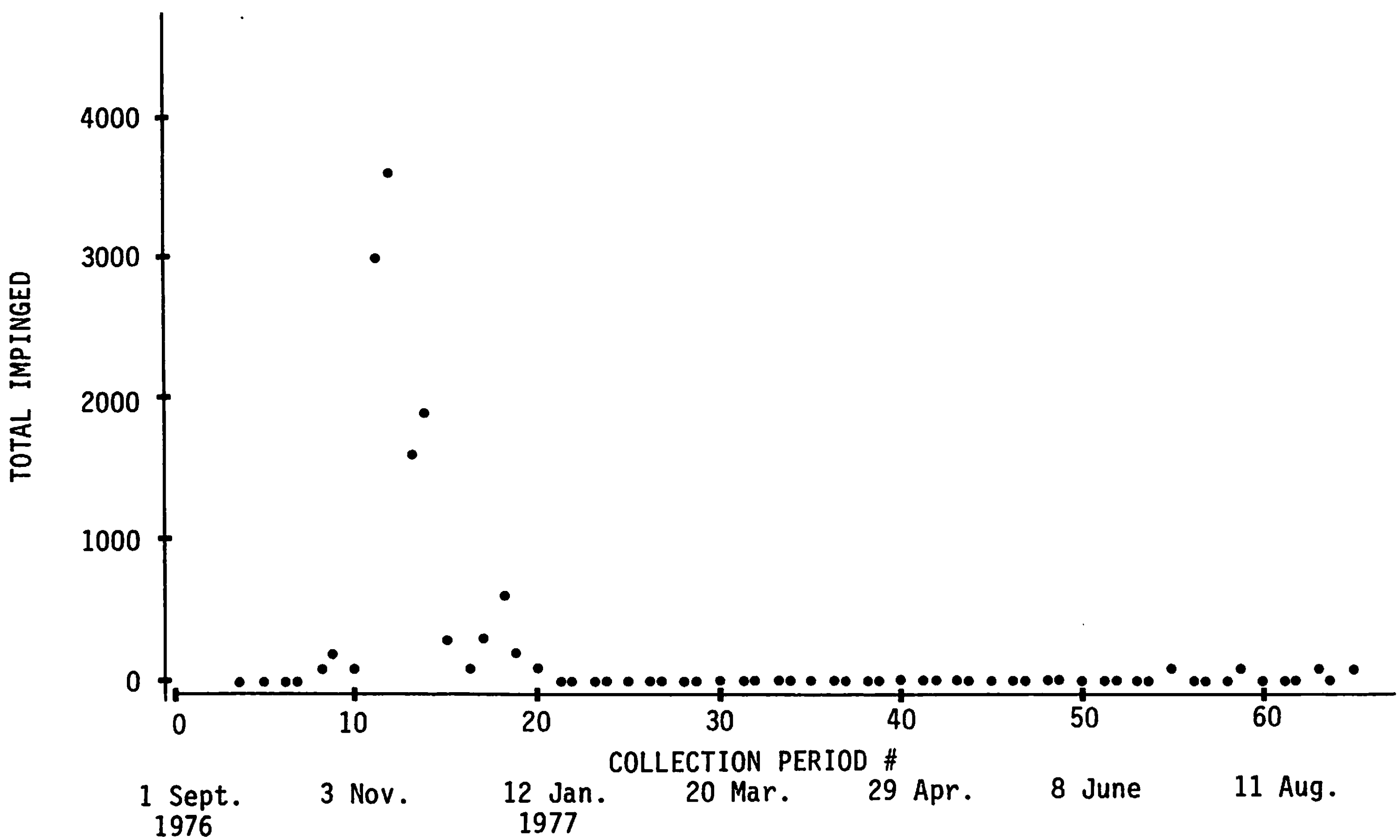
WEIGHT OF ALEWIVES IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - TO 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 17

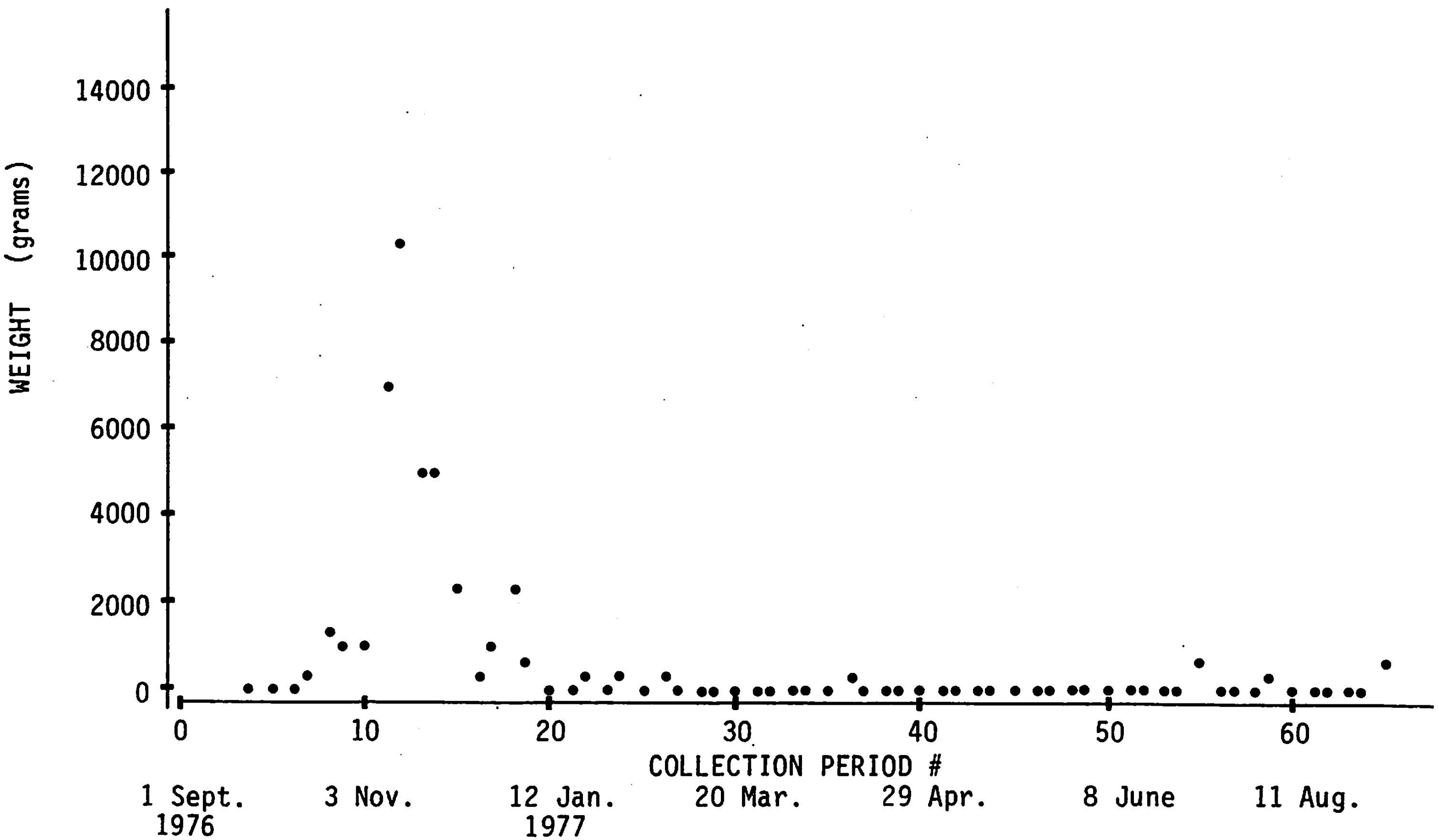
NUMBER OF RAINBOW SMELT IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 18

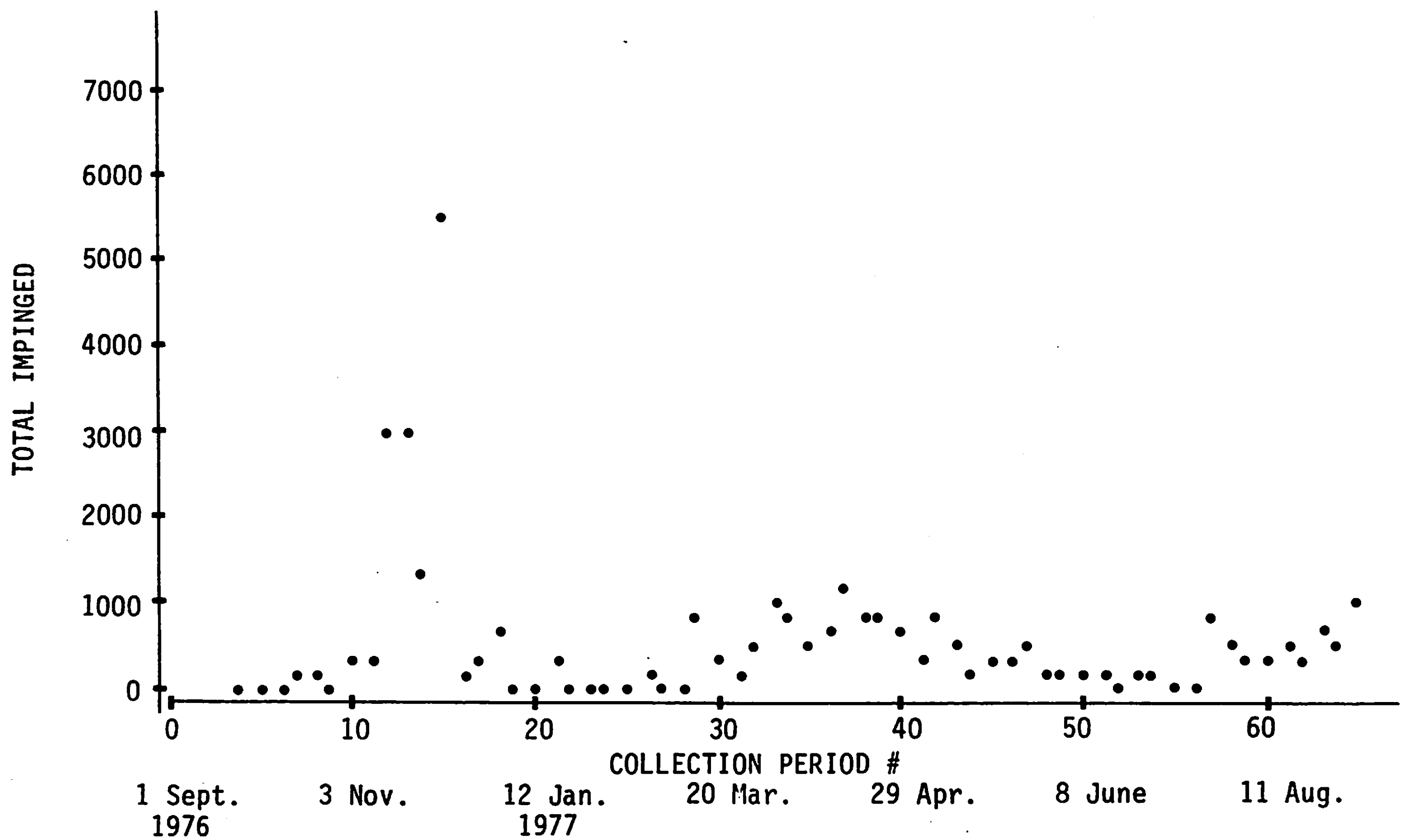
WEIGHT OF RAINBOW SMELT IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 19

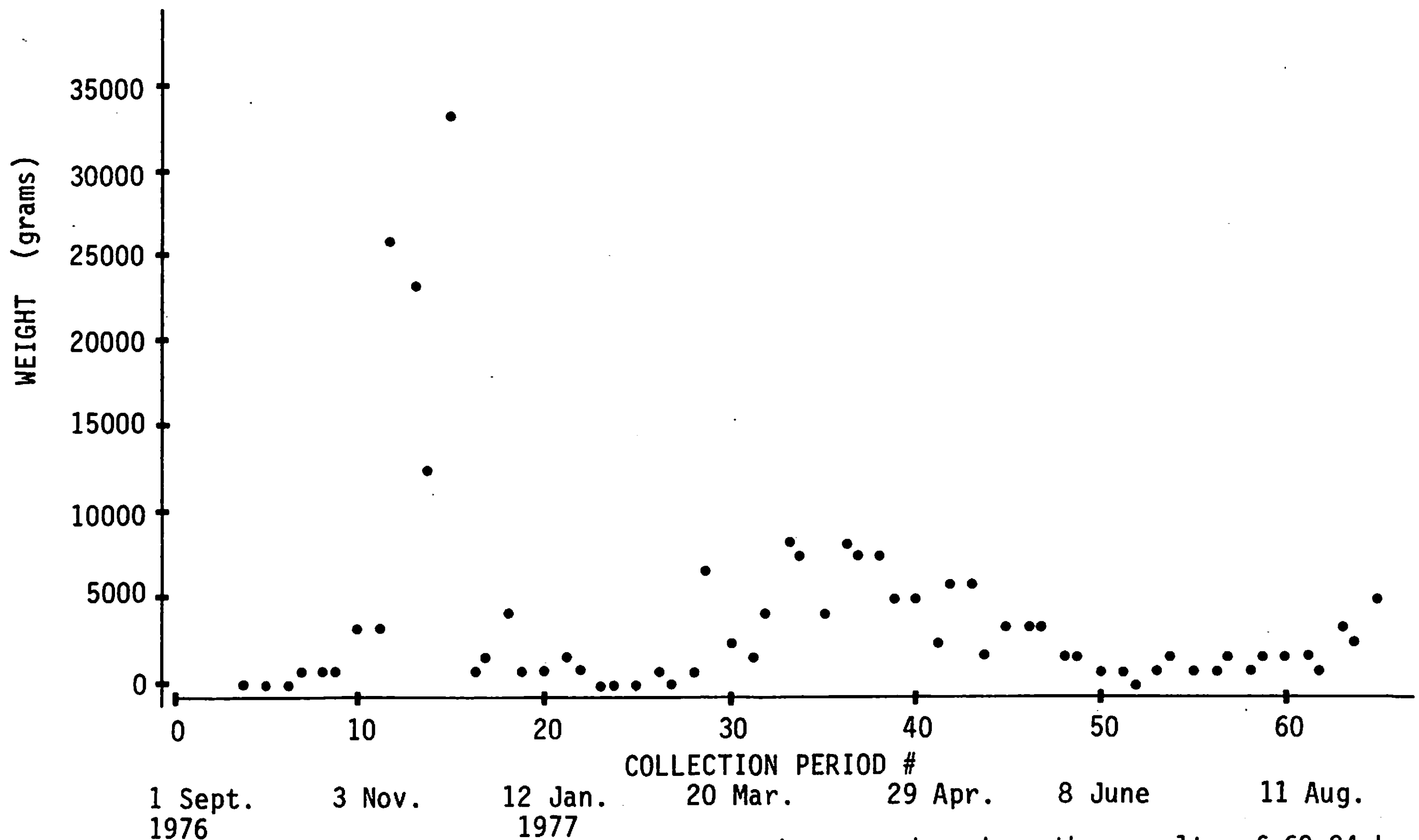
NUMBER OF SPOTTAIL SHINERS IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 20

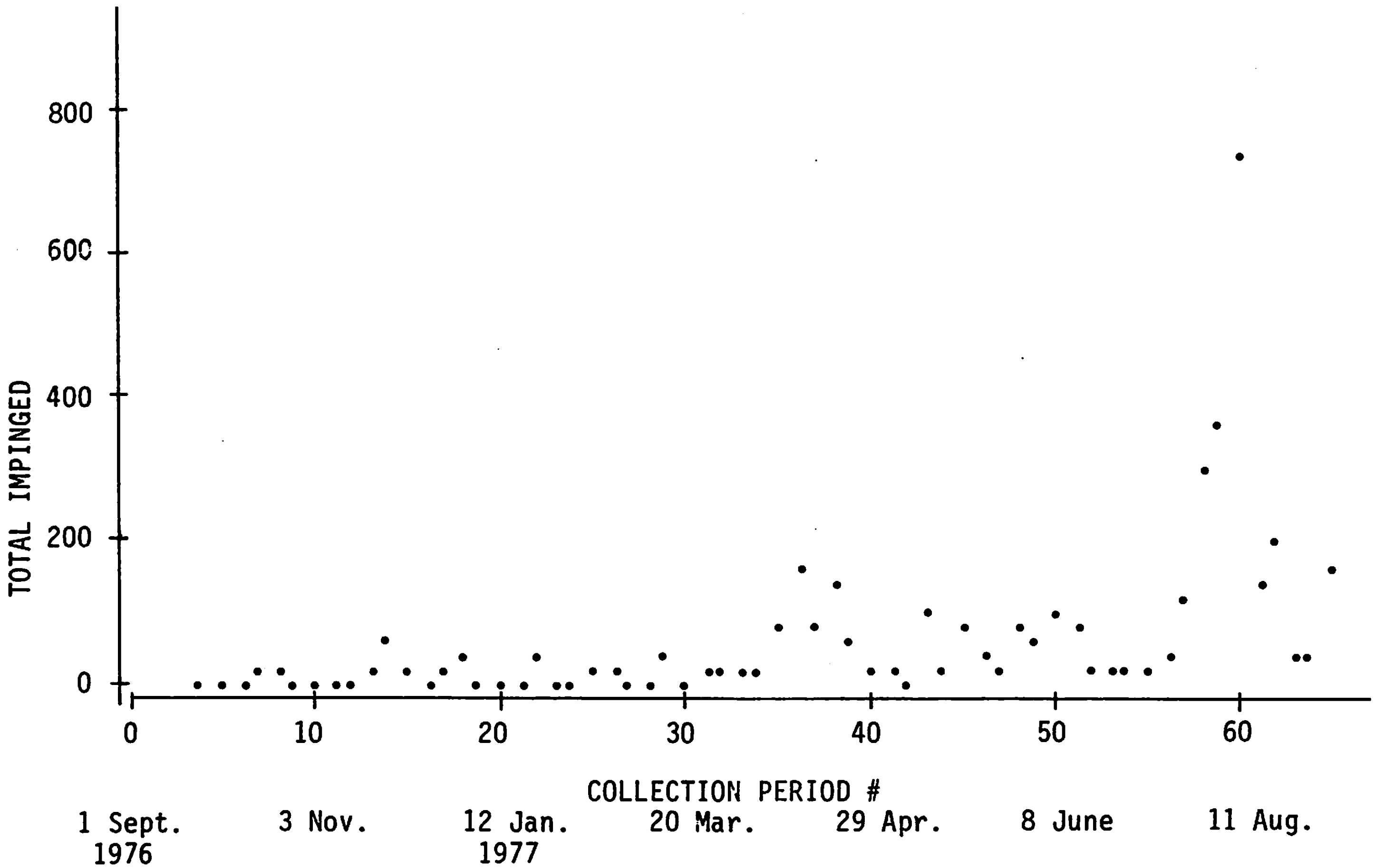
WEIGHT OF SPOTTAIL SHINERS IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 21

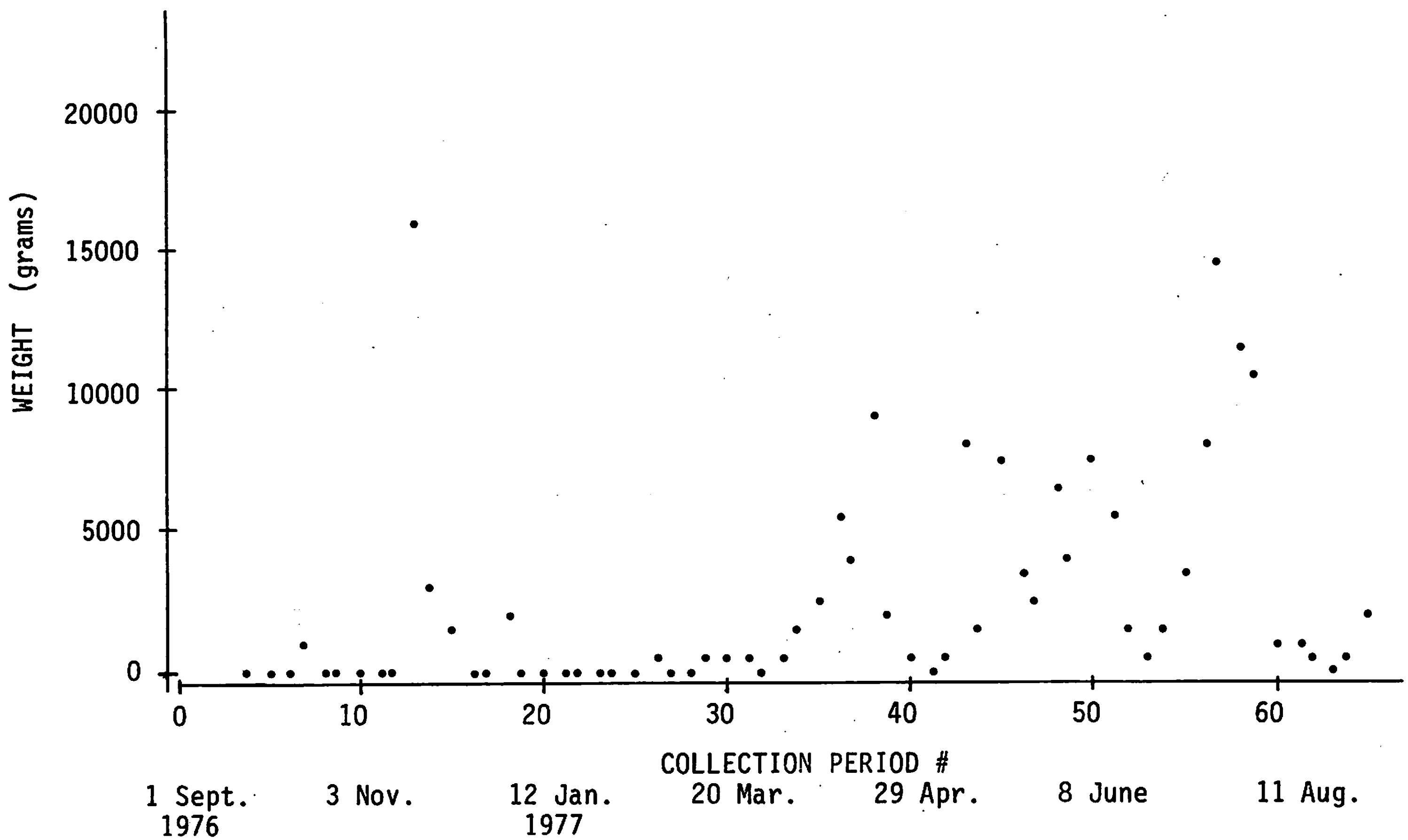
NUMBER OF CHANNEL CATFISH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 22

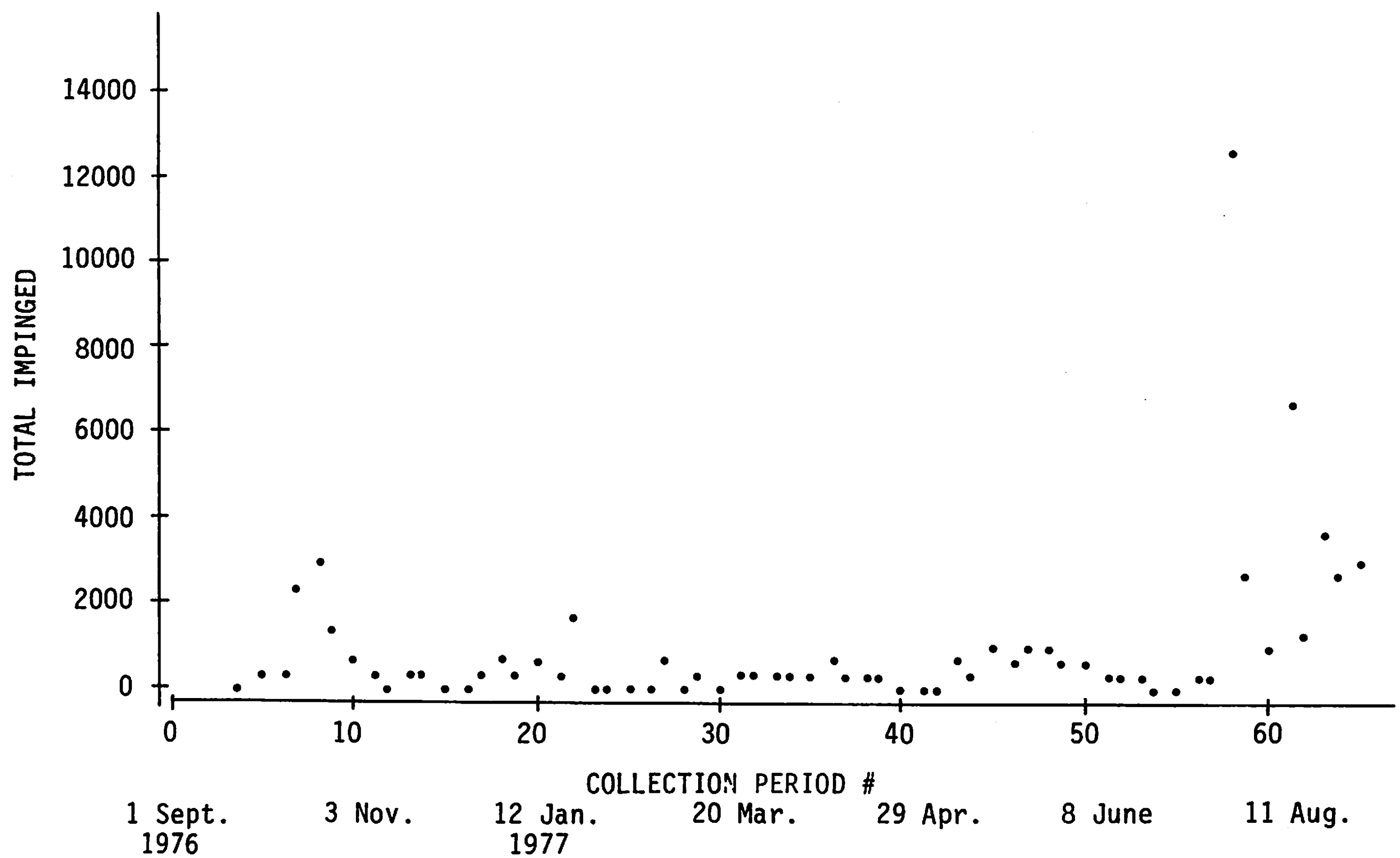
WEIGHT OF CHANNEL CATFISH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 23

NUMBER OF FRESHWATER DRUM IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *

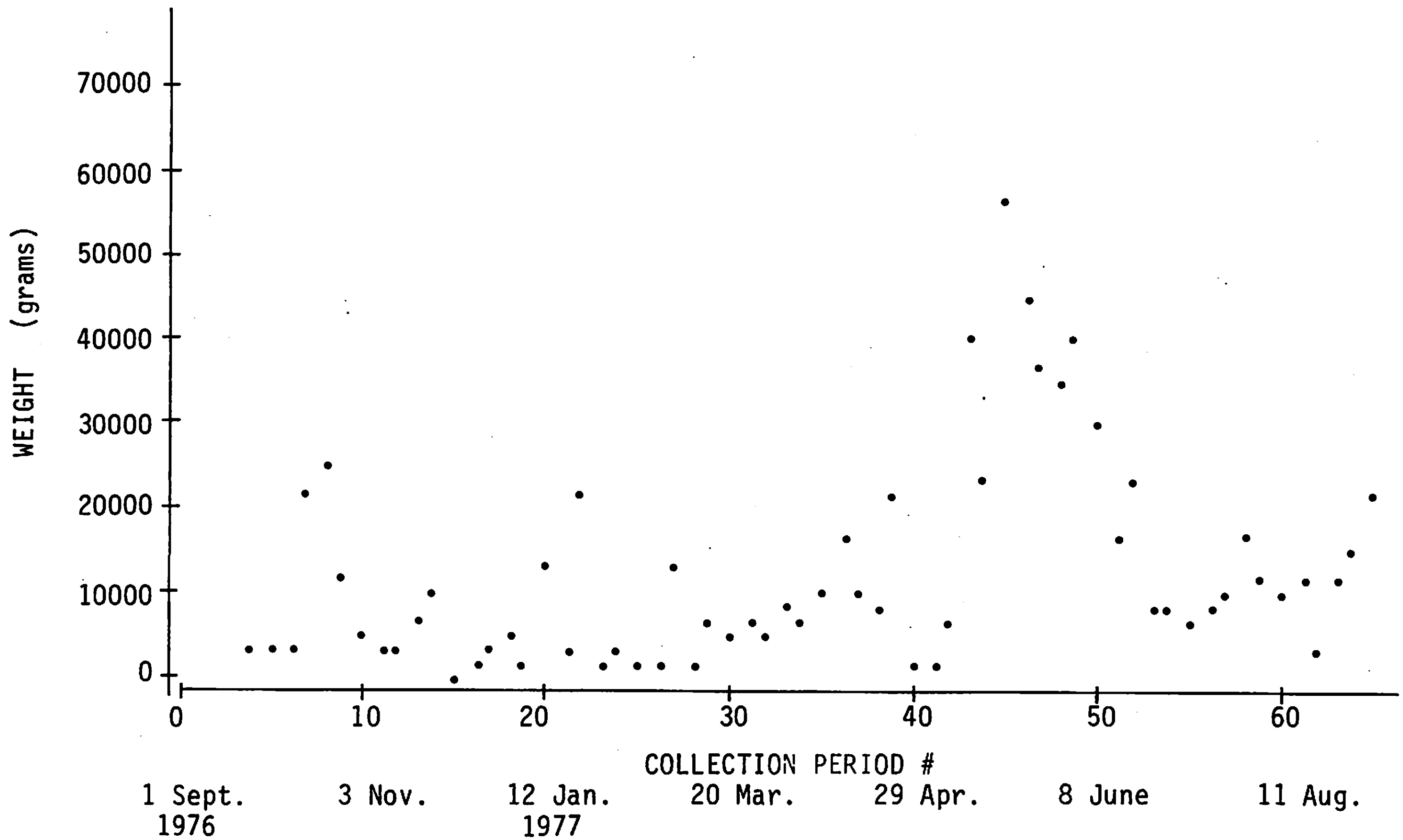


* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 24

WEIGHT OF FRESHWATER DRUM IMPINGED AT THE BAY SHORE POWER STATION

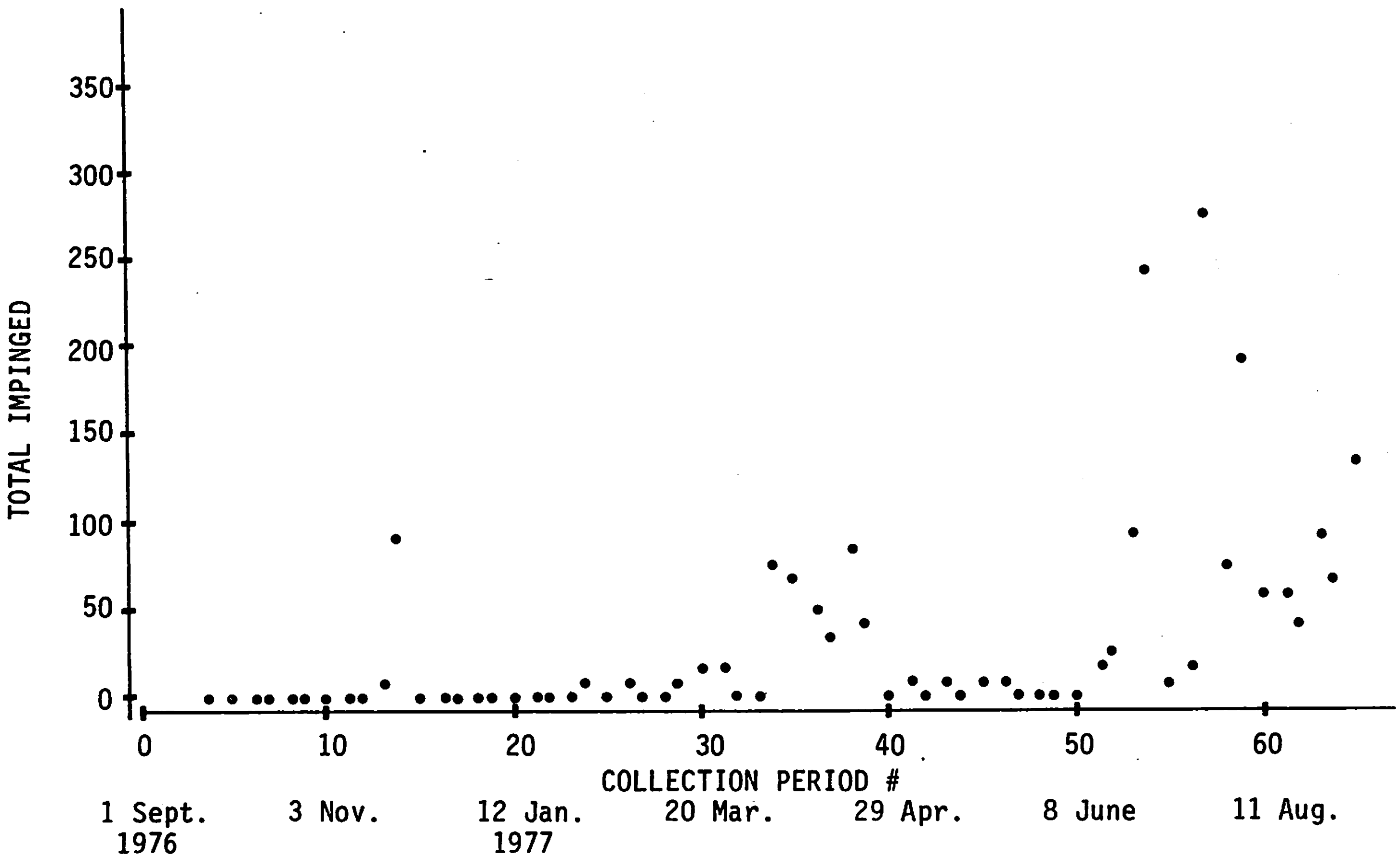
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 25

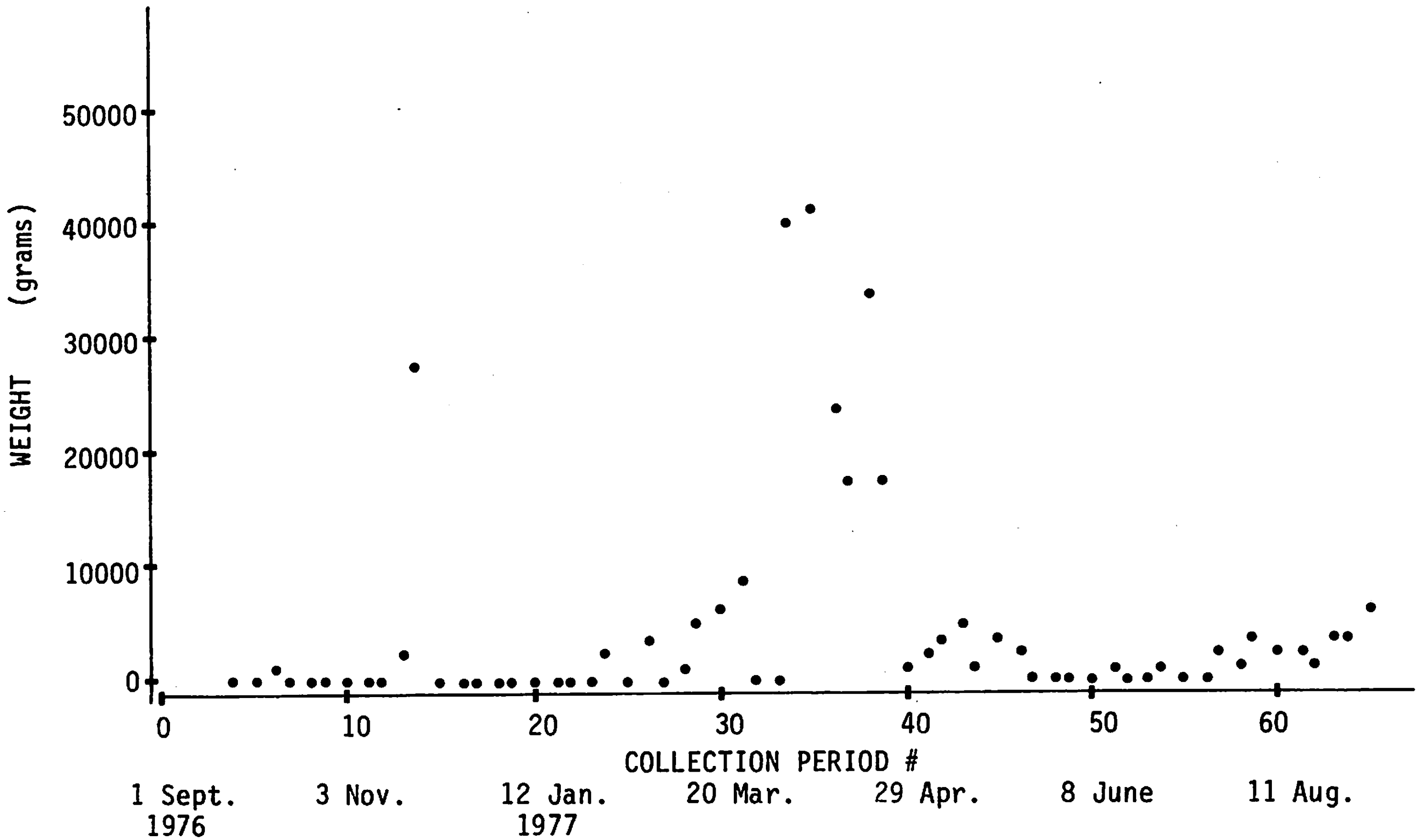
NUMBER OF WALLEYE IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 26

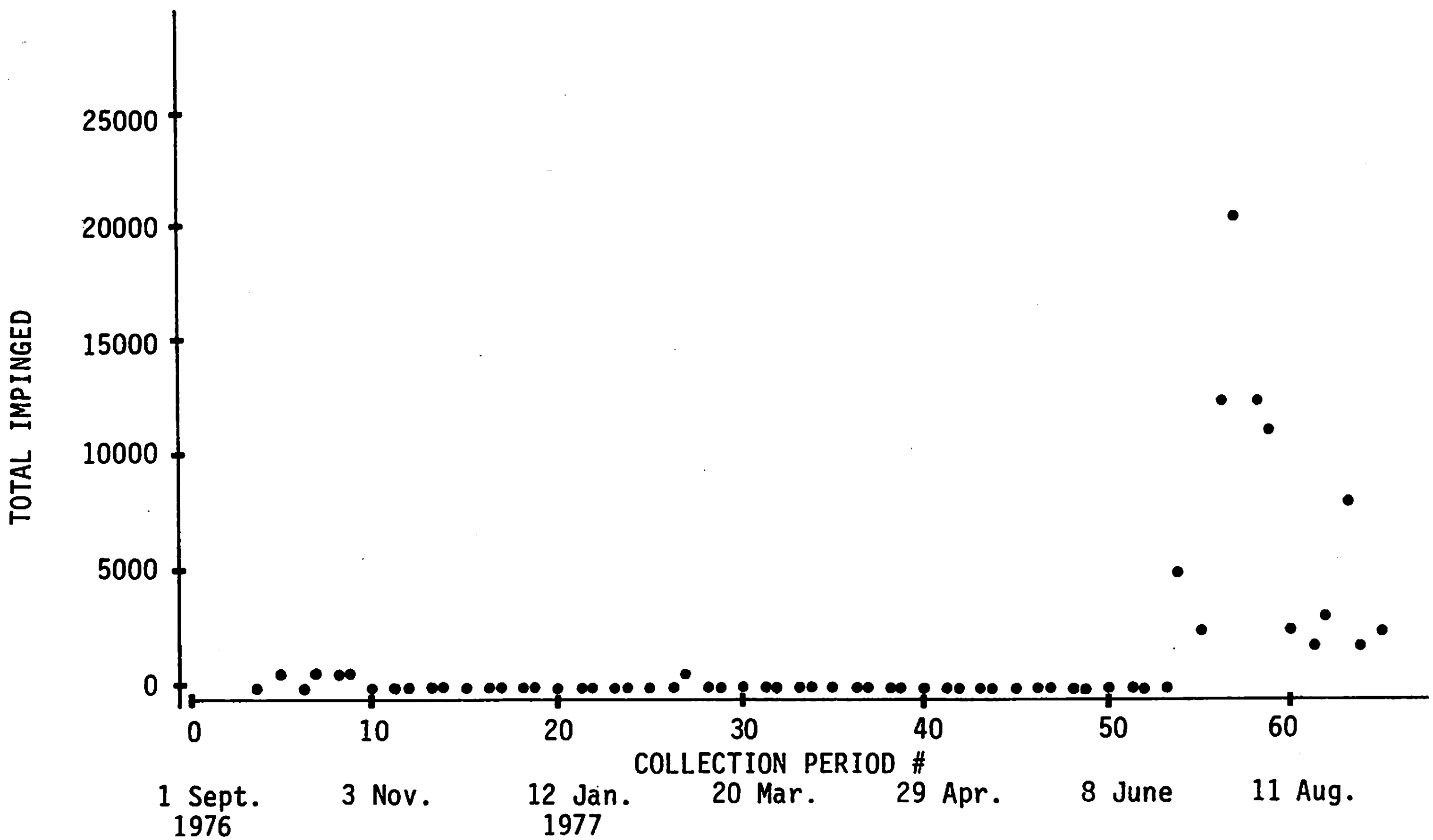
WEIGHT OF WALLEYE IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 27

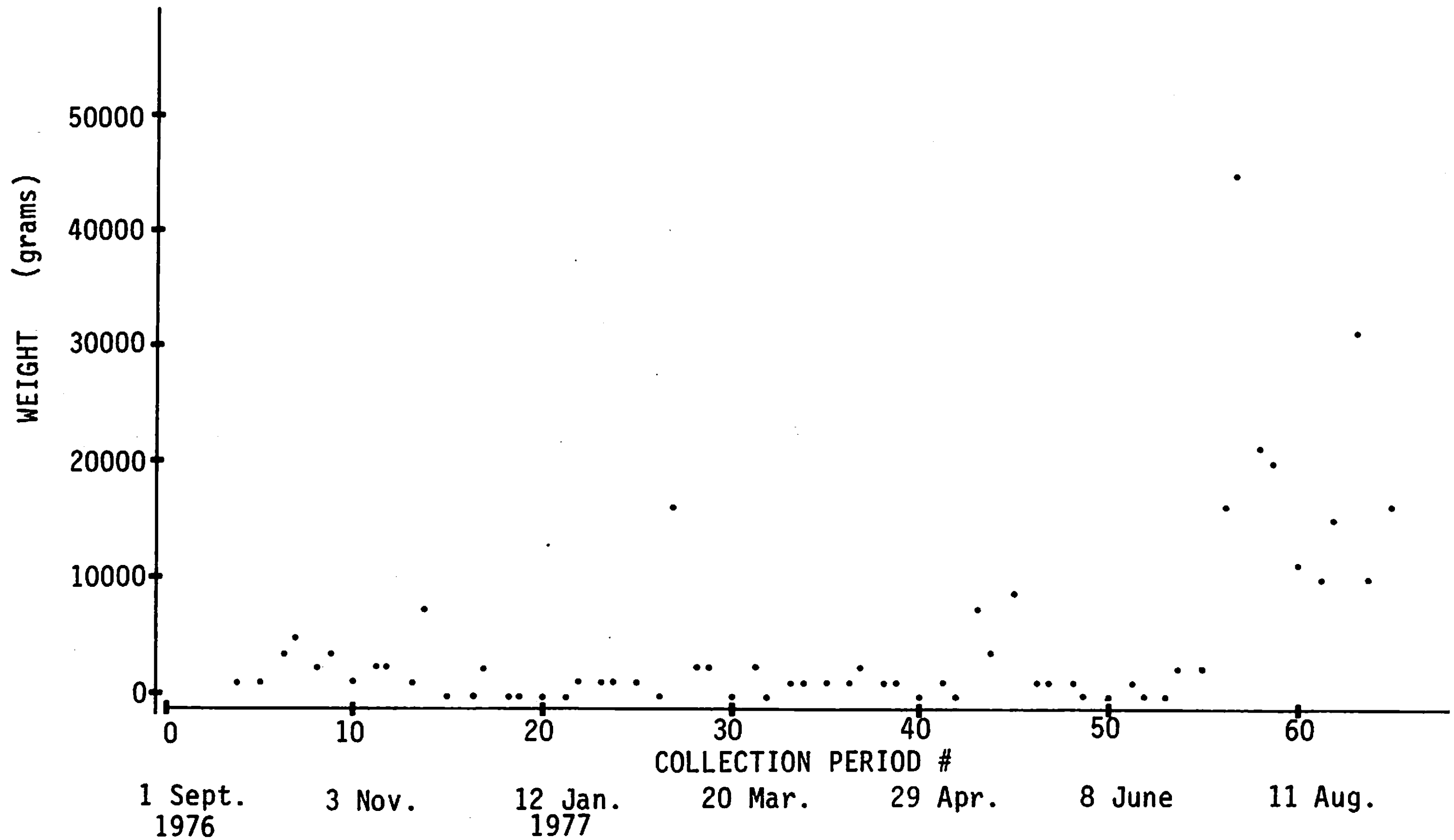
NUMBER OF WHITE BASS IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 28

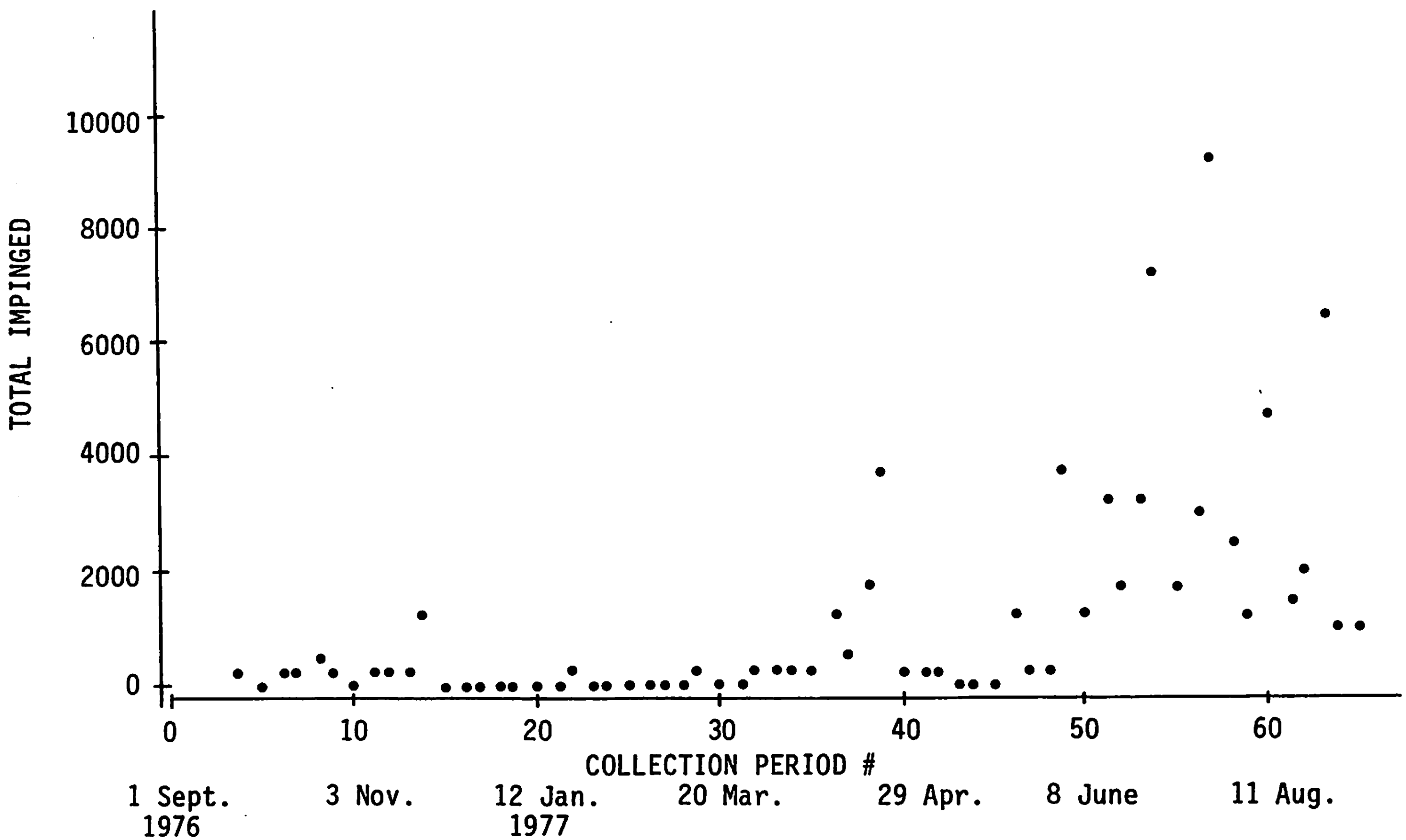
WEIGHT OF WHITE BASS IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 29

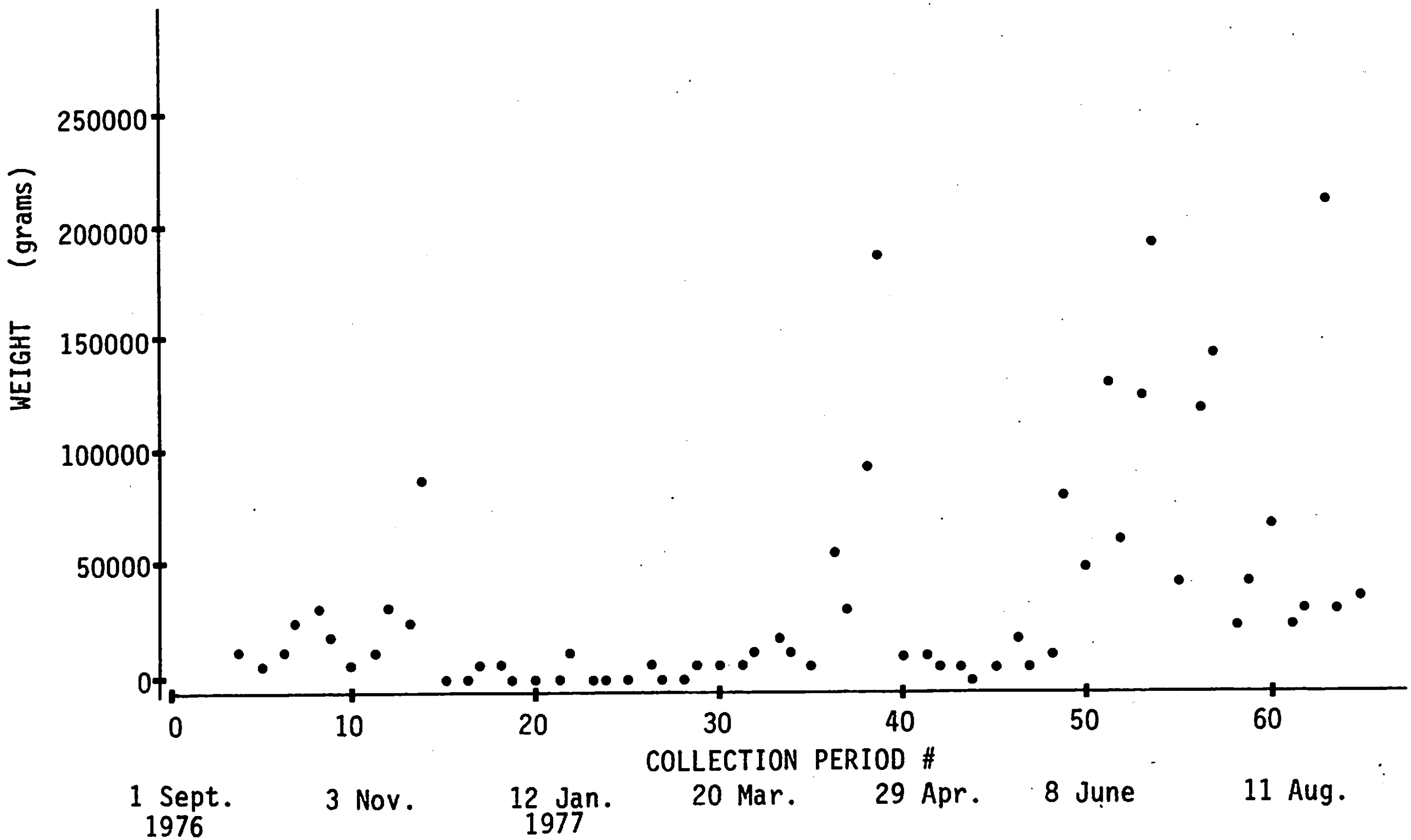
NUMBER OF YELLOW PERCH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 30

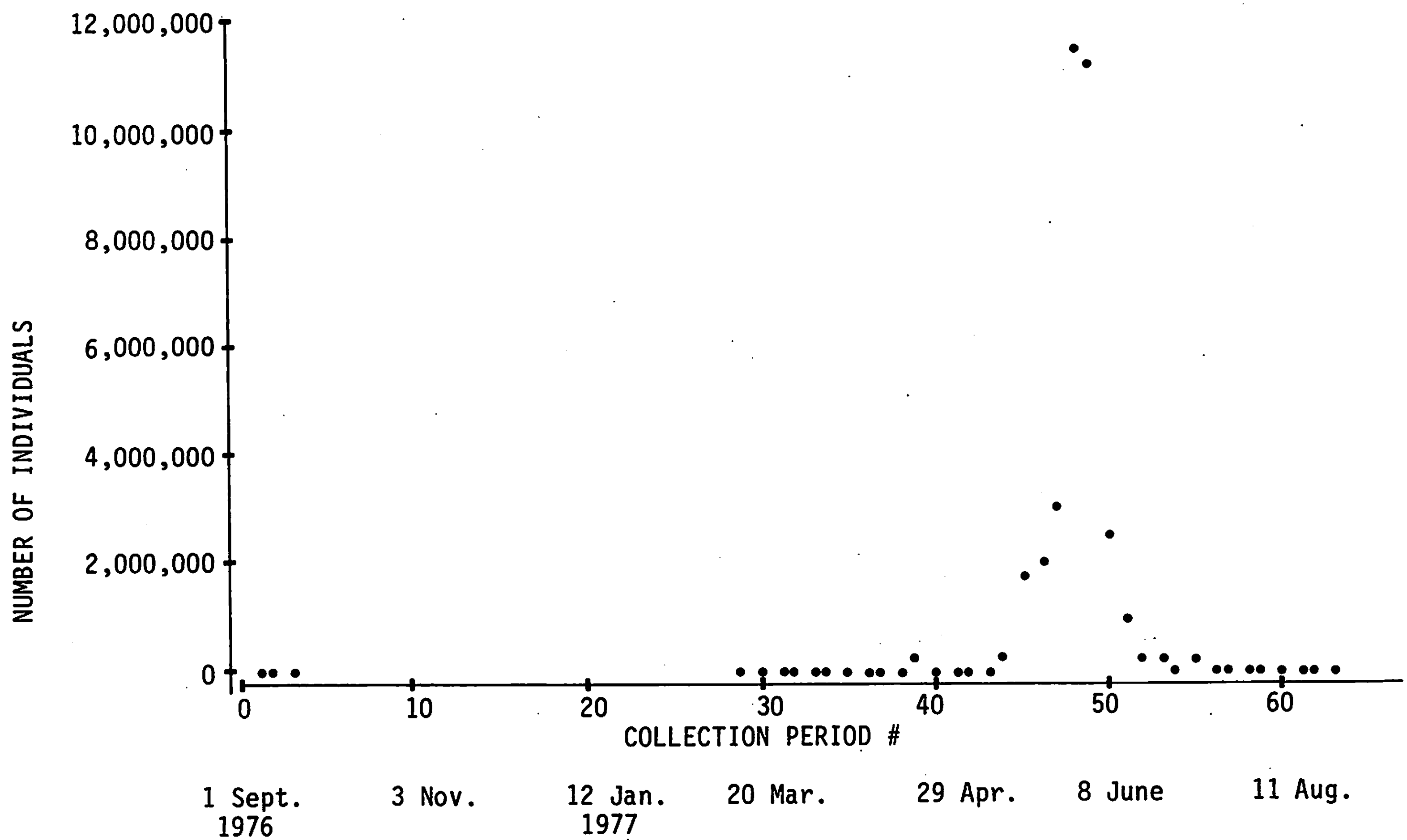
WEIGHT OF YELLOW PERCH IMPINGED AT THE BAY SHORE POWER STATION
FROM 15 SEPTEMBER 1976 - 15 SEPTEMBER 1977 *



* Estimates projected over the entire year based on the results of 62 24-hour collections.

FIGURE 31

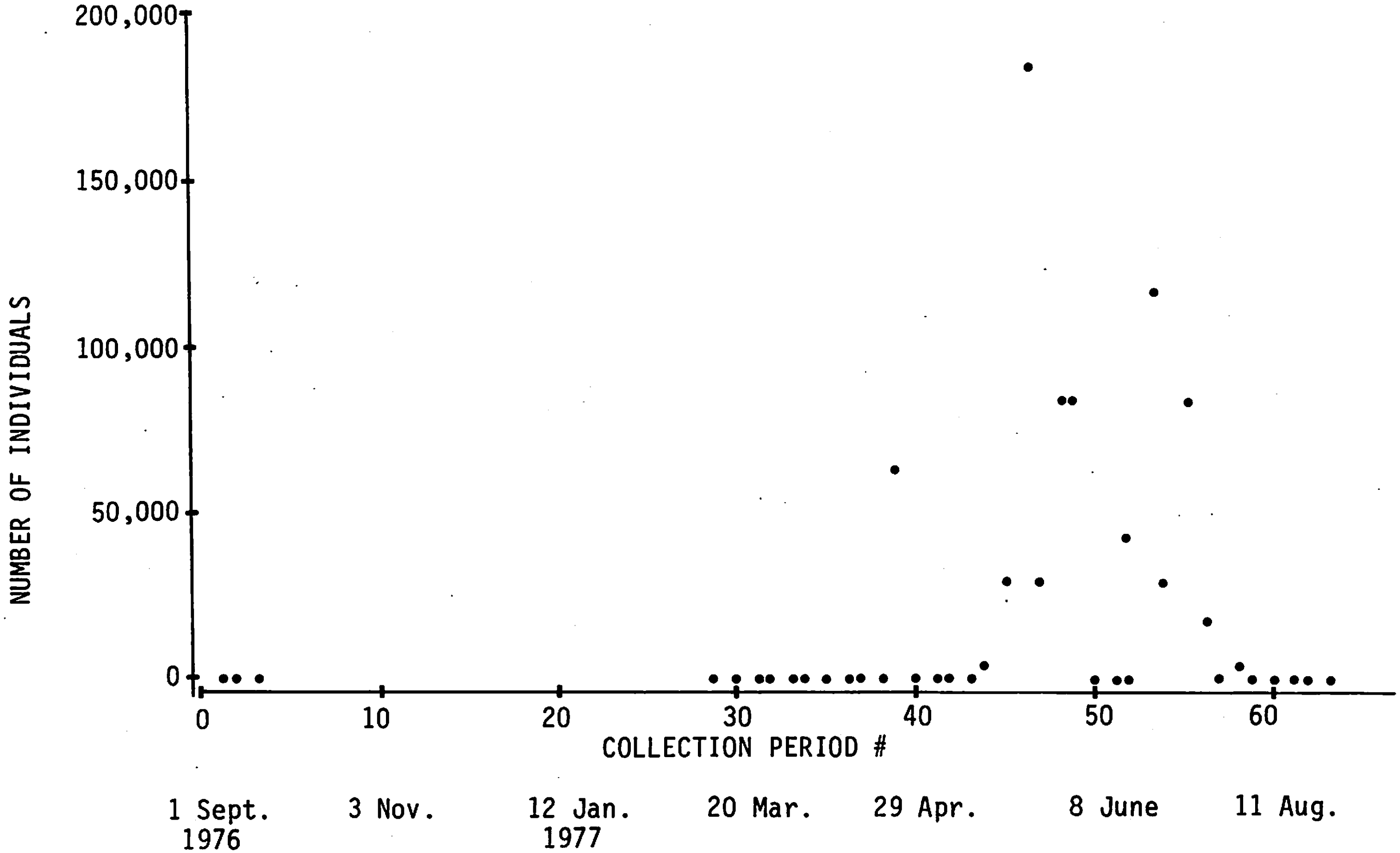
NUMBER OF FISH LARVAE ENTRAINED AT THE BAY SHORE POWER STATION
FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977 *



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 32

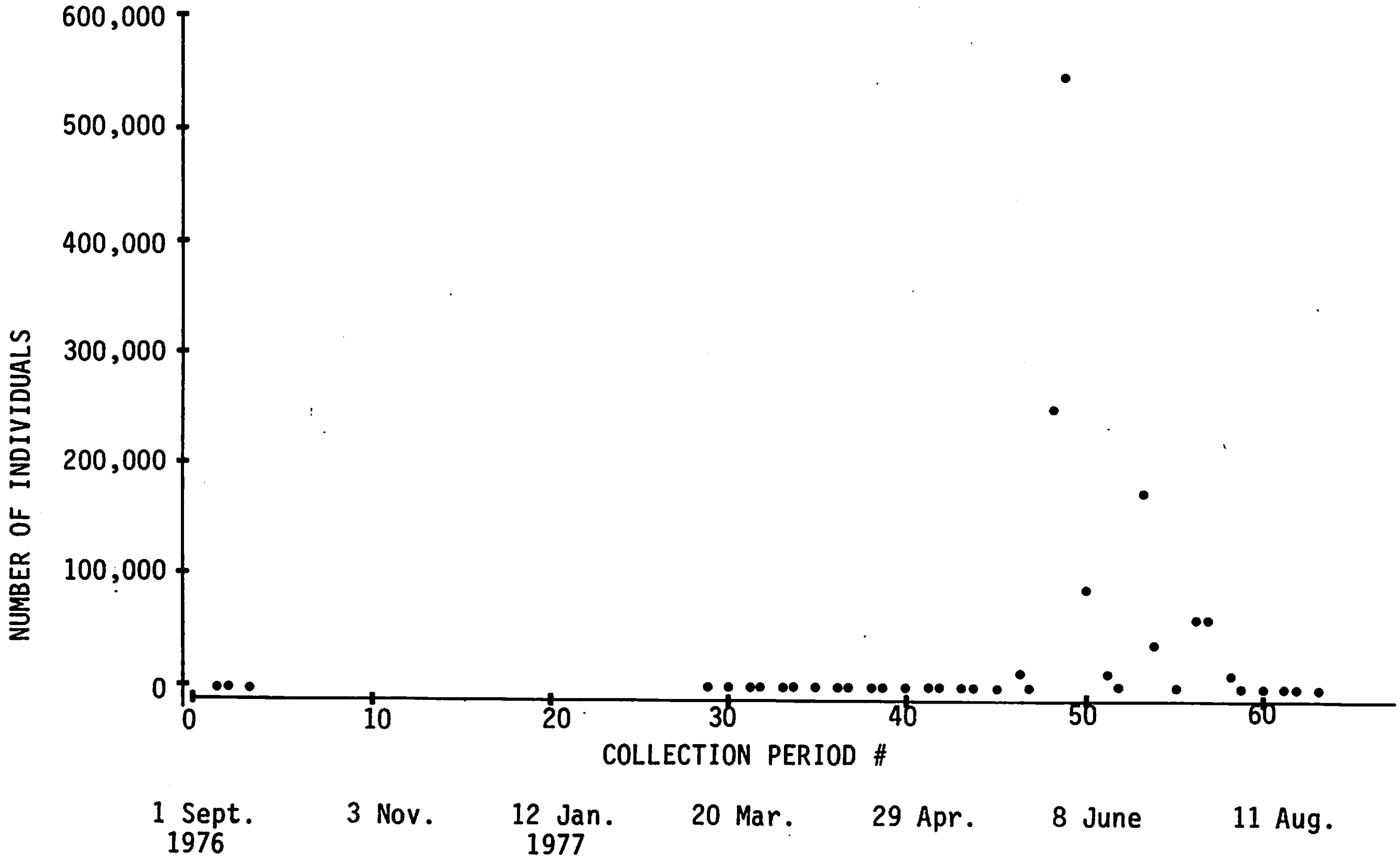
NUMBER OF CARP LARVAE ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 33

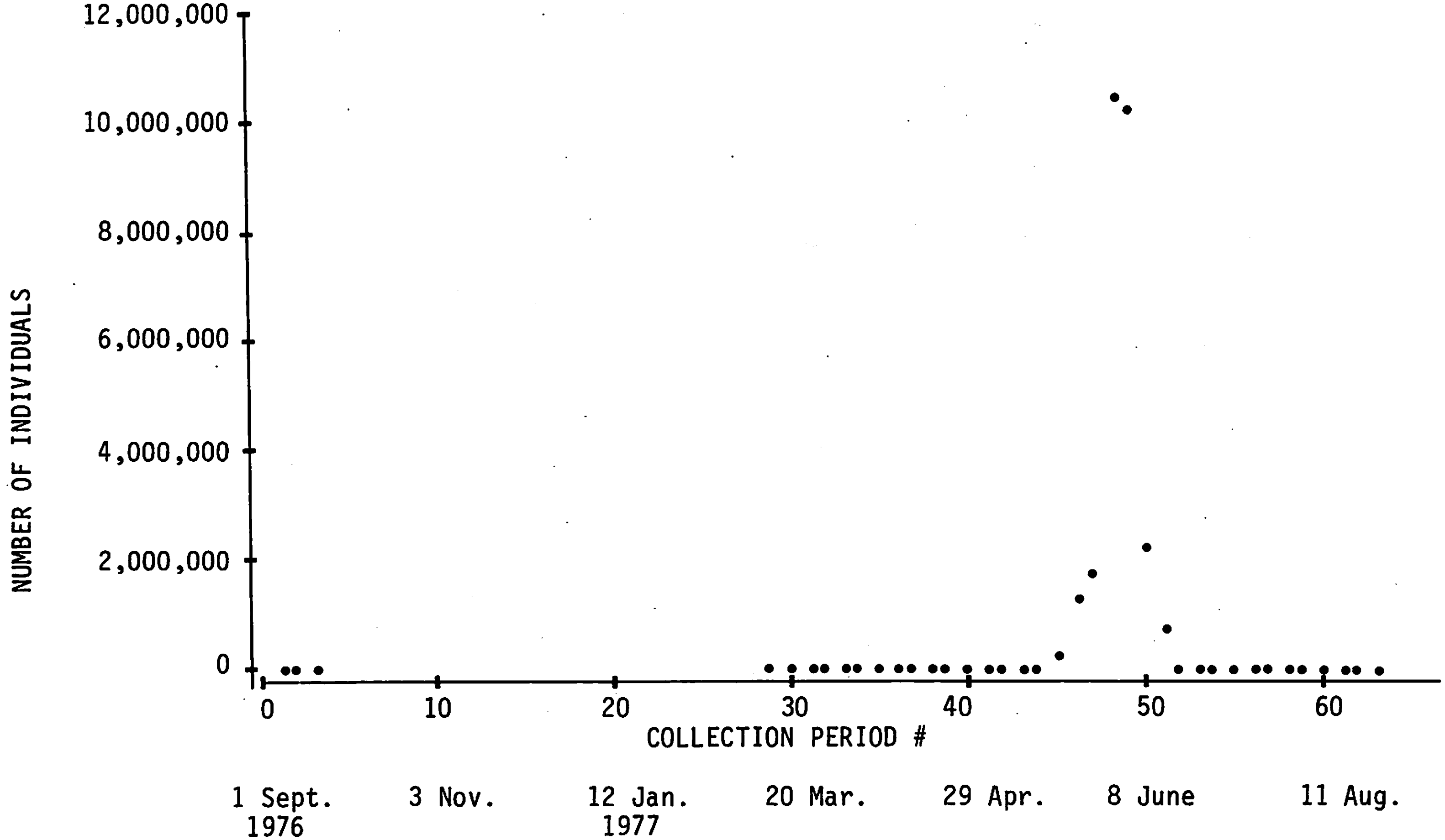
NUMBER OF FRESHWATER DRUM LARVAE ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMEBR 1976 - 1 SEPTEMBER 1977 *



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 34

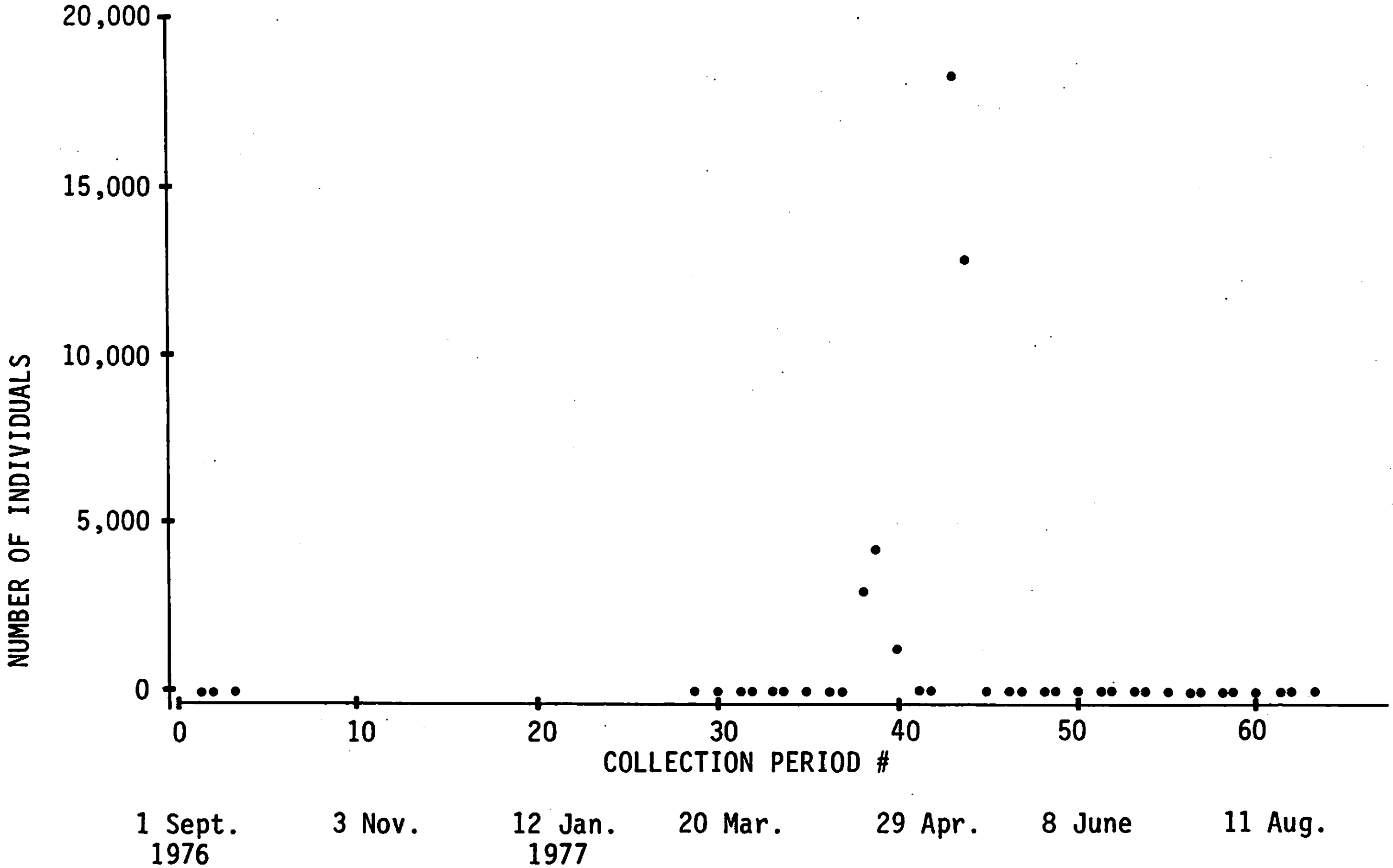
NUMBER OF GIZZARD SHAD LARVAE ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 35

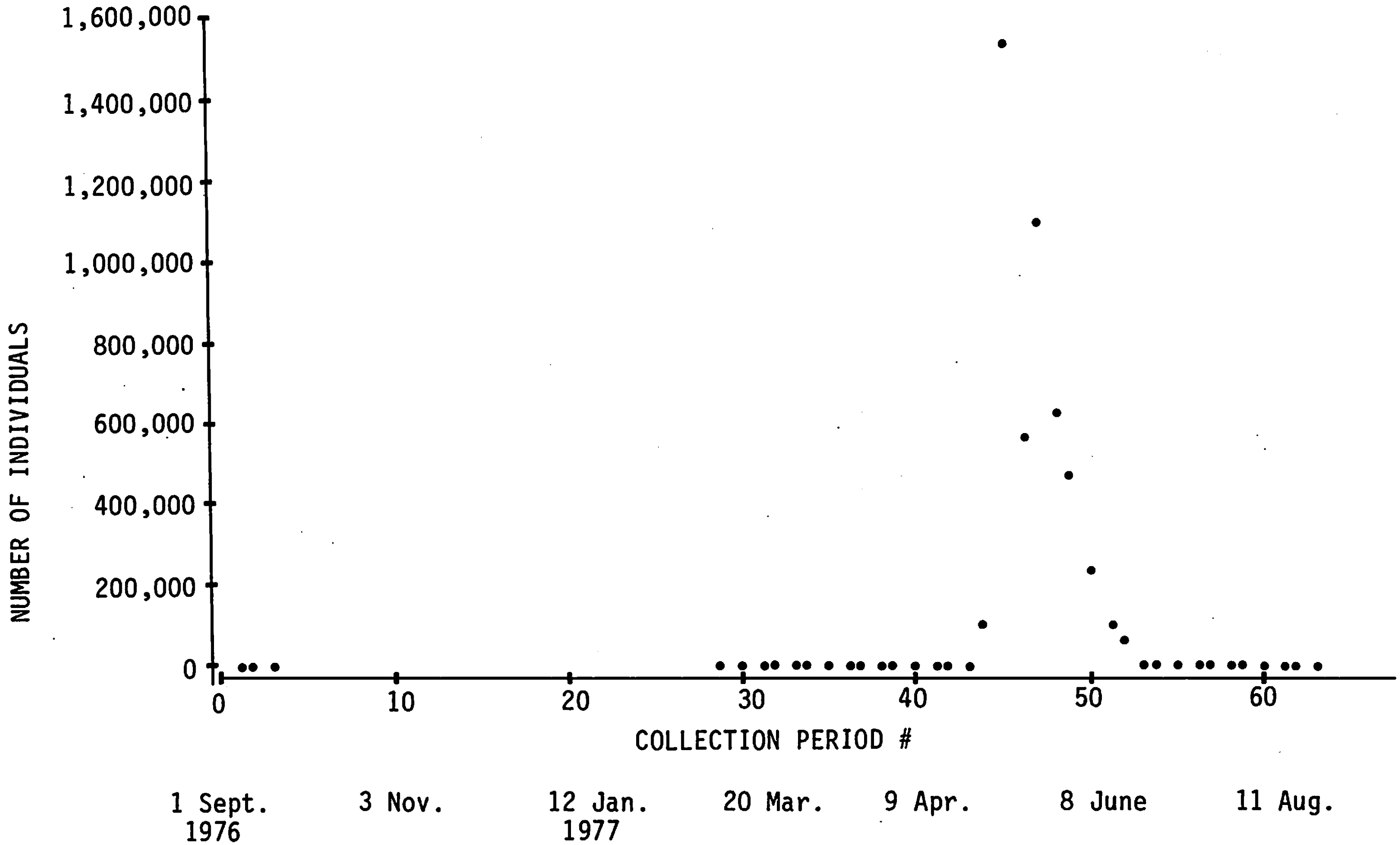
NUMBER OF WALLEYE LARVAE ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 36

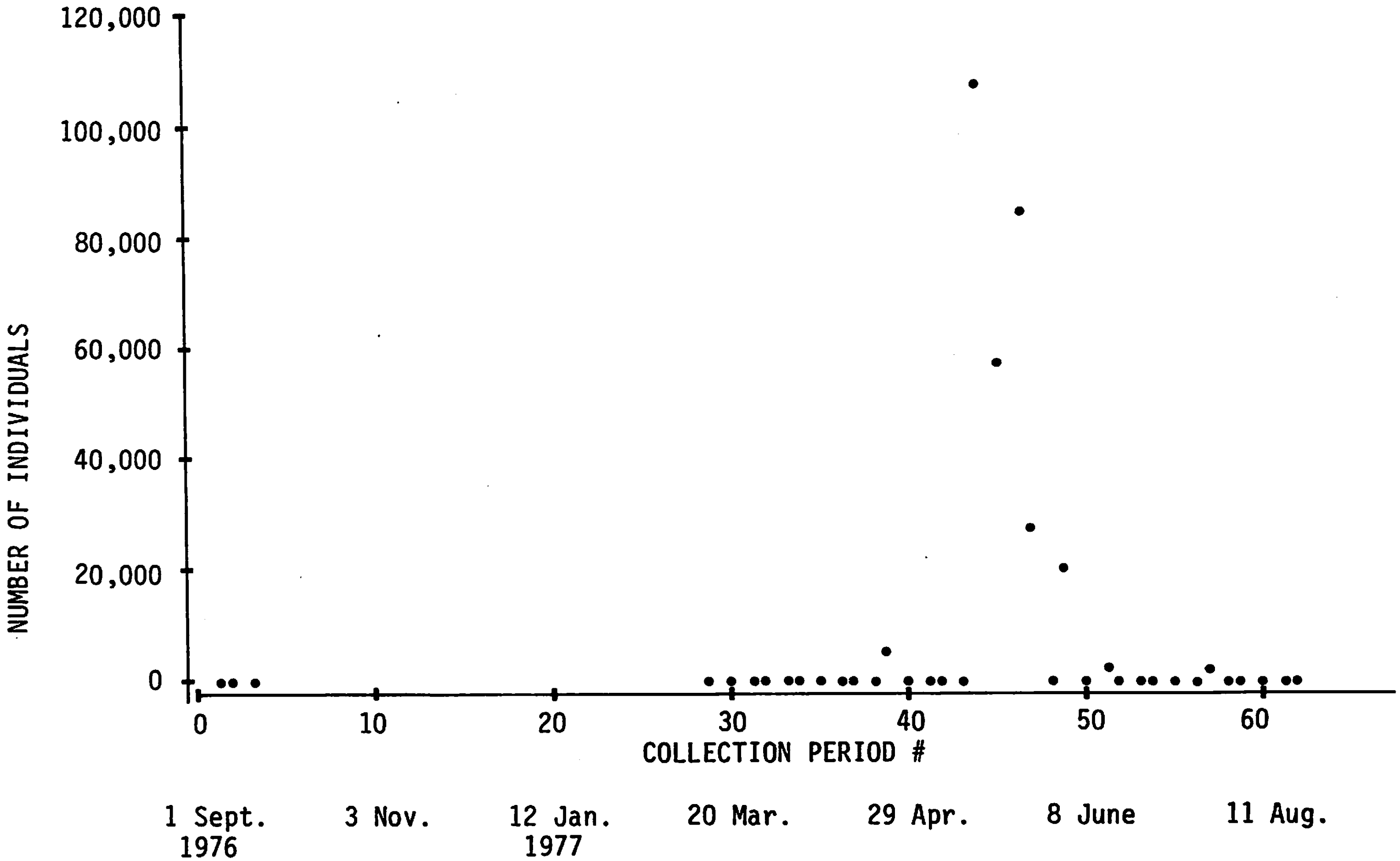
NUMBER OF WHITE BASS ENTRAINED AT THE BAY SHORE POWER STATION
FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 37

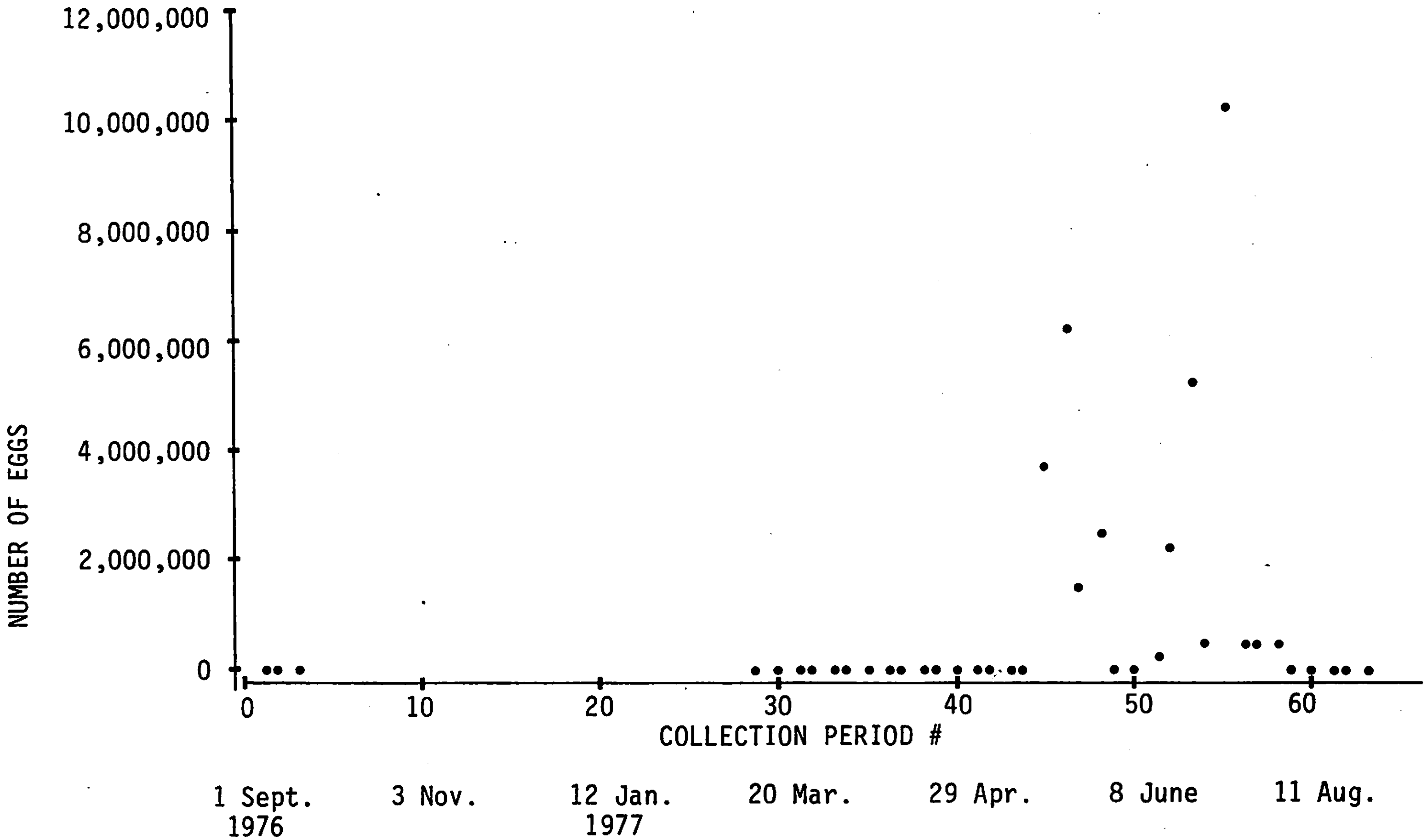
NUMBER OF YELLOW PERCH LARVAE ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977 *



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 38

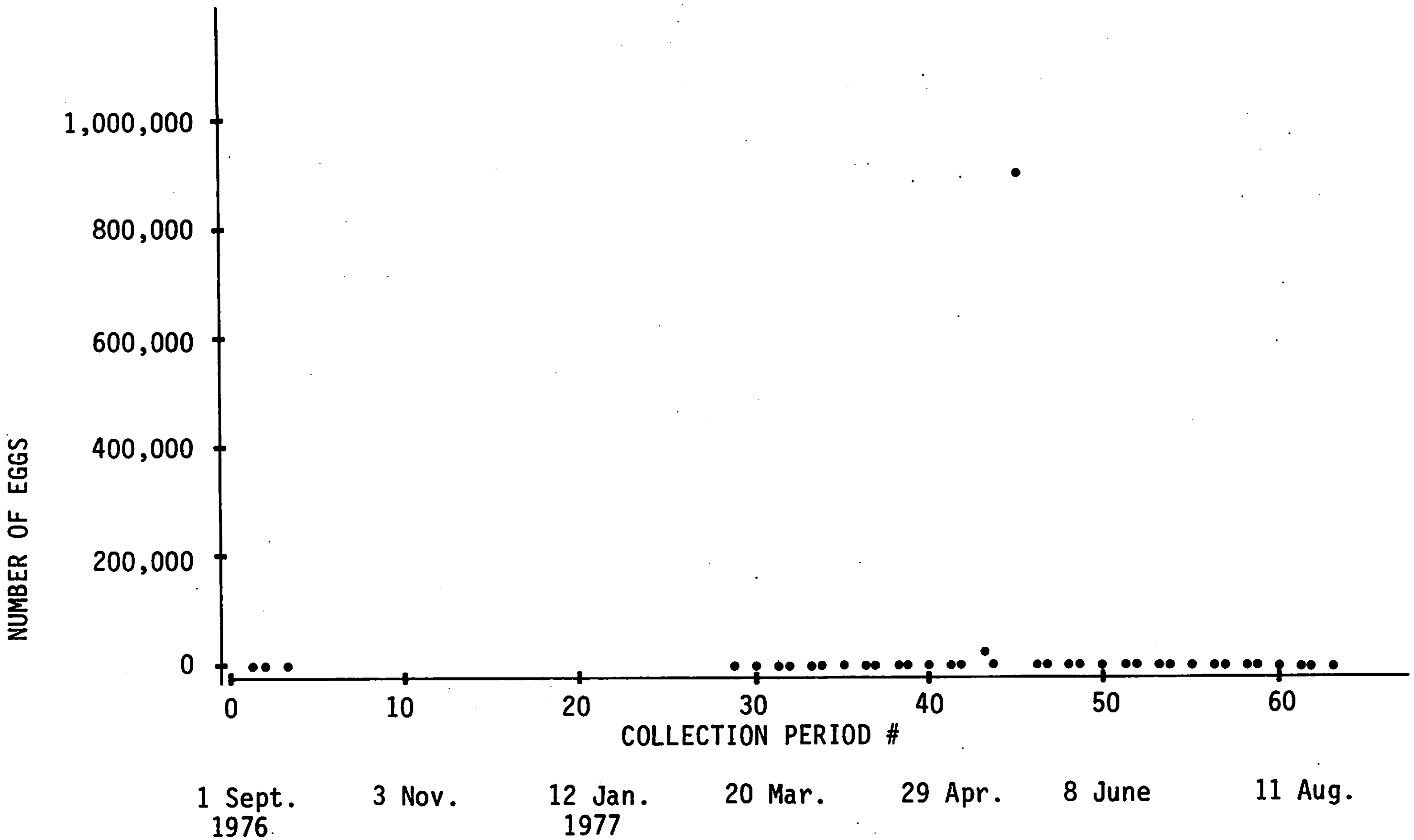
NUMBER OF FRESHWATER DRUM EGGS ENTRAINED AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 39

NUMBER OF EGGS EXCLUDING FRESHWATER DRUM EGGS ENTRAINED
AT THE BAY SHORE POWER STATION FROM 1 SEPTEMBER 1976 - 1 SEPTEMBER 1977*



* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

FIGURE 40

AMBIENT WATER TEMPERATURE AS OBSERVED AT THE MOUTH OF THE BAY SHORE POWER STATION INTAKE