Donald C. Cook Nuclear Plant • Units 1 & 2

Annual Environmental Operating Report

January 1 Through December 31, 1982

Indiana & Michigan Electric Company
Bridgman, Michigan

Docket Nos. 50-315 & 50-316
License Nos. DPR-58 & DPR-74

AMERICAN ELECTRIC
AEP
POWER SYSTEM

DONALD C. COOK NUCLEAR PLANT
UNITS NOS. 1 AND 2
INDIANA & MICHIGAN ELECTRIC COMPANY
ANNUAL ENVIRONMENTAL OPERATING REPORT
JANUARY 1 THROUGH DECEMBER 31, 1982

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I. Introduction

Appendix B Environmental Technical Specifications, Part II, Section 5.4.1 requires that an annual report be submitted to the NRC which details the results and findings of ongoing environmental radiological and non-radiological surveillance programs. This report serves to fulfill these requirements and represents the Annual Environmental Operating Report for Unit Nos. 1 and 2 of the Donald C. Cook Nuclear Plant for the reporting period ending December 31, 1982.

During this reporting period Unit No. 1 generated 5,554,070 Mwh gross of electrical energy. Monthly Operating Reports indicate that this Unit was operating at a Unit Service Factor of 62.7% at an average Unit Capacity Factor of 58.5%.

Unit No. 2 generated a total of 7,249,770 Mwh gross of electrical energy. Monthly Operating Reports indicate that this Unit was operating at a Unit Service Factor of 76.9%, at an average Unit Capacity Factor of 73.8%.

The semi-annual radioactive effluent release reports for the reporting 1982 year indicated no adverse effects to the environment and general public within a sixty mile radius of the D. C. Cook Plant.

II. Changes to the Environmental Technical Specifications

A - On May 6, 1982, the NRC issued Amendments 54 and 40 to the Operating Licenses for Units 1 and 2, respectively, making the following changes to the Appendix B Environmental Technical Specifications:

> The Appendix B Environmental Technical Specifications were deleted in their entirety and replaced with new Appendix B Environmental Technical Specifications consisting of three parts;
>
> a) Part I - Radiological
> b) Part II - Non-Radiological, Environmental Protection Plan (EPP)
> c) Part III - Non-Water Quality, Non-Radiological

B - On October 22, 1982, the NRC issued Amendments 65 and 46 to the Operating Licenses for Units 1 and 2, respectively, making the following change:

> The Appendix B Environmental Technical Specifications, Part III - Non-Water Quality, Non-Radiological were deleted in their entirety.

III. Non-Radiological Environmental Operating Report

Environmental Protection Plan (EPP)

III.1. PHYSICAL OBSERVATIONS

(Specification 2.1.8)

A. Visual Observations of the Intake and Discharge Structure Areas

Twenty dives were performed during the reporting period: four in April and May, two in June, three in July and August, and two in September and October.

Placement of the concrete scour pads in front of the discharges appears to have alleviated scour adjacent to the structures. Examination of the scour pads revealed no significant pitting, scoring or disintegration of these structures. The riprap surrounding the south intake structure was undisturbed; the sand/riprap interface surrounding the intake structures appeared stable. Accumulations of floc typically ranged from 1 to 5 mm thick. Large depressions in the bottom (10 m across by 1 m deep and containing a silt overburden 20-40 cm thick) were encountered occasionally during 1982 as in some previous years at reference stations north of the Cook Plant.

Both uni-directional and eddy current patterns were detectable throughout the water column within 100 m of the discharges; at stations more than 300 m from the discharges weak currents were occasionally noted, but no directional pattern was established. Variable current speeds were encountered at the south intake structure, but current was strongest adjacent to the base of the structure on the north and east sides. Increased current and possible recirculation of water were noted at the south intake structure during 7-pump operation.

Trash (primarily from fishermen) was observed in decreasing quantities during 1979-1982. Reduction in numbers of beverage containers was particularly noticeable. Relative to concentrations in control (sand substrate) areas, organic debris (algae and terrestrial vegetation) was concentrated in the riprap zone by the trapping action of the uneven substrate, but appreciable accumulations were not noted. Dead fish (alewives and perch discarded by fishermen) and fecal pellets were seen occasionally, but accumulations of dead alewives on the bottom, even during the annual die-off period, have never been observed.

In 1980-1982, periphyton growth remained reduced on top of the south intake structure, relative to earlier years. During 1979, periphyton growth was quite luxuriant within 5 m of the base, but growth was reduced during 1980-1982. Peak lengths of periphyton were attained during June-August. Periphyton growth on top of the south intake was minimal in 1982. Macrophytes were not observed. Attached invertebrates (sponge, bryozoans and Hydra) increased steadily in numbers during 1973-1976, but numbers of sponge and bryozoan colonies appeared to plateau during 1977 and have declined subsequently. During 1980-1982, the rate of decline in numbers of sponge colonies appeared to slow somewhat. Hydra remained extremely abundant. Numbers (concentrations) of snails decreased dramatically during 1977-1978; snails were not observed during 1979-1982. Density of crayfish in the riprap area during 1978-1982 was less than one-half that estimated during 1975 (the year of maximum abundance). Riprap macroinvertebrates showed a predictable pattern of opportunistic colonization followed by peaking and then by declining numbers of species and individuals in accordance with initial niche exploitation, saturation and subsequent change (decline) in resource availability.

Alewife, perch and possibly spottail shiner and/or carp eggs were noted during 1982 (as in previous years), documenting continued minor (excluding alewife) spawning in the vicinity of Cook Plant. Eggs were observed attached to periphyton, entangled in loose algae and lying loose on the sand.

Eleven species of fish were observed during the reporting period. Listed in descending frequency of observation they were: alewife, yellow perch, trout-perch, sculpin (*Cottus* spp.), johnny darter, spottail shiner, carp, rainbow smelt, burbot, redhorse (*Mosostoma* spp.), and chub (*Coregonus* spp.). Carp were observed primarily in the discharge area. Young-of-the-year (YOY) alewife were very abundant during September-October, a pattern previously documented. Yellow perch YOY were observed in large numbers during the August 1982 night dive. Relative to numbers observed in control areas, fish congregated near the structures (alewife, spottail shiner, yellow perch) and in riprap areas (demersal species, e.g., johnny darter and sculpin). Numbers, diversity, and activity of fish were highest at night and during summer months. The majority of fish species impinged and field-caught at Cook Plant were not observed by divers which was partly a reflection of the relatively incidental occurrence (low numbers) of many species in the study area. Abundance and seasonal observation of major species (e.g., alewife, perch, etc.) and YOY fish documented by divers usually paralleled occurrence in the study area documented by fishery studies.

Presence of Cook Plant structures and riprap has created an atypical, more sheltered and more diverse habitat that attracts and concentrates biota which follow a predictable successional pattern. Diver-observed effects of plant operation upon the local environment were minimal. Barring a large change in Cook Plant operation, future diver observation of major or significant ecological changes in the study area are not anticipated.

For further details, see Appendix A.

III.2 Ice Studies

A. Ice Conditions

(Specifications 2.1.1 and 2.1.2)

In the winter of 1981-82 the first ice at Cook Plant formed during the night of January 6-7 and, the weather turning much colder, built up rapidly. The mature ice complex which developed consisted of an icefoot, a first lagoon, a first ice ridge, a second lagoon, a second ice ridge, a third lagoon, and a third ridge. Outside the third ridge open water alternated with an extensive field of ice floes that moved in response to wind.

In front of the plant the third ridge was only semi-permanent. When the ridge was present the melt-hole from discharged water was outside the second ridge in the third lagoon. When the third ridge was breached or absent, the third lagoon tended to be filled with loose floes in which a melt-hole seldom developed.

From first ice until mid-February the winter was colder than usual and the ice complex stayed well developed. In mid-February there was a warm spell and the ice underwent melting. During this period an influx of warmer air over the snow-covered ground produced a period of foggy days in which our charter-flight pilots refused to fly our ice-survey overflight. When flight conditions became acceptable, melting of the shore was well along.

On 25 February 1982 the shore ice of Lake Michigan from Michigan City, Indiana, to Grand Haven, Michigan was overflown during melting conditions and easterly winds. Broken ice extended an estimated 3-10 miles from shore while along shore the ice complex showed the remains of a normal well-developed 3-ridge and 3-lagoon structure.

Despite melting in front of the plant, there always remained sufficient shore ice to protect the plant site from wave action.

Final melting took place on 1 April.

For further information, see Appendix D.

III.2.B Circulating Water Chlorination

(Specification 2.1.3)

No chlorination of the circulating water was done during 1981. No periods of chlorine experimentations took place in 1982.

III.3 AQUATIC STUDIES

(Specifications 2.1.6 and 2.1.7)

A. Zooplankton Studies

i. Lake Surveys

Lake survey data from May to November 1982 are discussed in this report. Normal temporal succession patterns were observed in the numerically dominant taxa. As in previous years, there was no strong evidence suggesting that power plant operation had an ecologically significant disruptive effect on zooplankton populations in the vicinity of the plant.

Zooplankton mean abundances in the operational period were compared with their abundances in the preoperational years. Analyses (Mann-Whitney U test) of the numerically dominant taxa were made by month and by zone. Seven years of operational July and October data (1975 to 1981) were used in these analyses. For each cruise-month analysis, several taxa occurred in significantly ($\alpha=0.05$) different preoperational and operational zone mean concentrations. Differences in the inshore plume zone were of most interest.

In the statistical analyses of July zone 2 data, calanoid copepods, immature and adult *Diaptomus* spp., and adult *Cyclops* spp. were significantly ($\alpha=0.05$) less abundant in the operational period while *Daphnia* spp. and *Asplanchna* spp. were more abundant. *Asplanchna* spp. was very abundant in 1981, resulting in a higher operational than preoperational mean, the reverse of earlier analyses employing the 1975 to 1980 operational data set. While *Bosmina longirostris* and total zooplankton tended to be more abundant in the operational period, such differences were not statistically significant.

In October, total zooplankton were significantly (α=0.05) more abundant in the operational period than in the preoperational period. Nauplii, calanoid copepods, immature Cyclops spp., Bosmina longirostris, and Eubosmina coregoni were significantly (α=0.05) more abundant while adult Cyclops spp. and Daphnia spp. were less abundant.

Mesocyclops edax, a cyclopoid which occurred in relatively high concentrations in the survey area in the autumn of 1978 continues to occur in concentrations similar to those observed in previous years. However, Daphnia pulex, a cladoceran first observed in 1978, continues to be commonly observed in the zooplankton. A second species, Daphnia schloderi, recently was detected in the zooplankton. During a seperate study in 1982, it was observed throughout most of the year at a station 20 km offshore of Grand Haven. These new Daphnia occurrences provide further evidence that southeastern Lake Michigan is undergoing a gradual change in zooplankton community structure.

In order to further investigate long-term changes in zooplankton community struture, we have conducted a series of analyses comparing taxa abundances by zone and by year for each of the three inshore zones. We conclude that while the three zones differ in zooplankton abundance, such differences are not consistent and are smaller than differences between years. Since we are most interested in comparing zooplankton populations between years, we have combined all three zones into a single larger zone (ignoring the small differences between zones) and conducted a second series of preoperational versus operational comparisons. Such tests have confirmed that zooplankton populations between the 5-m and 10-m depth contours and along the 23 kilometers of shoreline are significantly ($\alpha=0.05$) different between preoperational and operational years.

We also have conducted a series of preliminary analyses to investigate causal factors affecting zooplankton population dynamics and their mode of operation (synergistic or antagonistic). These studies have shown possible interactions between alewife and Cyclops species, between Cyclops adults and rotifers, and between rotifer and cladoceran grazers and flagellates.

We discuss the results of studies examining sources of variation in zooplankton population estimates. Such knowledge is essential for understanding the overall statistical sensitivity and the strengths and weaknesses of our study design. We have concluded that our laboratory procedures (subsampling) and statistical approaches to investigate temporal and spatial changes are efficient. Moreover, we have quantified the statistical limitations of various comparisions (time and space) of our data sets.

Finally, we provide an update on our epibenthic and benthic study of crustaceans in the vicinity of the power plant. Many taxa occurred in significantly higher abundances in sediment troughs where organic matter accumulates (Dorr, underwater observations section), than in crests. Some taxa varied in abundance with respect to depth, while other taxa occurred in higher densities in the plume zone than in control zones. No evidence of gross disruptions in the epibenthic and benthic communities which warrant environmental concern were detected.

ii - Condenser Passage Studies

This report discusses mortality data collected from May to December

1981. In addition it discusses biomass and numbers of zooplankton entrained for the August 1980 to December 1981 period.

Zooplankton mortalities generally were low, averaging 11.5 % in the intake waters, 12.6 % in Unit 1 discharge waters, and 11.9 % in Unit 2 discharge waters. Statistical differences between intake and discharge mortalites of nine zooplankton taxa were examined using the Smirnov one-sided two-sample test. For the 0-hour incubation, the only statistically significant (α=0.05) difference between intake and discharge mortalities was for nauplii in September 1981. During this collection period, ΔT was 10.2 C° and discharge waters from both Units exceeded 32 °C. No significant differential mortality was detected in the 6-hour incubation samples. Immature Diaptomus spp. and Cyclops spp. copepodites had significantly higher discharge than intake mortalities in June and in September 1981 for the 24 hour incubation period.

For the August 1980 to December 1981 period, the numbers of zooplankton entrained ranged from a February 1981 low of 820 billion to an August 1980 high of 16,600 billion. The monthly biomass of zooplankton entrained ranged from a May 1981 low of 1,020 kg dry weight to a November 1981 high of 22,000 kg dry weight. Estimated maximum losses with both units operating were similar to those observed in previous years.

Statistical analyses of zooplankton abundance estimates as determined from intake sampling have demonstrated that this sampling location provides representative estimates of taxa abundances in the inshore region (zones 1, 2, and 3). We report the results of preliminary studies using time series analyses to investigate long-term changes in zooplankton populations in the inshore region based on entrainment sampling. Nauplii densities show a trend of increasing abundances from 1975 to 1978. A leveling off or slight decline appears to have occurred in subsequent years. However, minimum concentrations in winter have increased from $17/m^3$ in January 1975 to an estimated $294/m^3$ in December 1980.

For further information, see Appendix B-1.

B. Phytoplankton Studies

i. Lake Phytoplankton

The phytoplankton community in the Cook Plant vicinity has in 1981 continued an overall trend toward decreased abundance which began after a high in 1978. Declines in diatom abundances (attributed to reduced nutrient loading to the lake) have outweighed variations in the other categories and affected the totals. Coccoid blue-greens in 1981 continued to be low in abundance in spring and summer but to have abundance peaks in fall (attributed to late summer and fall depletion of silica in the epilimnetic water). Flagellates decreased in 1979 and 1980 but returned to their 1978 level in 1981. The remaining categories of phytoplankton have exhibited little variation in abundances over the twelve years of the study. Abundance changes at both inner and outer stations have generally been in the same directions and are considered to reflect changes in the lake, not any clear effect of Cook operation.

Statistically significant differences between mean abundances of phytoplankton categories at inner and outer stations have been low during the period of study (5.25% of the comparisons overall, 5.71% in preoperational years, and 4.97% in operational years). Except for the inner station group of depth zone 2, the distributions of significant differences between preoperational and operational years appear to be within the normal range of variation. The increase in numbers of differences in zone 2 inner in operational years may possibly be an effect of plant operation on blue-green algae densities in that area, but of the 563 paired comparisons in operational years it is a minute (2.30%) effect.

Mean diversity indices have varied somewhat from season to season and from year to year during the twelve years of the study. The annual curves of diversity indices indicate, in each depth zone and station group, a gradual trend toward higher indices from 1970 through 1976 followed in subsequent years by a slow trend toward lower levels. In all depth zones and both station groups, species diversities indicated by the indices continue to be higher than in the preoperational years. These analyses show no adverse effect of Cook Plant operation.

In 1979, phytoplankton redundancy values rose to preoperational levels after a period of slowly diminishing values from 1973 through 1978; they have remained at preoperational levels in 1980 and 1981. There is nothing in this analysis of phytoplankton to indicate that operation of Cook Plant has had any adverse impact on the local phytoplankton community.

ii- Entrained Phytoplankton

During the period of December 1981 through May 1982, all samples for both enumeration and viability studies were collected. Because of loss during analysis, the number of replicates on October 13, 1981 number less than the three required.

Comparison of phytoplankton major group mean concentrations for 1975 through 1980 gave the following general observations: 1) coccoid blue-green algae and desmids were least abundant during 1976; 2) flagellates were most abundant during 1977; 3) filamentous blue-green algae, coccoid green algae, and centric diatoms were least abundant in 1977; 4) other algae were most abundant in 1978; 5) filamentous green algae were most abundant in 1976; and 6) pennate diatoms and total algae were least abundant in 1979. Low abundances in 1979 may result from the absence of June samples, a time when abundances are usually high. Therefore, the 1979 abundances may be low-biased.

The number of forms of phytoplankton was relatively high in 1976 and 1978, redundancy was highest in 1977, and diversity was relatively high in 1976 and 1978 and lowest in 1977. These changes in community structure statistics mimic changes noted in the major groups, especially for 1977. Decreases in filamentous blue-green algae, coccoid green algae, centric diatoms, pennate diatoms, and total algae in 1977, the increased redundancy in 1977, and the decreased diversity in 1977 describe a phytoplankton community considerably different from those of 1975, 1976, and 1978.

With the exception of 1977 when the character of the entrained phytoplankton community was such that a relatively large negative impact on viability was noted, no consistent long-term statistically significant alteration in viability based on chlorophyll concentrations has been observed that can be attributed to the plant. Using chlorophyll a intake/discharge comparisons, there is a greater occurrence of viability decreases in all years except 1975 and 1979.

Viability based on primary productivity showed a large reduction in the discharge water ranging from 16% to 80% as compared to the intake water. The cause of this reduction can be directly attributed to the passage of the water through the condenser cooling system. However, the level of reduction is not observed when comparing the discharge plume to ambient lake water. The factors causing this reduction are not yet clear. Based on the experiments conducted, inhibition from heat or microelements are the most plausible explanation for this reduction.

For further information, see Appendix B-2.

C. Benthos Studies

i. Lake Surveys

The single 1982 seasonal survey occurred in April. Four replicate Ponar grabs were collected at each of 10 stations shallower than 8 m, and two replicates were collected at each of 20 stations at greater depths. The 30 stations are divided into three depth zones: 0-8 m (Zone 0), 8-16 m (Zone 1) and 16-24 m (Zone 2). For each zone, there are five stations within 1.6 km of the plant (Inner area) and five reference stations 3.2-11 km away from the plant (Outer area).

Eighteen statistical tests were performed on the April 1971-1982 density data, with one *t*-test yielding a significant result at $0.02 < P < 0.05$. The significant test involved Inner-Outer area differences for *Pontoporeia hoyi* density at Zone 2. Trends in the past have indicated *Pontoporeia* to be generally more numerous in the Outer than in the Inner region, particularly in Zone 2. Given the inherent variability associated with *Pontoporeia* populations in the vicinity of the Cook Plant, the duration of trends from year to year is suspect at $P > 0.02$. Were probabilities found at the 0.01 level we would be more inclined to assign importance to observed results. At $P < 0.01$ annual population fluctuations likely would be of little consequence in changing the significance of the test.

ii. Entrainment Studies

Concentrations of the four major species of malacostracans, Pontoporeia hoyi, Mysis relicta, Gammarus sp. and Asellus sp. were measured in the intake and discharge forebays of the cooling water which circulates through the Cook Plant. Samples were taken in the intake and discharge forebays twice monthly from January through May 1982. On sampling dates, collections were made during four consecutive approximately 6-hour periods (depending on the season of the year) corresponding to midnight-sunrise, sunrise-noon, noon-sunset and sunset-midnight.

The 1982 concentrations of the four major crustaceans in entrainment samples were at levels similar to one or more of the previous operational years. Both the seasonal pattern and average annual abundance of M. relicta in the entrainment were most similar to those of 1975 and 1980. Densities of Gammarus sp. were similar to levels recorded during most previous years. Asellus sp. occurs in such small numbers that year to year comparisons are difficult; however, average annual abundances have shown virtually no change since the earliest years. Large numbers of Asellus entrained in December 1981 were attributed to storm activity. No effect of plant operation has been detected on lake populations of P. hoyi. The causes of yearly fluctuations of M. relicta, Gammarus sp. and Asellus sp. populations are not known as our collection methods are not designed to sample their lake populations with assurance.

iii. Impingement Studies

The total impingement of the crayfish Orconectes propinquus for 1981 (29 kg) is less than 1980 (48 kg) but similar to 1978 (33 kg) and considerably less than previous operational years (1975, 90 kg; 1976, 92 kg; and 1977, 70 kg). The average weight per individual in 1981 (7.4 gm) was considerably greater than that observed for previous years 1975-1980 (5.5-6.8 gm). The effect of impingement and other plant operations on crayfish populations is unknown. Crayfish were rare in the area of the plant until the riprap was established.

iv. Corbicula Studies

In an attempt to monitor for Corbicula fluminea (the Asiatic clam) entrainment samples from May, August and October were microscopically examined for veliger larvae and small clams. No larvae were found. No adult Corbicula were collected in the April Benthos surveys. Two beach walks were made (September and October) at the D. C. Cook Plant and at the mouth of the St. Joseph River to see if specimens had washed up. Again, no Corbicula were collected. At this time, Corbicula does not seem to have become established either near the D. C. Cook Plant or at any other location in Lake Michigan.

For further details, see Appendix B-3.

D. Periphyton Studies

The Cook Plant's underwater intake and discharg structures plus the associated riprap field constitute an artificial reef, providing shelter and solid substrates in a region naturally devoid of them.

After their completions, the underwater installations underwent a period of modifications of surfaces followed by colonization with periphytic algal and animal species. The single preoperational year, 1974, was insufficient for the installations to become fully colonized. Valid pre- vs post-operational comparisons of periphyte abundances and constituent taxa cannot be made because of additional colonization and changes due to natural ecological succession which took place after 1974.

This study uses diver-collected periphyton samples from the underwater installations to determine the taxa living there, and it examines intake entrainment samples for these taxa as a means of assessing the efficiency of entrainment as a monitor of the offshore periphyton community.

The numbers of periphyte taxa taken by the divers have been: in 1975, 97; 1976, 67; 1977, 97; 1978, 117; 1979, 131; and in 1980, 141. Of the 1980 taxa list there were 39 that were present in each of the six years of the study; 13 that were present in five of the six years; 11 that were present in four of the six; 15 that were present in three of the six; 25 present in two of the six; and 38 that were present in 1980 only.

Dominant periphyte taxa in 1980 were: the green, Cladophora sp., the blue-green, Oscillatoria sp., the green, Scenedesmus quadricauda, and diatoms of the genera Amphora, Fragilaria, Navicula, Nitzschia, and Stephanodiscus. Nineteen seventy nine and 1980 were the first two years in which the divers did not collect Cladophora and Oscillatoria in each month of the diving season; the diatom genera were diver-collected in each month of the season, but only one, Navicula tripunctata, was present in all the their samples. Increased numbers of taxa and decreased abundances are characteristics of the post-pioneer stages of ecological succession.

With capture rates in intake entrainment sampling ranging from 74% to 89% of the resident offshore taxa, intake entrainment sampling is considered adequate to monitor the periphyton community in months when diving is not possible.

The changes observed in the periphyton community are consistent with advancing stages of "artifical reef" ecological succession, not with any effect of Cook Plant operation.

For further information, see Appendix B-4.

E. Fish Studies

Data on field distribution and abundance of larval, juvenile, and adult fish were evaluated to detect any possible effect of operation of the D. C. Cook Plant on these life forms. Entrainment and impingement data provide estimates of direct impact of the plant on fish populations. One of the main features of the 1982 impingement data set was the reduced water flow through the plant because of unit shutdowns; reduced flows apparently caused impingement losses to be considerably lower than 1981 values. Based on data collected through August, alewife populations continued their decline in our catches, undoubtedly a reflection of lake-wide changes. Entrainment losses reached a record high in 1981 even though water flow through the condenser cooling system at the plant was reduced during months of greatest larval fish abundance.

Results of field larvae ANOVAs (analysis of variance) of beach stations for 1973 to 1980 showed alewives were most abundant in 1973 (3,342/1000 m^3) and least abundant in 1980 (38/1000 m^3). A complete ANOVA for 1973-1982 is planned when 1982 data have been entered on disk files. From 1973 to 1980, alewife larvae abundance continually declined in the study areas, but in 1981 they were moderately abundant. Highest monthly field larvae abundance of alewives for all years combined occurred in July. No plant impact on beach zone larval alewives was observed. A similar result, no differences in densities between Cook and Warren Dunes, was found for open water larval alewives, based on 1973-1980 ANOVAs.

The ANOVAs for larval spottail shiners (1973-1980) showed mean catches were significantly different for Month and Year, a demonstration of the variable nature of spottail recruitment. No plant effects, however, were documented. Yellow perch in open water were equally distributed at Cook and Warren Dunes. A number of other species were collected, including common carp, which was only observed at Cook Plant stations. Results of larval fish sampling as well as adult sampling have documented carp reproduction and attraction exclusively to the Cook Plant area.

In 1981, almost 140 million fish larvae and one billion fish eggs were entrained at the Cook Plant. Eleven species of fish larvae were represented. This year's loss was the highest of all the sampling years. The next highest larval fish entrainment loss (137 million) occurred in 1979. Among larvae entrained, alewife comprised 80% (111.5 million) of the total annual loss. June was the peak month (61%) for larval alewife entrainment. Spottail shiner was the second-most often entrained species (7.3 million), followed by rainbow smelt (2.6 million), yellow perch (2.5 million), and slimy sculpin (1.0 million). Trout-perch, quillback, common carp, ninespine stickleback, and johnny darter were other species entrained in low numbers.

Inspection of the forebay to monitor presence of fish occurred monthly during 1982 as it has in previous years. Twelve live fish were observed, including three alewives, three salmonids, and six common carp.

Our previous ANOVAs for 1973-1981 catches of adult and juvenile alewives indicate that the Cook Plant has had no long-term detectable effect on southeastern Lake Michigan alewife populations. Most statistical interactions can be associated with large, possibly lakewide, annual changes in alewife abundance. Our data indicate that the alewife decline begun in 1975 has continued through 1981. Catches of alewife in January-August 1982 continued this trend because they were the lowest ever recorded. All age-groups seem to be affected.

Factors acting to reduce alewife populations include salmonid predation and competition from bloaters; water intakes also account for a small percentage of this loss.

The bloater population in the study areas has shown a dramatic increase since 1977. The 1981 total catch was more than three times greater than in any previous study year, making bloater the fifth-most abundant species in 1981. These population changes reflect a lake-wide increase which is not related to plant operation. However, in recent years, smaller trawl catches at the Cook Plant compared with Warren Dunes may be related to plant operation. Bloater catch in January-August 1982 was 1,423 fish, a considerable decline from the 9,912 fish caught during all of 1981. A possible plant effect was again noted with preliminary 1982 data, as smaller trawl catches were consistently observed at the Cook Plant when compared with Warren Dunes.

Rainbow smelt ANOVAs for 1973-1981 indicate that most statistical interactions were indicative of successful spawning in 1980, and a continued trend of increasing abundance since 1976. Low numbers of young-of-the-year in field catches from August to October suggest that 1981 spawning was not as productive as the two previous years. Changes in the distribution and abundance of smelt over the years appear to be unrelated to plant operation and are most likely due to natural shifts in smelt abundance and utilization of the study area. Data for 1982 confirm these conclusions. Total catch through August, when compared with 1981 data, showed that the Lake Michigan smelt population may be declining after its 1981 peak.

Spottail shiner ANOVAs for 1973-1981 indicate that most statistical interactions were associated with the complex interrelationships of year-class variability, seasonal behavior patterns and gear selectivity. Year-class variability and behavioral characteristics of the species appear to overshadow any influence of plant operation upon local spottail populations. During 1982, January-August catch was the lowest of any year. Reduced seine catches due to construction activity on the discharge pipes may have disrupted normal beach zone nursery areas.

Trout-perch catch data for 1982 were consistent with patterns established in earlier years. Population fluctuations indicated by the 1973-1981 ANOVAs probably reflect natural changes in trout-perch abundance in southeastern Lake Michigan, rather than the effects of plant operation. In 1982, catch through August was only 211 fish, the lowest of any year to date. Apparently the population in 1982 was at a low level. Fluctuations similar to this have occurred in the past and are considered normal for Lake Michigan. No impact of the plant on trout-perch was observed.

The 1981 total standard series catch of yellow perch was more than twice as large as any previous year's catch, mostly due to large numbers of yearlings from an exceptionally large 1980 year class. ANOVA results gave ambiguous evidence of possible plant effects, but there was an indication that large perch are being attracted to the Cook Plant area. Many yellow perch were impinged in 1980 and 1981, and future field data should be examined for evidence that impingement may be locally depleting numbers of perch. In 1982, yellow perch catch was still high but down from peak levels in 1980. The 1980 year class was still a dominant part of 1982 catches.

Among the common species, both common carp and gizzard shad have become more abundant at Cook Plant stations but not Warren Dunes, suggesting that they are attracted to the warm water of the plant discharge. Addition of the Unit 2 discharge in 1979 did not substantially increase this attraction. Common carp spawned at the Cook Plant in operational years but not in preoperational years. Slimy sculpin population fluctuations appear to be natural rather than plant-related, though larger numbers at Cook stations compared with Warren Dunes show that sculpins are attracted to the riprap around the intake and discharge structures. Lake trout have increased somewhat in number at Warren Dunes stations since the plant began operation, remained the same at Cook 9-m stations, and decreased at Cook 6-m stations. This may indicate that lake trout are avoiding the plume area. Johnny darters were more abundant at Cook 6-m stations than at Warren Dunes because this species is attracted to the plant's riprap. Longnose sucker and white sucker were more abundant at Warren Dunes than at Cook during all sample years. These two sucker species may be repelled from the Cook area because of construction activities and the discharge currents. Catch data on other common species: brown trout, chinook salmon, coho salmon, emerald shiner, longnose dace, ninespine stickleback, and rainbow trout showed no changes which could be directly attributed to plant operation.

Estimated weight and number of fish impinged at the Cook Plant (1975-1982) were recalculated using a new method which determines species composition from fourth-day samples, then incorporates the weight of fish impinged on non-sample days into total weight and estimates total number of fish impinged each month. The most dramatic changes were in estimates of numbers of fish impinged during periods of two-unit operation. An estimated 2,307,101 fish were impinged in 1980, 2,052,964 were impinged in 1981, and from January through August 1982, an estimated 886,183 were impinged on the Cook Plant screens. Species composition of the 1982 impingement losses was similar to that recorded for previous years, except alewife comprised a higher than normal percentage (92% by number, 81% by weight) of the total. Fewer than 100 bloaters were impinged in 1982;

previous year's totals ranged to over 22,000 fish. Coho salmon (519) and lake trout (215) were impinged in unusually high numbers in 1982, more than any previous year for the same January to August period. Most were adults which was also contrary to previous year's trends when mostly newly planted individuals appeared in impingement samples.

For further information, see Appendix B-5.

III.4. Consistency Requirements

A. Plant Design and Operation

(Specification 3.1)

Approximately 1100 ft. of the D. C. Cook Plant's Unit 1 and Unit 2 circulating water system discharge pipe lengths were covered with riprap. Approximately 40,000 cubic yards of sand was excavated from around the existing pipes. Twenty thousand (20,000) square yards of filter cloth, 13,000 tons of mattress stone, and 15,000 tons of cover stone were placed in the manner shown on the following documents. Excavation of sand around the pipes began on August 1, 1982. As of the end of this reporting period, the project has been 100% completed. The riprap will stabilize the pipe sections, which up until this time have shown a tendency to flex during storm conditions.

The State of Michigan DNR and Corps of Engineers Permits, Corps of Engineers Joint Public Notice, and the results of studies required by these permits are included (See Appendix C-1). Item #11 in the Corps of Engineers Joint Public Notice states in effect that the permit request was for remedial work, therefore, no Environmental Impact Statement was necessary

B. Reporting Related to the N.P.D.E.S. Permits and State Certifications

(Specification 3.2)

Violations of the N.P.D.E.S. Permit and State Certification for 1982 are included in the following section under Special Reports. There were two violations for 1982.

N.P.D.E.S. Permit No. MI 0005827 expired in October of 1979. A final draft proposal of the permit was not issued by the State of Michigan Department of Natural Resources until December of 1982. A copy of this draft permit is included as per the requirements of this specification (See Appendix C-2).

SPECIAL REPORTS

DATE	DOCKET NO.	OCCURRENCES
8/9/82	50-315 & 50-316	High iron concentration in the heating boiler blowdown discharge on 8/1/82 indicated 6.0 ppm, a violation of the N.P.D.E.S. Permit limit of 1.0 ppm. Blowdown was maintained to remove iron from the boiler. An N.P.D.E.S. Permit modification which exempts the plant heating boiler from iron and copper limits was approved by the Michigan Water Resources Commission on March 21, 1979, although the staff had never formally modified the permit to reflect the administrative action.
12/27/82	50-315 & 50-316	On 12/9/82 oil overflowed a turbine room lubricating oil tank and entered the turbine room sump. Sump analysis indicated 131 ppm oil and grease, which exceeded the Michigan State Permit MI 00764 limit of 10 ppm oil and grease. A small amount of oil was pumped to the absorption pond before the sump was isolated. Pond water analysis indicated 2.3 ppm oil and grease. The sump oil skimmer was placed in service along with oil booms in the sump and at the pond. At 2000 hours the same day, the oil and grease in the sump was reduced to <2 ppm.

III.5 Environmental Monitoring

Herbicide Application

(Specification 4.2.1)

For approximately one week in November of 1982, selective cutting of trees and brush was performed on Cook Plant lands. Approximately 3 gallons of Tordon RTU was used to treat the stumps of cut trees and brush to control resprouting. A letter of transmittal describing the work performed is included.

Attachment #8

INDIANA & MICHIGAN ELECTRIC COMPANY

AMERICAN ELECTRIC
AEP
POWER SYSTEM

April 4, 1983

T: Herbicide Use - Cook Plant

H. E. Brooks

Eric Mallon - Cook

Attached are copies of the time sheets for a crew that worked for about a week on Cook Plant lands. They used approximately 3 gallons of Tordon RTU to treat the stumps of cut trees and brush to control resprouting.

This was all of the right-of-way maintenance work performed in 1982.

H. E. Brooks

HEB:et

Attach.

cc: J. Druckemiller - w/o attach.
E. W. Hermansen - w/o attach.
R. F. Tanner/N. J. Williams - w/o attach.

III.6 Nonroutine Reports

(Specification 5.4.2)

The following is a list of nonroutine reports for 1982:

DATE	DOCKET NO.	AEO NO.	OCCURRENCES
1/19/82	50-316	82-001/04T-0	During de-icing, the Circulating Water System Discharge temperature exceeded the Appendix B Technical Specification limit of 56°F on several occasions.
1/25/82	50-315	82/003/04T-0	Unplanned gas release was detected by an elevated Unit Vent Radiation Monitor R-26 reading. The release was within Technical Specification limits.
3/19/82	50-315	82/010/04T-0	Unplanned gas release occurred without the sampling and analytical requirements. The release was within Technical Specification limits.
3/19/82	50-316	82-015/04L-0	Flow indicator SFR-201 for Turbine Gland Seal Leakoff failed. Instrumentation was declared inoperable. Continuous flow measurement is required by Technical Specification.
4/12/82	50-316	82-020/04T-0	Unplanned gas release occurred without sampling requirements. The release was within Technical Specification limits.
4/29/82	50-316	82-028/04L-0	Flow indicator SFR-201 for Turbine Gland Seal Leakoff failed high. Instrumentation was declared inoperable. Continuous flow measurement is required by Technical Specification.
6/1/82	50-315	82-030/04L-0	During normal operation, flow indicator for SFR-201 Turbine Gland Seal Leakoff failed low. Instrumentation was declared inoperable. Continuous flow measurement is required by Technical Specification.

DATE	DOCKET NO.	AEO NO.	OCCURRENCES
9/24/82	50-315	82-078/03L-0	An unplanned gas release was occurred without the sampling and analytical requirements. The release was within Technical Specification limits.
10/12/82	50-315	82-084/04L-0	An unplanned gas release was detected by an elevated R-26 reading. Release was occurred without the sampling and analytical requirements. The release was within Technical Specification limits.

IV. Radiological Environmental Operation Report

See Appendix E.

V. CONCLUSIONS

In accordance with the objective of our Appendix B Environmental Technical Specifications, the operation of Units 1 and 2 of the Donald C. Cook Nuclear Plant had no detrimental impact on the surrounding ecological environment during 1982.

Data from the environmental radiological monitoring program during this year were within their respective expected normal ranges. None of the samples contained radioactivity that could be attributed to operation of the Cook Plant. The results of the data analysis show no abnormal environmental conditions that will cause adverse environmental effects from the operation of the Plant.

APPENDIX A

ENVIRONMENTAL OPERATING REPORT

UNDERWATER OBSERVATIONS AT THE DONALD C. COOK NUCLEAR PLANT

VISUAL INSPECTIONS

INTRODUCTION

The underwater observation program has been designed to facilitate visual monitoring of the study area. The program enables divers to assess macroscopic physical and biological conditions of locations within one half kilometer of the intake and discharge structures. Observational methodologies have been designed to allow divers to observe previously itemized conditions which, by changing, might indicate alteration of the ecological system at the monitoring locations. Data gathered during the dives and analysis of samples collected are used to write reports on underwater operations.

Prior to June 1982, the Technical Specifications required a schedule which included five dives each month (April-October), weather permitting, at standard locations. These locations and dive times were: one day dive in the area of the discharge structures, one day dive in the area of the intake structures, one night dive at a depth of 9 m (30 ft) to compare day and night observations, and two day dives in control areas outside the plume. As a result of seven circulation pump operation, dangerously strong currents were produced in the discharge area. Safe diver-entry into the discharge area was not possible except during periods when one or both units were shut-down. During periods of circulation pump shut-down, dives were made to examine the areas surrounding the discharge structures. The reduced environmental schedule enacted during June 1982 required two dives per month, April-October: one day and one night dive in the area of the intake structures. During periods of circulation pump shutdown, dives were made to examine the areas surrounding the discharge structures.

A total of 20 dives were performed during 1982 in the vicinity of the study area (Tables 1 and 2). Required dives completed (Table 3) were: four in April and May, two in June, three in July and August, and two in September and October. Dangerous currents prohibited dives in April-June and September-October in the discharge area. The control dives were performed April-May in areas north and south of the riprap field, in line with the discharge structures and at locations within and outside of areas immediate to the plume.

Discussion of observations is presented in previously utilized categorical format: scour, sediment, turbidity, current, inorganic debris, organic detritus, periphyton, loose algae, macrophytes, invertebrates (attached invertebrates, molluscs, crayfish, others), fish, eggs, fish and other observations. Discussion integrates data from preceding years with 1982 observations, notes significant preoperational/operational changes (if any) and describes any diver-observed plant effects.

RESULTS AND DISCUSSIONS

Scour

Examination of riprap areas directly in the flowpath of high velocity water discharge has been limited (1975 - one dive, 1978 - one dive, 1979 - one dive, 1980 - three dives, 1981 - three dives, 1982 - two dives) because of diver inability to enter the areas during pumping. Displacement of some riprap immediately adjacent to the north discharge structure prior to placement of the concrete scour pad in 1979 has been discussed previously. The north scour pad was examined twice (July and August) during 1982 and appeared relatively free of sediment, periphyton and invertebrates. The top and sides of the pad were intact and evidenced minor pitting, scouring or disintegration - no major change

Table 1. Summary of January through December 1982 diving activities near the Donald C. Cook Nuclear Plant.

Dive no.	Date	Location	Depth (m)	Day or night	Start time	Under-water time	No. of divers
1	Apr 28	N. reference stations	4-6	D	1700	10	2
2	Apr 28	S. reference stations	4-6	D	1720	10	2
3	Apr 28	S. intake structure	3-9	D	1745	30	2
4	Apr 28	S. intake structure	3-9	N	1900	10	2
5	May 19	N. reference stations	4-6	D	1700	10	2
6	May 19	S. reference stations	4-6	D	1722	10	2
7	May 19	S. intake structure	3-9	D	1755	30	2
8	May 19	S. intake structure	3-9	N	2020	30	2
9	Jun 17	S. intake structure	3-9	D	1900	30	2
10	Jun 17	S. intake structure	3-9	N	2130	30	2
11	Jul 27	N. discharge structure	3-6	D	1845	25	2
12	Jul 27	S. intake structure	3-9	D	1915	20	2
13	Jul 27	S. intake structure	3-9	N	2030	30	2
14	Aug 30	N. discharge structure	3-6	D	1745	15	2
15	Aug 30	S. intake structure	3-9	D	1810	30	2
16	Aug 30	S. intake structure	3-9	N	1930	30	2
17	Sep 28	S. intake structure	3-9	D	1805	30	2
18	Sep 28	S. intake structure	3-9	N	2010	30	3
19	Oct 25	S. intake structure	3-9	D	1739	16	3
20	Oct 25	S. intake structure	3-9	N	2115	20	2

Table 2. Summary of underwater time accrued during January through December 1982 diving activities near the Donald C. Cook Nuclear Plant.

	Daylight		Night		Total	
Month	No. dives	Time (min)	No. dives	Time (min)	No. dives	Time (min)
April	3	50	1	10	4	60
May	3	50	1	30	4	80
June	1	30	1	30	2	60
July	2	45	1	30	3	75
August	2	45	1	30	3	75
September	1	30	1	30	2	80
October	1	16	1	20	2	36
Total	13	266	7	180	20	446

Table 3. Record of completion of 1982 dives required by the technical specifications (given favorable weather conditions). The number of each dive from Table 1 is shown.

	Daylight				Night
Month	Intake area	Discharge area	First control area	Second control area	9 m (30 ft)
April	3	*	1	2	4
May	7	*	5	6	8
June	9	*	**	**	10
July	12	11	**	**	13
August	15	14	**	**	16
September	17	*	**	**	18
October	19	*	**	**	20

* Strong currents did not permit safe diver-entry into the discharge area.
**Stations not required in reduced monitoring plan effective June 1982.

in its appearance was noted between 1979 and 1982. Riprap scour adjacent to the south discharge structure was noted and discussed in previous reports. In 1981, the concrete scour pad placed in the flowpath of the south discharge structure was examined during April. Sediment, periphyton and invertebrates were not observed on the pad. Only minor evidence of scour or pad disintegration was noted; extensive scour adjacent to the sides or back of the structure was not observed. The south discharge pad and area were not examined during 1982. Both scour pads have shown some undercutting of the pad on the lakeward side (the side opposite the discharge points). But this undercutting appears to have been stabilized by placement of additional concrete. Diving and observations in other areas of the discharge zone were not conducted during 1982. Scour has never been observed in the vicinity of the intake structures and observations made during 1978-1982 indicate that the southwest sand/riprap interface is relatively stable. Ice or wave scour has never been observed, but extensive ice damage to all three intake structure ice guards has been noted periodically during 1977-1980. The intake structure had little evidence of over-winter damage when examined in April 1981 and April 1982.

Sediment

Encroachment of sand onto the riprap in the discharge area has been documented previously. Limited observations during 1982 in the vicinity of the discharge structures revealed no noticeable changes in sand encroachment in this area. Observations in the riprap area between the intake and discharge structures were made in previous years but not during 1982. Previous reports have documented suspension and transport of floc (loose accumulation of sediment, some periphyton and loose algae, diatomaceous material, and organic detritus) in the area. Floc layers during 1974-1982 usually ranged from a trace (discernible, but not measurable to 5 mm in thickness; 2-3 mm was typical. Depressions (e.g., ripple mark troughs and riprap interstices contained more floc than did elevated surfaces (e.g., ripple mark crests, tops of structure). Reference stations south of Cook Plant typically were relatively free of floc. Discharge areas examined were devoid of floc.

As in some previous years, occasional depressions 5-10 m across containing silt 20-40 cm thick overlying sand were encountered during 1982 in the north reference station area. Lumps of clay 5-10 cm in diameter were noted about 100 m north of the discharge riprap field during 1979 and 1981 but not during 1982.

As in previous years, ripple marks were frequently observed in sandy sediments. Generation usually appeared to have occurred from the northwest or southwest. Although usually small (wavelength less than 15 cm, amplitude less than 5 cm, length along crests less than 100 cm), occasional large ripple marks (wavelength 1 m, amplitude 0.3 m, length 10 m or more) were observed during 1974-1982. These large ripple marks were observed exclusively in very coarse sand; pebbles were often present in the troughs. Large ripple marks were observed primarily north of Cook Plant. Ripple marks in areas observed south of Cook Plant were usually absent or small and assymetric in shape and pattern.

Current

Dives were made in the discharge area only when one of the units was not circulating water and currents were minimal. At reference (control) stations 100 m north and south of the discharges, currents (about 30 cm/sec) were noticeable but were variable in direction; occasionally, current was directed toward the discharges. At stations more than 300 m from the discharges, weak currents were occasionally noted, but no directional pattern was established.

At the south intake structure, current was noticeably stronger during 7-pump circulation than when fewer pumps were operating during a unit outage. Current was most evident along the top edge of the structure. Intake current was directed toward the south intake structure from all directions at 5 m or less from the structure base. But the strength of the current varied depending upon (compass) position. Currents were strongest at the base on the north and east sides and weakest on the south side. Intake current was often discernible 40 m southwest of the south structure. As previously noted, fish in the vicinity of the south intake often exhibited pronounced positive rheotaxis and some position-holding. Pelagic fish (e.g., alewife, yellow perch) were most often observed in areas where currents were weakest in the vicinity of the south intake.

Inorganic Debris

Input of debris by fishermen continued to be observed. But most debris was tackle or related fishing and boating gear. Little trash (e.g., food and beverage packaging materials) was observed during 1982. Some large debris persists from the construction period.

Organic Detritus and Dead Animals

Organic detritus (primarily terrestrial vegetation and dead algae) and dead animals (crayfish and fish) were observed occasionally during 1982, as in previous years. Appreciable accumulations or patterns of distribution were not evident. In contrast with some preceding years, few large sections of trees (branches, logs, trunks) were noted in the riprap area during 1982. But tree trunks were occasionally encountered adjacent to the north discharge structure. Comparison of observations within and outside the riprap area suggested that the rough substrate tends to trap organic detritus. Large sections of trees were also encountered during swims in the reference (control) areas in previous years, but not during 1982. Accumulation of large detritus and damage to in-lake structures is probably correlated with the severity of spring and fall storms, and development and movement of inshore ice. Large debris may be uncovered or transported onshore during severe inshore processes (currents, wave action, ice scour and movement).

Occasionally, fecal pellets of fish (alewife and carp) were observed in great abundance, primarily during the summer on sand-substrate areas. Surprisingly few dead fish were observed during 1980-1982; dead alewives were occasionally seen in riprap and sand bottom areas. A few dead perch were noted but usually appeared to have been caught by fishermen and returned to the lake. Dead crayfish were occasionally noted.

Turbidity

Regions of reduced visibility (i.e., turbid water masses) were encountered during 1979-1982 immediate to the south intake structure and at the southwest edge of the sand/riprap interface. Visibility was often reduced 25-50%. Abrupt decreases in temperature were often associated with these turbid water masses. Presence of warm, less turbid water masses suggests some possible recirculation of water, particularly during 7-pump circulation.

Periphyton

Periphyton, predominately the filamentous green alga, Cladophora, attained peak lengths (50-60 mm, average 1975-1981) on top of the south intake structure and surrounding riprap during July. In 1981, peak length (100 mm) of periphyton on the structure top occurred during June. Periphyton was practically absent on the structure top in 1982. During the past few years, about 25-50% of the structure top surface area had supported periphyton. Mechanical (buoy line, construction-diver activity) and ice-scouring reduced periphytic growth during the summer and winter, respectively. Occurrence of scour was evidenced in that maximum length of Cladophora on top of the structure occurred in protected areas (crevices, oblique surfaces). Maximum length of Cladophora on riprap surrounding the south intake structure was 60 mm during July 1980, 15 mm during June 1981, and 30-50 mm in August 1982. About 50% of the upper surfaces of the riprap supported periphyton. Periphytic growth on riprap appeared to be less extensive during 1980-1982 compared with maximum length (150 mm) and percentage (nearly 100) of riprap supporting periphyton in earlier years. As previously noted, luxuriant growth was confined to riprap located within 5 m of the structure. More distant riprap supported notably reduced periphytic growth, possibly as a function of increased depth (reduced light penetration) and decreased current velocity (a cleaning or silt removal mechanism).

Limited observations during 1981-1982 at the north discharge structures revealed that periphyton grew on top of the structure to lengths of 80-100 mm. But riprap adjacent to the structure was devoid of noticeable periphytic growth.

Since 1973, periphyton growing on the intake structures and riprap have provided a substrate for fish spawning (alewife and spottail shiner). Periphyton have provided an expanded, but probably minor, habitat for fish spawning (Jude et al. 1979) that would not be present if the structures and riprap were absent. Riprap continued to provide suitable substrate for periphyton but the top of the intake structures has supported less periphyton in the past few years, perhaps the result of aging (e.g., rusting, slime formation) and abrasion to the surface.

Loose Algae and Macrophytes

Small clumps (10- to 50-mm diameter) of loose algae were observed occasionally in the control areas (densities ranged from zero to 10 clumps/m^2) and less frequently in riprapped areas. Loose algae appeared to be concentrated along the edge of the sand/riprap interface, particularly in the vicinity of the intake structures. The observed concentration of algae along this interface was probably the result of trapping action of the rough substrate acting upon algae in transport along the lake bottom. Large accumulations (i.e., masses or mats) of algae were not observed. Random occurrence of algae clumps has been observed regularly during 1974-1982. Dead algae appeared to be the major constituent of most clumps, and fish eggs were often entangled in them. Macrophytes have never been observed during underwater observations in the vicinity of Cook Plant.

Invertebrates

As previously documented, numbers of attached invertebrates (Hydra, bryozoans, and freshwater sponge) increased steadily during 1973-1976. During 1977-1978, rate of increase slowed, and in 1979 numbers of bryozoan and freshwater sponge colonies appeared to decrease, particularly in areas of heavy Cladophora growth adjacent to the south intake structure. During 1980-1982, numbers of bryozoan colonies observed remained low, but there appeared to be a slightly noticeable increase in numbers of sponge colonies attached to riprap.

During 1980-1982, finger-like extensions (1 cm long) of sponge were observed occasionally. Hydra continued to be observed in tremendous numbers, particularly on riprap lateral and undersides where algal growth was reduced. Heavy algal growth combined with a flocculent overburden may preclude growth of attached invertebrates; the slight reduction in algal growth observed on the riprap in 1980-1982 may have permitted increased growth (size and numbers) of sponge colonies.

Numbers of unattached invertebrates remained greatly reduced relative to earlier years (1973-1975). Live snails were not observed during 1979-1982. Observance of empty and fragmented mollusc shells (sphaeriids, pisids, and gastropods) was common in sand substrate (reference station) areas; shells were rarely observed in riprapped areas except in sandy areas immediately adjacent to the discharge structures where shells appeared to have accumulated perhaps as a result of (eddy) current transport.

Abundance of crayfish has followed a pattern similar to that observed for snails; one of increasing, peaking, and subsequent declining abundance. In 1975, maximum density (no./10 m^2 ± S.E.) of crayfish attained during July in the intake area was 27 ± 15. During 1981 crayfish were observed every month but June and October; five in April, ten in May, four in July, one in August, and one in September. Numbers of crayfish (and density) seen in 1982 paralleled numbers seen in 1979-1981, reflecting the continued depressed population size relative to earlier years. Decline in crayfish abundance has been further documented by pronounced reduction in numbers of crayfish impinged during 1979-1982 (see Benthos section).

Causes of declining abundance of freshwater sponge, bryozoans, snails and crayfish are probably related to changes in habitat and predation. Ageing of the riprap "reef" has resulted in increased periphytic growth (primarily *Cladophora*) and accumulation of flocculent material. Plugging of interstices by algae or flocculent material may have reduced water circulation and/or increased biological oxygen demand at the substrate/water interface. Changes in microenvironmental conditions may have resulted in a shift in diversity and abundance of biota associated with the riprap area. Succession of predators (sculpin, yellow perch) as they initially encounter, inhabit, and exploit the reef's resources (habitat, prey - snails, crayfish, demersal fish) may also account for the observed shift in biotic composition of the reef over time. Initially high exploitation followed by subsequent successional decline in species "richness" have been documented for marine artificial reefs (Smith 1978), possibly as a result of competition and/or a decline in available resources, e.g., food and suitable habitat.

Fish Eggs

Presence of fertile eggs of alewife, spottail shiner, yellow perch, sculpin (*Cottus bairdi* or *Cottus cognatus*), and johnny darter has been documented previously. During June 1982, eggs of alewife and possibly spottail shiner and/or carp were observed attached to periphyton growing on the riprap surrounding the south intake structure. Numbers and densities of observed eggs were high but not noticeably different from numbers and densities noted during previous years.

Fish

Eleven species of fish were observed during 1981 and listed in descending frequency of sightings (measured as presence or absence, not as numbers of fish) within and across dives were: alewife, yellow perch, sculpin (Cottus spp.), johnny darter, spottail shiner, carp, rainbow smelt, trout-perch, burbot, redhorse (Moxostoma spp.), and chub (Coregonus spp.). As in previous years, multiple sightings of the first four species often occurred during a dive; numbers of fish seen were usually less than ten. Adult alewife and perch were observed commonly in schools (10 - perch, 10-50 - alewife) during early summer, and schools of hundreds of YOY alewife were seen during September and October. Only incidental sightings of other species occurred.

Several generalizations related to fish may be made based upon observations made over the period 1973-1982 (Table 4): alewife, spottail shiner, yellow perch, sculpin and johnny darter were the most frequently (occasions and numbers) observed species. Trout-perch, smelt and carp were often but not regularly observed in the discharge area only. Alewife, spottail shiner, and yellow perch in particular were sighted primarily during warm-water months (late May through October). Thousands of adult alewives, sighted in previous years during the May-June spawning season, were not observed in 1980-1982. In general, fewer alewives were seen in 1980-1982 than in previous years. Sculpin and darters were locally abundant on the riprap and were conspicuous because of their demersal nature. Numbers of sculpin and darters observed during 1979 declined relative to previous years and have fluctuated for 1980-1982. Observations of alewife, spottail shiner, and yellow perch generally followed patterns documented in previous Environmental Operating Reports. Dorr and Jude (1980) presented additional analysis and discussion of fish abundance and

Table 4. Rank abundances of fish observed by divers in southeastern Lake Michigan in the vicinity of the D. C. Cook Nuclear Plant, 1973-1982[1].

Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Alewife	1	3	1	1	1	1	1	3	1	1
Johnny darter	2	2	5	3	3	2	6	2	3	4
Cottus spp.[2]	6	1	6	2	2	3	4	1	4	3
Yellow perch	3	4	7	5	4	4	3	4	2	2
Spottail shiner	4	5	9	4	6	7	2	6	6	5
Trout-perch	5			7		8	5	7	5	8
Carp		7	2	6	5	5	9	8	7	6
Rainbow smelt				8	7	6	7	5	8	7
Emerald shiner		8								
Burbot		6	8	9			8	9		9
White sucker			3		8	9		12		
Longnose sucker						8	10			
Lake trout		8						11	9	
Moxostoma spp.[3]							11			10
Brown trout								10		
Black bullhead		8								
Channel catfish		8								
Walleye						10				
Smallmouth bass			4							
Largemouth bass			10							
Coregonus spp.[4]										11

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[1] Rank of species (ranked by year in descending order of numbers of fish observed by divers).

[2] *Cottus bairdi* (mottled sculpin) or *C. cognatus* (slimy sculpin).

[3] One of several possible species of redhorse (see Fisheries section for documentation of species occurrence).

[4] Probably *Coregonus hoyi* (bloater) but possibly *C. artedii* (cisco or lake herring).

behavior in the vicinity of Cook Plant during 1975-1978.

The majority of fish species impinged and field-caught at Cook Plant were not observed by divers. This is partly a reflection of the generally low numbers and incidental occurrence of these species in the study area. Species of fish commonly field-caught (alewife, spottail shiner, yellow perch, rainbow smelt, and trout-perch) and impinged (previous species plus sculpin and darters) were also frequently observed by divers. Seasonal occurrence of young-of-the-year (YOY) fish in field and impingement catches was paralleled by diver observations. Demersal fish such as sculpin and darters concentrated in the riprap area (relative to the surrounding sand-bottom areas) and consequently were observed and impinged in relatively high numbers.

The remaining species were observed infrequently during 1973-1982; little can be inferred from data related to the incidental sightings of these species. Large fish such as salmonids, burbot and suckers were rarely seen in the study area, probably because they detect diver presence and flee the area unnoticed.

As in previous years, carp continued to be observed in the vicinity of the discharge structures. Carp were also seen in the south intake area during May (three fish) and August (six fish) 1982. Comparison of preoperational and operational data (1973-1981) indicate that carp are attracted to and are more abundant in the vicinity of the discharge structures. An explanation for the attraction of carp to the discharge area was not readily available. Visual observations suggest that carp may be attracted to the warmer water rather than associated turbulence because fish were seldom observed at reference stations within the plume but outside the area of noticeably elevated temperature. However, Cook Plant was never at full circulation capacity (i.e., maximum discharge of heated water) during dives in the area. Elevated concentrations of macroinvertebrates (prey or potential food items) were not observed within the plume. Carp appeared to concentrate in the discharge area and wander to neighboring areas. Gill net data also suggest concentration of carp near the discharges but document concurrent incidental presence elsewhere in the study area.

Fish were observed in greater numbers and species diversity at night than during the day. Fish abundance and diversity was highest during June-August 1982. Activity levels were also higher at night (only perch appeared to be consistently less active at night) with fish concentrating near the bottom or absent in the area during daytime. Numbers of fish observed within riprap areas were much higher than numbers observed in control areas. Daytime observations of fish in sand-bottom reference areas were very infrequent, often equalling less than five sightings per year and usually as schools of adult or YOY alewives or a solitary darter or sculpin. During 1978-1982, a night station was examined in a sand area near the intake structures; fish (sculpin, spottail shiner, alewife, trout-perch, johnny darter, smelt and burbot) were sighted in numbers much larger than numbers observed at daytime reference stations but far less than numbers of fish observed within the riprap area. Species observed at the night sand station were also observed in riprapped areas.

Schooling was manifested by several species including: alewife, spottail shiner, perch, and carp. Young-of-the-year alewife, smelt, and perch also exhibited schooling behavior. Alewife and perch schooled more tightly during the day; schooling was rarely observed at night. Numbers of alewife per school ranged from 10 to 100 for adults and to several hundred for YOY. Spottail shiner schooling was loose and observed infrequently. Carp were rarely observed at night, and were always solitary.

Large schools of young-of-the-year alewife were observed in September-October 1982 as in previous years. Young-of-the-year perch were observed in great abundance during the August night dive.

Other Observations

Reduction of floc and periphyton in the immediate flowpath of discharge water, heightened nocturnal abundance, diversity and activity of biota, uneven (patchy) distribution of biota, seasonal trends in biological activity and diversity, and attraction of biota to riprapped areas were biological pattern documented in earlier Environmental Operating Reports that were observed again during 1982.

Shifts (declines) in numbers and/or frequency of observations of various invertebrates (snails, crayfish, bryozoans, freshwater sponge) indicate continued but stabilizing ecological succession in the riprapped area. Species richness and abundance of invertebrates appears to have peaked prior to 1978 and subsequently declined. Operations of Cook Plant during 1982 have had no major diver-observed physical or biological effects that have not been noted in previous reports. Data analysis to date suggests that, barring a major change in Cook Plant operation, future changes in study area ecology may occur on a small scale relative to changes observed immediately following deposition of riprap. These changes will probably be subtle and too small and variable to be reliably detected and defined through diver observations. Also, the interaction of plant effects and natural variation and change will confound interpretation of ecological change in the area.

SUMMARY

Twenty dives were performed during the reporting period: four in April and May, two in June, three in July and August, and two in September and October.

Placement of the concrete scour pads in front of the discharges appears to have alleviated scour adjacent to the structures. Examination of the scour pads revealed no significant pitting, scoring or disintegration of these structures. The riprap surrounding the south intake structure was undisturbed; the sand/riprap interface surrounding the intake structures appeared stable. Accumulations of floc typically ranged from 1 to 5 mm thick. Large depressions in the bottom (10 m across by 1 m deep and containing a silt overburden 20-40 cm thick) were encountered occasionally during 1982 as in some previous years at reference stations north of the Cook Plant.

Both uni-directional and eddy current patterns were detectable throughout the water column within 100 m of the discharges; at stations more than 300 m from the discharges weak currents were occasionally noted, but no directional pattern was established. Variable current speeds were encountered at the south intake structure, but current was strongest adjacent to the base of the structure on the north and east sides. Increased current and possible recirculation of water were noted at the south intake structure during 7-pump operation.

Trash (primarily from fishermen) was observed in decreasing quantities during 1979-1982. Reduction in numbers of beverage containers was particularly noticeable. Relative to concentrations in control (sand substrate) areas, organic debris (algae and terrestrial vegetation) was concentrated in the riprap zone by the trapping action of the uneven substrate, but appreciable accumulations were not noted. Dead fish (alewives and perch discarded by fishermen) and fecal pellets were seen occasionally, but accumulations of dead alewives on the bottom, even during the annual die-off period, have never been observed.

In 1980-1982, periphyton growth remained reduced on top of the south intake structure, relative to earlier years. During 1979, periphyton growth was quite luxuriant within 5 m of the base, but growth was reduced during 1980-1982. Peak lengths of periphyton were attained during June-August. Periphyton growth on top of the south intake was minimal in 1982. Macrophytes were not observed. Attached invertebrates (sponge, bryozoans and *Hydra*) increased steadily in numbers during 1973-1976, but numbers of sponge and bryozoan colonies appeared to plateau during 1977 and have declined subsequently. During 1980-1982, the rate of decline in numbers of sponge colonies appeared to slow somewhat. *Hydra* remained extremely abundant. Numbers (concentrations) of snails decreased dramatically during 1977-1978; snails were not observed during 1979-1982. Density of crayfish in the riprap area during 1978-1982 was less than one-half that estimated during 1975 (the year of maximum abundance). Riprap macroinvertebrates showed a predictable pattern of opportunistic colonization followed by peaking and then by declining numbers of species and individuals in accordance with initial niche exploitation, saturation and subsequent change (decline) in resource availability.

Alewife, perch and possibly spottail shiner and/or carp eggs were noted during 1982 (as in previous years), documenting continued minor (excluding alewife) spawning in the vicinity of Cook Plant. Eggs were observed attached to periphyton, entangled in loose algae and lying loose on the sand.

Eleven species of fish were observed during the reporting period. Listed in descending frequency of observation they were: alewife, yellow perch, trout-perch, sculpin (Cottus spp.), johnny darter, spottail shiner, carp, rainbow smelt, burbot, redhorse (Mosostoma spp.), and chub (Coregonus spp.). Carp were observed primarily in the discharge area. Young-of-the-year (YOY) alewife were very abundant during September-October, a pattern previously documented. Yellow perch YOY were observed in large numbers during the August 1982 night dive. Relative to numbers observed in control areas, fish congregated near the structures (alewife, spottail shiner, yellow perch) and in riprap areas (demersal species, e.g., johnny darter and sculpin). Numbers, diversity, and activity of fish were highest at night and during summer months. The majority of fish species impinged and field-caught at Cook Plant were not observed by divers which was partly a reflection of the relatively incidental occurrence (low numbers) of many species in the study area. Abundance and seasonal observation of major species (e.g., alewife, perch, etc.) and YOY fish documented by divers usually paralleled occurrence in the study area documented by fishery studies.

Presence of Cook Plant structures and riprap has created an atypical, more sheltered and more diverse habitat that attracts and concentrates biota which follow a predictable successional pattern. Diver-observed effects of plant operation upon the local environment were minimal. Barring a large change in Cook Plant operation, future diver observation of major or significant ecological changes in the study area are not anticipated.

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APPENDIX B-1

ZOOPLANKTON LAKE SURVEYS AT
THE DONALD C. COOK NUCLEAR PLANT

ZOOPLANKTON, JANUARY TO DECEMBER 1981

ZOOPLANKTON LAKE SURVEYS

Introduction

Prior to 1982, lake surveys were conducted once per month from April through November. Technical Specifications required that three major surveys and five short surveys be conducted. Major surveys (30 stations) were conducted in April, July, and October and provided detailed information on zooplankton spatial distributions over the 250 km^2 area of the survey grid during spring, summer, and autumn. Short surveys (14 stations) were conducted in the remaining months to provide information on zooplankton temporal succession patterns and long-term population trends.

In early 1982 zooplankton monitoring studies were discontinued. Consequently, lake survey cruises were conducted only in April and May of 1982. A total of 88 of the required 88 samples were collected.

In late 1981 and early 1982, our emphasis in conducting the zooplankton investigations shifted somewhat. In earlier Environmental Operating Reports and in the Great Lakes Research Division Special Reports (Evans *et al*. 1978, 1982), we focussed our efforts on determining species abundance and composition and on evaluating plant effects by considering changes in the abundances of the dominant taxa. On the basis of these studies, we concluded that the operation of the Donald C. Cook Nuclear Power Plant had no significant adverse effect on the biota. This conclusion remains unchanged. However, we now are expanding our research efforts. One investigation includes the evaluation of our overall study design. We were interested in quantifying the sensitivity of our study plan to detect shifts in zooplankton populations. In addition, we have critically examined laboratory and field procedures and are obtaining more precise estimates of sources of variability in our various data sets. The results of these studies are included in this report.

In addition to these methodological studies, we have concentrated more of our efforts into investigating the ecology of the survey area. The last such study was conducted by Stewart (1974) who summarized, for most of the preoperational period, the distributional ecology of the major zooplankton crustaceans: this summarization was based on abundance estimates, some sex-ratio data, and some copepod instar data. However, no attempt was made at that time to interrelate zooplankton with other components of the aquatic community.

The operational studies at the Donald C. Cook plant have provided strong evidence that zooplankton populations in the vicinity of the plant differ in many respects from populations in the preoperational period. We have indicated that these changes most likely are related to eutrophication and/or changes in fish standing stocks. However, we have not investigated this hypothesis and thus are unable to support such claims. Therefore, in order to better understand why zooplankton populations in the vicinity of the power plant differ between the operational and preoperational periods, we have initiated studies investigating zooplankton ecology. The results of these preliminary studies are included in this report.

Statistical analyses of the preoperational and operational data base continue. As has been discussed in previous reports, the survey grid has been divided into eight zones: three inner, three middle, and two offshore zones (Fig. 1). Preoperational versus operational zone mean comparisons for the numerically dominant taxa during each major survey cruise continue to be performed using the Mann-Whitney U test. Such comparisons have been made for seven years of operational July and October (1975 to 1981) data: examination of the 1982 April cruise samples is not complete, and these comparisons were not made. In addition to these tests, we have conducted parametric tests combining the three inner zones and then analyzing for preoperational versus operational differences for the entire area within the 10-m depth contour.

Examination of long-term seasonal trends in the abundance of major taxa in the inshore plume zone (Fig 1: zone 2) is continuing. In addition, in the Entrainment section of this report, we discuss our evaluation of using power plant intake sampling as a representative 'sampling location' for the inshore region. On the basis of such sampling, we are investigating long-term trends in zooplankton populations through the use of various mathematical models. The distribution of rare taxa collected during lake surveys continues to be considered, although such data have not been subject to the same intensity of statistical analyses as the numerical dominants. New species occurences and shifts in abundances of these taxa are of particular interest because they may be more sensitive indicators of change than the more ubiquitous dominant taxa.

LAKE SURVEY RESULTS AND DISCUSSIONS

In 1982, two lake surveys were conducted: a major (30 station) survey in April, and a short (14 station) survey in May. No other

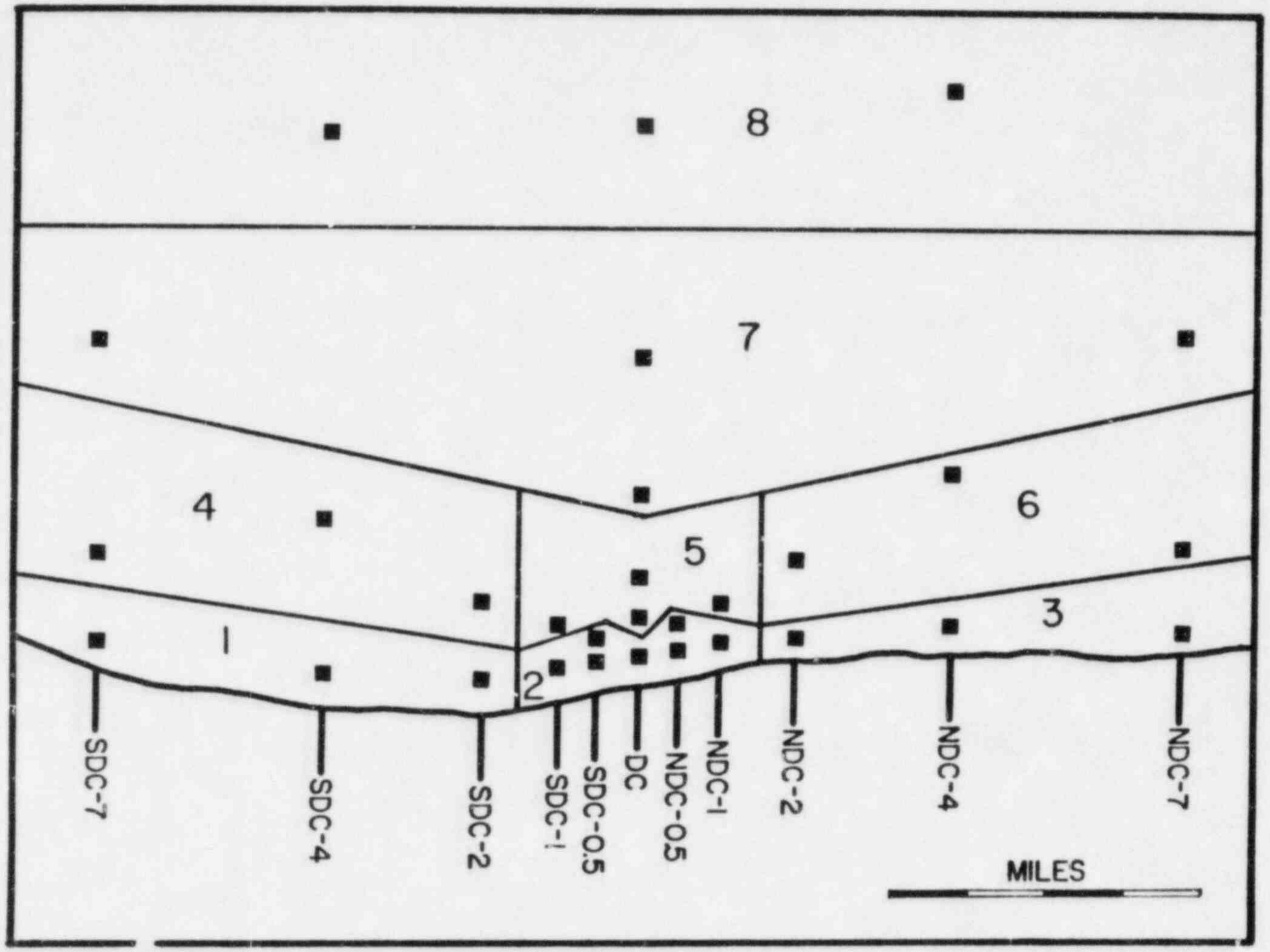

Figure 1. The survey grid divided into 8 zones. Squares indicate major survey stations. The zones are: 1) southern inshore, 2) plume inshore, 3) northern inshore, 4) southern middle, 5) plume middle, 6) northern middle, 7) inner offshore, and 8) outer offshore.

surveys were conducted after May when the sampling program was ended. All of the required samples were collected, but none as yet have been examined. Samples collected in May through November 1981 have been examined and the data analyzed.

For the statistical analyses of the preoperational and operational data base, the 250 km^2 survey grid was divided into 8 zones: three inner, three middle, and two offshore zones (Fig.1). Mann-Whitney U tests were performed to compare preoperational and operational means of major zooplankton taxa during major cruises in each of the zones. These comparisons have been made for seven years of operational data (1975 to 1981). Long term seasonal trends in abundance of major taxa in the inshore plume zone (zone 2) are also examined as are new occurances and shifts in abundances of rare taxa. These rare taxa are especially important since they may be more sensitive indicators of environmental changes than the more dominant taxa.

Physical Data (April and May 1982)

Ambient surface water temperatures on 15 April 1982 ranged from 1.7 °C to 7.0 °C. The thermal bar was located 1.5 km to 2.5 km offshore. The surface temperatures were 2 C° to 3 C° less than the April 1981 temperatures. The thermal plume was small and located within 1/2 to 1 km of the discharge jets. The temperature over the discharge jets was about 4 °C above the ambient inshore temperatures.

Surface water temperatures increased to 7.9 °C to 13.3 °C by 12 May 1982. These temperatures were 4 C° to 5 C° warmer than those in May 1981. There was no observable thermal plume. Temperatures over the discharge jets (13.0 C°) were within the range of ambient lake temperatures. Thermal stratification of the lake had begun but was not well developed.

Secchi disc depths for April 1982 ranged from 1.0 m to 5.6 m and increased to 3.9 m to 6.3 m in May 1982. April 1982 depths generally were less than April 1981 depths while May 1982 depths were greater than May 1981 depths. The secchi disc depths were similar in the plume and control stations for both months, suggesting that suspended particulates were similar in plume and ambient waters.

Zooplankton Data (May to November 1981)

The May inshore zooplankton population was dominated by copepod nauplii and by the cladoceran *Bosmina longirostris*. Immature *Diaptomus* spp. copepodites were of secondary importance. In the offshore regions, immature *Diaptomus* spp. copepodites were the dominant taxa, and copepod nauplii also were abundant. Also common were immature *Cyclops* spp. copepodites and *Limnocalanus macrurus* copepodites. The density of total zooplankton generally was lower inshore ($4,000/m^3$ to $8,000/m^3$) than offshore ($21,000/m^3$ to $31,000/m^3$). There was no evidence of gross alterations of zooplankton distributions in the vicinity of the plant.

In June, the inshore zooplankton community was composed primarily of *Bosmina longirostris* (about 80 % by numbers). Copepod nauplii, immature *Cyclops* spp. and *Diaptomus* spp. copepodites, and the rotifer *Asplanchna* spp. also were numerically important. Offshore, immature *Diaptomus* spp. copepodites were the major taxa. Copepod nauplii, immature *Cyclops* spp. copepodites, adult *Cyclops bicuspidatus thomasi*, adult *Diaptomus* spp. (mainly *D. ashlandi*), *Bosmina longirostris*, and *Daphnia* spp. were of secondary abundance. Total densities were slightly greater inshore and averaged 32,000/m^3. There were no indications of gross alterations of zooplankton distribution in the vicinity of the plume.

The July inshore zooplankton were composed mainly of Bosmina longirostris and Asplanchna species. Although Asplanchna spp. was not a dominant taxon in the past, it comprised between 3 % and 79 % of the inshore area zooplankton and averaged 29 %. There was no clear distributional pattern, but Asplanchna generally comprised a greater portion of the population south of the plant. Directly over the discharge jets (DC-1) Asplanchna spp. percent compositon was low (7 %). Other taxa which were abundant inshore were copepod nauplii, immature Cyclops spp. copepodites, and Eurytemora affinis copepodites. Offshore, the zooplankton community was composed primarily of Bosmina longirostris and immature Diaptomus spp. copepodites. Also abundant were copepod nauplii, immature Cyclops spp. copepodites, adult Cyclops bicuspidatus thomasi, and adult Diaptomus spp. (mainly D. ashlandi). Densities of total zooplankton were less than 100,000/m^3 in the inshore and offshore zones. Higher densities (100,000/m^3 to 300,000/m^3) were found in the middle zones, especially in a region about 1km offshore of the plant.

In August, the zooplankton community was numerically dominated by Bosmina longirostris and by copepod nauplii. Immature Diaptomus spp., Eurytemora affinis and Epischura lacustrus copepodites also were common. The offshore dominant taxa were immature Diaptomus spp. and Cyclops spp. copepodites with copepod nauplii, Daphnia spp. (especially D. retrocurva), and Bosmina longirostris . Total zooplankton densities generally were between 20,000/m^3 and 30,000/m^3 over the entire survey area. There was no indication of gross disruptions in zooplankton densities in the vicinity of the plant.

In September, *Bosmina longirostris*, and immature *Diaptomus* spp. copepodites were the primary components of the inshore zooplankton community. Copepod nauplii also were abundant. Immature *Diaptomus* spp. copepodites were the main component of the offshore population. Also common were copepod nauplii, immature *Cyclops* spp. copepodites, adult *Tropocyclops prasinus mexicanus*, adult *Diaptomus* spp. (mainly *D. minutus*), *Bosmina longirostris*, and *Daphnia* spp. (primarily *D. galeata mendotae*). Densities of total zooplankton generally were greater offshore. There were no indications of changes in zooplankton distributions in the vicinity of the plant.

The October inshore zones were numerically dominated by *Bosmina longirostris* and by copepod nauplii. Immature *Diaptomus* spp. and *Cyclops* spp. copepodites were of secondary dominance inshore and were the dominant offshore taxa. Copepod nauplii and *Bosmina longirostris* also were abundant. Adult *Tropocyclops prasinus mexicanus* were common over the whole survey area. Zooplankton densities were similar inshore and offshore (10,000/m^3) except at NDC .5-1 where densities reached 24,000/m^3: this was 2 to 5 times higher than abundances at surrounding stations.

In November, *Bosmina longirostris* and immature *Diaptomus* spp. and *Cyclops* spp. copepodites were the major components of zooplankton populations over the survey area. Inshore populations were dominated by *Bosmina longirostris* while immature *Diaptomus* spp. and *Cyclops* spp. copepodites were the major components of the offshore community. In general, total densities were greater inshore than offshore. At SDC 7-1, zooplankton populations were about 4 times greater than other inshore populations (115,000 versus 25,000/m^3). There was no evidence of major disruptions in zooplankton distributions in the vicinity of the plume.

Species Shifts

In the autumns of 1978 and 1979, we observed increases in the abundance of the predaceous cyclopoid Mesocyclops edax which we attributed to a combination of changes in planktivorous fish and algal standing stocks. In 1981, the copepod was observed in low numbers (10/m^2) in September, October, and November. The species was sporadic in occurrence and tended to occur in the deeper (>20 m) regions of the survey grid. These data suggest that Mesocyclops edax is not exhibiting a consistent trend of population increase.

Daphnia pulex, a cladoceran, first was observed in the survey area in 1978 and 1979. The species continues to be observed, although in low numbers. Two new Daphnia species occurrences have been noted. Beginning in 1978, we encountered low numbers of Daphnia spp. which were not any of the three species (D. galeata mendotae, D.longiremis, D. retrocurva) previously observed in the study area. In 1981, we collected a sufficient number of specimens to identify these Daphnia as members of D. schodleri. In 1980 and 1981, specimens were collected primarily in the autumn. Independent zooplankton collections made in 1982 (April to November) at a station 20 km offshore of Grand Haven confirm that D. schodleri has recently become an important component of the Daphnia community in offshore waters (100 m) of southeastern Lake Michigan. A second new species to be recognized in the Cook study area is D. catawba. This species was collected in December (intake sampling) and, unlike *D. pulex* and *D. schodleri*, probably occurs only incidentally in the plankton. *Daphnia parvula*, a species first observed in May 1979, was observed in a few intake samples in September 1978. Its occurrence in lake collections probably is incidental as well.

General Features of Statistical Comparisons between Preoperational and Operational Abundances

Statistical comparisons of zooplankton abundances in the preoperational and operational time periods have been based on non-parametric statistical analyses of the eight zones comprising the survey grid. Such analyses have shown and continue to to show that zooplankton abundances in the vicinity of the power plant are statistically different between the two time periods. Since zooplankton abundances in control zones located to north and south of the inshore and offshore plume zones (Fig. 1) show similar trends, we conclude that such preoperational-operational differences probably are not directly due to power plant operation.

In order to investigate long-term changes in zooplankton populations in the survey area, particularly in the inshore region (<10 m), we conducted analyses to determine whether or not the three zones comprising the inshore region were statistically different in terms of the abundances of the major taxa in April, July, and in October. A two-way (Year x Zone) analysis of variance was performed for each of the taxa of interest in a given major survey month: a fixed-effects model was used. Such analyses were performed for the preoperational and for the operational period using log-transformed data (density + 1). A third series of analyses were performed for the entire study period.

For April analyses, both year and zone were statistically significant ($\alpha=0.05$) main effects for most taxa, indicating that zooplankton densities varied significantly among the three zones and among years. However, variance due to years generally was substantially larger than variance due to spatial effects. In addition, the interaction term generally was not statistically significant and accounted for a small component of the total variance. Similiar results were obtained for July analyses. In July and in April, zone differences were detected more frequently in the preoperational than in the operational period. Dredging in the vicinity of the power plant may have been an important factor contributing to this observation. In October, significant differences in the three zones were confined to the operational period (either alone or in combination with the preoperational data set).

Overall, these analyses show that zooplankton vary in abundance both between the three inshore zones and between years. We are in the process of investigating what factors may produce zone differences in zooplankton abundance. However, it is important to note that these zones were not derived on the basis of ecological differences in the region but on the basis of proximity to the plant. Differences may be related to water mass movement through the area, localized events such as upwellings and stream inflow, and small differences in station depth.

A second point is that while zooplankton vary in abundance between zones, such variation is less than the variation in zooplankton abundance between years for a given cruise month. Since we are interested in investigating long-term changes in zooplankton populations in the nearshore region of southeastern Lake Michigan, such small spatial differences are of less concern. By including all stations between the 5-m and 10-m depth contours in various time series analyses, we have a more powerful capability to investigate causal factors. We are in the process of investigating the possible interactions between zooplankton abundances and the abundances of various phytoplankton taxa and fish species. Some of these preliminary analyses are discussed later in this report.

In this section, we report the results of the Mann-Whitney U tests of taxa abundances by major survey cruise and for each of the eight zones. In addition, we report the results of combining the three inshore zones (Fig 1: zones 1 to 3) and then using the parametric Student's t-test to determine whether or not zooplankton populations within the 10-m depth contour differ between the preoperational and operational period.

Statistical Comparisons of July Preoperational with Operational (1975 to 1981) Abundances

Thirteen taxa were examined for preoperational-operational differences in each of the eight zones of the survey grid. All taxa, with the exception of *Eurytemora affinis*, exhibited statistically significant (α=0.05) differences between preoperational and operational periods in at least one of the eight zones (Table 1).

Total zooplankton mean densities generally were statistically similar for the preoperational and operational periods (Fig. 2). The one exception was the outer offshore zone (zone 8) where operational densities were approximately half those observed in the preoperational period.

Table 1. Results of the Mann-Whitney U tests comparing July preoperational and operational densities of thirteen zooplankton taxa in each of eight zones. The preoperational period is 1971-74 or a subset ending in 1974, and the operational period is 1975-81. In column 1, results shown are from student's t-test analysis ($p < 0.05$) of the 3 inshore zones combined.

Taxon	Zone									Period
Order and Suborder Level	1-3	1	2	3	4	5	6	7	8	
Cladocerans	NS	NS	NS	NS	NS	NS	NS	NS	*	71-81
Copepod nauplii	NS	*	NS	NS	NS	NS	NS	NS	NS	72-81
Cyclopoids (C1-C6)	NS	NS	*	NS	NS	NS	NS	NS	*	71-81
Calanoids (C1-C6)	*	NS	*	NS	NS	NS	NS	NS	NS	71-81
Genus, *species*, *or developmental stage*										
Bosmina longirostris	NS	NS	NS	NS	NS	NS	NS	NS	*	72-81
Daphnia spp.	*	*	*	*	*	*	*	*	*	71-81
Cyclopoids (C1-C5)	NS	NS	*	NS	NS	NS	NS	NS	NS	73-81
Cyclops spp. C6	*	NS	*	NS	NS	NS	NS	NS	*	73-81
Diaptomus spp. (C1-C5)	*	NS	*	*	NS	NS	NS	NS	NS	73-81
Diaptomus spp. C6	*	NS	*	*	*	*	NS	NS	NS	73-81
Eurytemora affinis (C1-C6)	NS	NS	NS	NS	NS	NS	NS	NS	NS	73-81
Asplanchna spp.	*	NS	*	*	NS	*	*	*	NS	71-81
Total zooplankton	NS	NS	NS	NS	NS	NS	NS	NS	*	72-81

*significant difference, $\alpha = 0.05$.
NS not significant.

Among the crustaceans, nauplii densities (Fig. 2) were significantly (α=0.05) higher in the operational period than in the preoperational period only in zone 1, the southern inshore control zone. Operational densities were three times preoperational densities. Elsewhere, nauplii tended to be less abundant in the operational period than in the preoperational period, although such differences were not statistically significant.

Immature copepodites showed no consistent trends in change throughout the survey area (Fig. 2). Decreases in abundance occurred in approximately half of the zones of the survey grid. Only one contrast was statistically (α=0.05) significant: this occurred in the inshore plume zone 2. Statistically significant operational decreases (by a factor of about two) in abundance of Cyclops spp. adults (primarily C. bicuspidatus thomasi) were observed in the inshore plume zone (zone 2) and the outer offshore zone (zone 8). All other zone abundances generally were similar between the two time periods.

Immature Diaptomus spp. copepodites (Fig. 2) were less abundant in the operational period than in the preoperational period in seven of the eight survey area zones. The outer offshore zone was the only exception. Of these decreases, declines were statistically significant (α=0.05) only in the plume and northern inshore zones. In both of these zones, immature diaptomids were approximately half as abundant in the operational period as in the preoperational period. A similar trend was observed for Diaptomus spp. adults. Adults were significantly (α=0.05) less abundant in the operational period than in the preoperational period in the inshore plume and northern zones (by a factor of two to three), and in the middle plume and southern zones (by a factor of less

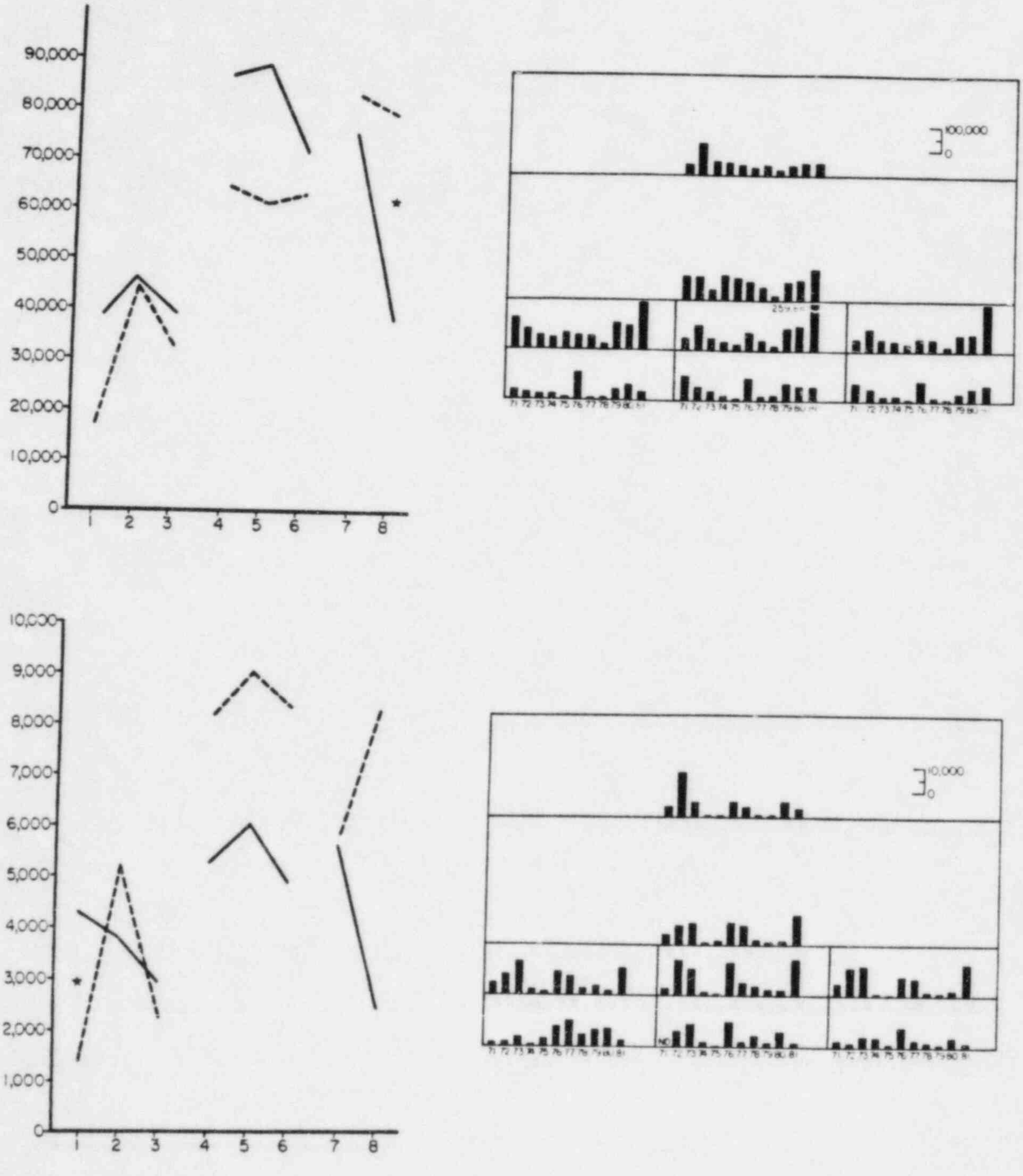

Figure 2. The mean densities of zooplankton taxa in July of each year, 1971-1981, are given in the histograms. The mean preoperative and operative period (dashed and solid lines, respectively) densities are plotted for each zone. Lines connect zones in the same depth grouping, inshore, middle, and inner and outer offshore zones. Stars indicate zones with significantly different preoperative and operative densities (Mann-Whitney U test $\alpha=0.05$). a) total zooplankton, b) copepod nauplii.

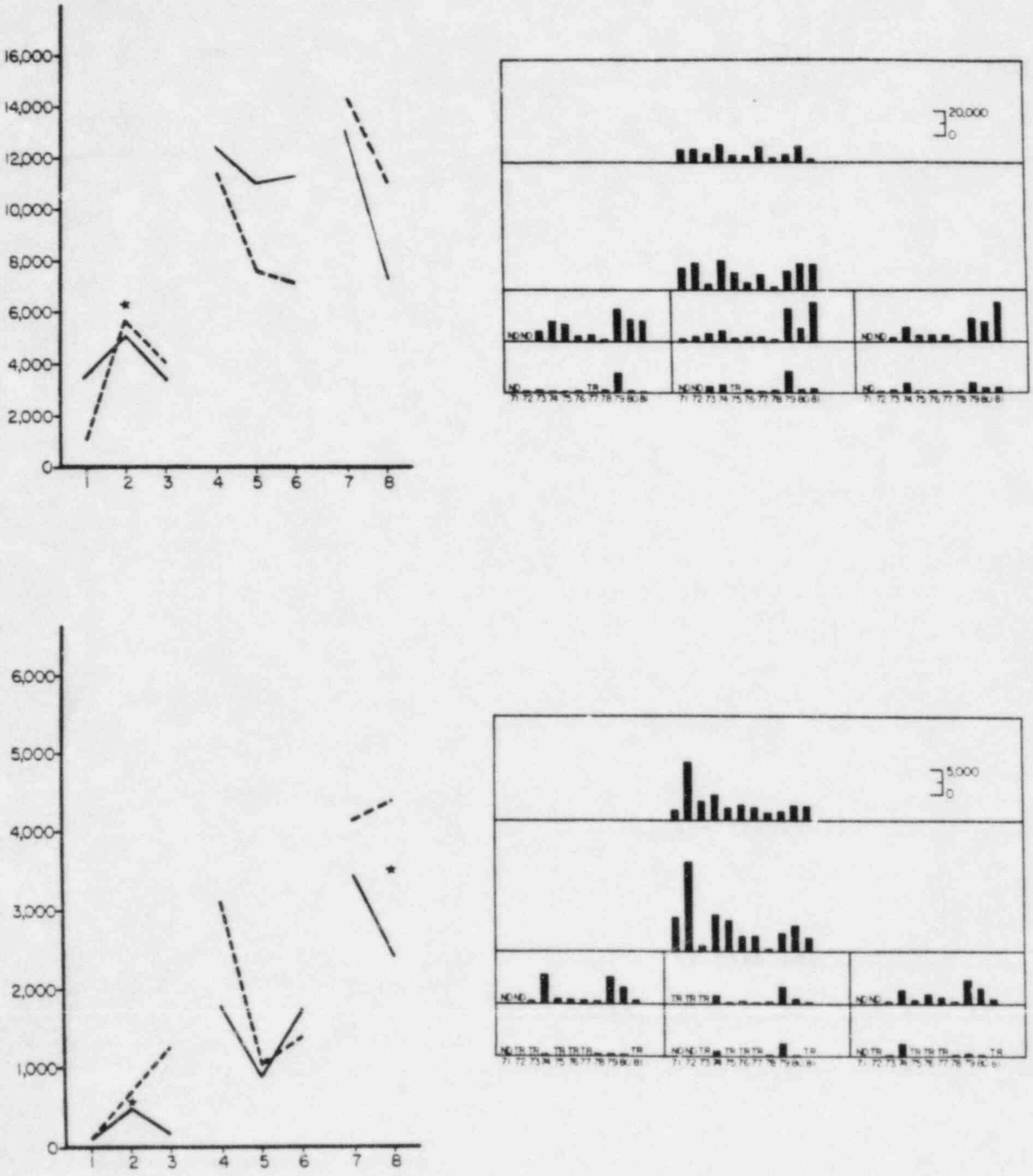

Figure 2 continued. c) immature cyclopoids, d) adult <u>Cyclops</u> spp.

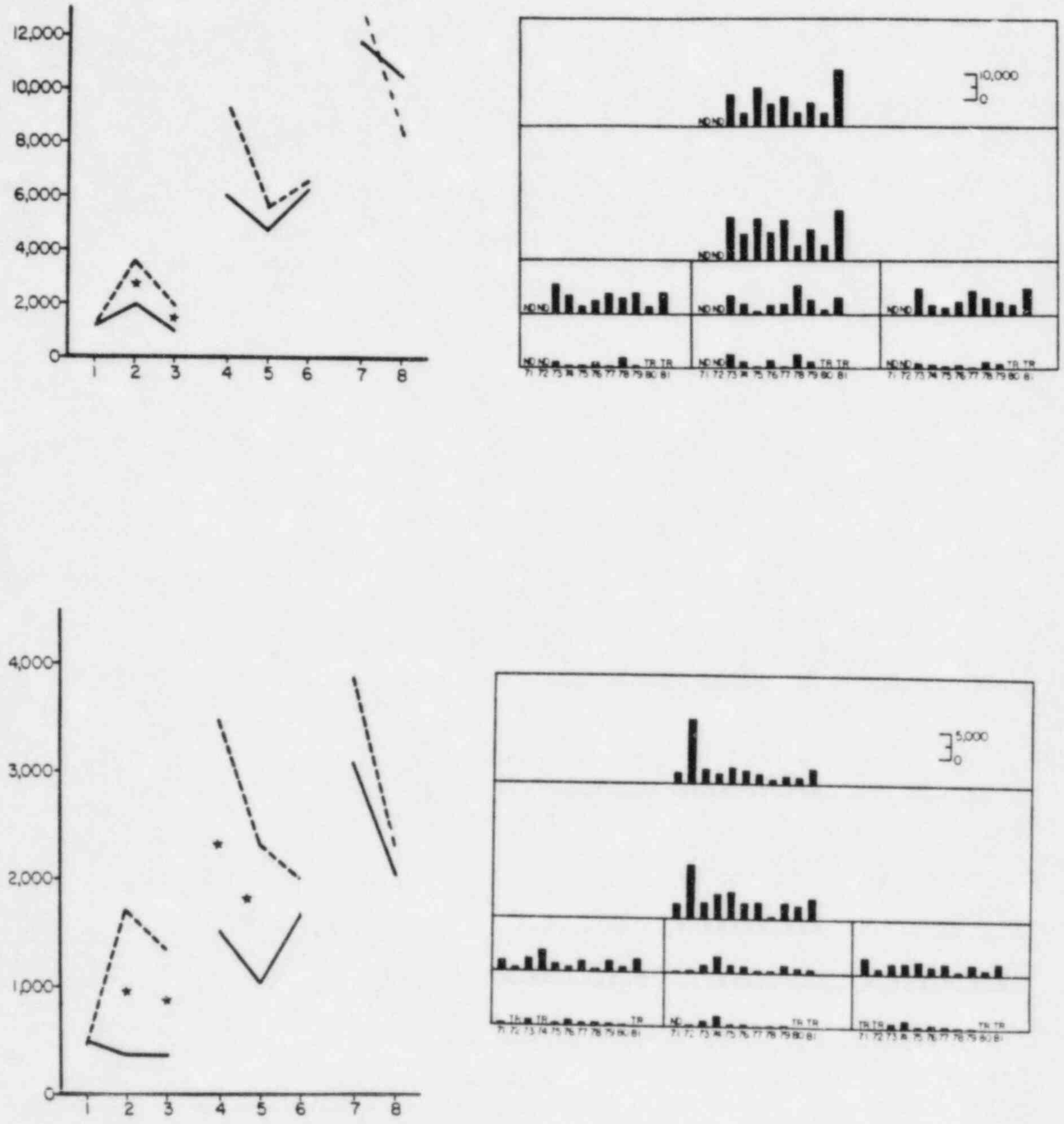

Figure 2 continued. e) adult <u>Diaptomus</u> spp., f) immature <u>Diaptomus</u> spp.

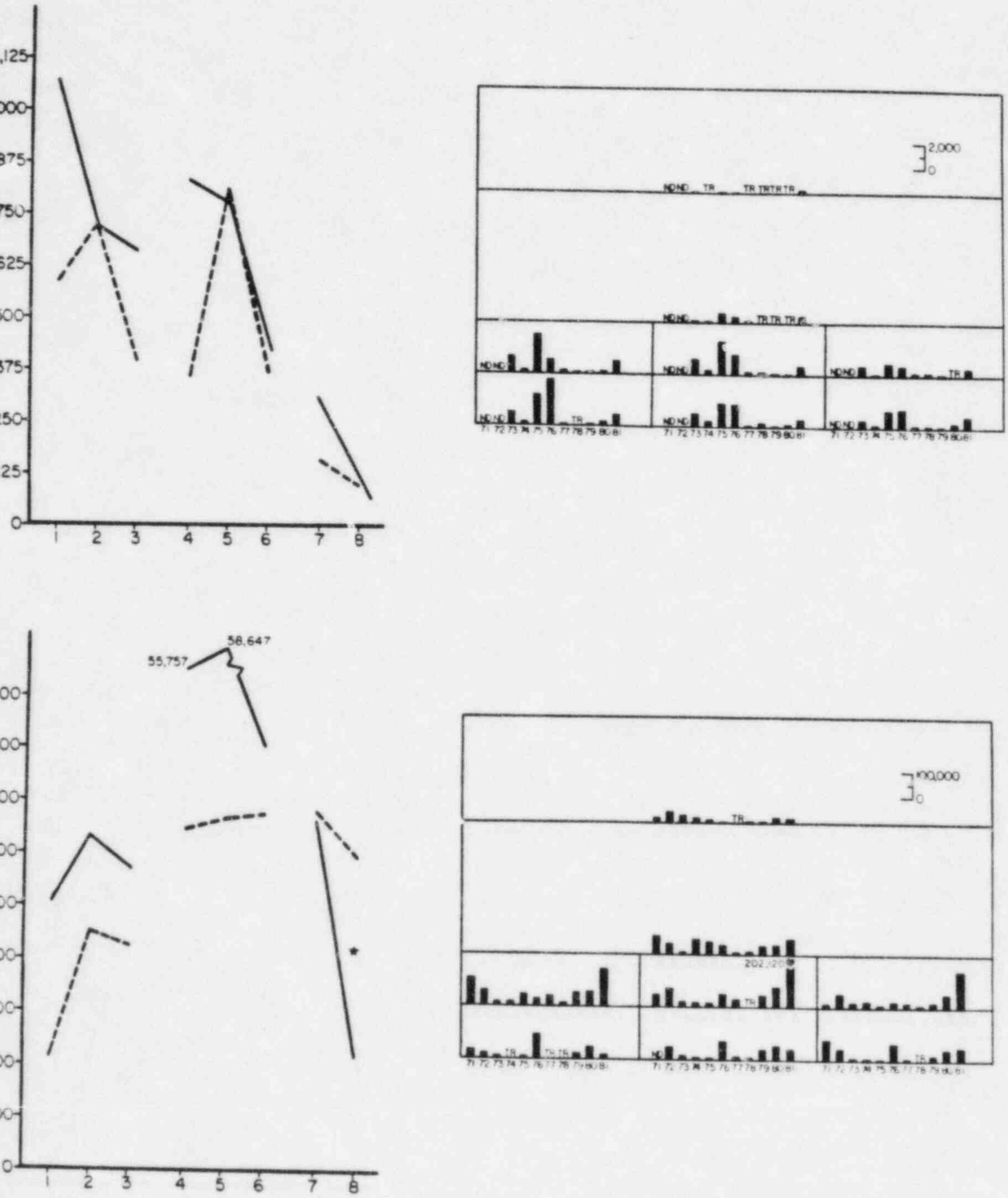

Figure 2 continued. g) Eurytemora affinis, h) Bosmira longirostris

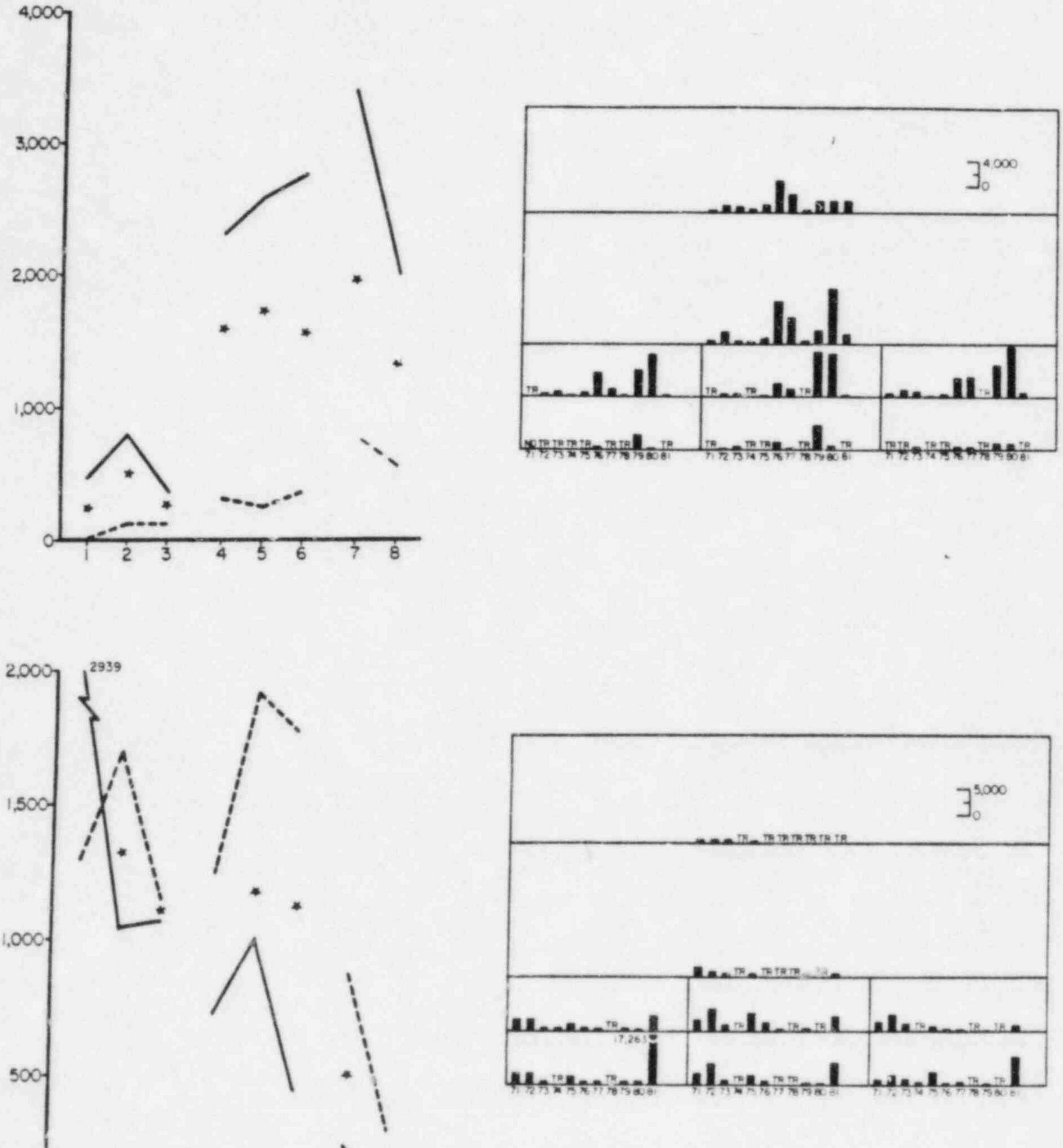

Figure 2 continued. i) Daphnia spp., j) Asplanchna spp.

than one).

Bosmina longirostris, the major cladoceran species of the July zooplankton assemblage, tended to be more abundant (by a factor of less than one) in the operational period than in the preoperational period in most zones of the survey grid: exceptions were the inshore northern zone and the inner and outer offshore zones (Fig. 2). Differences were statistically significant (α=0.05) only in the outer offshore zone (Table 1) where preoperational densities were approximately three times greater than operational densities.

Daphnia spp., the second most abundant cladoceran taxon, occurred in significantly (α=0.05) higher densities in the operational period (Fig. 2) than in the preoperational period in all eight zones of the survey grid. Differences were large, ranging from a factor of about four to more than twenty.

The only rotifer taxon analyzed was the predaceous Asplanchna. With the exception of the southern inshore zone, abundances were less in the operational period than in the preoperational period (Fig. 2). Statistically significant (α=0.05) differences were detected in the inshore plume and northern zones, the middle plume and northern zones, and in the outer offshore zone. Differences in abundance ranged from a factor of less than one to nearly four.

Results of the parametric Student's t-test using the combined inshore zone (zones 1, 2, and 3) data confirmed the results (Table 1) of the non-parametric analyses by individual zone. Calanoid copepods (immature and adult Diaptomus spp. copepodites) and adult Cyclops spp. were significantly (α=0.05) less abundant in the operational period, while Daphnia spp. were more abundant. Higher operational Asplanchna abundances were due to extremely high 1981 concentrations in zone 1. These combined analyses further suggest that the entire study area between the 5-m and 10-m depth contours differs in the abundance of the numerically dominant taxa between the preoperational and operational periods. This provides further circumstantial evidence that preoperational versus operational differences in zooplankton abundance in the inshore plume zone (zone 2) were most strongly related to wide-scale events and were not a direct result of power plant activity. Since similar preoperational versus operational zone mean differences were observed in at least one of the control zones in addition to the plume zone, there is no strong evidence that power plant activity has had a significant (i.e. detectable) effect on July zooplankton populations occurring in the thermal discharge area.

Statistical Comparison of October Preoperational with Operational (1975-1981) Abundances

A total of twelve taxa were analyzed for preoperational and operational density differences (Table 2). Nine of the twelve taxa examined exhibited statistically (α=0.05) significant differences between preoperational and operational zone mean densities. Only immature and adult Diaptomus spp. copepodites and cladocerans exhibited similar preoperational and operational densities. However, at the genus level, cladocerans did vary significantly in abundance between the two time periods.

Total zooplankton were more abundant (by less than a factor of two) in the operational period than in the preoperational period with the exception of the outer offshore zone (Fig. 3). Such differences were statistically significant only for the northern middle zone (zone 6).

Nauplii were up to twice as abundant in the operational period (Fig. 3) than in the preoperational period. However, differences were statistically significant only for the inshore plume zone, the middle plume and middle northern zones, and the inner offshore zone. Similar magnitudes of change were observed in plume and control zones.

Although immature *Cyclops* spp. copepodites were less abundant in October 1981 than in previous operational years (Fig. 3), operational zone means (1975-1981) were greater than preoperational: differences were less than a factor of two. Statistically significant (α=0.05) differences were detected in the southern and plume middle zones (Table 2). *Cyclops bicuspidatus thomasi* adults were less abundant in the operational period (by less than a factor of two) with the exception of the northern inshore zone. However, it was only in the inshore plume zone that these differences were statistically significant.

The cladoceran *Bosmina longirostris* occurred in higher densities (by factors ranging from less than one to more than three) in the operational than in the preoperational period (Fig. 3). Differences were statistically significant in the inshore plume zone, the middle plume and northern zones, and the inner offshore zone (Table 2). Despite such preoperational-operational differences, *B. longirostris* abundances in 1981 were lower than in other operational years.

Daphnia spp. occurred in relatively low densities (Fig. 3) in 1981. With the exception of the northern middle zone and the inner offshore zone, densities were lower (generally less than a factor of two) in the operational period than in the preoperational period. Differences were statistically significant (α=0.05) only for the inshore plume and

Table 2. Results of the Mann-Whitney U tests comparing October preoperational and operational densities of twelve zooplankton taxa in each of eight zones. The preoperational period is 1972-74 or a subset ending in 1974, and the operational period is 1975-81. Stations in zone 8 were not sampled in 1975 or 1976 (see text). In column 1, results shown are from student's t-test analysis ($p < 0.05$) of the 3 inshore zones combined.

Taxon	Zone									Period
Order and Suborder Level	1-3	1	2	3	4	5	6	7	8	
Cladocerans	NS	NS	NS	NS	NS	NS	NS	NS	NS	72-81
Copepod nauplii	*	NS	*	NS	NS	*	*	*	NS	72-81
Cyclopoids (C1-C6)	NS	NS	NS	NS	NS	*	NS	NS	NS	72-81
Calanoids (C1-C6)	*	*	NS	NS	NS	NS	NS	NS	NS	72-81
Genus, species, or developmental stage										
Bosmina longirostris	*	NS	*	NS	NS	*	*	*	NS	72-81
Eubosmina coregoni	*	NS	*	NS	NS	NS	NS	NS	*	72-81
Daphnia spp.	*	NS	*	*	NS	*	NS	NS	NS	72-81
Cyclopoids (C1-C5)	*	NS	NS	NS	*	*	NS	NS	NS	73-81
Cyclops spp. C6	*	NS	*	NS	NS	NS	NS	NS	NS	73-81
Diaptomus spp. (C1-C5)	NS	NS	NS	NS	NS	NS	NS	NS	NS	73-81
Diaptomus spp. C6	NS	NS	NS	NS	NS	NS	NS	NS	NS	73-81
Total zooplankton	*	NS	NS	NS	NS	NS	*	NS	NS	72-81

*significant difference, $\alpha = 0.05$.
NS not significant.

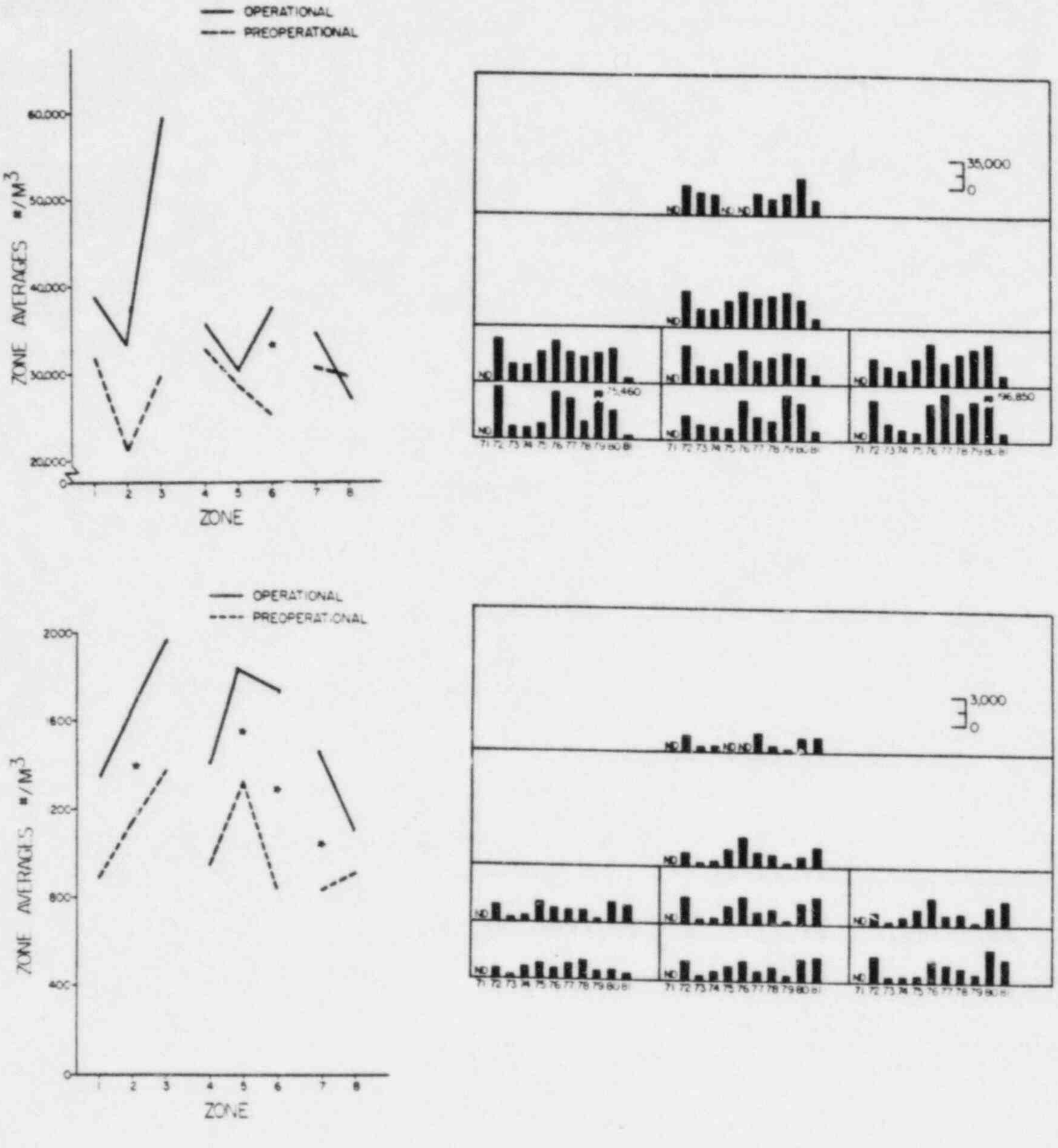

Figure 3. The mean densities of zooplankton taxa in October of each year, 1971-1981, are given in the histograms. The mean preoperative and operative period (dashed and solid lines, respectively) densities are plotted for each zone. Lines connect zones in the same depth grouping, inshore, id dle, and inner and outer offshore zones. Stars indicate zones with significantly different preoperative and operative densities (Mann-Whitney U tests $\alpha=0.05$). a) total zooplankton, b) copepod nauplii

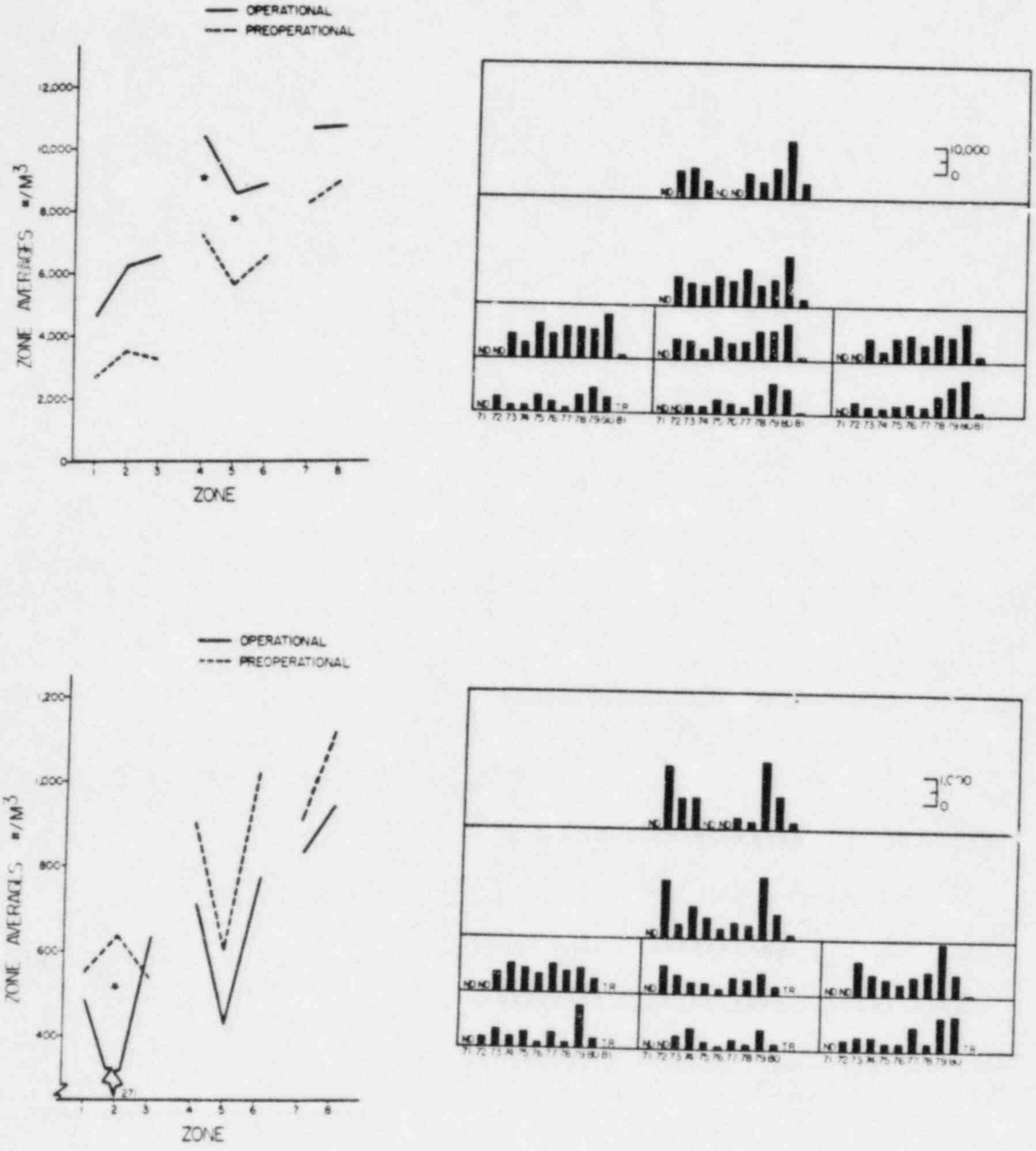

Figure 3 continued. c) immature cyclopoids, d) adult _Cyclops_ spp.

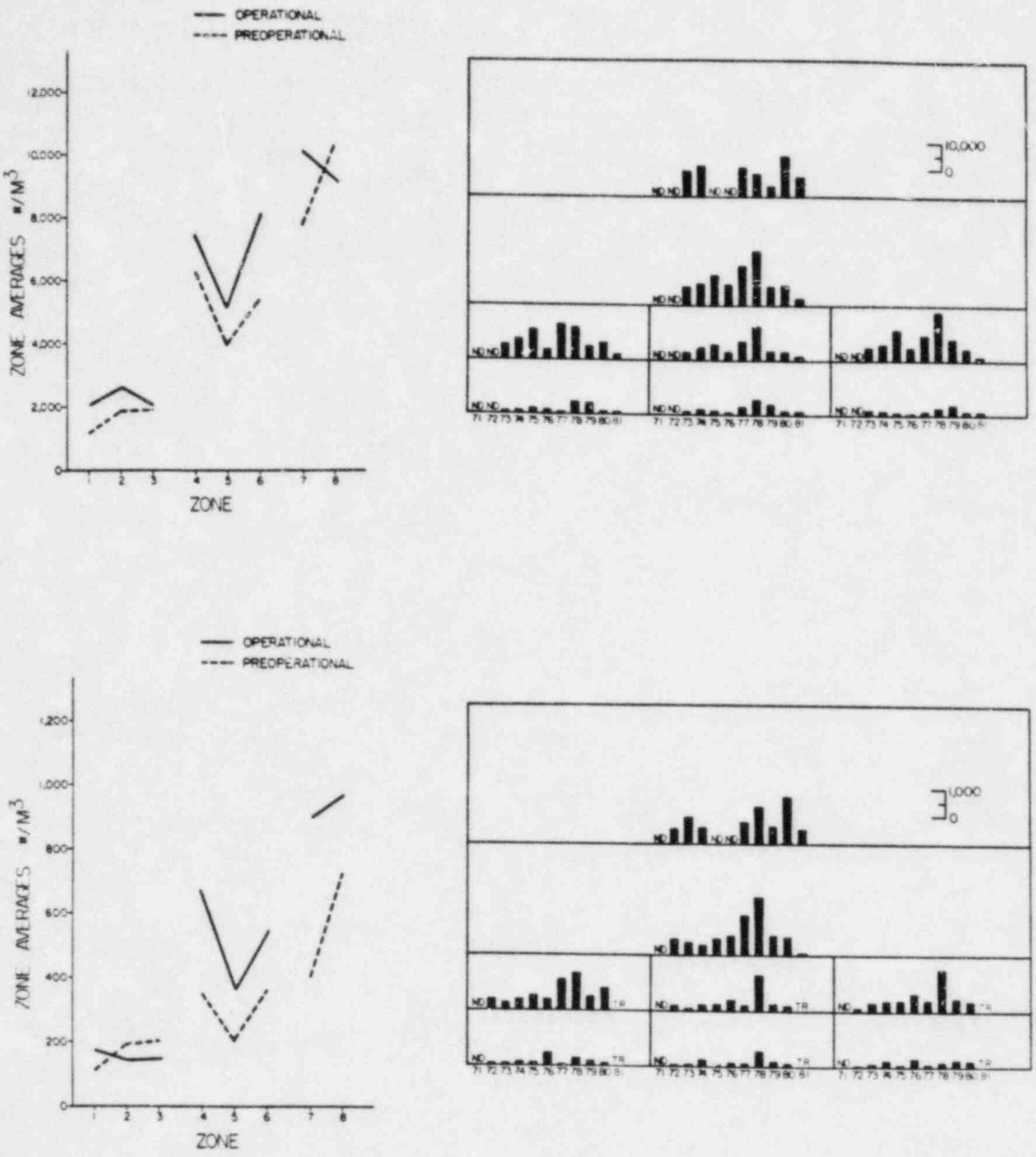

Figure 3 continued. e) immature Diaptomus spp., f) adult Diaptomus spp.

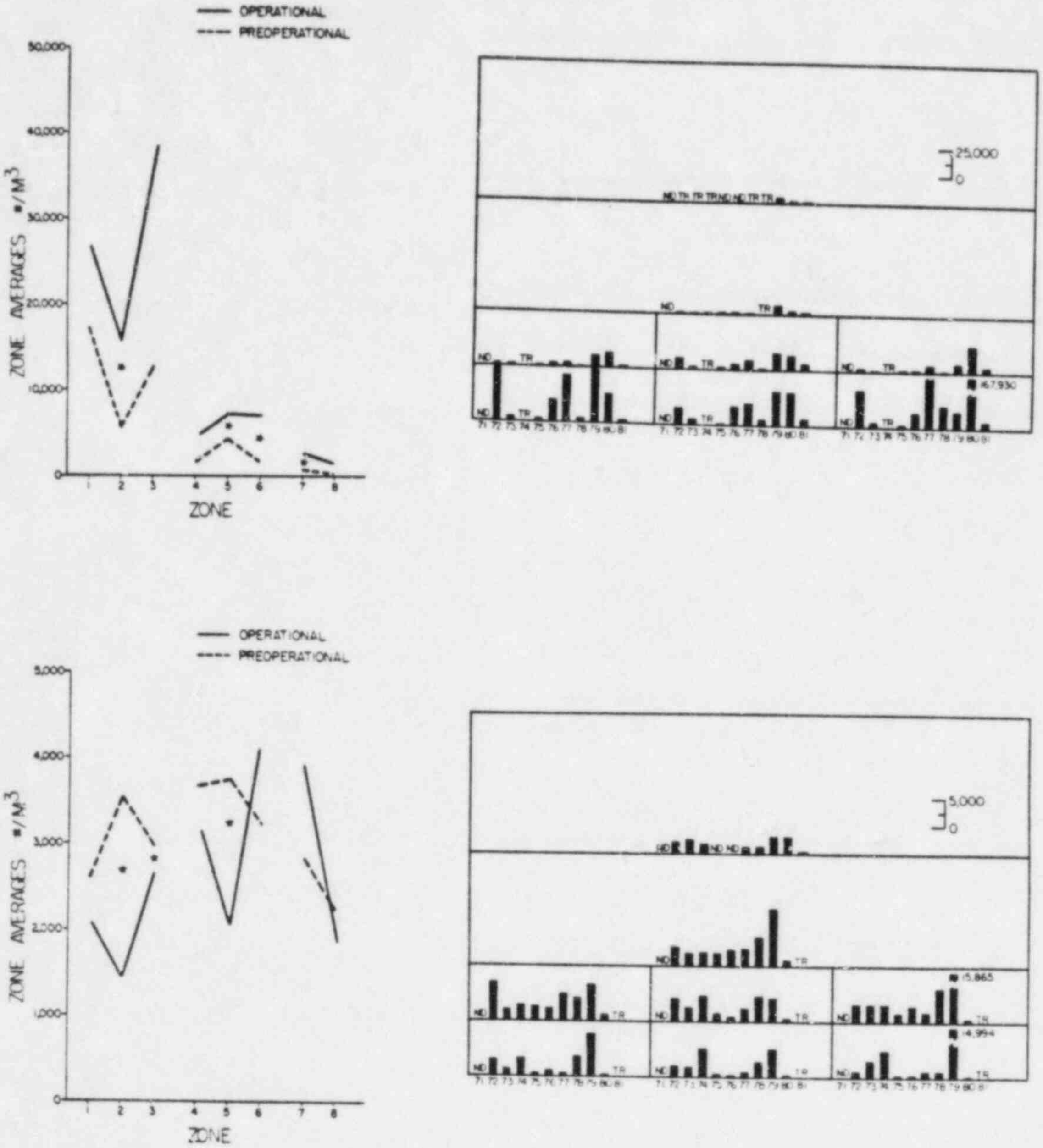

Figure 3 continued. g) *Bosmina longirostris*, h) *Daphnia* spp.

northern zones (Table 2) with the greatest magnitude of change occurring in the plume zone.

With the exceptions of the northern inshore zone, the southern middle zone, and the outer offshore zone, Eubosmina coregoni was more abundant in the operational period than in the preoperational period (Fig. 3). Differences were statistically significant for the three inshore zones, the middle plume zone, and the outer offshore zone. Preoperational versus operational differences in zone mean concentrations in the two plume zones were similar in magnitude to those observed in at least one control zone.

Analysis of the combined inshore zones (Table 3) confirms that the numerically dominant zooplankton taxa differ in preoperational and operational mean concentrations. Calanoid copepods, nauplii, immature Cyclops spp. copepodites, Bosmina longirostris, Eubosmina coregoni, and total zooplankton tended to be more abundant in the operational period while adult Cyclops spp. and Daphnia spp. were less abundant in the operational period. Such differences further support the hypothesis that the inshore region of southeastern Lake Michigan has undergone change over the last several years and thus contributes to preoperational versus operational differences observed in zooplankton densities in the plume zone.

Seasonal Cycles of Zooplankton in the Inshore Plume Zone (Zone 2)

Seasonal cycles of zooplankton abundances in the inshore plume zone (Fig. 4) generally were similar in the preoperational and operational periods. Total zooplankton occurred in low numbers in the spring, increased in abundance through the summer, and declined over the late autumn and winter.

Copepod nauplii, cyclopoid copepodites, immature calanoid copepodites, adult Diaptomus spp., and Eurytemora affinis exhibited similar preoperational and operational seasonal cycles with plant operation apparently neither advancing nor retarding developmental cycles (Fig. 4). Cladocerans (Bosmina longirostris, Eubosmina coregoni, and Daphnia spp.) exhibited similar cycles in the preoperational and operational periods as did the rotifer Asplanchna.

We have been conducting an extensive series of analyses to investigate time series trends in zooplankton populations in the inshore region. While these analyses are still being conducted, results to date indicate that the entire inshore region, i.e. zones 1, 2, and 3, can be combined to investigate long-term trends. At present, because the field survey program does not include the entire twelve month period of each year, such analyses are being based on the entrainment data. The results of these preliminary analyses are presented in the entrainment section.

Sampling and Subsampling Studies

As discussed in the last Environmental Operating Report, we have been conducting studies to investigate the accuracy and precision of our field and laboratory programs. One such study consisted of the statistical analysis of subsampling and an evaluation of the Folsom plankton splitter. This study recently has been published (Sell and Evans 1982) in Hydrobiologia. As reported before, we concluded that while the Folsom plankton splitter does not always provide truly random samples, departures from randomness are such that it is necessary to

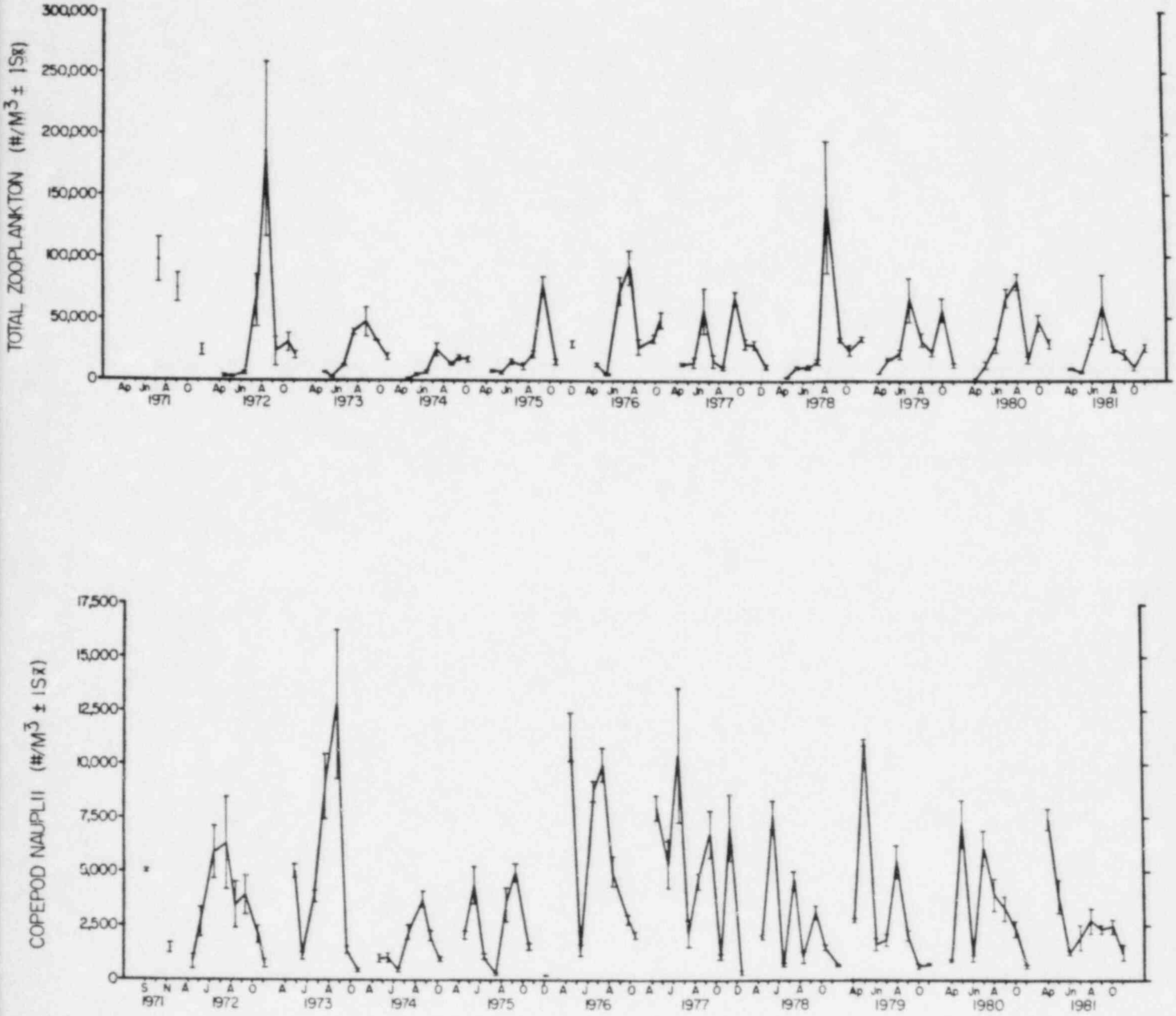

Figure 4. The monthly abundance of zooplankton in the inshore plume zone (zone 2) between 1971 and December 1981. a) total zooplankton, b) copepod nauplii

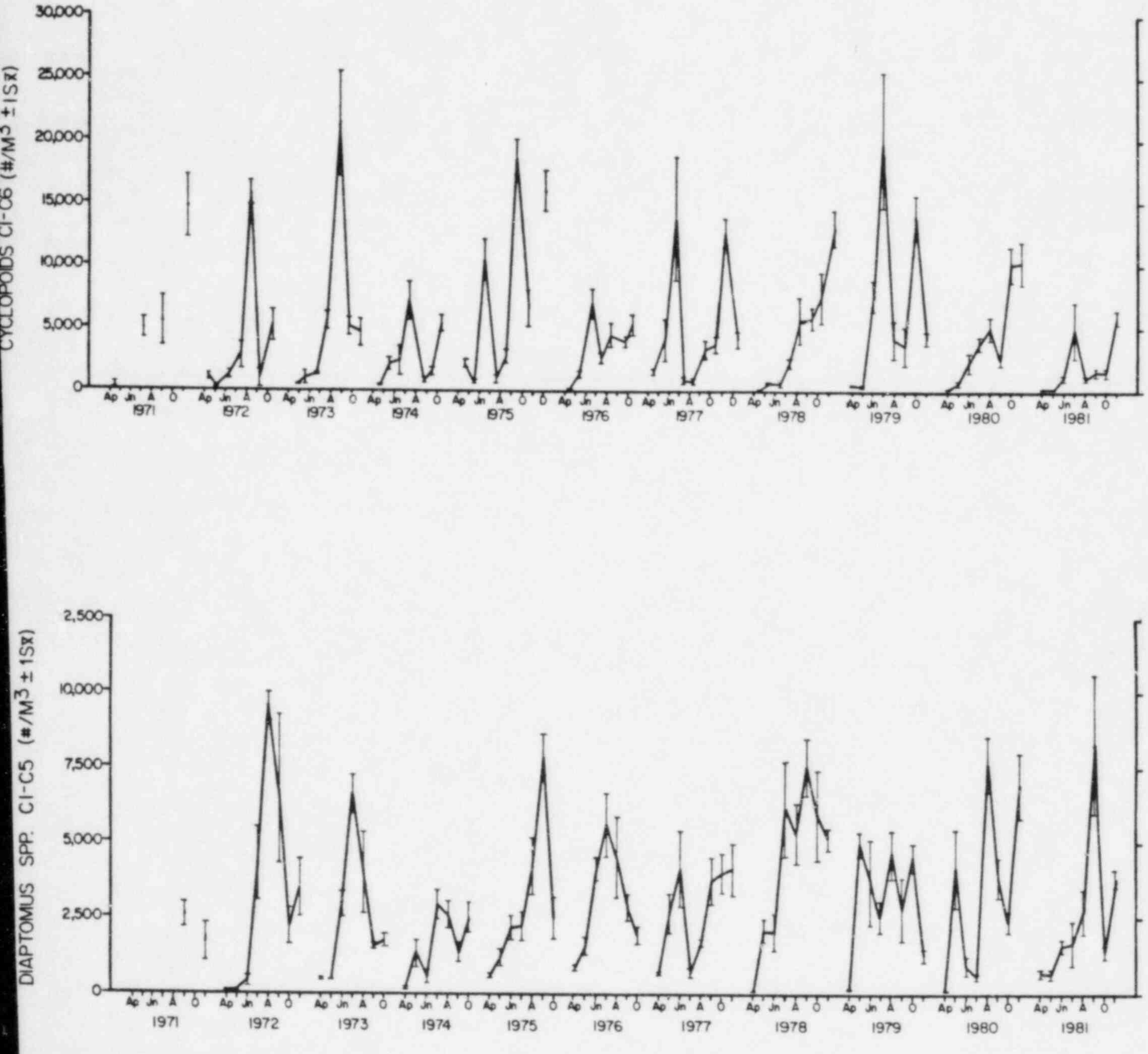

Figure 4 continued. c) cyclopoids, d) immature calanoids

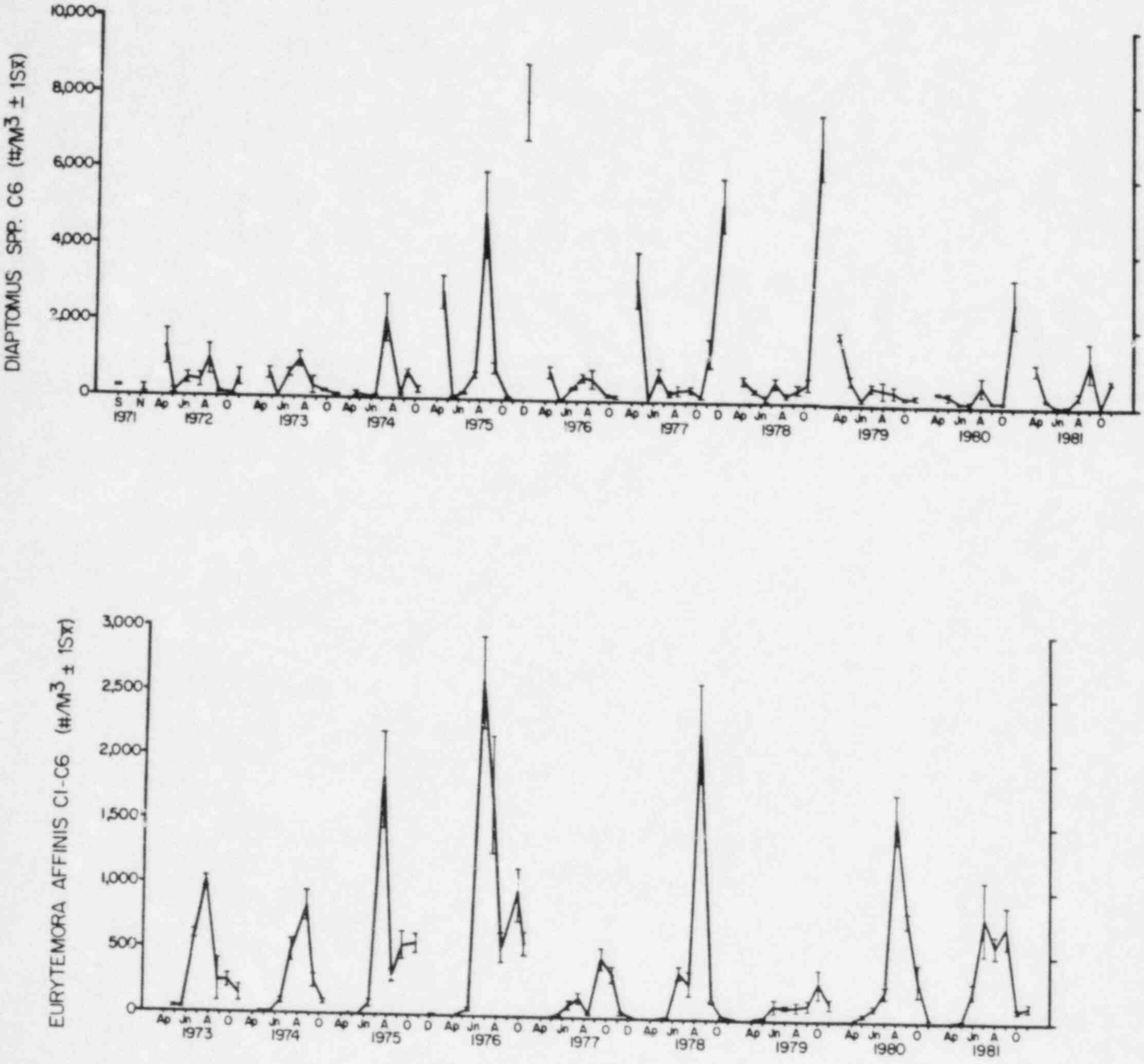

Figure 4 continued. e) adult <u>Diaptomus</u> spp., f) <u>Eurytemora</u> <u>affinis</u>

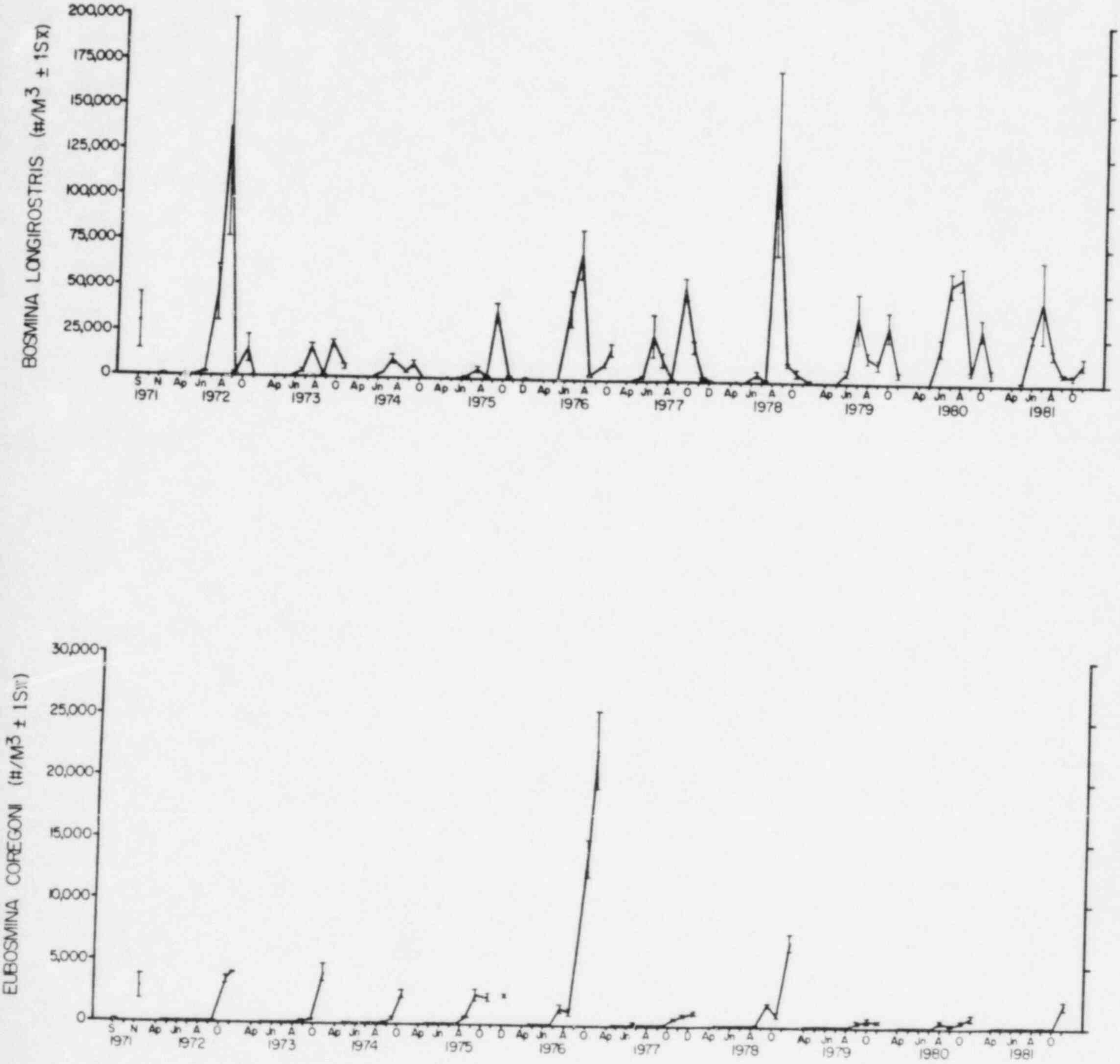

Figure 4 continued. g) Bosmina longirostris, h) Eubosmina coregoni

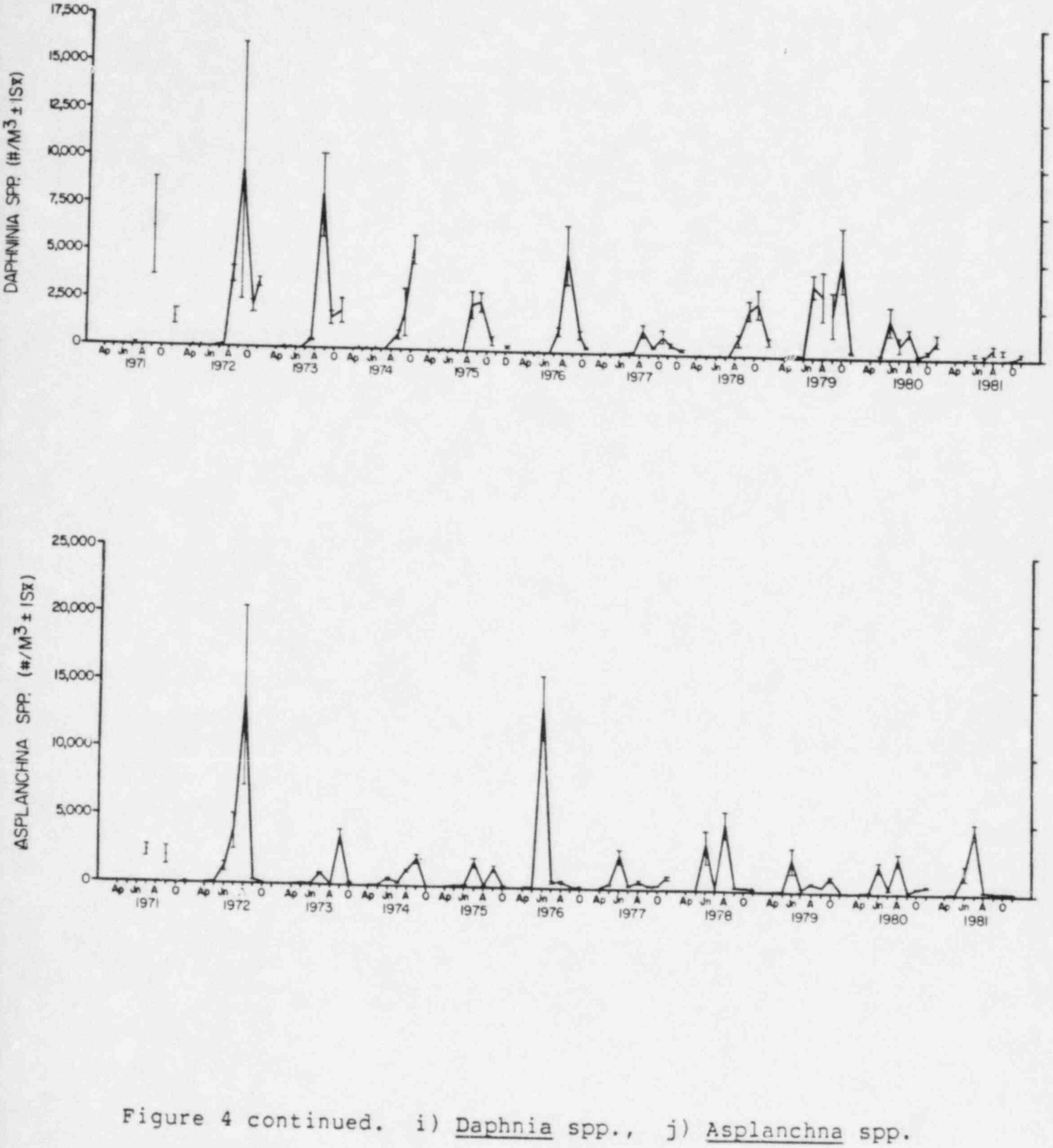

Figure 4 continued. i) Daphnia spp., j) Asplanchna spp.

analyze only one to three samples to obtain our desired level of precision. Furthermore, variation between replicate net hauls was larger than variation between subsamples: this was observed both for the number 10 net (156 μm) routinely used in our study and the finer number 20 net (76 μm). An allocation procedure was employed to estimate the most effective sampling and subsampling scheme depending on the relative magnitude of variances due to subsampling and sampling and relative costs. For our data set, the desired range of subsamples to be examined per sample is from one to three. Overall, our analyses have suggested that current sampling and subsampling procedures are cost effective (Sell and Evans 1982).

We also have conducted a second study examining zooplankton sampling strategies for environmental studies. The results of this study will be published early in 1983 (Evans and Sell, in press).

The goals of this study were several. First, we were interested in determining the contribution of time, space, and the time-space interaction to zooplankton abundance estimates in the inshore region. Secondly, given particular sources of variation, we were interested in determining the sensitivity of various sampling programs (or statistical approaches) to detect various shifts in the population mean. Finally, we were interested in investigating how our sampling program might be improved to increase its sensitivity to detect temporal and spatial alterations in zooplankton abundance.

Our studies showed that the largest source of variance is associated with time factors, particularly seasonal events. Conversely, variation due to sampling and subsampling is relatively small. The mean coefficient of variation for subsampling is 6.1 %, for replicate sampling is 15.1 %, while the mean coefficient of variation between stations on a given cruise is 39.0 %. For a given station and year, the mean coefficient between years (eg. station DC-1 in July for the 1975 to 1981 period) is 73.4 %. For a single station in a given cruise season, the between-month (eg April to November, 1978) coefficient of variation averages 95.1 %. Since the ability to detect differences in population means (plume zone versus control in a given month or preoperational versus operational for a given zone) is a function of the inherent variability of the data set (in addition to sample size), spatial differences in population means are more readily detected than temporal differences in population means.

We concluded that, with a mean between-station coefficient of variation of about 40 % and with approximately five stations in the plume region and five in the control regions (major survey cruises), our study is sensitive enough to detect a 100 % to 150 % change in population means: smaller differences are below our detection limits. As we have reported previously (Evans et al. 1982), we believe that the true loss of zooplankton in the vicinity of the plant is less than 10 %, a loss now shown to be below detection limits.

We also concluded that for a given month, with a between-year coefficient of variation of about 70 %, four years of preoperational and four years of operational sampling, our study is sensitive enough to detect a population shift of about 150 % between the two time periods. This has been substantiated in our preoperational versus operational comparisons where most significant differences have been at least by a factor of two. Smaller differences which have been noted were not of statistical significance.

We also concluded that we are employing the most efficient approach to detect spatial and temporal alterations resulting from power plant activity. Spatial alterations are most efficiently detected by considering data on a cruise by cruise basis while temporal events are most efficiently examined by considering differences in population means for a given month across years. The current combination of major survey cruises (providing information on spatial distributions) and short survey cruises (providing information on temporal events) is ideal. Since spatial variability accounts for less variance than temporal and because the goal is the detection of temporal trends, sampling effort is best expended in frequent temporal sampling rather than in intensive spatial sampling. In order to obtain more precise information on temporal trends, sampling should be conducted more frequently within a year because the seasonal component of variability is relatively large. As is discussed in the entrainment section, intake sampling represents an effective way for obtaining such detailed information. Such a conclusion is not surprising. Many of the studies reporting long-term changes in phytoplankton populations have been based on intake sampling (Damann 1960; Davis 1964; Nicholls *et al*. 1977; Danforth and Ginsburg 1980). To our knowledge, ours is the first study to demonstrate the effectiveness of intake sampling for monitoring long-term changes in zooplankton populations.

Epibenthic and Benthic Microcrustacean Study

In our last Environmental Operating Report, we discussed the results of a July 1980 study investigating the distribution of epibenthic and benthic microcrustaceans in the vicinity of the power plant. This study was similar to a study conducted in 1974 (Evans and Stewart 1977). While we have not completed all stages of the July 1980 study it is appropiate at this time to provide an update of the progress of this investigation.

This study was conducted to investigate whether or not plant operation produced localized alterations in the abundances of epibenthic and benthic organisms. Of particular interest was the possibility that dead organisms settling from the plume provide an additional food source to the benthic community thus resulting in a localized increase in standing stock, particularly of detritivores.

Three basic statistical analyses were performed. First, we were interested in determining whether or not benthic and epibenthic organisms were more abundant in sediment troughs, where organic matter is assumed to accumulate (see Dorr for direct observations), than in crests. Secondly, we were interested in determining whether or not taxa varied in abundance with water depth. Finally, we analyzed the data to determine if epibenthic and benthic taxa were more or less abundant in the plume zone than in control zones.

A number of taxa differed significantly in abundance between trough and crest samples. These included chironomids, Cyclops bicuspidatus thomasi, C. vernalis, Eucyclops agilis, E. prionophorus, Eurycercus lamellatus, Leydigia sp., Alona affinis, and Alona guttata. All species have strong benthic affinities. Taxa abundances were significantly (α=0.05) higher in sediment troughs than in crests.

Nineteen of the 79 taxa analyzed exhibited significant (α=0.05) differences in abundance with respect to depth. The depth region (2-6 m, 6-11 m, >11 m) of maximum abundance varied with the taxon.

Several taxa occurred in statistically significant (α=0.05) different densities in plume and control regions. Eurytemora affinis, Disparalona rostrata, chironomids, and total animals were more abundant in the plume zone than in the control zone. Conversely, Daphnia retrocurva, Alona guttata, and Pontoporeia hoyi were less abundant in the plume region.

In order to complete this study, we are in the process of determining organic carbon and nitrogen concentrations in a single sediment sample collected from each of the twenty-six stations. This will allow us to determine if organic matter varies in concentration as a function of depth or proximity to the power plant (but not between sediment troughs and crests).

As we concluded in our last Environmental Operating Report, this study continues to suggest that the power plant may exert subtle effects on the benthic and epibenthic community in the vicinity of the discharge jets. Certain taxa may occur in enhanced densities in regions impacted by the peripheral plume (where plume velocities and water temperatures are close to ambient). No evidence of gross disruptions in the epibenthic and benthic communities were detected which warrant environmental concern. Final laboratory analyses will be directed at investigating the probable factors producing localized alterations in populations.

Copepod Population Dynamics: Sex Ratios and Instar Analysis

To begin investigating why certain changes in zooplankton community structure have occurred in the study area, we have conducted a series of studies investigating copepod community structure. The last such study was conducted in the preoperational period and was reported by Stewart (1974).

As a first step, we have examined sex ratio data and absolute abundance data (based on intake and lake sampling) of the numerically dominant adult copepod species. Abundances and sex ratios were then correlated with water temperature, density of algae, chlorophyll concentration, and the abundances of various planktivorus fish species in order to investigate factors affecting the adult copepod population. Similar correlations were conducted for combined immature copepodites of the various genera of interest. These correlation analyses are providing us with information on the number of population pulses per year of the various taxa of interest. Preliminary analyses suggest that adult sex ratios are not strongly affected by food levels, predation, or water temperature. This is contrary to the results of studies reported in the literature. While such factors have an important effect on the abundance and sex ratios of adult copepods, more sophisticated statistical analyses may be required to separate out the synergistic or antagonistic effects of food availability, fish predation, and temperature.

Rotifer Studies

We have conducted a small study (May to November 1979, 5 to 7 stations per cruise) of rotifer community structure in the study area. Such a study was deemed essential because rotifers are a significant component of the zooplankton of all the Great Lakes. In highly eutrophic areas, abundances may exceed 1,000,000/m^3. Rotifers have relatively short life cycles (in comparison to crustaceans) and probably have more rapid responses to changes in environmental conditions. Historically, the zooplankton study has not included rotifer analyses, yet we feel it is essential to obtain an understanding of these organisms in the study area.

Rotifers ranged in abundance from a low of $1,386/m^3$ (DC-6, May) to a high of $325,614/m^3$ (DC-5, July). In the inshore region (DC-1, DC-2), abundances were high in May ($>180,000/m^3$), declined slightly in June, increased in July to ($170,000/m^3$) and then declined through the summer and autumn. In the offshore region (DC-5, DC-6), abundances were low in May ($5,500/m^3$) increased through June to reach a July maximum of $256,000/m^3$, and then declined through the summer and autumn. The soft-bodied rotifer *Synchaeta* spp. was numerically important in May while *Keratella cochlearis cochlearis*, *Kellicottia longispina*, *Conochilus unicornis*, and *Polyarthra vulgaris* were numerically important summer species. *Keratella cochlearis cochlearis* and *Polyarthra vulgaris* continued as important November species.

In terms of abundance and species composition, rotifer population characteristics were more similar to those of the eastern and central basins of Lake Erie, and Lake Ontario (Nauwerck 1978). These lakes are considered mesotrophic. Rotifer standing stocks were not as low as in the main body of Lake Huron (Evans, in press), a lake which has suffered less from nutrient loading over the last few decades (Patalas 1972). Low numbers of species considered indicators of eutrophic conditions (primarily *Brachionus*) were observed further suggesting that the study area is experiencing some impact (although not quantified as yet) from external nutrient loading.

These data were further analyzed by a Ph.D. graduate student who tested his laboratory hypotheses with our field data. This student has now graduated and is working on a manuscript of these results in collaboration with us. Essentially, Dr. Stemberger was interested in investigating the effects of cyclopoid predation on rotifer community structure. These analyses show that cyclopoids apparently have a significant controlling effect on rotifer community structure in the inshore region. Further analyses have determined that flagellate algae apparently have a significant effect on the abundance and fecundity of certain rotifer taxa. In addition, rotifer and cladoceran grazing appears to be a major factor accounting for the summer decline in flagellates. Alewives appear to have a significant effect on the abundance of cyclopoid copepods in the nearshore region in the summer. These studies, while not complete, are providing fruitful insight into some of the factors affecting zooplankton (in addition the phytoplankton and fish) community structure in the survey area. Such insight should allow us to determine what are the causal factors and pathways which have resulted in long-term changes in zooplankton populations in the study area.

SUMMARY

The results of the 1981 and 1982 studies are similar to those of previous years. Differences were observed between preoperational and operational abundances of the numerically dominant taxa in the immediate vicinity of the power plant (inshore plume zone, zone 2; middle plume zone, zone 5). Many of these differences were statistically significant at the $\alpha=0.05$ level. However, we do not interpret these differences as resulting from localized, direct, and environmentally significant effects of power plant activity. Our reasons are as follows:

(1) Operational versus preoperational differences in zooplankton zone mean abundances were not restricted to the inshore plume zone but occurred over most of the survey area.

(2) Magnitudes of change similar to those observed in the plume zone, also were observed in at least one control zone.

(3) Statistical analyses of combined inshore zone data in addition to individual zone analyses indicate that zooplankton populations in this relatively large region stretching along 23 km of coastline have undergone change over the last several years. Given this spatial scale, we believe that such changes are related to broader events occurring in the nearshore region (changes in phytoplankton and fish populations) rather than to localized effects of power plant operation.

(4) New species occurrences have been noted in the study area, particularly *Daphnia* species. Such new occurrences have been independently confirmed at a study location 32 km offshore of Grand Haven, Michigan. These new occurrences, in addition to the presence of low numbers of rotifer species most commonly found in eutrophic waters, suggest that some of the recent changes observed in the study area during the preoperational period are related to changes in water quality, especially of nutrients.

(5) Results of our entrainment studies (next section) indicate that plant passage is lethal to only a small percentage of zooplankton. Mortality in the plume has not been measured, but on the basis of literature reviews, it is expected to be low. We have no basis for

predicting that power plant operation will result in detectable losses in the zooplankton community given the small percentage of dead zooplankton (less than 10 %) and the physical nature of the plume. Such low losses are below the detection limits of our study. Preoperational-operational differences which have been detected have been at least 100 % and more often 200 % or greater. Such changes have consisted of increases or decreases on scales which are beyond any direct plant effect.

The results of our studies indicate that zooplankton populations have undergone changes over the course of our study. By dividing the survey data into two time periods (preoperational and operational), we are able to document these changes. However, there is no evidence that these changes began in 1975. Rather, the data suggest that zooplankton populations in the early half of the decade differ from populations in the latter half. The time trends of these changes have not been analyzed to determine when the changes first began, the rates of changes, or how these rate changes have varied with time.

July zooplankton standing stocks have changed over the course of the decade. While total zooplankton standing stocks tend to be larger in the operational period, such differences are not of statistical significance ($\alpha=0.05$). Calanoid copepods, immature and adult Diaptomus spp., and adult Cyclops spp. were significantly ($\alpha=0.05$) less abundant in the operational period while Daphnia spp. and Asplanchna spp. were more abundant. Asplanchna was very abundant in 1981, resulting in a higher operational mean than preoperational, the reverse of the analyses employing the 1975 to 1980 data set. While Bosmina longirostris tended to be more abundant in the operational period, such differences were not statistically significant.

In October, total zooplankton were more abundant in the operational period than in the preoperational period. Nauplii, calanoid copepods, immature *Cyclops* spp., *Bosmina longirostris*, and *Eubosmina coregoni* were significantly (α=0.05) more abundant while adult *Cyclops* spp., and *Daphnia* spp. were less abundant.

Mesocyclops edax, a cyclopoid which occurred in relatively high concentrations in the survey area in the autumn of 1978, continues to occur in lower concentrations more similar to those observed in earlier years. However, *Daphnia pulex*, a cladoceran first observed in 1978, is commonly observed in the zooplankton. Both species are abundant in the eutrophic waters of Green Bay (Gannon 1972) and are particularly susceptible to fish predation (Galbraith 1967; Wells 1970). A second *Daphnia* species, *D. schloderi* recently has been detected in the study area in addition to more offshore locations and provides confirmation that southern Lake Michigan is undergoing gradual change in its zooplankton community structure. Two other new species, *D. catawba* and *D. parvula* appear to be less consistent in their occurrence in the plankton. Their occurrence probably is incidental and related to shoreline inputs from rivers and streams.

In general, the lake survey studies have shown that while long-term changes have occurred in the inshore region, they are small in magnitude and apparently do not follow a consistent trend of increase or decrease. The lack of such a consistent trend may be related to study design. A sufficient number of time intervals were not sampled during a given month to provide a precise estimate of mean population levels for that time period. Alternately, there are a number of factors producing changes but these factors are synergistic or antagonistic in nature. For example, increases in algal abundance may result in increased zooplankton productivity but an increase in fish predators may counteract this, resulting in only a slight increase in standing stocks. Moreover, each of these regulating factors may vary independently in importance from year to year resulting in yearly variations in the strength of effects produced. Time series analyses and ecological studies involving higher and lower trophic levels should resolve some of these ambiquities.

Although our data provide a clear indication that southeastern Lake Michigan has undergone subtle changes with respect to zooplankton populations over the course of the last ten years, we have not determined what are the significant causal factors. Such changes probably are related to a combination of changes in the algal community and in planktivorus fish predators. For example, while summer phytoplankton populations have increased, there has been a proportionately greater increase in blue green algae (Ayers 1978; Ayers and Wiley 1979; Chang et al. 1981). We are conducting ecological studies to investigate various causal factors and their mode of operation. Preliminary studies have shown apparently important interactions between alewife and Cyclops species, between Cyclops adults and rotifers, and between rotifer and cladoceran grazers on flagellates.

CONDENSER PASSAGE STUDIES

INTRODUCTION

Mechanical and thermal stresses have the potential to kill a significant percentage of the zooplankton passing through the condensers. Studies were conducted to evaluate the severity of such mortalities.

Zooplankton were collected monthly from the intake and discharge forebays of the operating units of the power plant in compliance with the Technical Specifications. The last collection period was May 1982. Because Unit 1 and Unit 2 discharges have different operating characteristics (water temperature, flow rate, ΔT), zooplankton mortalities were estimated at each location. Four samples were collected from each location within an hour or two of sunrise. Collection duration was two minutes. Each sample was divided into subsamples, each containing a few hundred organisms. Subsamples were visually examined for dead zooplankters which were identified and enumerated 0, 6, and 24 hours after collection at intake temperatures.

For the January 1982 to May 1982 period, when the sampling program was discontinued, 68 samples were collected (204 subsamples). Unit 1 was not operational in February, and 68 rather than the possible 72 samples were collected.

In this report, we present mortality data collected from May 1981 to December 1981 which were not included in the last report. We also report biomass and number of zooplankton passing through the plant for the August 1980 to December 1981 period. Analyses of the 1982 samples has not been completed.

RESULTS AND DISCUSSIONS

Temperature and Flow Rate

Intake temperatures ranged from a low of 6.2 °C in December 1981 to a high of 23.7 °C in August and September 1981. Unit 1 discharge water temperatures ranged from 17.1 °C in December to 34 °C in September 1981. Unit 1 ΔTs ranged from 7.7 C° in August to 10.9 C° in October and December with a mean of 9.7 C°. Minimum flow rate for Unit 1 occurred in December 1981 (1.08 X 10^9 gallons/day) and the maximum was recorded in October 1981 (1.19 X 10^9 gallons/day). Unit 1 mean flow rate for the May to December 1981 period was 1.154 X 10^9 gallons/day. Unit 2 discharge water temperatures ranged from 15.6 °C in December 1981 to 34.0 °C in August 1981. Unit 2 ΔTs ranged from 6.8 C° in July 1981 to 10.2 C° in August 1981. Mean ΔT for Unit 2 was 8.7 C°. Unit 2 flow rates averaged 1.51 X 10^9 gallons/day and ranged from 1.37 X 10^9 gallons/day in July 1981 to 1.63 X 10^9 gallons/day in November 1981.

Mortalities

Total zooplankton mortalities generally were low (Fig. 5) at initial collection times (0-hour), averaging 11.5 % in the intake water, 12.6 % in Unit 1 discharge water, and 11.9 for Unit 2 discharge water. Total zooplankton minimum intake mortality (5.9 %) occurred in July 1981 and maximum mortality (18.2 %) was observed in September 1981. Total zooplankton mortalities for Unit 1 discharge ranged from 5.9 % in June 1981 to 18.2 % in September 1981 and Unit 2 discharge ranged from 8.3 %

in October to 18.4 % in September. Generally, months with relatively higher discharge mortalities were those having high discharge temperatures (September 1981, 34 °C) or high ΔTs (December 1981, 10.9 C°). Discharge mortalities (Fig. 5) were similar to intake mortalities. The largest within-month difference between total zooplankton percent mortality in discharge and intake samples was 3.6 % and occurred in August 1981.

The numerically dominant taxa (Fig. 5) were copepod nauplii, immature Diaptomus spp. copepodites, immature Cyclops spp. copepodites, and Bosmina longirostris . These taxa generally accounted for most of the dead organisms.

For the 0-hour incubations (Table 3), the only statistically significant ($\alpha=0.05$) difference between intake and discharge mortalities (Smirnov one-sided two-sample test: Conover 1971) was for nauplii in September 1981. During this month, ΔT for Unit 1 was 10.2°C , and discharge water temperatures from both Units exceeded 32 °C. No significant differential mortality was found in 6-hour incubation samples. Two zooplankton catagories had significantly higher discharge than intake mortalities after the 24 hour incubation. These were immature Diaptomus spp. copepodites in June and October 1981 and immature Cyclops spp. copepodites in June and October 1981.

Entrainment Abundance

To estimate abundance, zooplankton samples were collected monthly from the intake and discharge forebays of the power plant. Samples were collected from a discharge forebay only if that unit was operating.

Two five-minute samples were collected from each of the two or

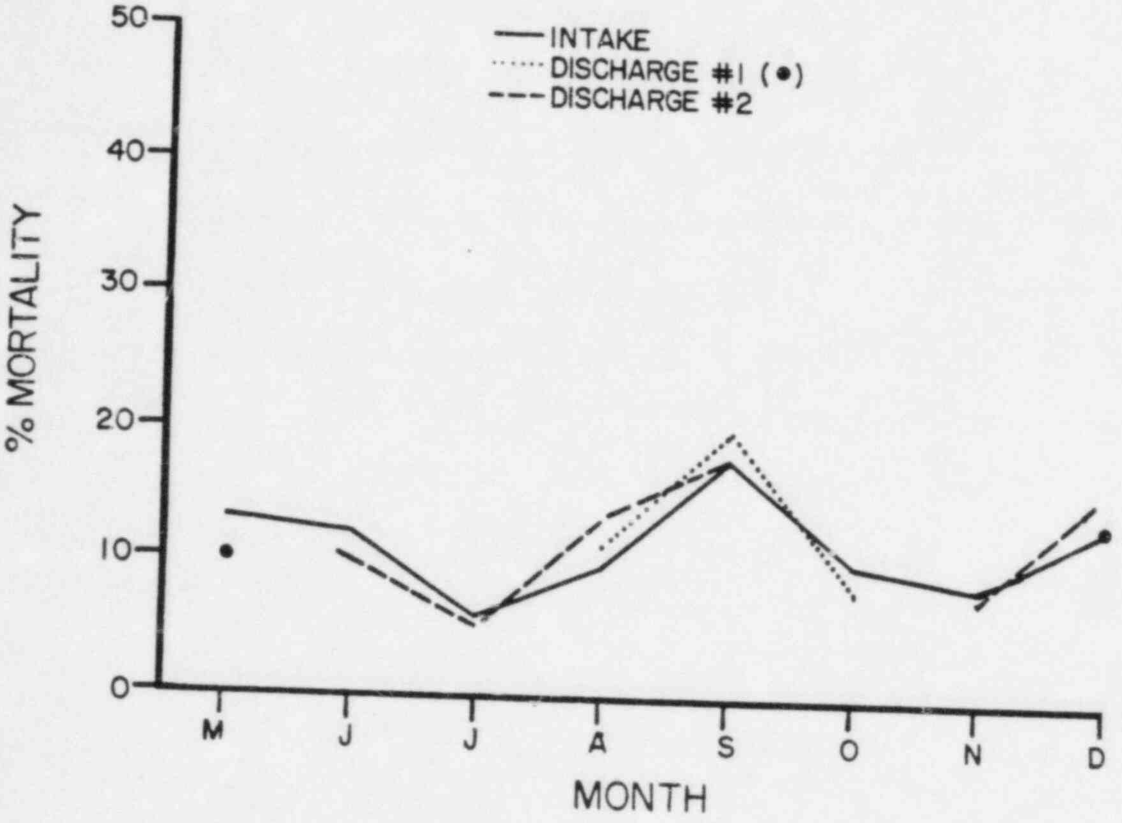

Figure 5. Total zooplankton mean mortality (%) immediately following collection (0 hour count) for zooplankton collected in the intake forebay (MTRI-5) and both Unit 1 and Unit 2 discharge bays.

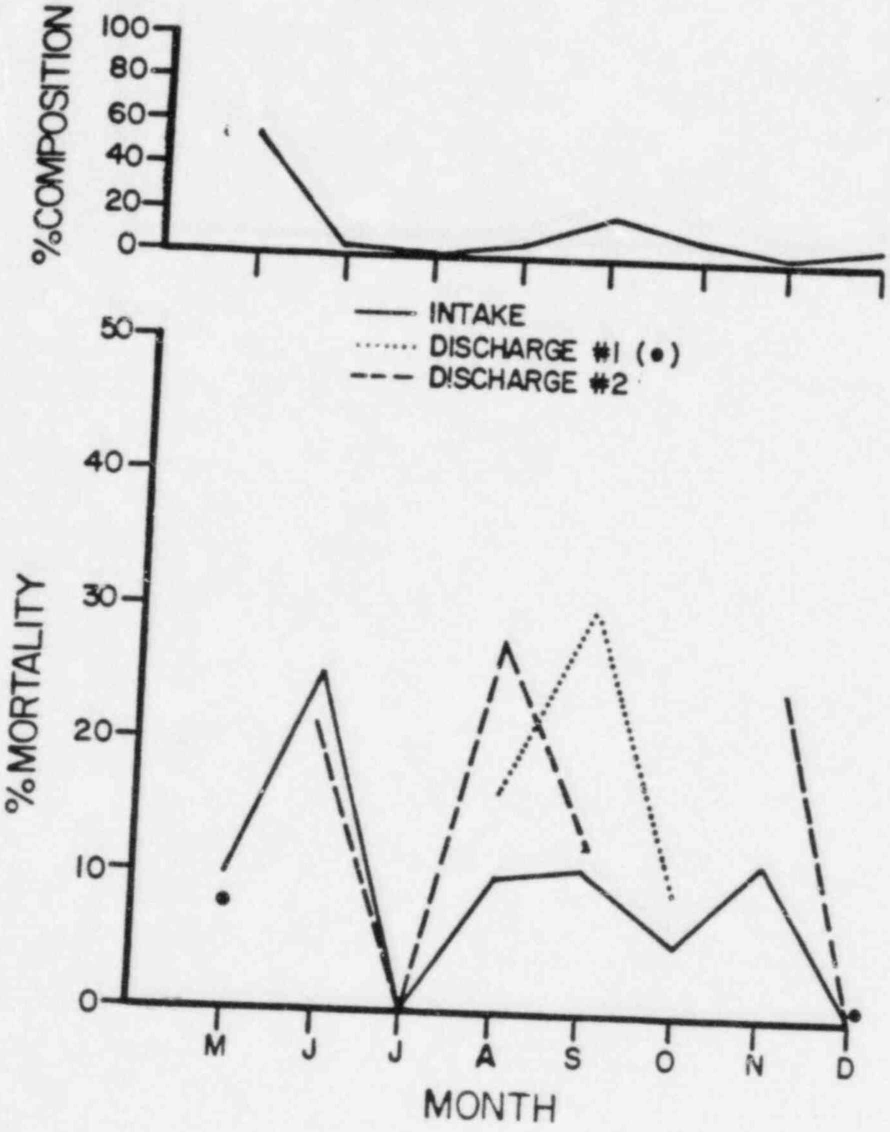

Figure 5 continued. The mean mortality (% dead) immediately following collection (0 hour count) and relative density (% composition) for zooplankton collected in the intake forebay (MTRI5) and both Unit 1 and Unit 2 discharge bays. a) copepod nauplii.

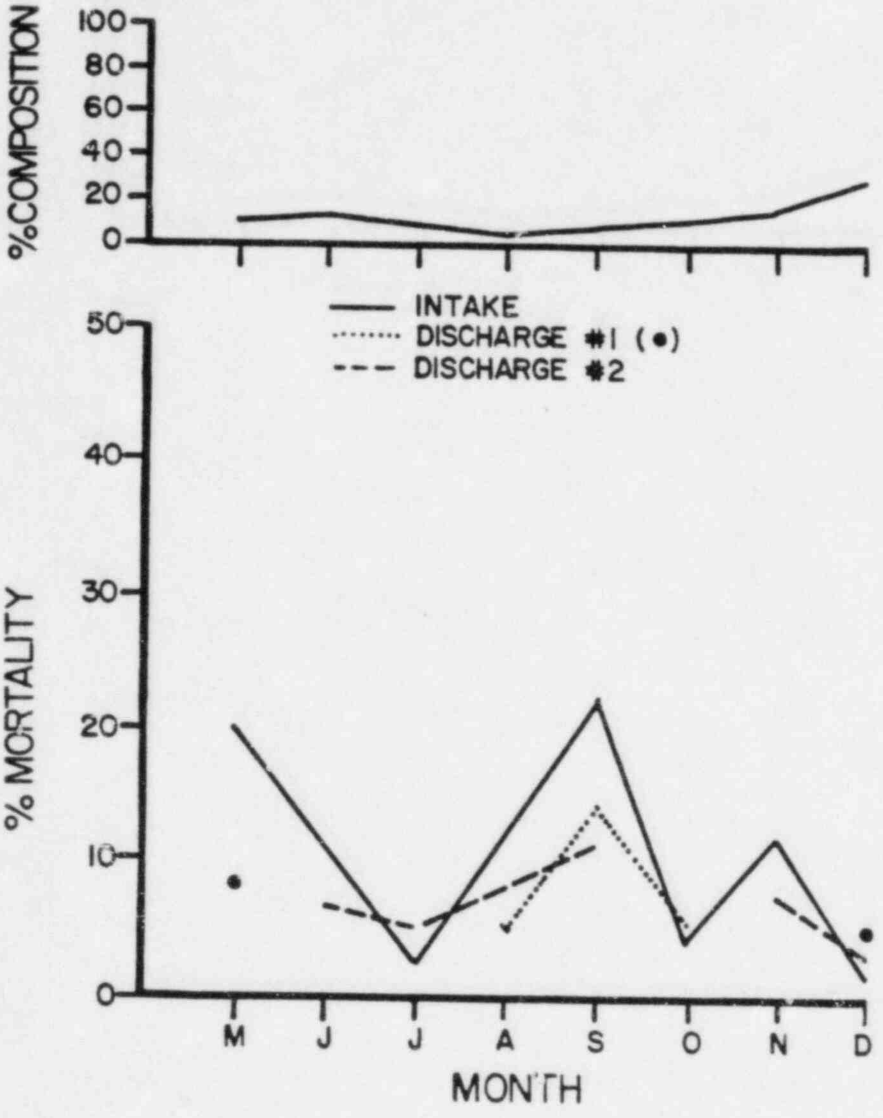

Figure 5 continued. b) Cyclops spp. C1-C5

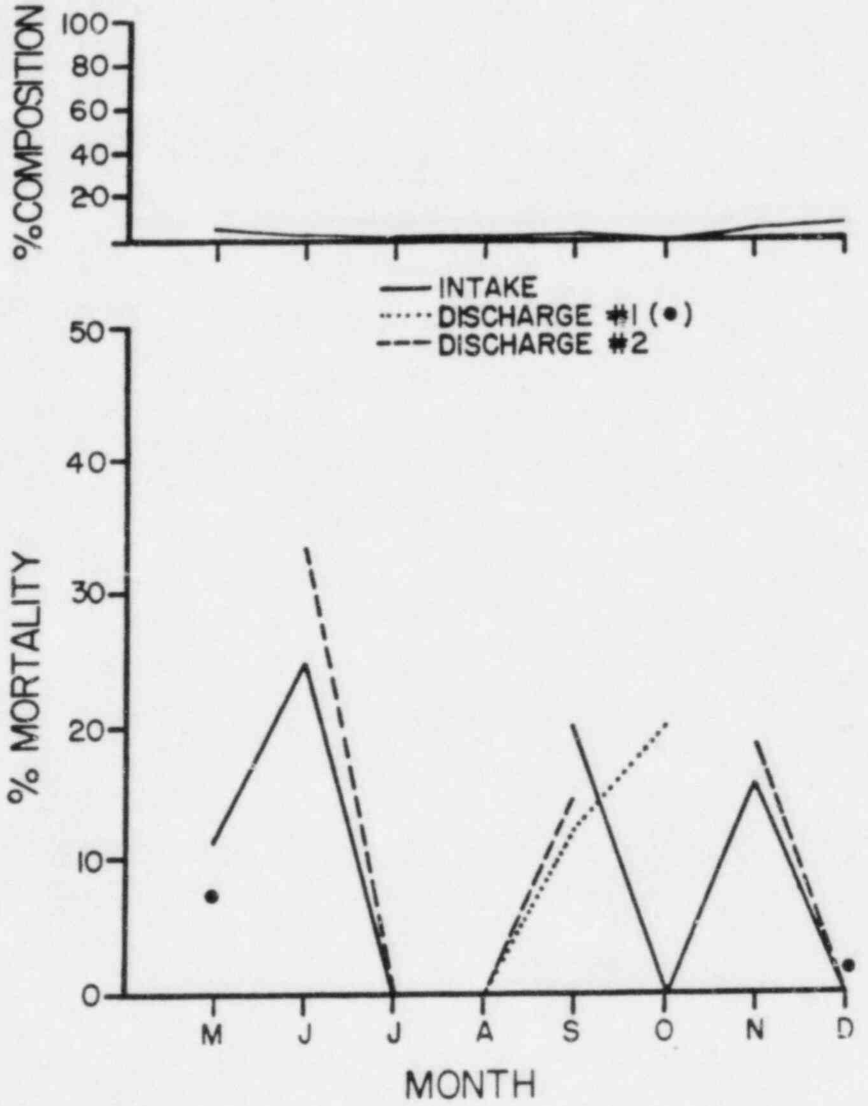

Figure 5 continued. c) Cyclops bicuspidatus thomasi C6

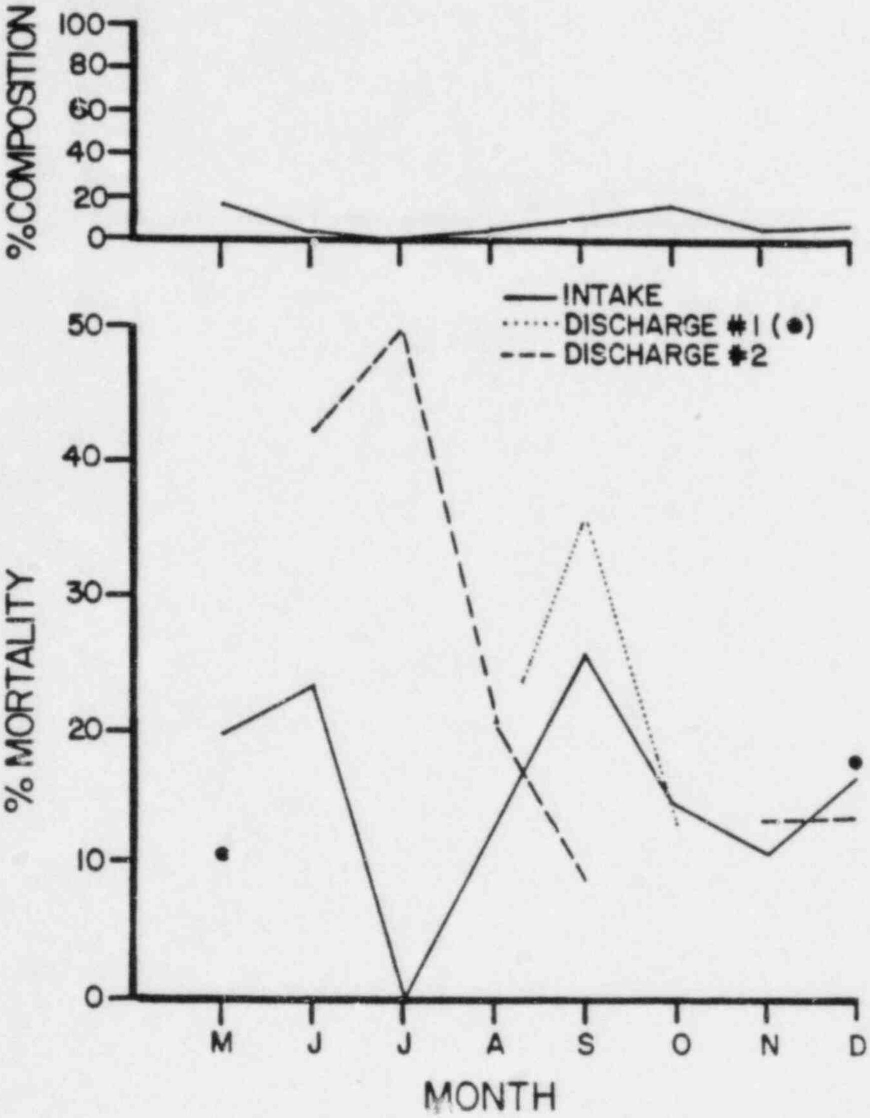

Figure 5 continued. d) <u>Diaptomus</u> spp. C1-C5

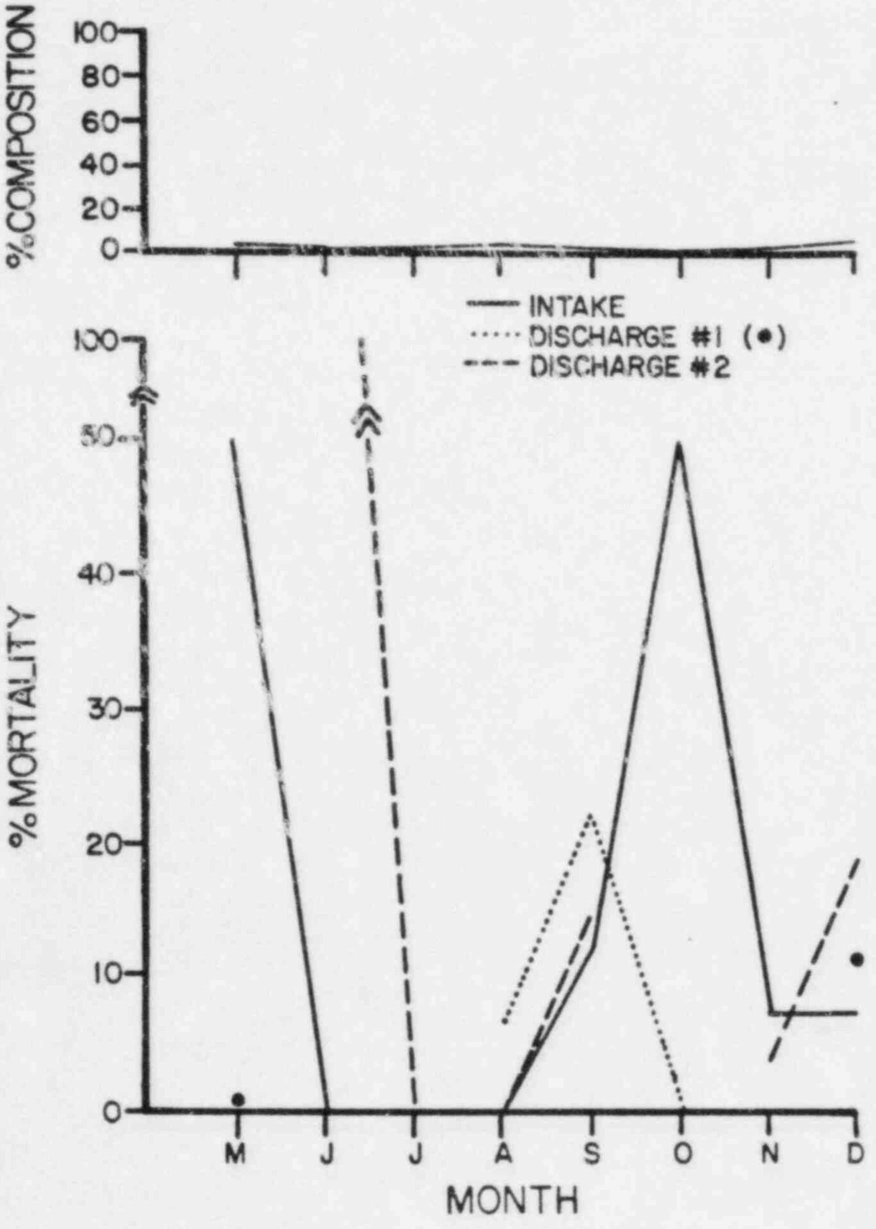

Figure 5 continued. e) Diaptomus spp. C6

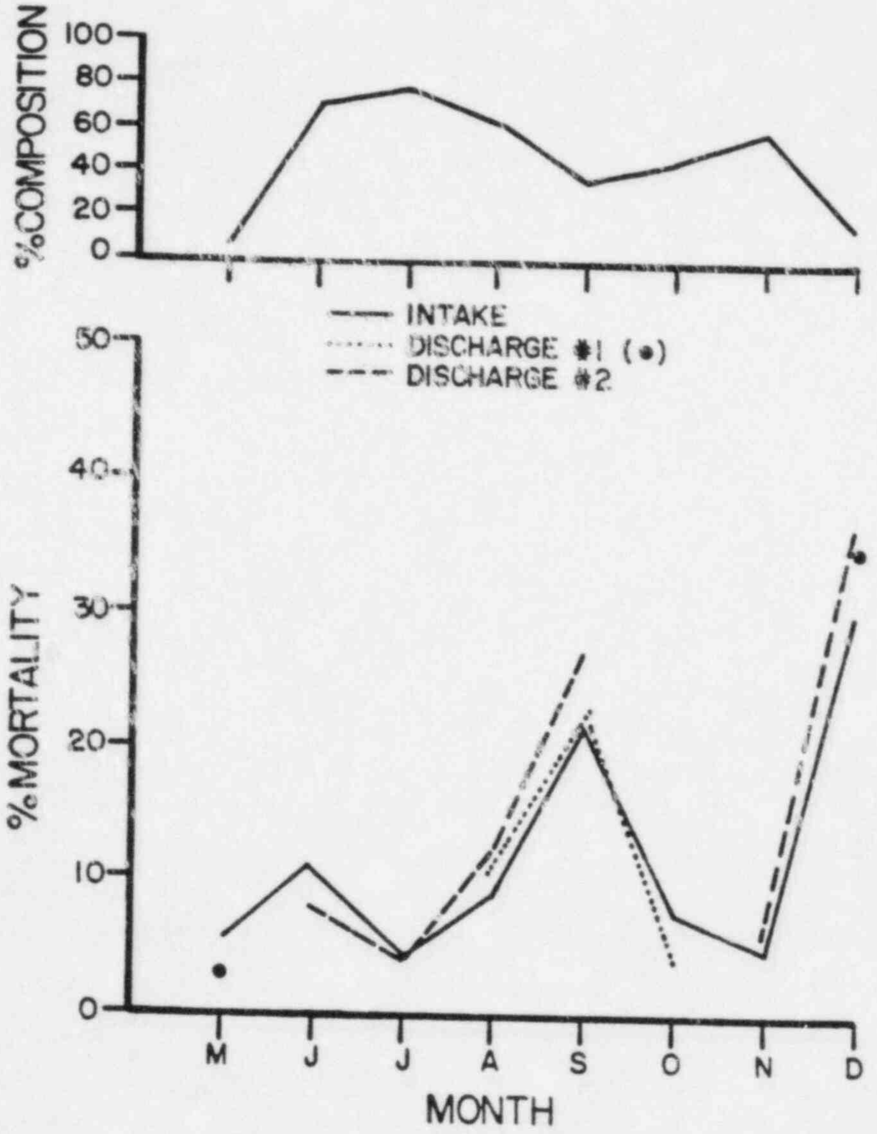

Figure 5 continued. f) Bosmina longirostris

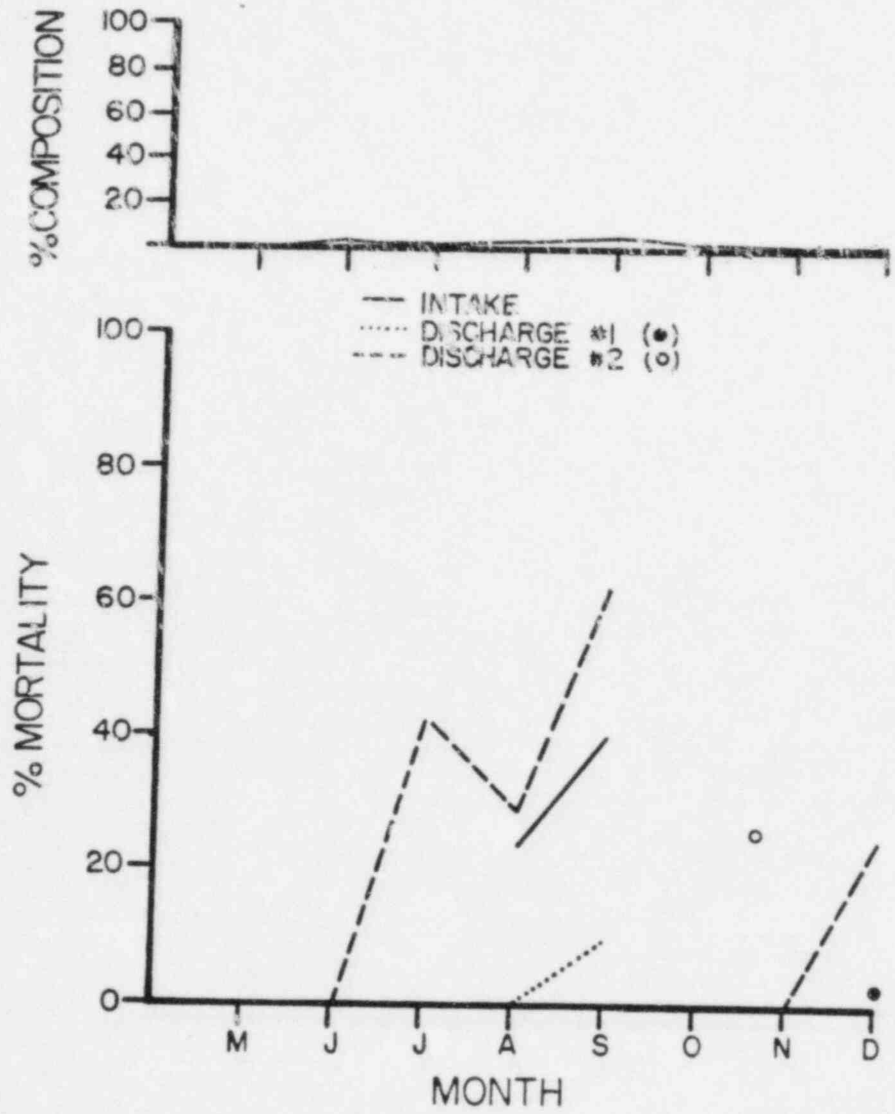

Figure 5 continued. g) *Daphnia retrocurva*

Table 3. Results of the Smirnov one-sided two-sample tests comparing discharge and intake 0- to 24-hour sample mortalities for nine zooplankton taxa categories by month of collection (1981). A -- indicates insufficient data for the test, NS indicates discharge mortalities were not significantly ($p > 0.05$) higher than intake values, and * indicates discharge mortalities were significantly ($p < 0.05$) higher than intake values.

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 Hour								
Copepod nauplii	NS	NS	NS	NS	*	--	NS	NS
Cyclops spp. C1-C5	NS	NS	NS	NS	NS	--	NS	NS
Cyclops spp. C6	NS	NS	NS	--	NS	--	NS	NS
Diaptomus spp. C1-C5	NS	NS	--	NS	NS	--	NS	NS
Diaptomus spp. C6	--	--	--	NS	NS	--	NS	NS
Bosmina longirostris	NS	NS	NS	NS	NS	--	NS	--
Eubosmina coregoni	--	--	--	--	--	--	NS	NS
Daphnia spp.	--	--	--	--	NS	--	--	--
Total	NS	NS	NS	NS	NS	--	NS	NS
6 Hour								
Copepod nauplii	NS	NS	NS	NS	NS	NS	NS	NS
Cyclops spp. C1-C5	NS	*	NS	NS	NS	NS	NS	NS
Cyclops spp. C6	NS	NS	--	--	NS	--	NS	NS
Diaptomus spp. C1-C5	NS	NS	--	NS	NS	NS	NS	NS
Diaptomus spp. C6	--	--	--	NS	--	--	NS	NS
Bosmina longirostris	NS	NS	NS	NS	NS	NS	NS	NS
Eubosmina coregoni	--	--	--	--	--	--	NS	NS
Daphnia spp.	--	NS	--	--	NS	--	NS	--
Total	NS	--	NS	NS	NS	NS	NS	NS
24 Hour								
Copepod nauplii	NS	NS	NS	NS	NS	NS	NS	NS
Cyclops spp. C1-C5	NS	*	NS	NS	NS	*	NS	NS
Cyclops spp. C6	NS	NS	--	--	--	--	NS	NS
Diaptomus spp. C1-C5	NS	*	--	--	NS	*	NS	NS
Diaptomus spp. C6	--	--	--	NS	--	--	NS	NS
Bosmina longirostris	NS	NS	NS	NS	NS	NS	NS	--
Eubosmina coregoni	--	--	--	--	--	NS	NS	NS
Daphnia spp.	--	NS	NS	--	NS	--	--	--
Total	NS	NS	NS	NS	NS	NS	NS	NS

three locations at sunset, midnight, sunrise, and noon. This resulted in a series of 16 samples for one-unit operation or 24 samples for two-unit operation. Data from these samples provided information on the density, composition, and biomass of zooplankters passing through the plant. This information coupled with the mortality data allowed the estimation of the maximum loss of zooplankton numbers and dry weight due to plant passage.

During the December 1981 to May 1982 period, 136 samples were collected. Samples were not collected from Unit 1 discharge in February 1982 when that unit was not operating. Analyses of samples collected from August 1980 to December 1981 which were not presented in the last report are discussed here. Samples collected in 1982 have not been completely examined.

In the August 1980 to December 1981 period, the concentration of zooplankton in the cooling waters peaked at $73,000/m^3$ in October 1980 and was lowest in February 1981 at $3,300/m^3$. August through December 1981 abundances were lower than the same period in 1980. The autumn increase in zooplankton abundance which generally occurred in October in previous years did not occur until November in 1981.

Numbers of zooplankton passing through the plant (Fig. 6) were related to plant pumping rates and animal abundances. Numbers entrained ranged from a low of 820 billion in February 1981 to a high of 16,600 billion in August 1980. Maximum estimated numerical losses generally followed the numbers entrained curve.

Biomass of Zooplankton Passing Through the Plant

The monthly biomass of zooplankton entrained (Fig. 7) for the

August 1980 to December 1981 period ranged from a low of 1,020 kg dry weight in May 1981 to a high of 22,000 kg dry weight in November 1981. Maximum loss estimates were lowest in October 1981 (70 kg dry weight) and highest in December 1981 (2,200 kg dry weight). Maximum loss estimates generally followed the dry weight entrained curve.

The biomass of zooplankton passing through the plant did not always follow the same temporal pattern as the numbers through the plant. Highest values for dry weight entrained occurred in colder months. This was because the mean dry weight of the zooplankters was 3 to 7 µg/individual in these cooler months, while in the warmer months, when zooplankton were somewhat more numerous, they were dominated by smaller animals with mean dry weights of 1 to 2 µg/individual.

Intake Sampling as a Representative Sampling Location for Lake Population Estimates

As we have discussed in previous Great Lakes Research Division Reports (Evans et al. 1978, 1982), zooplankton populations in the nearshore region are highly seasonal in abundance. A more definitive discussion of such seasonality is presented in Evans and Sell (In press). As a consequence of such variability, population estimates for a given month lack a high degree of precision. In order to investigate how representative a single sampling time within a month is of mean population levels for that month, we have supplemented monthly entrainment sampling with a more frequent sampling effort. Weekly samples have been collected during the warmer summer and autumn months and biweekly samples during the cooler winter and spring months. As reported in Evans et al. (1978, 1982), we have determined that

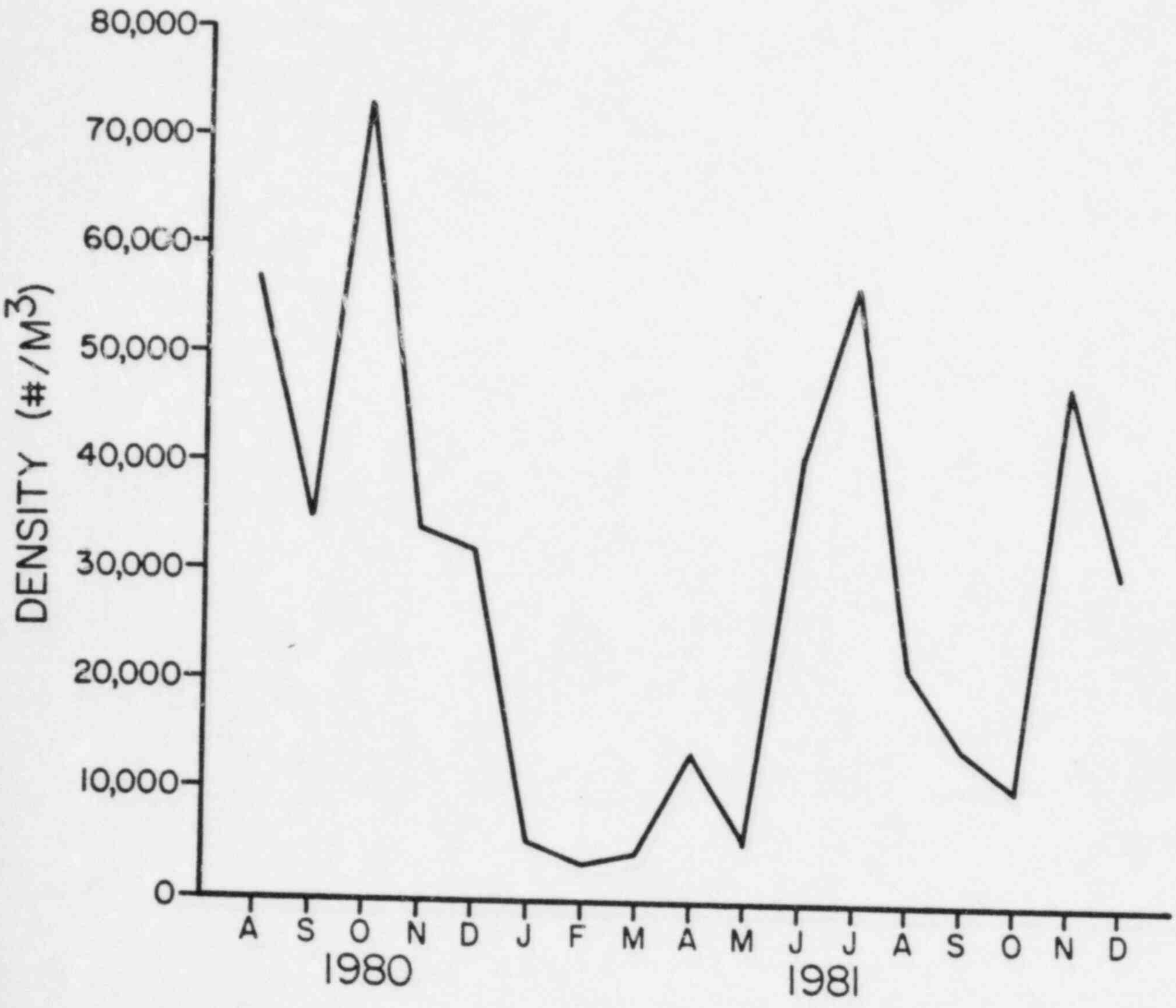

Figure 6. Total zooplankton densities ($\#/m^3$) in monthly entrainment samples taken from the intake forebay.

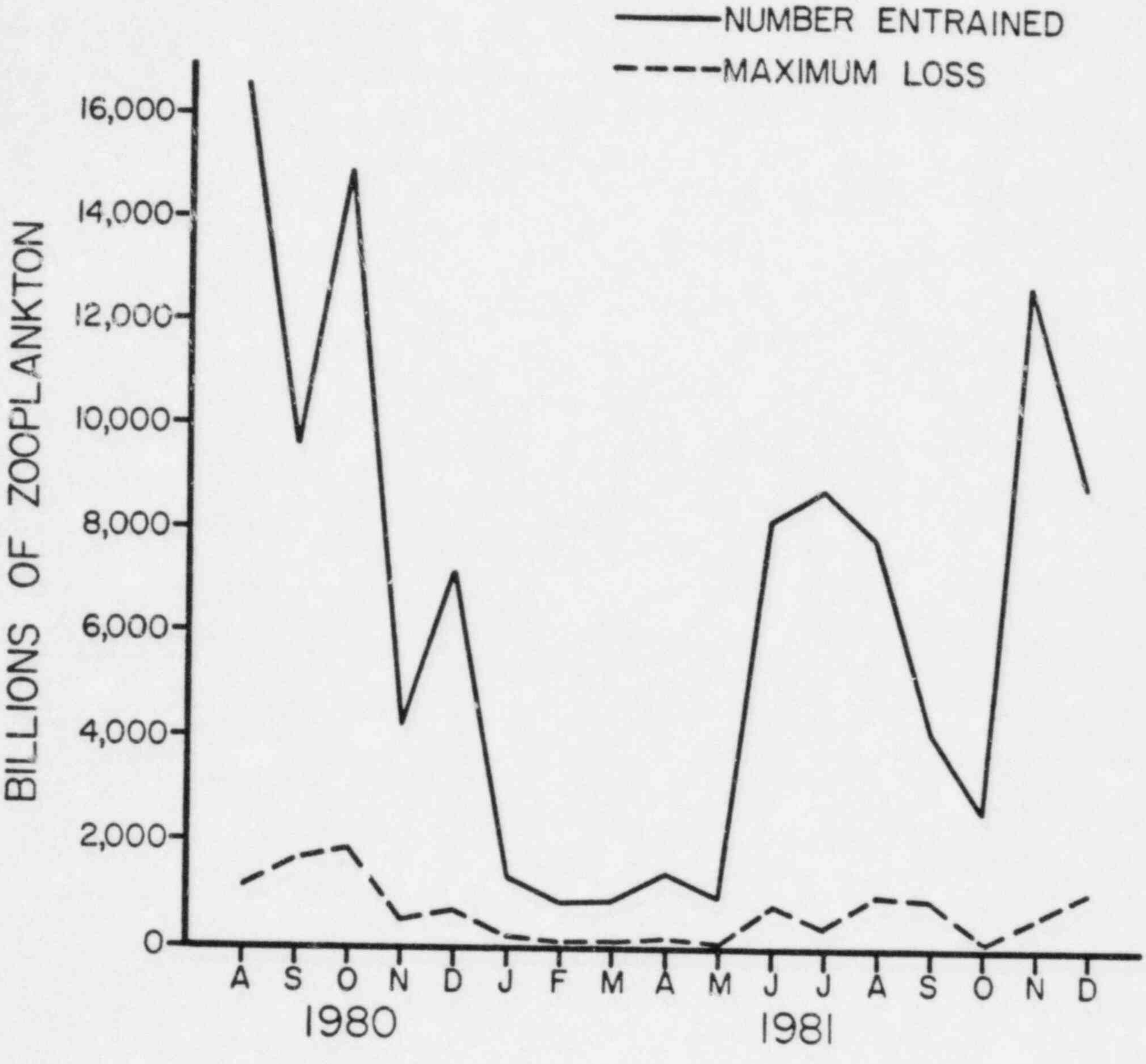

Figure 7. Estimates of zooplankton numbers entrained and maximum numbers lost from August 1980 to December 1981. manimum loss values are estimates for Unit 1 only. maximum loss values are estimates for Unit 2 only.

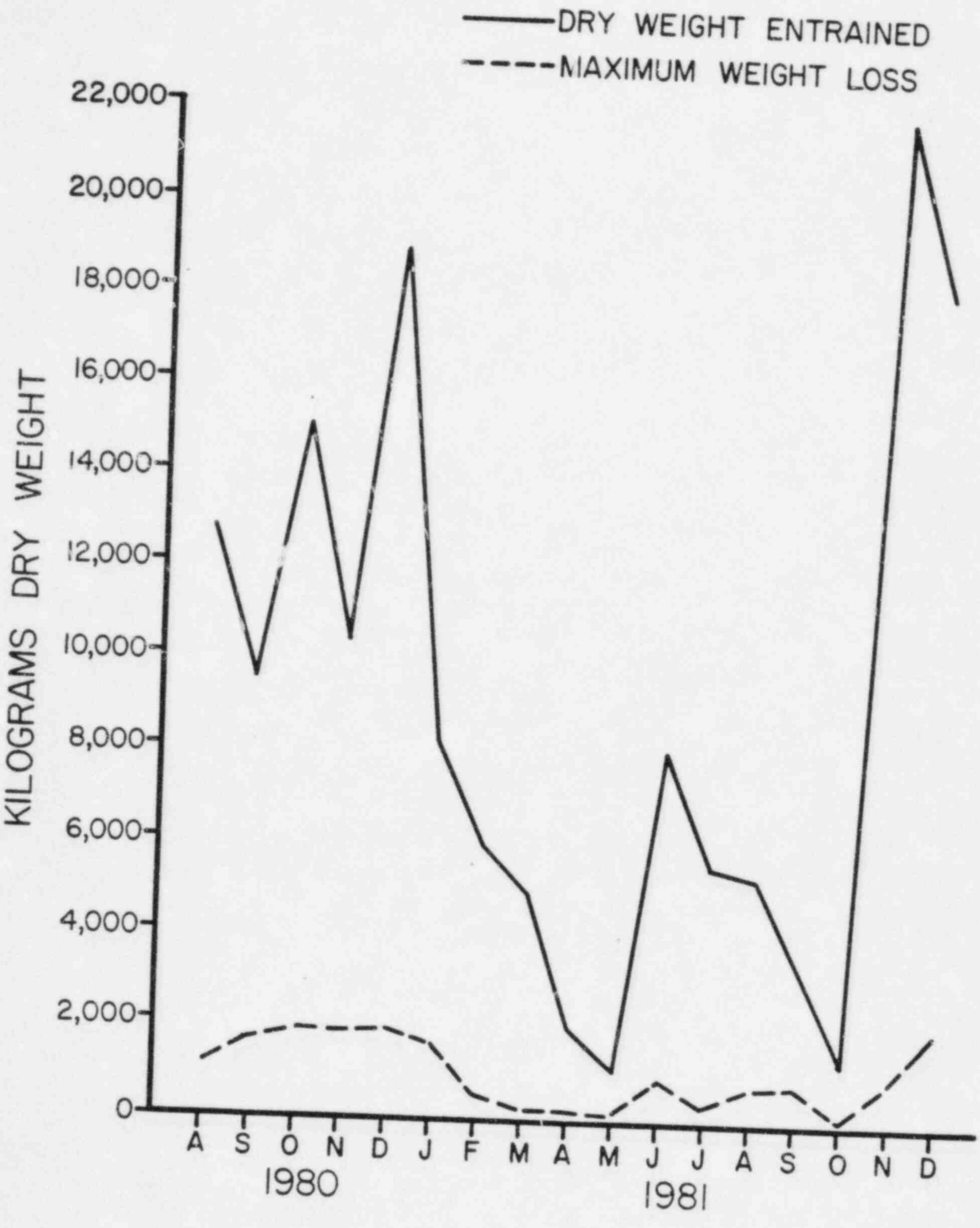

Figure 8. Estimates of entrained zooplankton dry weights and maxiumum losses from August 1980 to December 1981. maximum loss values are estimates from Unit 1 only. maximum loss values are estimates from Unit 2 only.

zooplankton frequently exhibit as much variation in abundance between successive weeks as between successive months. This indicates that population highs observed in one year and lows in another year (for the same month) may be related to small (a matter of days) differences in population cycles between years. Slightly warmer waters, long periods of calm lake conditions, an earlier algal bloom, a small shift in fish distributions as well as natural spatial variability (patchiness) all may result in small differences in zooplankton populations over the course of a few days. Such differences necessitate caution in comparing population levels across years. Moreover, with infrequent sampling within a year, this seasonal variability can confound the detection of long-term (years) population trends.

Sampling with the use of expensive research vessels which are restricted by lake conditions to certain time periods, is not the most effective way of obtaining detailed information on inshore plankton populations. Intake sampling provides a realistic alternative for obtaining information on nearshore zooplankton ecology. Many of the long-term changes in Great Lakes phytoplankton populations have been documented through such sampling (Damann 1960; Davis 1964; Nicholls *et al*. 1977; Danforth and Ginsburg 1980).

We have been conducting a series of analyses to determine how representative intake sampling is as an estimator of zooplankton populations in the nearshore region. Such determinations allow us to use our more temporally-detailed intake population estimates to more fully understand long-term changes in zooplankton populations in the nearshore region, i.e., between the 5 and 10-m depth contours. In addition, our understanding of zooplankton winter population characteristics is derived entirely from intake sampling. It is essential that we determine the correspondance between lake and entrainment sampling before interpreting winter events.

As a first step in investigating the correspondance between lake and entrainment sampling, we conducted a series of correlations of abundance estimates for the two locations. Lake population estimates were based on the mean abundance of zooplankton in zones 1, 2, and 3 (between the 5 and 10-m depth contours). Such analyses were conducted for the numerically dominant taxa and for the entire 1975 to 1980 period (Fig. 10). All such correlations were statistically (α=0.05) significant (Table 4). Correlation coefficients ranged from a low of +0.40 for *Cyclops* spp. adults to +0.93 for *Daphnia* spp. and *Bosmina longirostris*. While the abundance of the soft-bodied nauplii and *Asplanchna* tended to be underestimated in intake sampling (possibly because these animals were forced through the net by the flow velocities of the diaphragm pump) and the abundances of epibenthic taxa such as *Cyclops* spp. and *Eurytemora affinis* tended to be overestimated, these differences generally averaged less than 50 % (Table 4). Since larger magnitudes of abundance shifts occur through seasonal events, we conclude that entrainment sampling does provide a reliable estimate of zooplankton abundances in the inshore region. This is further shown in Figure 8 where zooplankton abundance estimates as determined from lake and entrainment sampling are presented on the same graph. The correspondance between lake and entrainment population estimates was excellent.

Entrainment sampling, because of the relatively low collection costs and the feasibility of sampling during ice cover or the worst of

Table 4. Comparison of density data for selected zooplankton taxa from entrainment abundance and inshore field survey samples. Correlation coefficients (4), their significance, significance of the median test (M), and the geometric mean of the ratio of densities (field survey/entrainment) for $n = 32$ sampling dates during 1975-1980,
ns indicates not significantly different at $p < 0.05$,
* indicates significance at the 0.05 level, and
** at the 0.01 level.

Copepod nauplii	.59**	ns	1.4
Immature Cyclopoids	.67**	ns	.8
Cyclops C6	.40**	**	.3
Tropocyclops C1-C6	.83**	ns	1.0
Diaptomus C1-C5	.51**	ns	.9
Diaptomus C6	.88**	ns	1.1
Epischura C1-C6	.61**	ns	1.0
Eurytemora C1-C6	.85**	*	.7
Limnocalanus C1-C6	.35**	ns	.6
Bosmina	.87**	ns	1.0
Daphnia	.93**	ns	.7
Eubosmina	.93**	*	1.1
Asplanchna	.65**	ns	1.4
Total Zooplankton	.83**	ns	.9

autumn storms, provides an ideal opportunity to investigate long-term population trends. We have begun a series of analyses utilizing 1975 to 1980 data to investigate such trends in the numerically dominant zooplankton. One such approach has been to use a deterministic time series model (Box and Jenkins 1976). This approach incorporates seasonal change in addition to identifying long-term trends.

We have examined population trends in the abundance of copepod nauplii for the 1975 to 1980 period (Fig. 9). This taxon was selected because it appears to be increasing in abundance in the inshore region in all the major survey months. In addition, it is found in high numbers in the zooplankton during all months of the year, unlike taxa such as cladocerans which are more seasonal in occurrence. The time series model explained 62 % of the variability in nauplii density and was statistically significant ($p<0.001$). The model shows that while seasonal changes have remained constant within a year, a long-term trend in nauplii densities also occurred. Summer nauplii densities increased annually from 1975 to reach a peak in 1978. A leveling off or slight decline appears to have occurred in subsequent years. However, winter lows appear to have increased in magnitude from year to year from a January 1975 estimate of $17/m^3$ to a December 1980 estimate of $294/m^3$.

SUMMARY

Results of the entrainment studies indicate that mortalities averaged 11.5 % in intake waters, 12.6 % in Unit 1 discharge waters, and 11.9 % in Unit 2 discharge waters. As has been discussed in previous reports, intake mortalities do not reflect true mortalities in inflowing waters but rather mortalities induced by sample collection. Mortalities

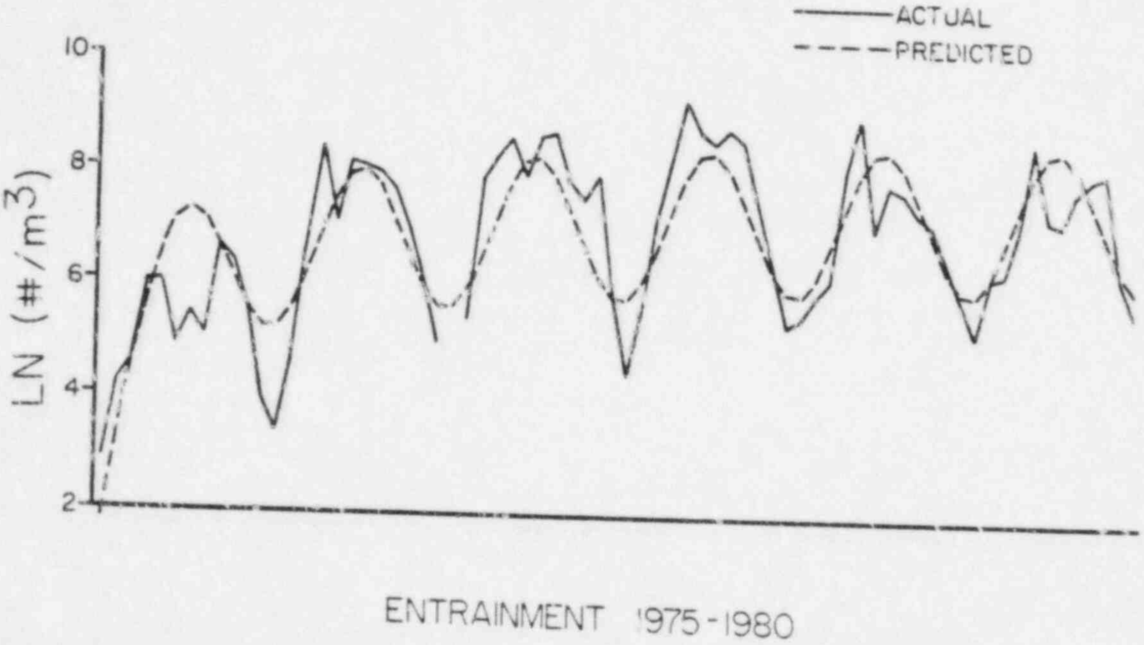

Figure 9. Log of nauplii densities together with densities as predicted by a deterministic time series model. (After Box and Jenkins 1976). Data were obtained from entrainment samples taken on a monthly basis from January 1975 to December 1980.

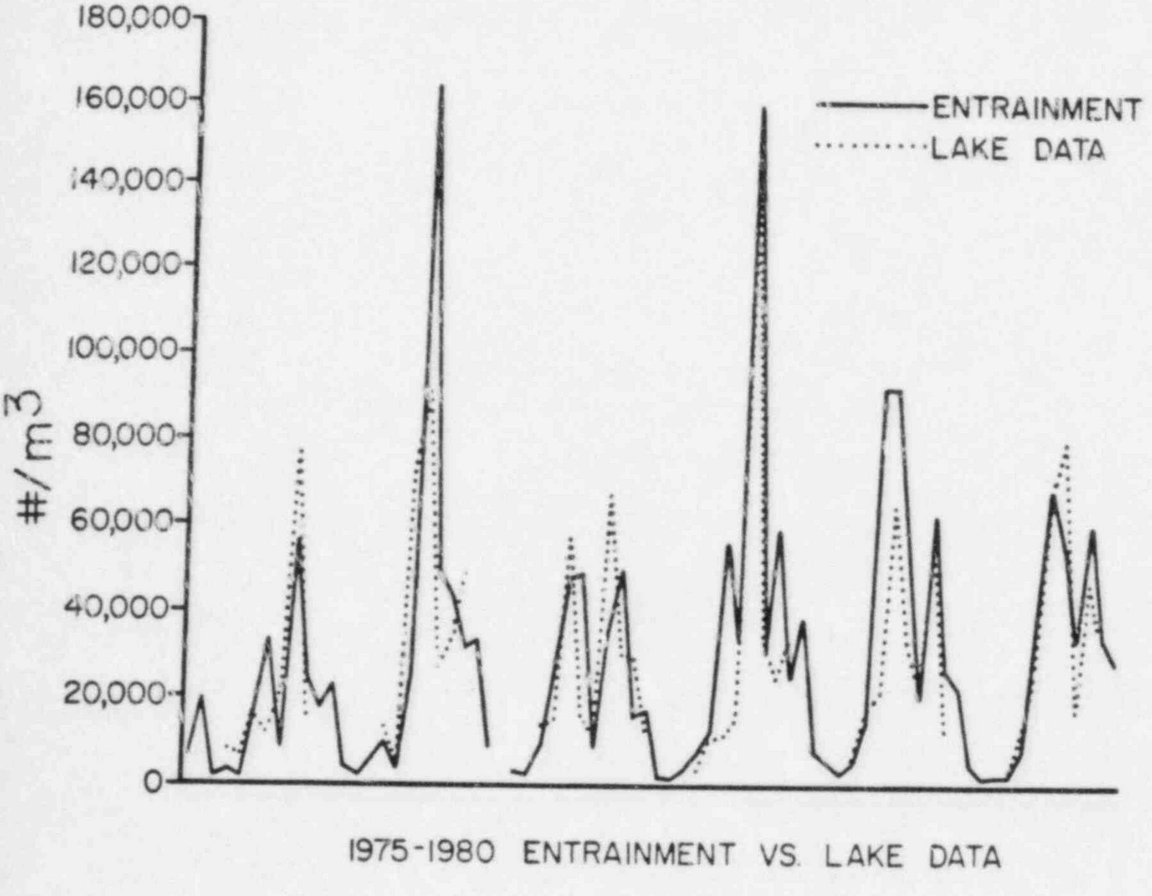

Figure 10. Total zooplankton densities as determined from field samples and entrainment samples for the period 1975 to 1980. Field sampling was conducted monthly from April to November (or December) and entrainment sampling was conducted monthly, twelve months per year.

due to plant passage can be estimated in three ways. The first is to use the absolute value of the discharge mortality estimate as an upper estimate of mortalities due to plant passage and discharge back into the lake: thus mortalities are estimated as ranging from 11.9 % (Unit 2) to 12.6 % (Unit 1). A second estimate is based on subtracting intake mortality from discharge mortality: thus mortalities are estimated as ranging from 0.4 % (Unit 2) to 1.1 % (Unit 1).

The third estimate corrects for mortalities in intake waters and then considers the additional mortality in discharge samples. The actual formula is:

$$Mp=\frac{(Md-Mi)\ X\ 100}{100-Mi}$$

where:

Md= percent mortality in the discharge

Mi= percent mortality in the intake

Mp= mortality due to plant passage

Using this approach, the conservative estimates for intake mortality are 0.4 % for Unit 2 and 1.1 % for Unit 1.

Exact causes of mortality during plant passage are not known but are the result of a combination of thermal and mechanical stresses. Mechanical stresses probably are a major cause of mortality under current operating conditions. On the basis of previous literature reviews (see Evans <u>et al</u>. 1982), we conclude that 35 °C approaches the upper lethal temperature for short-term exposures. If discharge temperatures remain below 35 °C and ΔT's do not rise substantially above 10 C° to 12 C°, it is expected that zooplankton mortalities will remain low. The highest 1981 mortalites occurred when these conditions were approached.

The ecological significance of the loss of zooplankton due to plant passage remains unknown. Such losses cannot be detected in the lake because of the low magnitude of change relative to the inherent variability in the system. In addition, not enough is known about zooplankton population dynamics to predict effects. While detrital zooplankton settling from the plume may affect benthic community structure by providing additional food materials, our study of epibenthic and benthic animals in the vicinity of the thermal discharge indicates that such effects are not large.

Our studies show that entrainment sampling does provide a reliable estimate of zooplankton populations in the inshore region of the study area. As a result, we have begun to construct mathematical models to investigate long-term events in this region of the lake. Such studies will provide a valuable supplement to the lake survey program.

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APPENDIX B-2

PART I

PHYTOPLANKTON LAKE SURVEYS AT THE DONALD C. COOK NUCLEAR PLANT

LAKE PHYTOPLANKTON

INTRODUCTION

The Technical Specifications require that phytoplankton in the Cook Plant region be sampled monthly from April through November, with major surveys over the 36-station sampling grid in April, July, and October and with short surveys over a reduced 11-station grid in the intervening months.

The phytoplankton surveys are designed to provide a broad background of phytoplankton numbers in spring, summer, and fall. They also provide species compositions, diversities, and redundancies under preoperational conditions against which the same parameters from surveys similarly conducted under operational conditions can be contrasted to determine long-term changes that may be attributable to Cook Plant operation.

The short surveys give a continuum between major surveys and provide a means of better watching temporal changes that might be missed or only partially covered by the major seasonal surveys.

November is notorious for storms on Lake Michigan and November surveys in 1973, 1974, 1975, and 1976 were missed for this reason.

Phytoplankton sampling at station SDC-4-1 was accidentally omitted in the survey of July 1977.

The phytoplankton samples of 1982 are still being worked up and are not yet available for analysis.

This report extends our reporting of the in-lake phytoplankton by adding the surveys of 1981. The phytoplankton surveys of previous years are given by Ayers et al. (1971), Ayers, Mozley, and Roth (1973), Ayers, Mozley, and Stewart (1974), Ayers (1975), Ayers, Southwick, and Robinson (1977), Ayers (1978), Ayers and Wiley (1979), and Ayers and Feldt (1982).

In accordance with the Technical Specifications requirement to report summaries, interpretations, and statistical analyses, the great bulk of the new raw data from 1981 are not presented here; they will be reported later.

The strategy for detecting changes in the phytoplankton community near Cook Plant involves comparisons of phytoplankton parameters at stations in three depth zones near the plant (inner stations, less than 2 miles N or S of the plant) to the same parameters at stations in the same depth zones two miles or more away from the plant (outer stations). In any one survey these comparisons are spatial, but, repeated over time, they allow temporal comparisons as well. The temporal comparisons consist primarily of comparing preoperational conditions to conditions in operational years. Conditions in preoperational years provide a measure of natural variation against which variations in operational years may be compared to detect possible plant-related perturbations.

This report continues through 1981 our analyses of possible plant effects on the phytoplankton according to the strategy outlined above.

Phytoplankton samples in all surveys are collected and treated according to the techniques reported in the Cook Plant Environmental Operating Report for 1977, pages B2-58 through B2-60. Beginning with the samples of 1974, the individual cells of nearly all blue-green algae have been counted; prior to that, colonies were counted as one organism. The counting change resulted in an apparent increase in blue-greens beginning with 1974.

RESULTS AND DISCUSSIONS

In this section, the results obtained and discussions of those results have not been separated. We believe that thethe reader will have no difficulty in distinguishing between our objective presentation of the results and our subjective discussions of the results.

Inner-Outer Graphical Comparisons: Phytoplankton Abundances by Algal Categories

This section applies the inner-outer graphical analysis method to the abundances (in cells per mL) of ten major categories of phytoplankton and extends previously reported tabulations, figures, and discussions to include the seasonal surveys of 1981. Three water-depth zones are used: zone 0 (0-8 m), zone 1 (8-16 m), and zone 2 (16-24 m).

The phytoplankton categories used are: total algae, coccoid blue-greens, filamentous blue-greens, coccoid greens, filamentous greens, flagellates, centric diatoms, pennate diatoms, desmids, and other algae. The use of major algal groups bypasses difficulties stemming from inability to always identify to species, and it is justifiable on the basis that members of each category have more or less similar functions in the ecosystem.

Table 1 presents, for the seasonal surveys of 1981, the means, standard errors, and numbers of observations of abundances of total algae and the nine major groups of planktonic algae in the three depth zones and the inner and outer stations groups. These are graphed with the preceding years in Figure 1.

Desmids (Fig. 1A) have shown almost no variation in abundance during the entire twelve years of the study.

Table 1. Means, standard errors, and numbers of observations of phytoplankton abundances by seasons, depth zones, and inner and outer station groups in Cook Plant major surveys during 1981. Units are cells per mL. B-G = blue-greens, Filam. = filamentous.

Zone	Inner Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae
10 APRIL 1981											
0	Inner										
	Mean	389.09	17.69	88.98	0.55	1632.91	702.74	1603.33	0.83	232.13	4668.28
	S. E.	112.01	3.80	19.87	0.55	121.78	74.43	201.58	0.59	33.29	352.68
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	427.13	28.28	1005.45	0.66	2159.63	559.43	1267.42	1.98	1380.65	6830.73
	S. E.	189.31	8.14	949.54	0.66	623.81	47.86	5.14	1.12	1195.76	2785.42
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	445.47	11.03	27.63	0	1620.47	333.83	603.53	0	123.80	3165.83
	S. E.	322.06	4.83	19.55	0	205.54	63.40	144.35	0	10.55	570.72
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	248.73	9.53	28.63	0.43	1427.60	313.38	518.55	1.65	98.65	2647.13
	S. E.	188.33	3.98	18.37	0.43	206.77	49.79	110.70	1.65	13.64	474.48
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	0	26.50	41.45	9.15	1219.50	185.70	408.70	1.65	73.80	1966.45
	S. E.	0	19.90	34.85	4.15	7.50	6.60	72.10	1.65	14.10	132.65
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	4.15	4.55	24.88	0	1464.90	245.80	248.73	0.43	88.30	2081.70
	S. E.	4.15	0.79	17.48	0	70.51	36.51	68.51	0.43	41.17	208.71
	N	4	4	4	4	4	4	4	4	4	4

Table 1 continued.

Zone	Inner Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae
8 JULY 1981											
0	Inner										
	Mean	42.83	977.02	156.07	1.93	940.68	76.13	593.87	0.14	32.47	2821.13
	S. E.	42.83	350.39	40.59	1.19	163.07	24.63	185.10	0.14	6.97	506.90
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	155.86	1510.83	112.59	3.15	1484.79	57.36	379.69	0	13.09	3717.37
	S. E.	138.07	466.55	58.69	1.98	324.35	17.14	130.40	0	5.27	888.37
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	7.20	434.43	112.47	5.00	1094.33	42.27	247.03	0.57	27.10	1970.33
	S. E.	7.20	205.27	97.95	4.18	369.28	26.69	133.15	0.57	13.57	571.84
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	26.53	456.18	77.53	4.15	1176.20	115.23	202.90	1.45	19.88	2080.05
	S. E.	24.38	194.70	16.85	1.44	213.57	15.68	47.88	0.71	5.79	289.10
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	0	803.30	15.75	7.05	986.15	88.70	211.80	0	17.85	2130.65
	S. E.	0	682.30	15.75	5.35	57.65	2.50	76.70	0	12.85	669.85
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	0	1232.78	292.23	3.73	1637.38	179.08	254.50	2.50	64.68	3666.80
	S. E.	0	865.01	181.57	2.17	528.25	76.93	88.60	1.45	39.02	1693.37
	N	4	4	4	4	4	4	4	4	4	4

Table 1 continued.

14 OCTOBER 1981

Zone	Inner Outer	Coccoid B-G	Filam. B-G	Coccoid greens	Filam. greens	Flagel-lates	Centric diatoms	Pennate diatoms	Desmids	Other algae	Total algae
0	Inner										
	Mean	2062.34	35.07	197.83	3.45	2125.63	824.20	613.63	2.35	174.68	6020.98
	S. E.	355.84	19.20	44.74	1.16	163.95	102.26	64.45	1.36	19.32	548.55
	N	12	12	12	12	12	12	12	12	12	12
	Outer										
	Mean	1394.76	133.95	250.70	1.82	1675.47	742.15	487.81	1.16	381.39	4773.73
	S. E.	419.44	125.22	52.23	0.71	154.48	87.34	73.98	0.70	189.34	613.83
	N	10	10	10	10	10	10	10	10	10	10
1	Inner										
	Mean	1460.29	72.93	259.80	0.57	1805.60	767.13	436.97	1.10	138.13	5017.30
	S. E.	669.39	71.29	124.85	0.57	83.06	205.68	172.30	1.10	12.75	987.61
	N	3	3	3	3	3	3	3	3	3	3
	Outer										
	Mean	1311.95	12.43	142.60	0.83	1602.13	676.88	361.85	0	130.58	4239.25
	S. E.	376.35	12.43	50.90	0.83	264.54	130.81	100.92	0	62.62	887.01
	N	4	4	4	4	4	4	4	4	4	4
2	Inner										
	Mean	958.35	24.85	289.35	6.65	2038.60	542.20	768.50	1.65	199.80	4829.95
	S. E.	484.15	18.25	35.65	6.65	166.60	97.80	422.00	1.65	95.30	1291.65
	N	2	2	2	2	2	2	2	2	2	2
	Outer										
	Mean	1402.30	1.25	129.75	0	1399.83	309.65	189.83	0	89.95	3522.55
	S. E.	575.17	0.79	45.46	0	237.98	57.33	58.44	0	23.33	940.52
	N	4	4	4	4	4	4	4	4	4	4

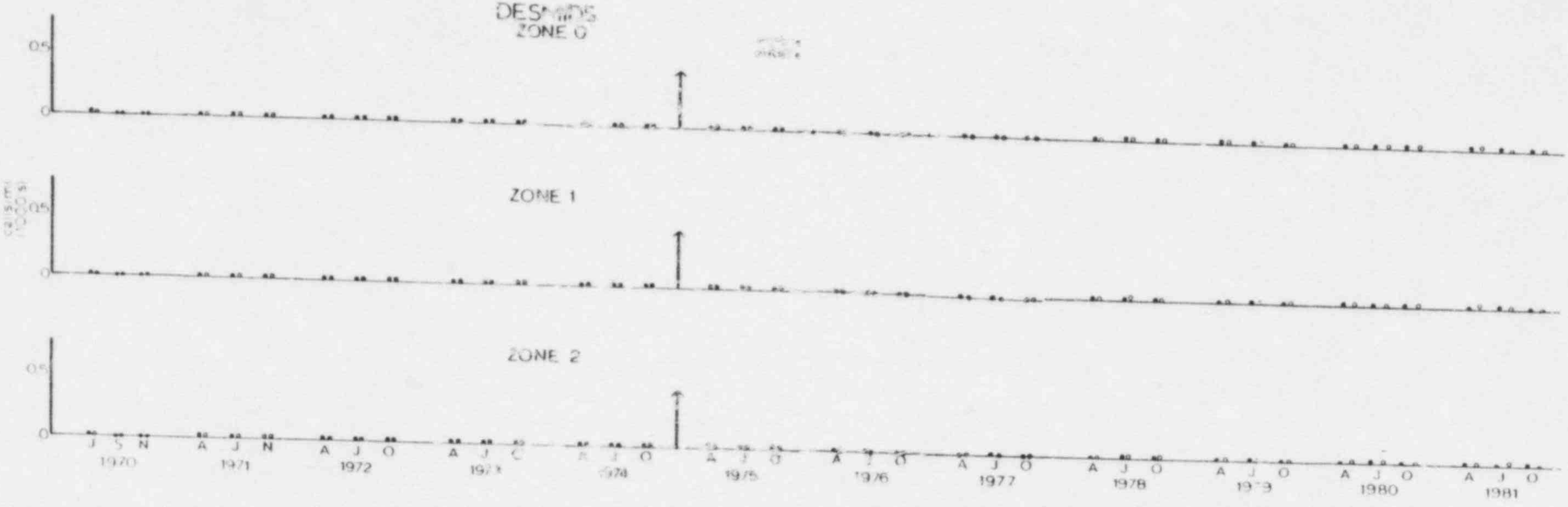

Fig. 1A. Mean abundances of desmids in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Space does not permit the drawing of standard error bars. See Table 1 for standard errors and numbers of observations.

Filamentous green algae (Fig. 1B), which in April 1976 had somewhat increased abundances in both station groups and all three depth zones, returned to preoperational levels in July of that year and have remained there ever since.

Other algae (Fig. 1C), after increased abundances in July and October of 1978, diminished in 1980 to levels comparable to other operational years. The anomalously high mean at zone 0 outer stations in April 1981 was due to a one-sample collection of 12,137 cells/mL at station SDC-2-0; with that station omitted the mean becomes 185.50 ± 42.81 cells/mL, otherwise the abundance of these algae in 1981 was comparable to those of preceding years.

Filamentous blue-green algae (Fig. 1D) generally showed elevated summer abundances in 1975 through 1979; in 1980 their abundances in all three seasons, both station groups, and all three depth zones were among the lowest measured in the operational years. Elevated summer abundances were again present in 1981.

Coccoid blue-greens (Fig. 1E), which had been recorded in small numbers during most of the preoperational surveys, increased notably in October 1974 (due in part to a change in counting method that year) and this pattern has been characteristic in the years since. The increases have taken place in both inner and outer stations, but not in a consistent manner. This continued in 1981.

Coccoid green algae (Fig. 1F) have been present in all depth zones and both station groups in variable abundances of about 500 cells per mL in each survey of the study area. An unusually high mean abundance at zone 0 outer stations in April 1981 was due to a single-sample collection of 9,550 cells/mL at station SDC-2-0; with this sample omitted, the mean became 56.01 ± 15.53 cells/mL, otherwise their abundances in 1981 were comparable to those of the preceding years.

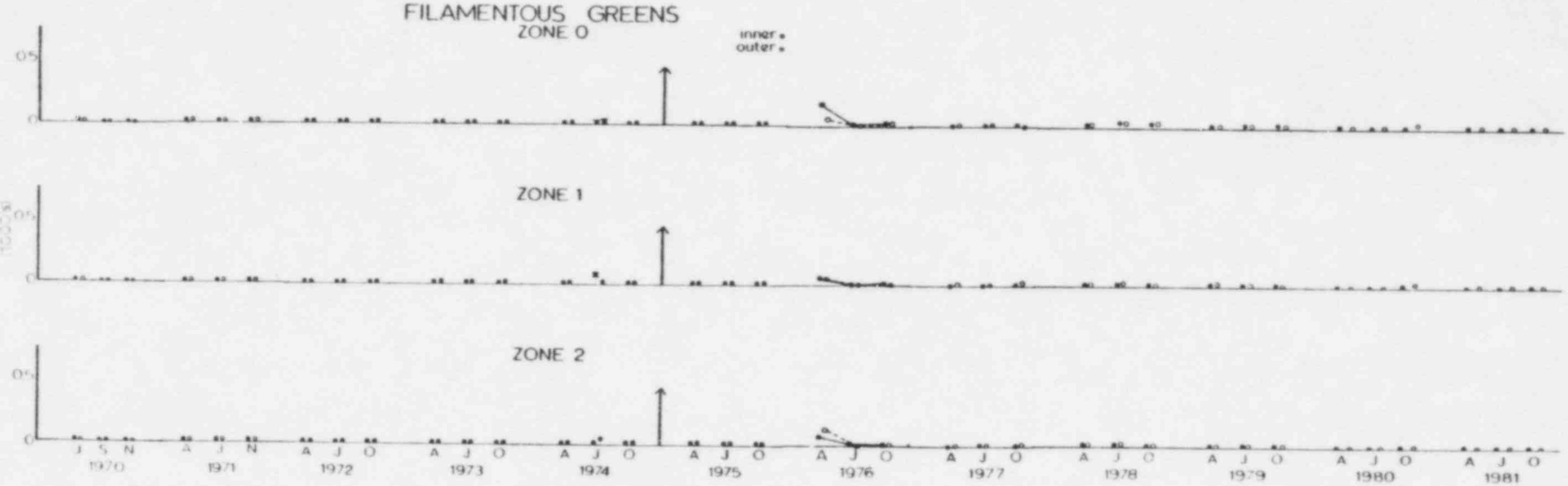

Fig. 18. Mean abundances of filamentous green algae in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Space does not permit the drawing of standard error bars. See Table 1 for standard errors and numbers of observations.

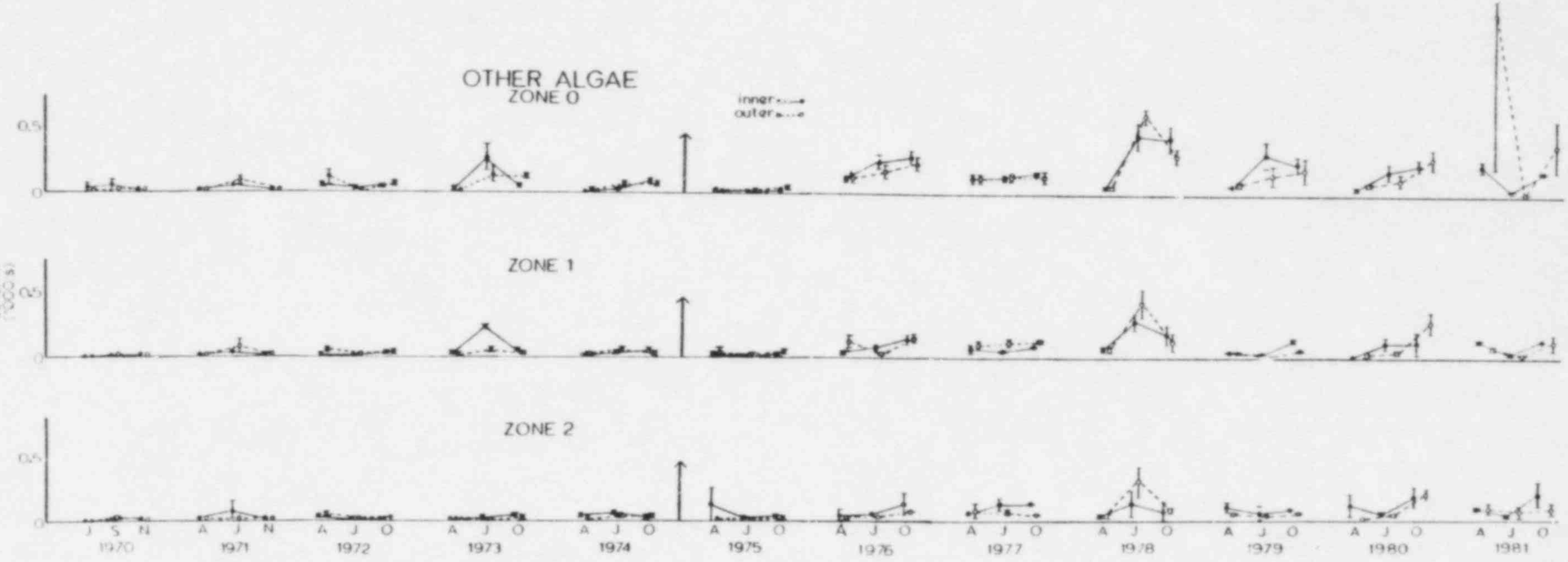

Fig. 1C. Mean abundances of "other algae" in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. The vertical bars show the standard errors. See Table 1 for numbers of observations.

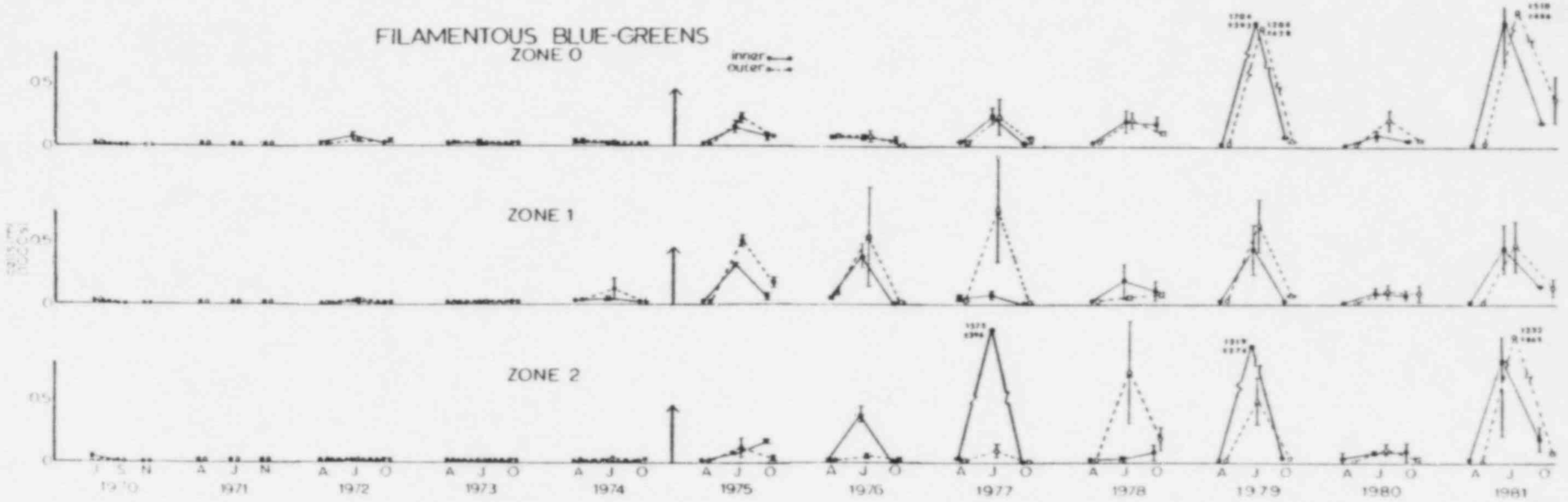

Fig. 10. Mean abundances of filamentous blue-green algae in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Where space permits, vertical bars show the standard errors. See Table 1 for other standard errors and for numbers of observations.

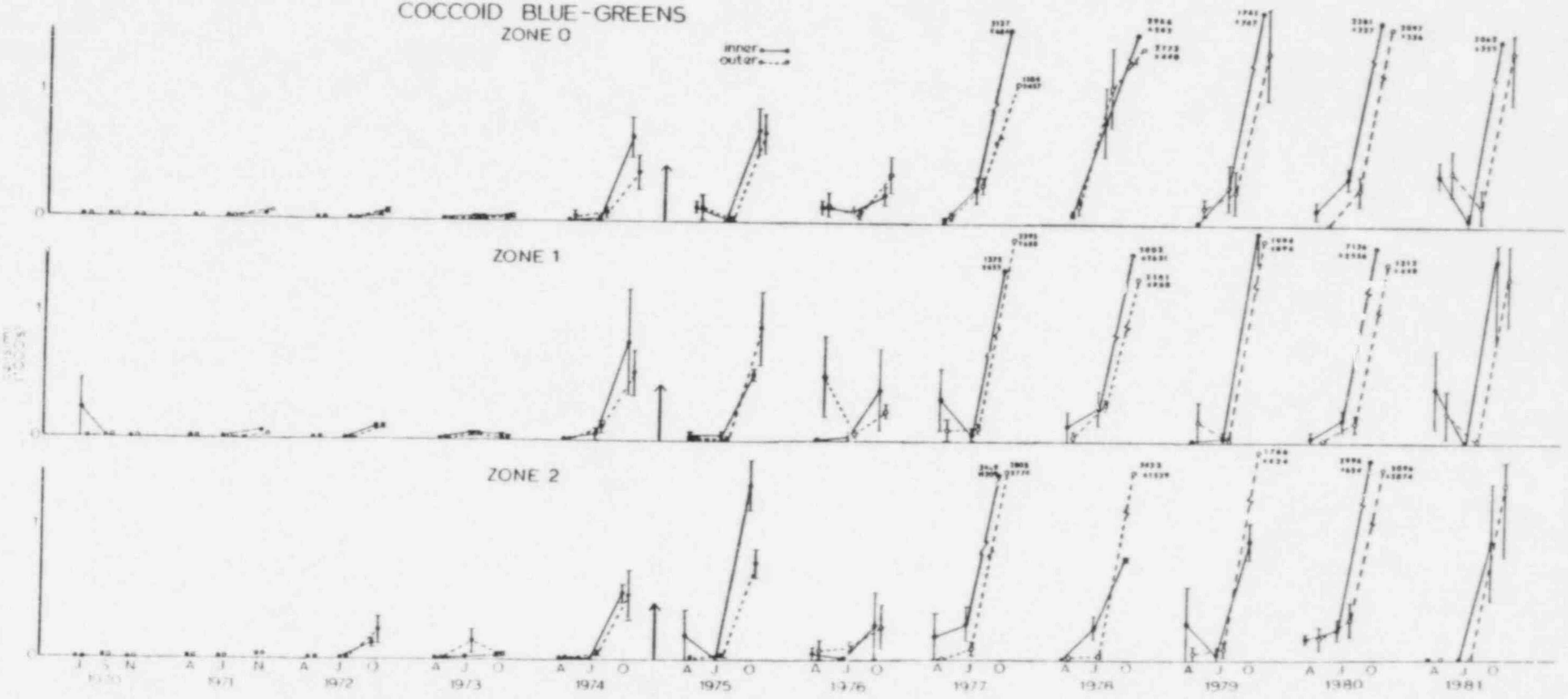

Fig. 16. Mean abundances of coccoid blue-green algae in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table I for numbers of observations.

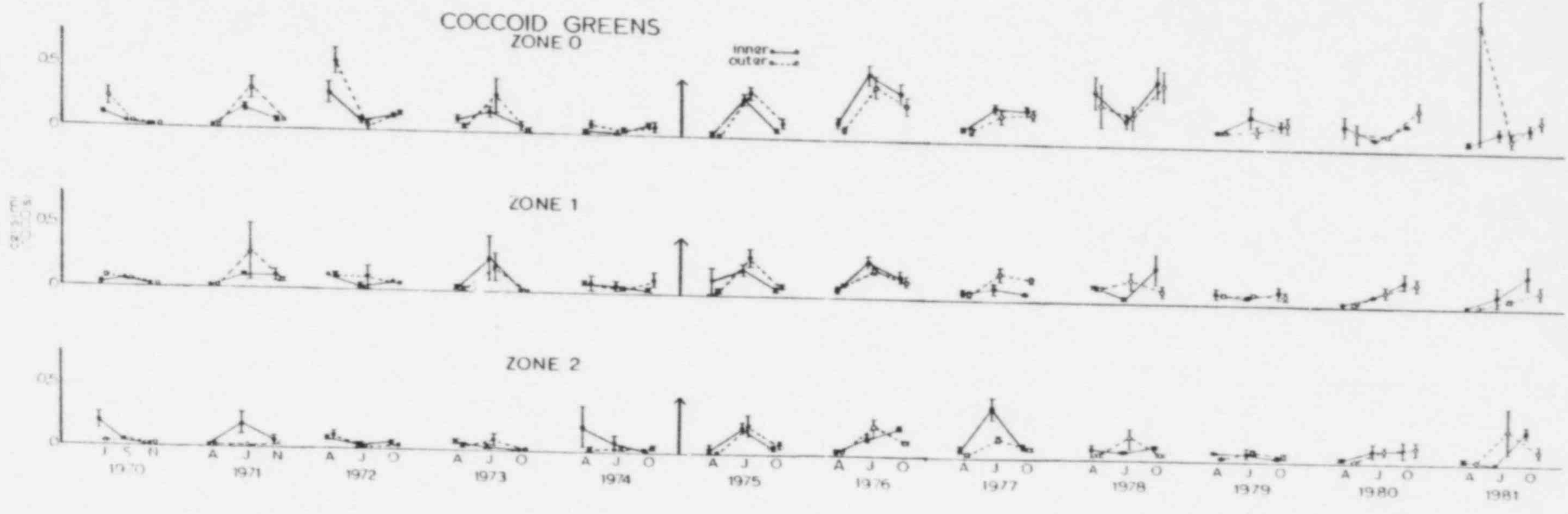

Fig. 1F. Mean abundances of coccoid green algae in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

Flagellates (Fig. 1G), after showing increasing abundances from 1970 through 1978, were somewhat less abundant in 1979 and 1980, but in 1981 they returned to their 1978 levels in zone 0 and attained their greatest recorded abundances in zones 1 and 2.

Pennate diatoms (Fig. 1H) in zone 0 showed summer abundance peaks (believed due to sampling during upwellings) that diminished from 1978 through 1980. In all three depth zones in 1981 the pennates returned to having the more typical summer abundance minima. The general impression from 1978 through 1981 is that pennates in all zones and both station groups have been diminishing in abundance.

Centric diatoms (Figs. 1I, 1J, 1K) in 1981 exhibited summer abundance minima in both station groups and in all three depth zones. In depth zone 0 the abundance of centrics has decreased drastically during 1978 through 1981; in zone 1 there has been a modest decrease during 1978-81; in zone 2 their diminution is less plain but 1981 is definitely less than 1978.

Total algae (Figs. 1L, 1M, 1N) in both station groups of zones 0 and 1 showed decreasing abundances from 1978 through 1981 after increasing from 1974 to 1978. Zone 2 showed these trends (but less clearly due to poor parallelism in the annual curves of 1977, 1978, 1979, and 1981), indeed, the rising trend in the early years appears to begin with 1971. In 1981 the curves for zone 0 and zone 1 exhibit summer abundance minima with higher abundances in spring and fall; the curves for zone 2 show abundance peaks in fall (inner stations) and summer (outer stations). The early-years rise and later-years decrease in total algae may be parts of a natural cycle of abundance, but it is interesting to note that the Great Lakes Water Quality Board (1981, p. 43) has reported to the

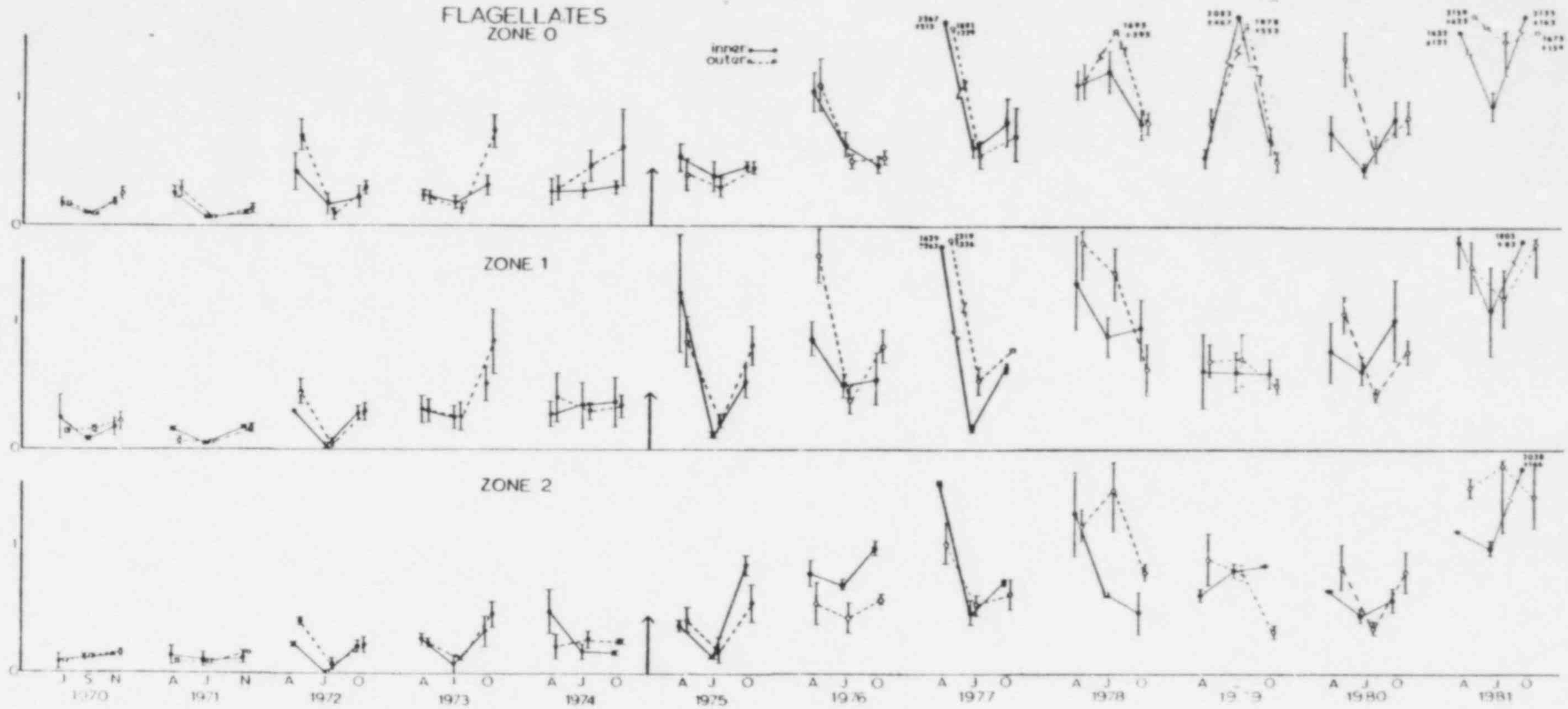

Fig. 16. Mean abundances of flagellates in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

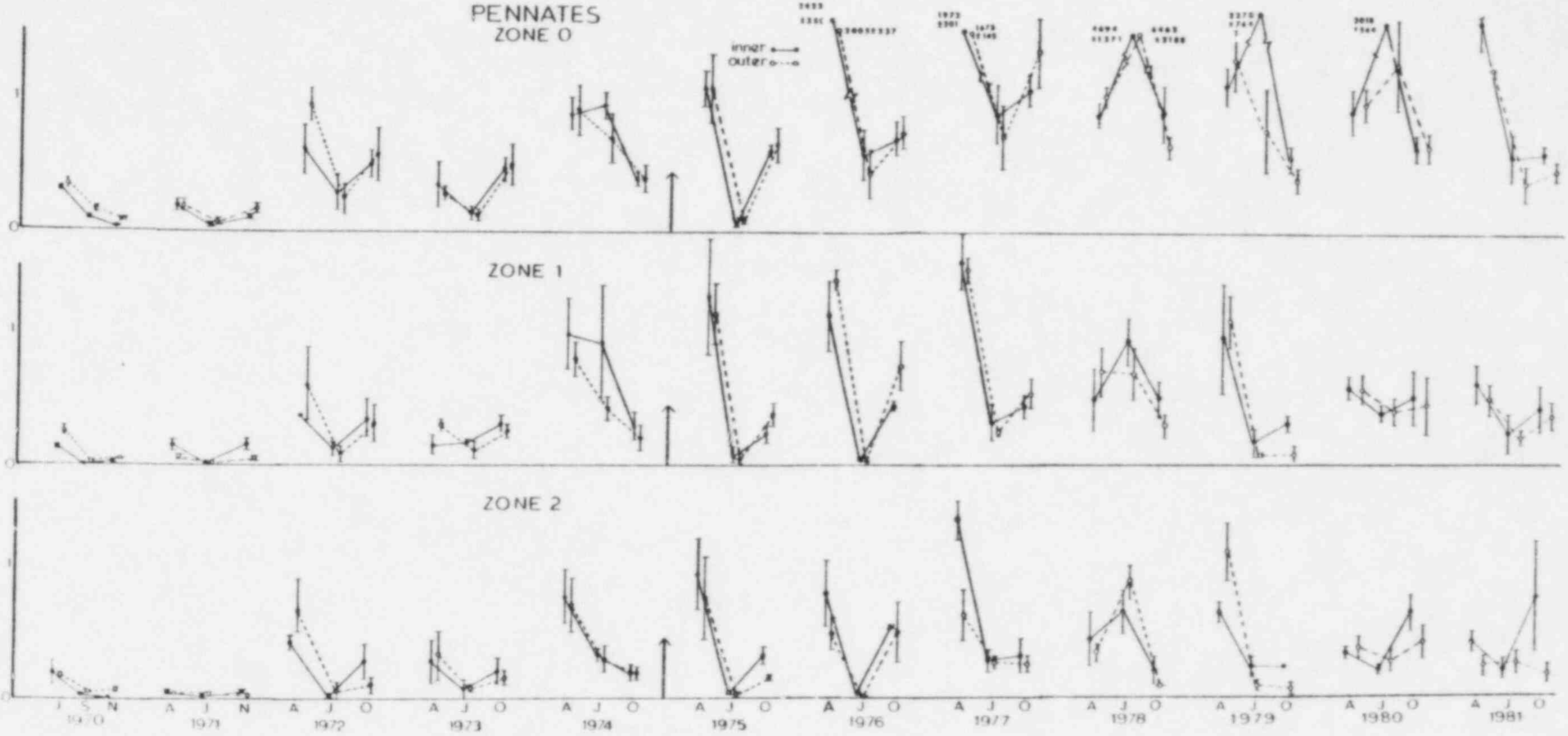

Fig. 18. Mean abundances of pennate diatoms in Cook Plant zones 0 - 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

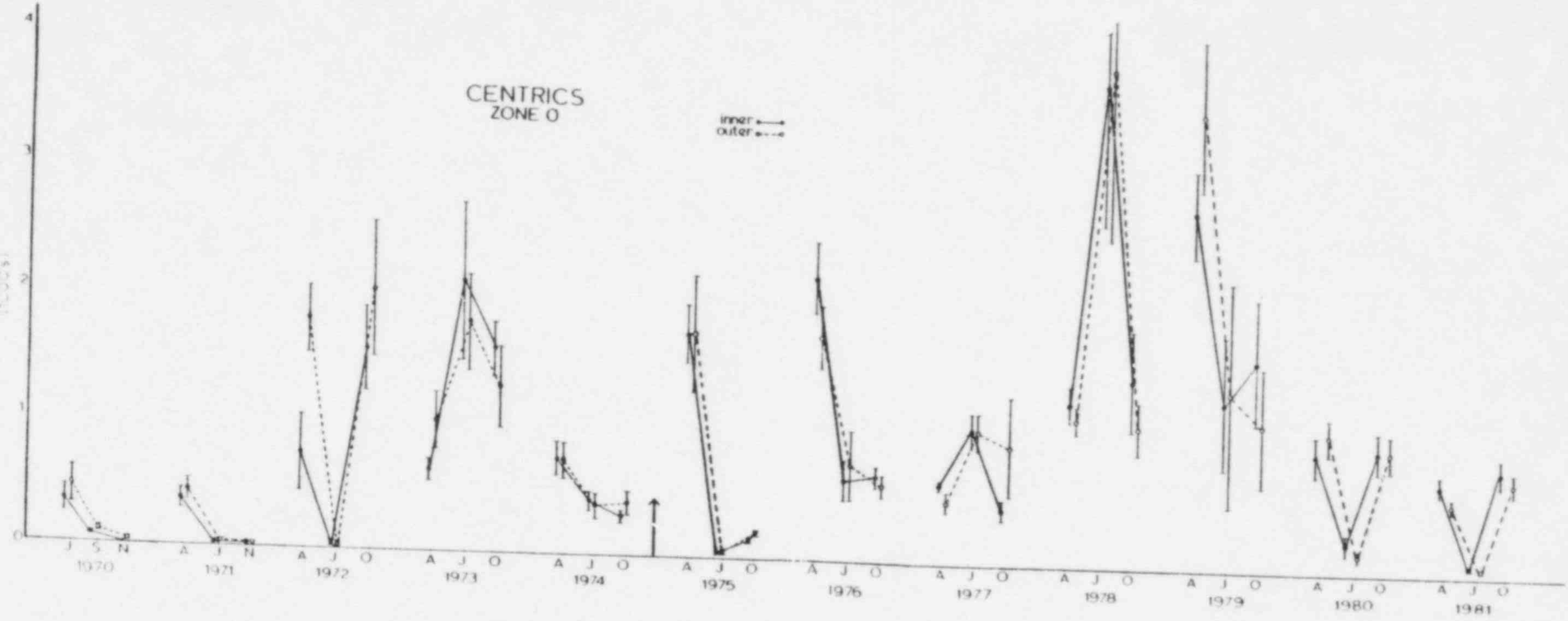

Fig. 11. Mean abundances of centric diatoms in Cook Plant zone 0 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

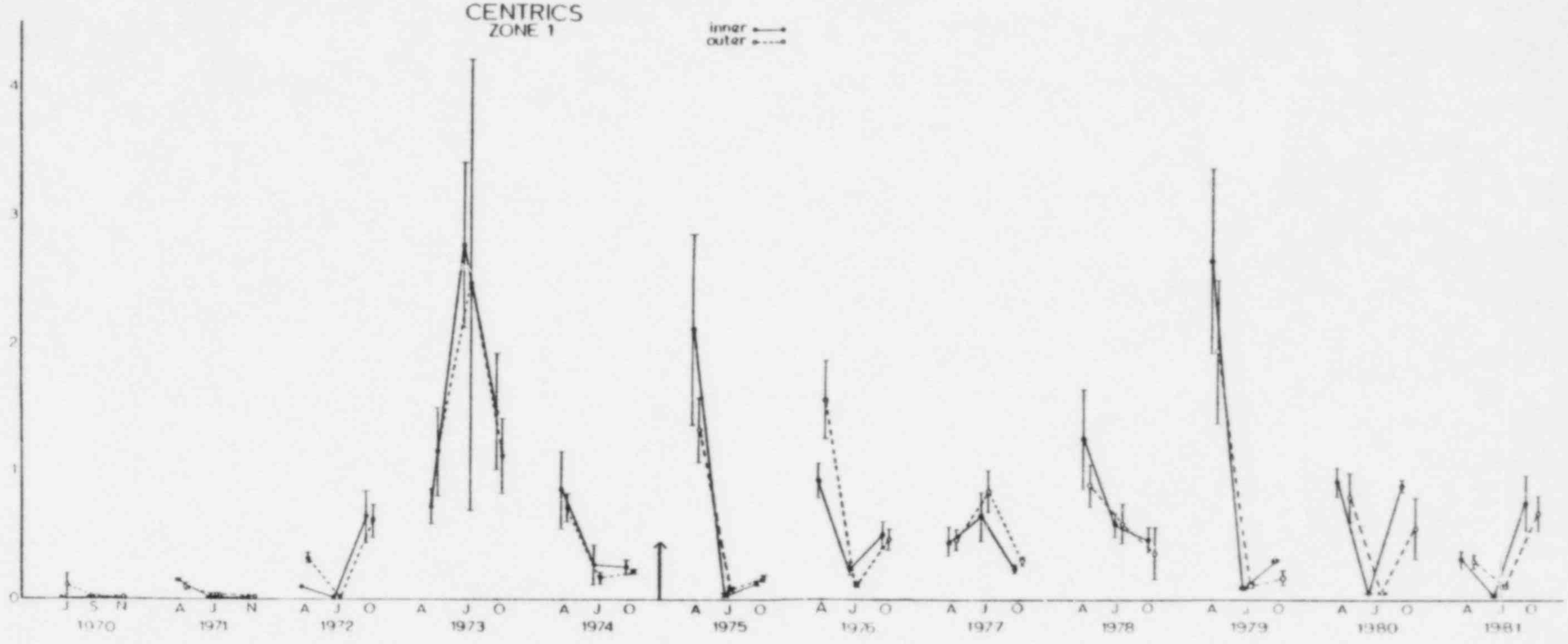

Fig. 11. Mean abundances of centric diatoms in Cook Plant zone 1 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

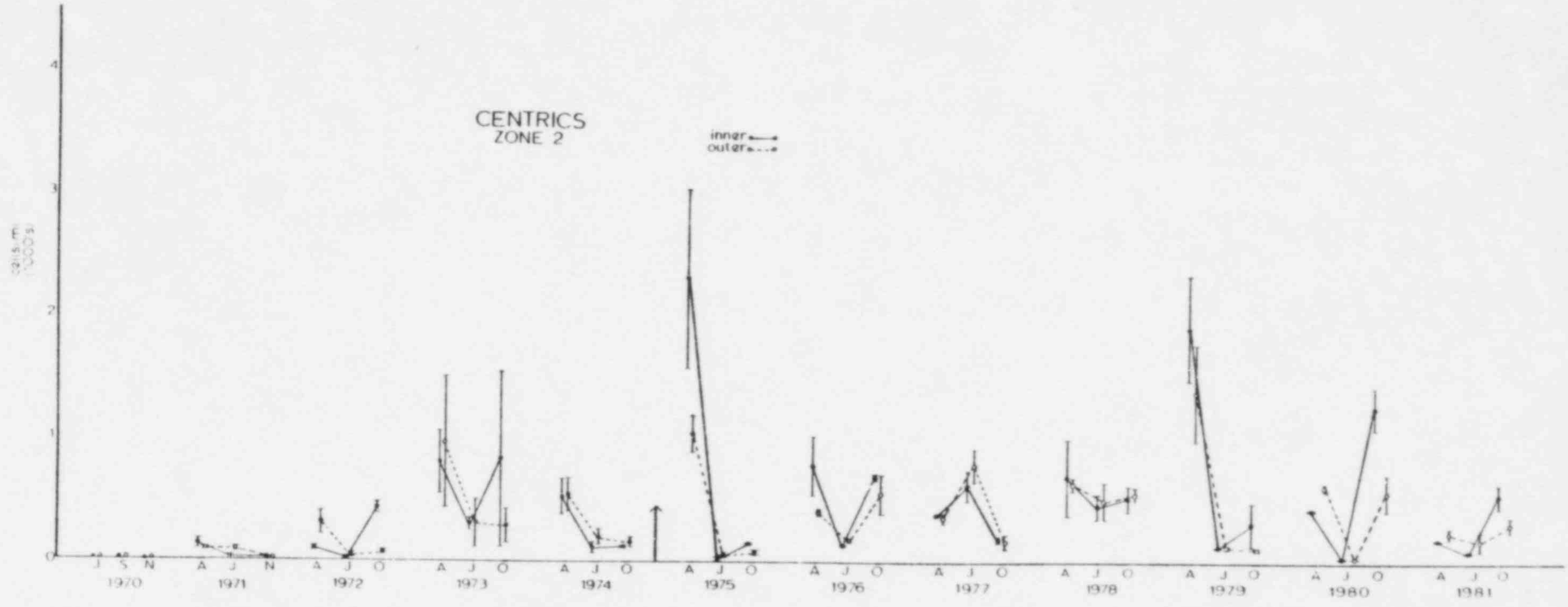

Fig. 1E. Mean abundances of centric diatoms in Cook Plant zone 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

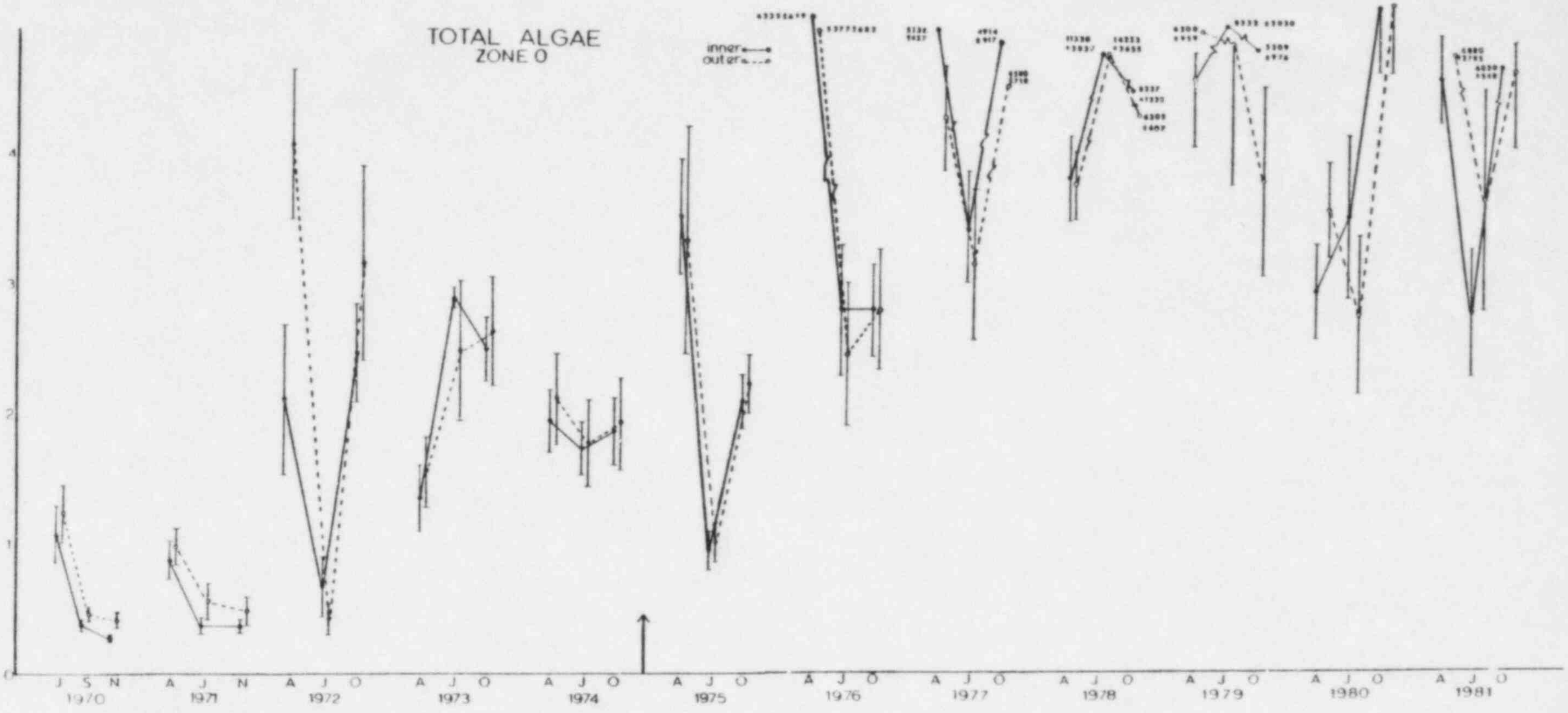

Fig. 16. Mean abundances of total algae in Cook Plant zone 0 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table I for numbers of observations.

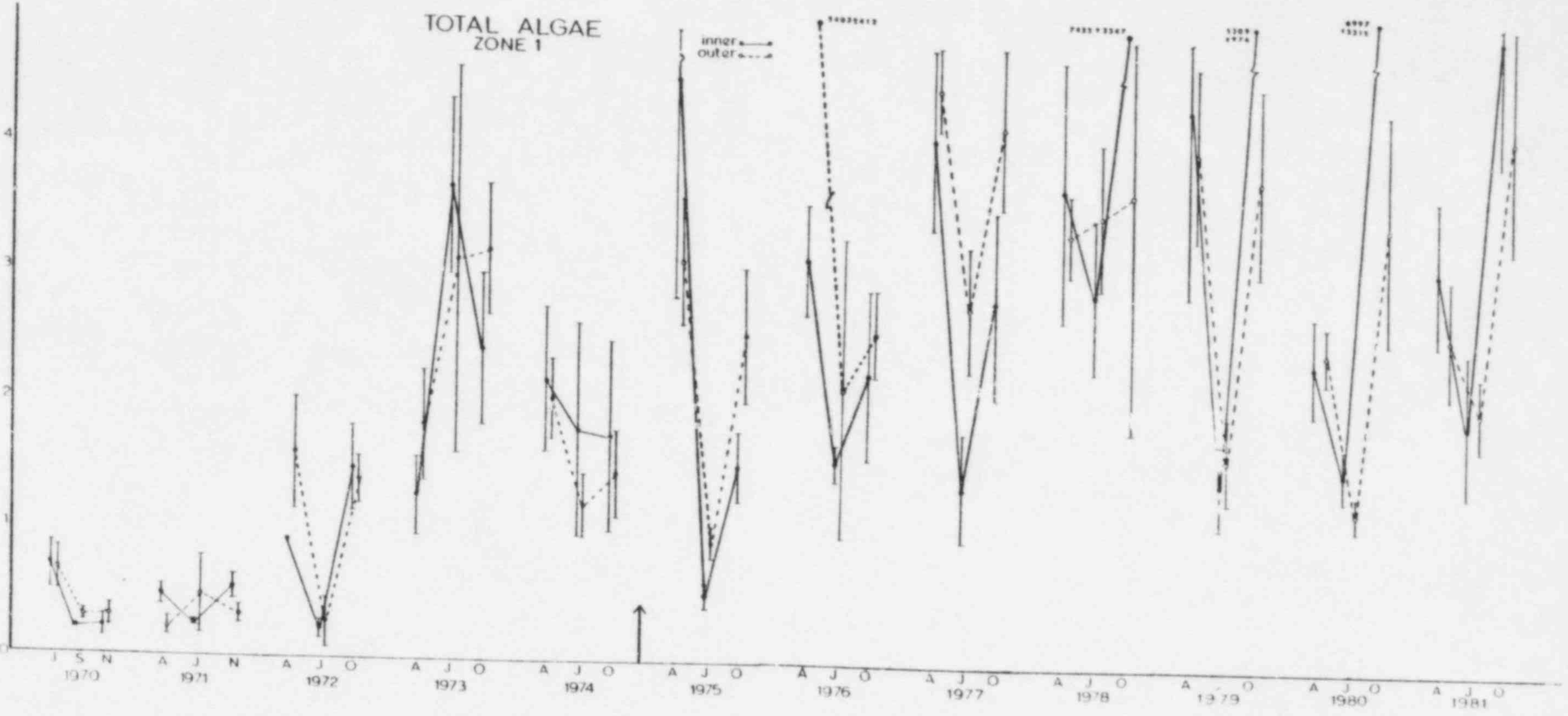

Fig. 18. Mean abundances of total algae in Cook Plant zone 1 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

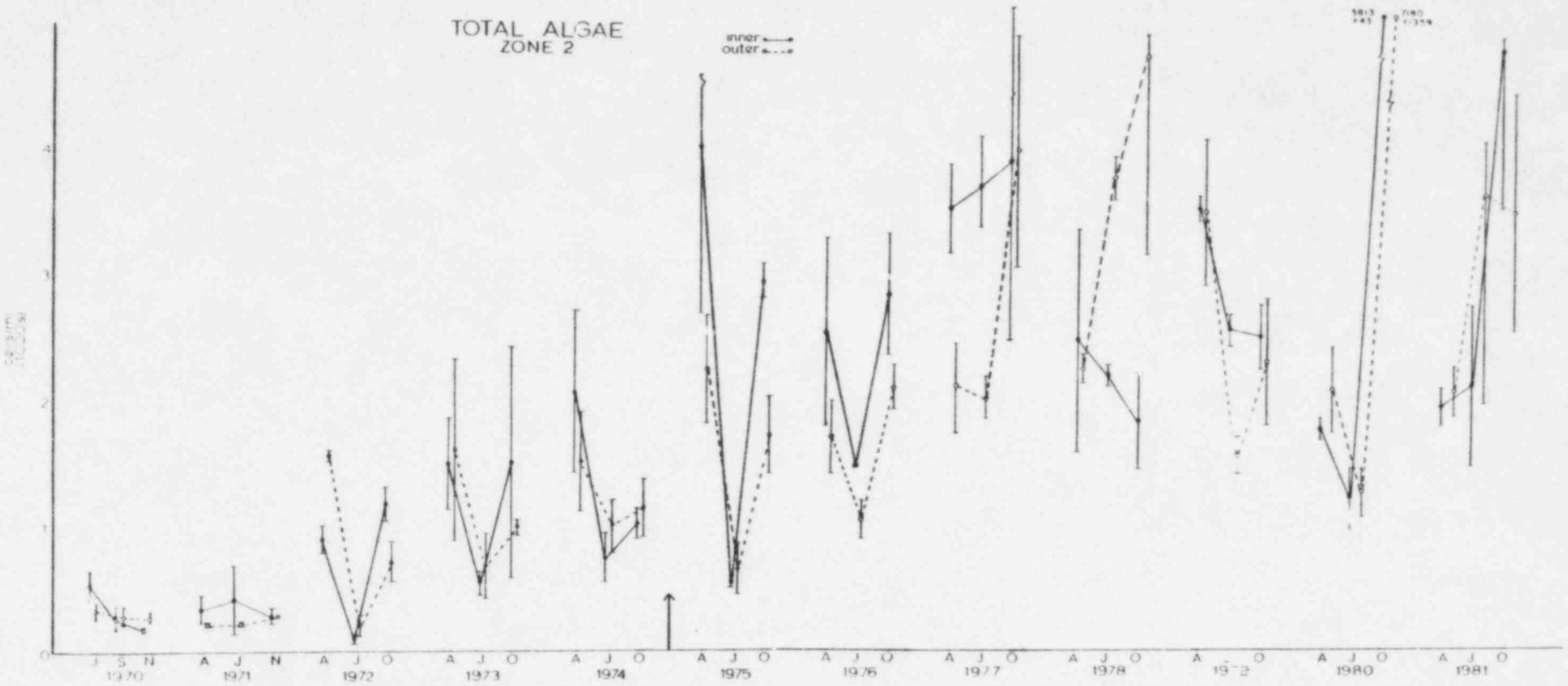

Fig. 1N. Mean abundances of total algae in Cook Plant zone 2 in spring, summer, and fall seasons at inner and outer station groups during 1970 through 1981. Vertical bars show the standard errors. See Table 1 for numbers of observations.

International Joint Commission that the phosphorus loading of Lake Michigan went from its high of 2,339 tonnes/year in 1976 to 1,045 tonnes/year in 1980.

Inner-Outer Statistical Comparisons: Phytoplankton Abundances by Algal Categories

In the Environmental Operating Report for 1977 we reported statistical tests for significant differences in the mean abundances of ten algal categories at inner vs. outer station groups in three depth zones during the seasonal surveys of 1970 through 1977; each subsequent EOR has extended the tests through another year; and this section extends them through 1981.

The strategy was that if plant-caused effects on the phytoplankton were present they could be expected to show as consistent significant differences in overall cell densities between the inner and outer stations. Corollary to this was the possibility that plant operation might influence cell densities in one or more affected zones but not in others. Another corollary was that plant operation might act selectively upon one or a few of the ten categories of algae, producing consistent significant differences in densities of the affected categories between inner and outer station groups.

For each season in each depth zone all available cell densities of each algal category were averaged to give seasonal mean abundances at the inner and outer station groups, and comparisons were made by two-sample t-test between inner and outer mean densities of each category in each depth zone.

Table 2 gives the means, variances, numbers of observations, and t-test of significance for each algal category in each season, station group, and depth zone during 1981.

Table 2. Algal abundances (cells/mL), by algal categories, at inner (treatment) and outer (control) station groups in three depth zones in April, July, and October of 1981. In each season in each depth zone the mean count of cells/mL at inner stations is compared to that at outer stations using a two-sample t-test. Symbols used: n.s. = no significant difference between the two groups; * = significance at the .05 level; ** = significance at the .01 level; and N = the number of stations for which data were available. No test was made if one of the groups contained only a single observation, or if one of the group variances was zero.

Survey	Station	Zone 0 (0-8m)				Zone 1 (8-16m)				Zone 2 (16-24m)			
		Means	Variance	N	t-test	Means	Variance	N	t-test	Means	Variance	N	t-test
COCCOID BLUE-GREEN ALGAE													
Spring	Inner	389.09	$.15056 \times 10^6$	12	0.8591 n.s.	445.47	$.31116 \times 10^6$	3	0.5979 n.s.	0	0	2	
	Outer	427.13	$.35839 \times 10^6$	10		248.72	$.14187 \times 10^6$	4		4.1500	68.890	4	
Summer	Inner	42.833	22016	12	0.4088 n.s.	7.2000	155.52	3	0.5409 n.s.	0	0	2	
	Outer	155.86	$.19063 \times 10^6$	10		26.525	2376.5	4		0	0	4	
Fall	Inner	2062.3	$.15195 \times 10^7$	12	0.2359 n.s.	1469.0	$.13463 \times 10^7$	3	0.8350 n.s.	958.35	$.46880 \times 10^6$	2	0.6520 n.s.
	Outer	1394.8	$.17593 \times 10^7$	10		1311.9	$.56655 \times 10^6$	4		1402.3	$.13233 \times 10^7$	4	
FILAMENTOUS BLUE-GREEN ALGAE													
Spring	Inner	17.692	172.89	12	0.2242 n.s.	11.033	69.853	3	0.8174 n.s.	26.500	792.02	2	0.1475 n.s.
	Outer	28.340	662.15	10		9.5250	63.149	4		4.5500	2.5100	4	
Summer	Inner	977.02	$.14733 \times 10^7$	12	0.3625 n.s.	434.43	$.12641 \times 10^6$	3	0.9426 n.s.	803.30	$.93107 \times 10^6$	2	0.7685 n.s.
	Outer	1510.8	$.21767 \times 10^7$	10		456.17	$.15163 \times 10^6$	4		1232.8	$.29929 \times 10^6$	4	
Fall	Inner	17.667	579.99	12	0.8377 n.s.	72.933	15247	3	0.3699 n.s.	24.850	666.12	2	0.1037 n.s.
	Outer	20.550	1632.3	10		12.4.5	617.52	4		1.2500	2.5000	4	
COCCOID GREEN ALGAE													
Spring	Inner	88.983	4739.1	12	0.3008 n.s.	27.633	1146.3	3	0.9723 n.s.	41.450	2429.0	2	0.6496 n.s.
	Outer	1005.4	$.90163 \times 10^7$	10		28.625	1350.1	4		24.875	1221.9	4	
Summer	Inner	156.07	19672.	12	0.5385 n.s.	112.47	28797.	3	0.6959 n.s.	15.750	496.13	2	0.3677 n.s.
	Outer	112.59	34447.	10		77.525	1135.8	4		292.22	$.13186 \times 10^6$	4	
Fall	Inner	197.03	24023.	12	0.4416 n.s.	259.80	46764.	3	0.3757 n.s.	289.35	2541.8	2	0.0897 n.s.
	Outer	250.70	27282.	10		142.60	10361.	4		129.75	8267.2	4	
FILAMENTOUS GREEN ALGAE													
Spring	Inner	0.5500	3.6300	12	0.8985 n.s.	0	0	3		9.1500	34.445	2	
	Outer	0.6600	4.3560	10		.42500	.72250	4		0	0	4	
Summer	Inner	1.9333	16.953	12	0.5907 n.s.	5.0000	52.390	3	0.8355 n.s.	7.0500	57.245	2	0.5110 n.s.
	Outer	3.1500	39.347	10		4.1500	8.2233	4		3.7250	18.762	4	
Fall	Inner	3.4500	16.259	12	0.2696 n.s.	.56667	.96333	3	0.8213 n.s.	6.6500	88.445	2	
	Outer	1.8200	5.1107	10		.82500	2.7225	4		0	0		
FLAGELLATES													
Spring	Inner	1632.9	$.17796 \times 10^6$	12	0.3764 n.s.	1620.5	$.12673 \times 10^6$	3	0.5474 n.s.	1219.5	112.50	2	0.0813 n.s.
	Outer	2159.6	$.38914 \times 10^7$	10		1427.6	$.17101 \times 10^6$	4		1464.9	19883.	4	
Summer	Inner	940.68	$.14015 \times 10^6$	12	0.1022 n.s.	1094.3	$.36598 \times 10^6$	3	0.8405 n.s.	986.15	6647.0	2	0.4577 n.s.
	Outer	1484.8	$.10520 \times 10^7$	10		1176.2	$.18244 \times 10^6$	4		1637.4	$.11162 \times 10^7$	4	
Fall	Inner	2125.6	$.32255 \times 10^6$	12	0.0628 n.s.	1805.6	20696.	3	0.5536 n.s.	2038.6	55511.	2	0.1604 n.s.
	Outer	1675.5	$.23863 \times 10^6$	10		1602.1	$.27991 \times 10^6$	4		1399.8	$.22654 \times 10^6$	4	

Table 2 continued.

Survey	Station	Zone 0 (0-8m)				Zone 1 (8-16m)				Zone 2 (16-24m)			
		Means	Variance	N	t-test	Means	Variance	N	t-test	Means	Variance	N	t-test
CENTRIC DIATOMS													
Spring	Inner	702.74	66474.	12	0.1378 n.s.	333.83	12060.	3	0.8067 n.s.	185.70	87.120	2	0.3352 n.s.
	Outer	559.43	22911.	10		313.37	9918.3	4		245.80	5339.5	4	
Summer	Inner	76.133	7279.8	12	0.5547 n.s.	42.267	2137.4	3	0.0536 n.s.	88.700	12.500	2	0.4773 n.s.
	Outer	57.360	2937.5	10		115.22	983.56	4		179.07	23670.	4	
Fall	Inner	824.20	$.12549\times10^6$	12	0.5578 n.s.	767.13	$.12691\times10^6$	3	0.7126 n.s.	542.20	19130	2	0.0907 n.s.
	Outer	742.15	76285.	10		676.87	68444.	4		309.65	13140.	4	
PENNATE DIATOMS													
Spring	Inner	1603.3	$.48760\times10^6$	12	0.2217 n.s.	603.53	62508.	3	0.6535 n.s.	408.70	10397.	2	0.2259 n.s.
	Outer	1267.4	$.26372\times10^6$	10		518.55	49015.	4		248.72	18773.	4	
Summer	Inner	593.87	$.41112\times10^6$	12	0.3740 n.s.	247.03	53188.	3	0.7384 n.s.	211.80	11766.	2	0.7770 n.s.
	Outer	379.69	$.17004\times10^6$	10		202.90	9170.1	4		254.50	31400.	4	
Fall	Inner	613.62	49851.	12	0.2125 n.s.	502.97	36165.	3	0.3919 n.s.	768.50	$.35617\times10^6$	2	0.1013 n.s.
	Outer	487.81	54731.	10		361.85	40740.	4		189.82	13682.	4	
DESMIDS													
Spring	Inner	.82500	4.2075	12	0.3509 n.s.	0	0	3		1.6500	5.4450	2	0.3632 n.s.
	Outer	1.9800	12.584	10		1.6500	10.890	4		.42500	.72250	4	
Summer	Inner	.14167	.24083	12		.56667	.96333	3	0.4007 n.s.	0	0	2	
	Outer	0	0	10		1.4500	2.0033	4		2.5000	8.3333	4	
Fall	Inner	2.3500	22.259	12	0.4730 n.s.	1.1000	3.6300	3		1.6500	5.4450	2	
	Outer	1.1600	4.8760	10		0	0	4		0	0	4	
OTHER ALGAE													
Spring	Inner	232.12	13298.	12	0.3032 n.s.	123.80	333.97	3	0.2298 n.s.	73.800	397.62	2	0.8275 n.s.
	Outer	1380.6	$.14298\times10^8$	10		98.650	744.09	4		88.300	6778.6	4	
Summer	Inner	32.467	582.94	12	0.0445 *	27.100	552.76	3	0.6093 n.s.	17.850	330.24	2	0.4722 n.s.
	Outer	13.090	277.54	10		19.875	133.93	4		64.675	6089.3	4	
Fall	Inner	174.67	4479.7	12	0.6327 n.s.	138.13	487.86	3	0.9235 n.s.	199.80	18164.	2	0.1818 n.s.
	Outer	199.32	25785.	10		130.57	15684.	4		89.950	2177.5	4	
TOTAL ALGAE													
Spring	Inner	4668.3	$.14926\times10^7$	12	0.4082 n.s.	3165.8	$.97716\times10^6$	3	0.5130 n.s.	1966.4	35192.	2	0.7396 n.s.
	Outer	6830.7	$.77586\times10^8$	10		2647.1	$.90053\times10^6$	4		2081.7	$.17424\times10^6$	4	
Summer	Inner	2821.1	$.30834\times10^7$	12	0.3717 n.s.	1970.3	$.98099\times10^6$	3	0.8593 n.s.	2130.6	$.89740\times10^6$	2	0.5826 n.s.
	Outer	3717.4	$.78921\times10^7$	10		2080.0	$.33432\times10^6$	4		3666.8	$.11470\times10^8$	4	
Fall	Inner	6021.0	$.36109\times10^7$	12	0.1446 n.s.	5017.3	$.29261\times10^7$	3	0.5855 n.s.	4829.9	$.33367\times10^7$	2	0.4642 n.s.
	Outer	4773.7	$.37679\times10^7$	10		4239.2	$.31471\times10^7$	4		3522.5	$.35383\times10^7$	4	

During the period July 1970 through October 1981, 913 paired comparisons of inner vs. outer station group cell density means have been possible; 350 were from preoperational years and 563 were from operational years. During the entire period there have been a total of 47 cases of significant differences in mean cell densities between inner and outer station groups; these amount to 5.25% of the possible comparisons. In preoperational years there were 20 cases of significant differences out of 350 paired comparisons, amounting to 5.71% of the possible comparisons. In operational years there have been 28 cases out of 563 comparisons, amounting to 4.97% of the comparisons.

The following tabulation summarizes the distribution of the cases wherein there were significant (at the .05 or .01 levels) differences between mean densities of phytoplankton categories at inner vs. outer station groups. In each case the order of the abbreviations is: year, depth zone, season (Sp, Su, Fa), and I or 0 indicating which station group had the greater mean density of cells. Cases in operational years are underlined.

Coccoid blue-greens	75,Z2,Fa,I	78,Z2,Su,I	79,Z0,Sp,0	
Filamentous blue-greens	75,Z1,Su,0	75,Z2,Fa,I	76,Z2.Su,I	77,Z2,Su,I
Coccoid greens	70,Z2,Su,I	71,Z2,Su,I	75,Z0,Fa,0	76,Z2,Fa,I
	77,Z2,Su,I			
Filamentous greens		None		
Flagellates	71,Z1,Su,0	72,Z2,Sp,0	73,Z1,Fa,0	74,Z2,Fa,0
	76,Z2,Fa,I	77,Z1,Su,0	77,Z1,Fa,0	79,Z2,Fa,0
	80,Z0,Sp,0	80,Z1,Su,I		
Centric diatoms	72,Z1,Sp,0	72,Z1,Fa,I	75,Z0,Fa,I	75,Z2,Fa,I
	80,Z2,Sp,0			
Pennate diatoms	70,Z1,Su,0	71,Z2,Su,0	73,Z1,Sp,0	75,Z2,Fa,I
	79,Z1,Fa,I			
Desmids	71,Z1,Su,0	71,Z2,Su,I		
Other algae	71,Z1,Sp,0	73,Z0,Sp,I	73,Z1,Su,I	73,Z2,Fa,I
	74,Z2,Sp,I	77,Z2,Fa,I	80,Z1,Sp,0	81,Z0,Su,I
Total algae	72,Z0,Sp,0	72,Z2,Sp,0	76,Z1.Sp,0	77,Z2,Su,I
	78,Z2,Su,0	79,Z2,Su,I		

Summarized by years the numbers of significant differences were:

1970 (2 seasons)	2	1975	7*
1971	6	1976	4
1972	5	1977	6
1973	5	1978	2
1974	2	1979	4
		1980	4
		1981	1

*Erroneously reported as 6 in previous reports.

Although seven significant differences in 1975 is the highest yet found, it is small relative to the 78 paired comparisons of that year. The numbers of significant differences appear to be within the natural range of variation; no effect of plant operation is evident in this analysis.

Summarized by depth zones, with the station group having the greatest density indicated, and with operational years underlined, the cases of significant difference were:

Zone 0	Zone 1	Zone 2
Inner greater 1 + 2	Inner greater 3 + 2	Inner greater 5* + 13
Outer greater 1 + 3	Outer greater 7 + 5	Outer greater 4 + 3

*Erroneously reported as 6, previously.

Except for the inner station group of depth zone 2, the distributions of significant differences between preoperational and operational years appear to be within the normal range of variation. The increase in numbers of differences in zone 2 inner stations in operational years may possibly be an effect of plant operation on blue-green algal abundances in that area, but of the 563 paired comparisons in operational years it is a minute (2.30%) effect.

Inner-Outer Graphical Comparisons: Diversity Indices

Cook Plant species diversity data for the years 1971 through 1975 have been presented by Ayers, Southwick, and Robinson (1977), Ayers (1978) extended them to include 1970 and 1976, Ayers and Wiley (1979) added 1977, Ayers and Feldt (1982) added 1978-79, and Ayers and Feldt (in preparation) will cover 1980-81. This section adds 1981 to previous EOR reports.

As was done in the reports cited above, the diversity index data have been stratified by three depth zones and by inner (treatment) stations near the plant and by outer (reference or control) stations away from the plant.
The Environmental Operating Report for 1977 presents the depth intervals used in each depth zone and the stations which comprise the inner and outer station groups in each depth zone.

The diversity index used is, as previously, that of Wilhm and Dorris (1968):

$$\overline{d} = -\sum_{i=1}^{S} (n_i/n)\log_2 (n_i/n)$$

where S is the number of species, n is the total number of phytoplankton in cells/ml, n_i is the number of phytoplankton of the i^{th} species.

Mean diversity indices and associated standard errors for each depth-zone-station-group combination in the major surveys of 1981 are given in Table 3. In Figure 2 the surveys of 1981 have been added at the end of the time plots of diversity indices and standard errors which were presented previously.

In Figure 2 the annual curves of mean diversity generally show substantial degrees of parallelism between inner and outer station groups, though parallelism was poor in all zones in 1971 and 1972, in zone 0 in 1974, in zone 1 in

Table 3. Means, standard errors, and numbers of observations of phytoplankton diversity indices by seasons, depth zones, and inner or outer station groups in Cook Plant major surveys during operational 1981. The diversity index used is that of Wilhm and Dorris (1968) based on log 2.

1981

			10 April	8 July	14 October
Zone 0	Inner				
		Mean	4.25	2.96	3.63
		S. E.	0.08	0.16	0.07
		N	12	12	12
	Outer				
		Mean	3.99	2.41	3.76
		S. E.	0.12	0.24	0.14
		N	10	10	10
Zone 1	Inner				
		Mean	3.48	2.89	3.52
		S. E.	0.17	0.44	0.18
		N	3	3	3
	Outer				
		Mean	3.66	2.97	3.74
		S. E.	0.14	0.21	0.11
		N	4	4	4
Zone 2	Inner				
		Mean	3.19	2.98	3.82
		S. E.	0.18	0.58	0.05
		N	2	2	2
	Outer				
		Mean	3.31	3.01	3.61
		S. E.	0.28	0.21	0.04
		N	4	4	4

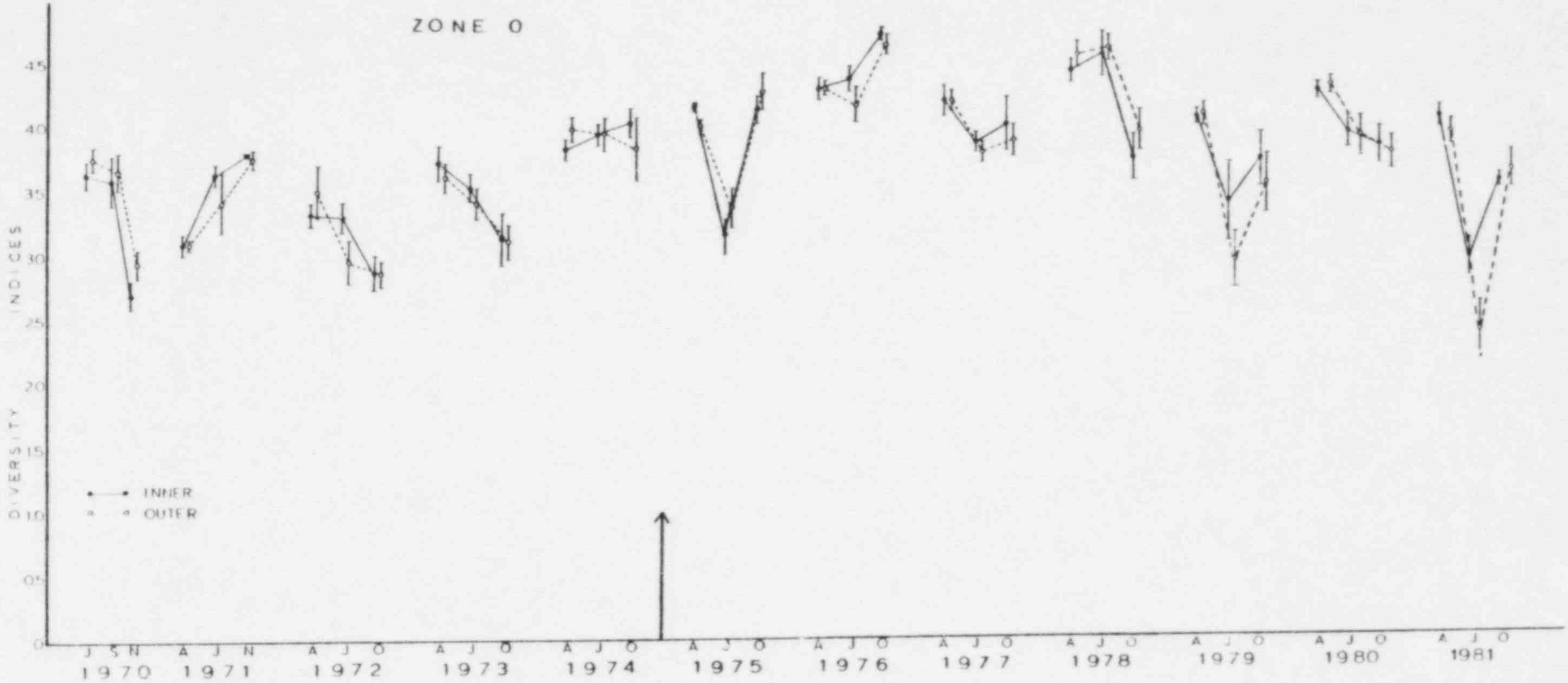

Fig. 7A. Mean diversity indices of phytoplankton collections in Cook Plant zone 0 in spring, summer, and fall seasons and at inner and outer station groups during 1970 through 1981. The vertical bars show the standard errors. See Table 3 for numbers of observations.

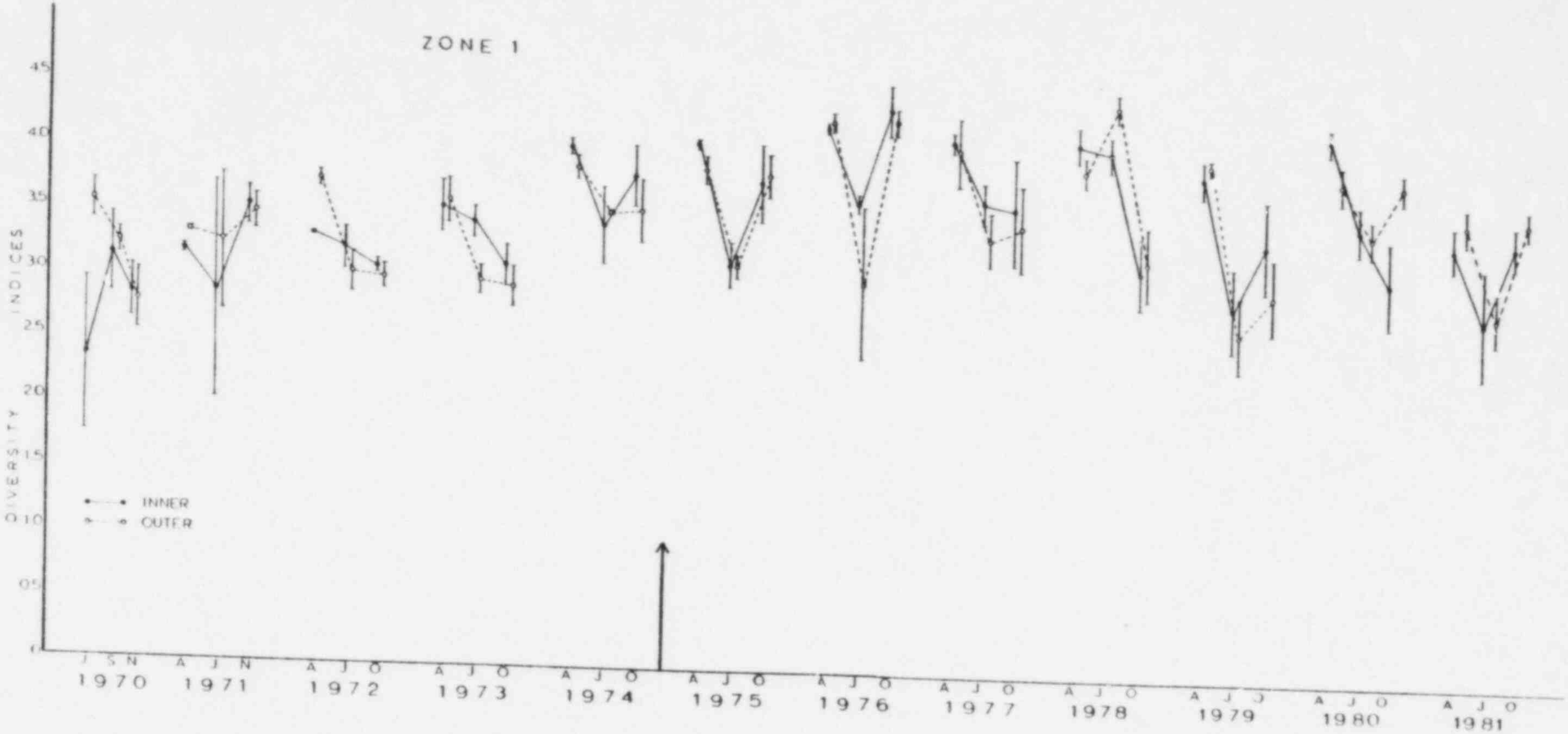

Fig. 28. Mean diversity indices of phytoplankton collections in Cook Plant zone 1 in spring, summer, and fall seasons and at inner and outer station groups during 1970 through 1981. The vertical bars show the standard errors. See Table 3 for numbers of observations.

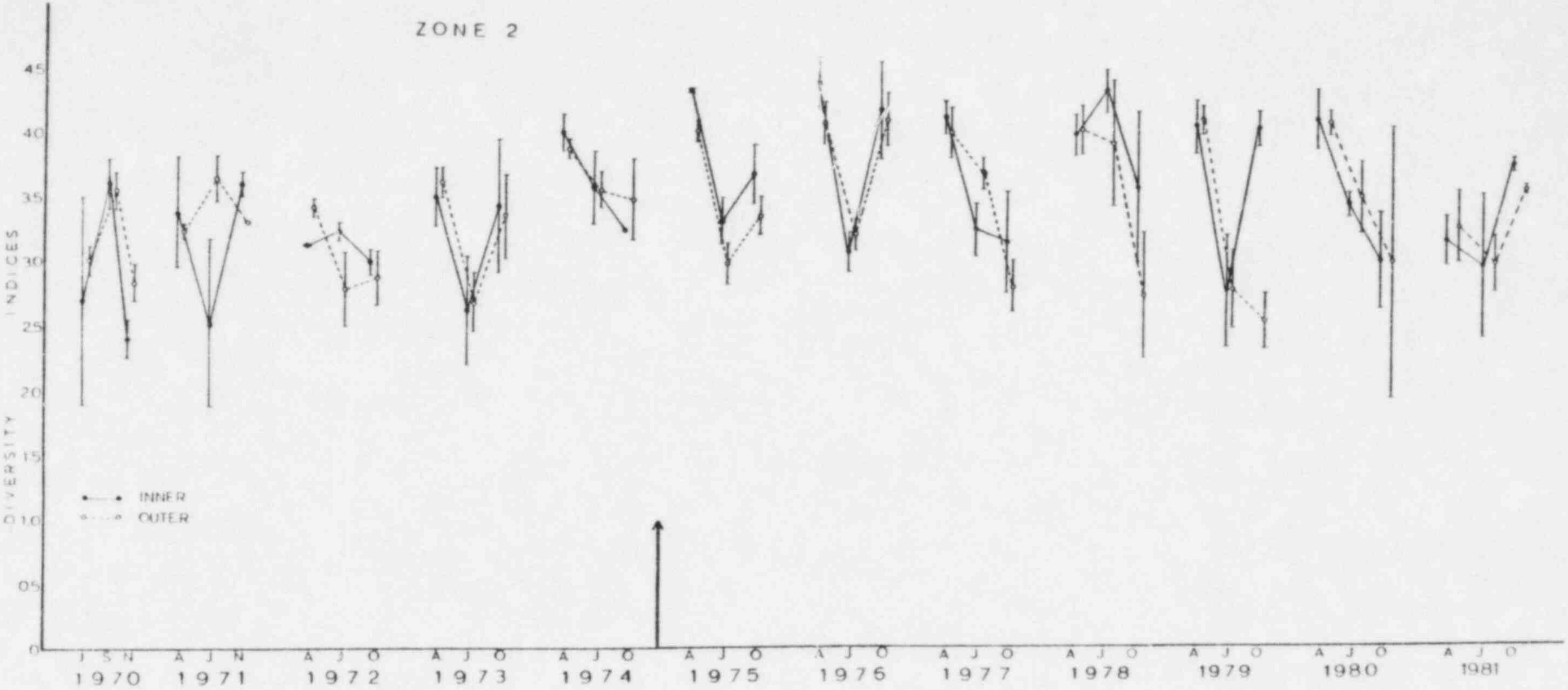

Fig. 2C. Mean diversity indices of phytoplankton collections in Cook Plant zone 2 in spring, summer, and fall seasons and at inner and outer station groups during 1970 through 1981. The vertical bars show the standard errors. See Table 3 for numbers of observations.

1970 and 1973, and zone 2 in 1977 and 1979. With the exceptions of zone 2 in July 1977 and October 1979, the parallelism of curves for inner and outer station groups in the operational years has been as good or better than in the preoperational years.

Mean diversity indices have varied somewhat from season to season and from year to year during the twelve years of the study. From the height-above-zero placement of the three-seasonal annual curves in the graphs of Figure 2, there is evident in each depth zone and station group a gradual trend toward higher indices from 1970 through 1976 followed in subsequent years by a trend toward lower levels. In all depth zones and both station groups, species diversities indicated by the indices continue to be higher than in the preoperational years. These analyses show no adverse effect of Cook Plant operation.

Inner-Outer Graphical Comparisons: Phytoplankton Redundancies

Redundancy values are derived from the diversity index of Wilhm and Dorris (1968) given in the preceding section. Diversity as presented here is not the true diversity since not all forms encountered can be identified to the species level. Therefore, this diversity must be viewed with caution. However, since these diversities do mean something about community structure they will be used to illustrate changes occurring within the phytoplankton population from year to year and for the derivation of redundancies.

Redundancy is a measure of the dominance of one or a few species within a given population. As presented by Wilhm and Dorris (1968) it is:

$$r = \frac{\overline{d}_{max} - \overline{d}}{\overline{d}_{max} - \overline{d}_{min}}$$

where $\overline{d}$ is the observed diversity as calculated above, $\overline{d}_{max}$ is the maximum diversity for a particular community, and $\overline{d}_{min}$ is the minimum possible diversity for a particular community. $\overline{d}_{max}$ is calculated using the following equation:

$$\overline{d}_{max} = (1/n)(\log_2 n! - s \log_2 [n/S]!)$$

and $\overline{d}_{min}$ is calculated using the equation:

$$\overline{d}_{min} = (1/n)(\log_2 n! - s \log_2 [n-(S-1)]!)$$

The values of r range between 0 and 1. An r equal to 0 implies that the species encountered in a community each have the same number of cells. An r equal to 1 implies that one species dominates the community of phytoplankton.

Redundancy values for the phytoplankton collections of 1970-1976 have been reported by Ayers (1978); those for 1977 by Ayers and Wiley (1979); those for 1978-79 by Ayers and Feldt (1982); and those for 1980-81 will be reported by Ayers and Feldt (in preparation).

Table 4 presents the means, standard errors, and numbers of redundancy observations for the phytoplankton collections at inner and outer station groups in three depth zones during the seasonal surveys of 1981. The means and standard errors for the years 1970 through 1981 are plotted on a time axis in Figure 3.

In 1979 redundancy values rose to preoperational levels after a period of slowly diminishing values from 1973 through 1978; they have remained at preoperational levels in 1980 and 1981.

Table 4. Means, standard errors, and numbers of observations of phytoplankton redundancies by seasons, depth zones, and inner or outer station groups in Cook Plant major surveys during operational 1981.

1981

		10 April	8 July	14 October
Zone 0	Inner			
	Mean	0.235	0.416	0.374
	S. E.	0.008	0.030	0.011
	N	12	12	12
	Outer			
	Mean	0.274	0.514	0.343
	S. E.	0.019	0.041	0.021
	N	10	10	10
Zone 1	Inner			
	Mean	0.340	0.420	0.396
	S. E.	0.009	0.072	0.023
	N	3	3	3
	Outer			
	Mean	0.329	0.414	0.360
	S. E.	0.019	0.039	0.016
	N	4	4	4
Zone 2	Inner			
	Mean	0.401	0.437	0.351
	S. E.	0.039	0.087	0.004
	N	2	2	2
	Outer			
	Mean	0.383	0.409	0.376
	S. E.	0.048	0.043	0.012
	N	4	4	4

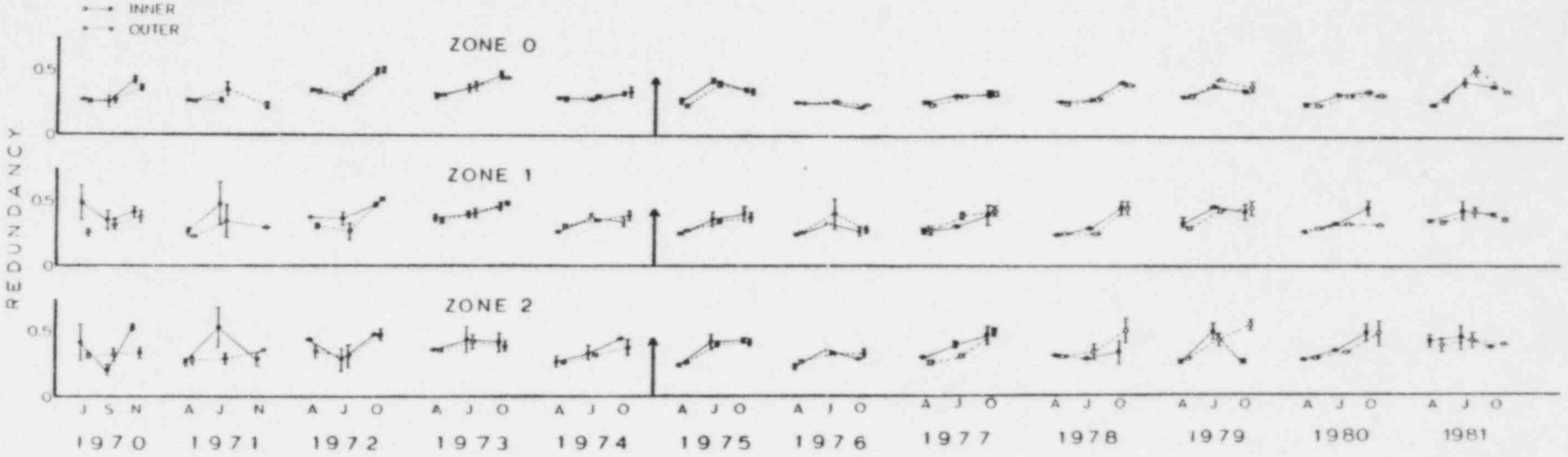

Fig. 3. Mean redundancies of phytoplankton collections from three depth zones in the Cook Plant area, in spring, summer, and fall seasons and at inner and outer station groups during 1970 through 1981. The vertical bars show the standard errors. See Table 4 for numbers of observations.

Except for October 1979 in zone 2, parallelism between annual curves of redundancies at inner and outer stations has been far better in later years than in preoperational years before 1972. Having begun in preoperational years and continued in the operational years, the trend for parallel changes in redundancy is attributed to some cause in the lake itself. There is nothing in this analysis of phytoplankton redundancies to indicate that operation of Cook Plant has had any adverse impact on the local phytoplankton community.

CONCLUSIONS

The phytoplankton community in the Cook Plant vicinity has in 1981 continued an overall trend toward decreased abundance which began after a high in 1978. Declines in diatom abundances (attributed to reduced nutrient loading to the lake) have outweighed variations in the other categories and affected the totals. Coccoid blue-greens in 1981 continued to be low in abundance in spring and summer but to have abundance peaks in fall (attributed to late summer and fall depletion of silica in the epilimnetic water). Flagellates decreased in 1979 and 1980 but returned to their 1978 level in 1981. The remaining categories of phytoplankton have exhibited little variation in abundances over the twelve years of the study. Abundance changes at both inner and outer stations have generally been in the same directions and are considered to reflect changes in the lake. not any clear effect of Cook Plant operation.

Statistically significant differences between mean abundances of phytoplankton categories at inner and outer stations have been low during the period of study (5.25% of the comparisons overall, 5.71% in preoperational years, and 4.97% in operational years). Except for the inner station group of depth zone 2, the distributions of significant differences between preoperational and operational years appear to be within the normal range of variation. The increase in numbers of differences in zone 2 inner in operational years may possibly be an effect of plant operation on blue-green algae densities in that area, but of the 563 paired comparisons in operational years it is a minute (2.30%) effect.

Mean diversity indices have varied somewhat from season to season and from year to year during the twelve years of the study. The annual curves of diversity indices indicate, in each depth zone and station group, a gradual trend toward higher indices from 1970 through 1976 followed in subsequent years by a slow trend toward lower levels. In all depth zones and both station groups, species diversities indicated by the indices continue to be higher than in the preoperational years. These analyses show no adverse effect of Cook Plant operation.

In 1979, phytoplankton redundancy values rose to preoperational levels after a period of slowly diminishing values from 1973 through 1978; they have remained at preoperational levels in 1980 and 1981. There is nothing in this analysis of phytoplankton redundancies to indicate that operation of Cook Plant has had any adverse impact on the local phytoplankton community.

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* BHPPLS = Benton Harbor Power Plant Limnological Studies.

APPENDIX B-2

PART II

PHYTOPLANKTON ENTRAINED AT THE DONALD C. COOK NUCLEAR PLANT

ENTRAINED PHYTOPLANKTON

ACKNOWLEDGMENTS

Thanks are due to Laurie E. Feldt, James Barres, James L. Hetzler, Marjorie E. Ladzick, Julie Wolin, and Martha Quenon for their assistance with the laboratory analyses and to Marion J. Luckhardt and Beverly J. McClellan for typing the manuscript. Special thanks to Thomas A. Kriesal of the Donald C. Cook Nuclear Plant staff who has been most helpful to us in obtaining these data.

INTRODUCTION

Technical Specification Requirements

The Environmental Technical Specifications for the Donald C. Cook Nuclear Plant require an assessment of phytoplankton abundance, viability, and species composition to be made on a monthly basis on samples collected in early morning, at mid-day, and in late evening. To this end, samples are collected at morning twilight, noon, and evening twilight from the intake and discharge forebays. Samples for microscopic counting are collected in duplicate and those for viability studies in quintuplicate. This report contains a discussion of the results of microscopic counting for 1975 through 1980, the results of viability studies based on chlorophylls for 1975 through May 1982 and the summary of viability studies based on primary productivity (C^{14}) between March 1980 and May 1982.

Disposition of Samples Collected

In the Environmental Operating Report for 1981, a table which listed the disposition of all samples for microscopic counting was included. Table 1 is a continuation of that table. Of the 102 required samples for the period December 1981 through May 1982, all were collected. All samples through January 1981 have been counted.

Of the 480 samples required for viability analysis, 480 were collected for the period of September 1981 through May 1982. These include samples collected to give five replicates rather than the three required replicates. These additional samples were collected to decrease the detectable difference between intake and discharge that can be measured at the 0.05 level of significance. At the time of preparation of this report, analyses of all samples were complete. Because of loss during analysis, the number of replicates on October 13, 1981 numbered less than the three required.

Temperature at Time of Collection

A summary of intake and discharge temperatures is present in Table 2 for the periods when phytoplankton entrainment samples were collected. Upwelling of colder bottom water along the eastern shore of Lake Michigan took place the week preceding the July 1981 entrainment collection. Upwelling transports colder bottom water rich in nutrients and containing its own phytoplankton assemblage to nearshore regions of the lake. Any mixing of these hypolimnetic and epilimnetic waters yields a water mass having characteristics of each and results in increased sampling variability. The increased heterogeneity is particularly important if upwelling occurs during sampling periods.

Table 1. Status of Phytoplankton Enumeration Samples.

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
			SAMPLE STATUS[1]		
June 1978					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA D2A D2B
July 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
August 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
September 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
October 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B

(continued)

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
November 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
December 1978					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
January 1979					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
February 1979					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
March 1979					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B

(continued)

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
April 1979					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA IB D2A D2B
May 1978					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA IB D2A D2B
June 1979			Plant not Operational		
July 1979					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA IB D2A D2B
August 1979					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
September 1979					
Evening Twilight	D1A D1B				IA IB D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B

(continued)

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
October 1979					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
November 1979					
Evening Twilight					IA IB D1A D1B
Morning Twilight					IA IB D1A D1B
Noon					IA IB D1A D1B
December 1979					
Evening Twilight					IA IB D1A D1B
Morning Twilight					IA IB D1A D1B
Noon					IA IB D1A D1B
January 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
February 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B

(continued)

[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
March 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
April 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
May 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
June 1980					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA IB D2A D2B
July 1980					
Evening Twilight					IA IB D2A D2B
Morning Twilight					IA IB D2A D2B
Noon					IA IB D2A D2B

(continued)

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
August 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
September 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
October 1980					
Evening Twilight					IA IB D1A D1B D2A D2B
Morning Twilight					IA IB D1A D1B D2A D2B
Noon					IA IB D1A D1B D2A D2B
November 1980					
Evening Twilight					IA IB D1A D1B
Morning Twilight					IA IB D1A D1B
Noon					IA IB D1A D1B
December 1980					
Evening Twilight					IA IB D1A D1B
Morning Twilight					IA IB D1A D1B
Noon					IA IB D1A D1B

(continued)

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
January 1981					
Evening Twilight				IA IB D1A D1B D2A D2B	
Morning Twilight				IA IB D1A D1B D2A D2B	
Noon				IA IB D1A D1B D2A D2B	
February 1981					
Evening Twilight				IA IB D1A D1B D2A D2B	
Morning Twilight				IA IB D1A D1B D2A D2B	
Noon				IA IB D1A D1B D2A D2B	
March 1981					
Evening Twilight				IA IB D1A D1B	
Morning Twilight				IA IB D1A D1B	
Noon				IA IB D1A D1B	
April 1981					
Evening Twilight				IA IB D1A D1B	
Morning Twilight				IA IB D1A D1B	
Noon				IA IB D1A D1B	
May 1981					
Evening Twilight			IA IB D1A D1B		
Morning Twilight			IA IB D1A D1B		
Noon			IA IB D1A D1B		

(continued)

[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
June 1981					
Evening Twilight			IA IB D2A D2B		
Morning Twilight			IA IB D2A D2B		
Noon			IA IB D2A D2B		
July 1981					
Evening Twilight			IA IB D2A D2B		
Morning Twilight			IA IB D2A D2B		
Noon			IA IB D2A D2B		
August 1981					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		
September 1981					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		
October 1981					
Evening Twilight			IA IB D1A D1B		
Morning Twilight			IA IB D1A D1B		
Noon			IA IB D1A D1B		
November 1981					
Evening Twilight			IA IB D2A D2B		
Morning Twilight			IA IB D2A D2B		
Noon			IA IB D2A D2B		

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

(continued)

Table 1 (continued)

Month and Sample	Not Collected	Lost	Not Yet Counted	Counted But Not Yet Available for Discussion	Complete
December 1981					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		
January 1982					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		
February 1982					
Evening Twilight			IA IB D2A D2B		
Morning Twilight			IA IB D2A D2B		
Noon			IA IB D2A D2B		
March 1982					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1A D2A D2B		
April 1982					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		
May 1982					
Evening Twilight			IA IB D1A D1B D2A D2B		
Morning Twilight			IA IB D1A D1B D2A D2B		
Noon			IA IB D1A D1B D2A D2B		

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[1] A and B are replicate designations
I is Intake
D1 is Discharge Unit #1
D2 is Discharge Unit #2

Table 2. Entrainment temperatures for 1978 through 1980.

Date	Time	Intake, °C	Discharge #1, °C	Discharge #2, °C
January 10, 1978	Morning Twilight	3.0	13.5	–[1]
11	Noon	2.8	14.0	–
11	Evening Twilight	5.6	17.0	–
February 6, 1978	Evening Twilight	0.8	10.6	–
7	Morning Twilight	0.8	10.9	–
7	Noon	0.8	10.2	–
March 6, 1978	Evening Twilight			–
7	Morning Twilight	0.8	12.1	–
7	Noon	0.6	1.6	–
April 10, 1978	Evening Twilight	4.2	–	8.7
11	Morning Twilight	2.8	–	8.1
11	Noon	4.8	–	10.2
May 9, 1978	Evening Twilight	8.9	–	17.6
10	Morning Twilight	9.9	–	18.8
10	Noon		–	17.8
June 12, 1978	Evening Twilight	17.8	–	26.3
13	Morning Twilight	17.8	–	25.8
13	Noon	9.9	–	11.0
July 10, 1978	Evening Twilight	10.0	21.5	15.2
11	Morning Twilight	11.0	21.5	16.4
11	Noon	10.7	22.2	17.7
August 7, 1978	Evening Twilight	19.0	31.0	28.2
8	Morning Twilight	20.8	32.2	30.0
8	Noon	21.0	32.6	29.9
September 11, 1978	Evening Twilight	26.5	36.5	35.1
12	Morning Twilight	26.2	36.0	35.1
12	Noon	25.1	36.0	35.0
October 9, 1978	Evening Twilight	17.4		25.0
10	Morning Twilight	15.1	26.0	23.2
10	Noon	16.8	26.7	25.0
November 13, 1978	Evening Twilight	11.2	22.0	
14	Morning Twilight	11.1	21.8	
14	Noon	11.0	21.6	
December 4, 1978	Evening Twilight	4.8	15.2	13.3
5	Morning Twilight	4.8	15.6	14.0
5	Noon	4.8	14.8	13.9

(continued)

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[1] Dashes appear when a unit was not operating. Blanks are for missing data.

Table 2 (continued)

Date	Time	Intake, °C	Discharge #1, °C	Discharge #2, °C
January 8, 1979	Evening Twilight	1.0	13.5	11.8
9	Morning Twilight	1.8	14.0	12.0
9	Noon	1.2	14.5	16.0
February 12, 1979	Evening Twilight	6.2	17.0	15.6
13	Morning Twilight	6.2	16.8	16.2
13	Noon	6.8	17.0	16.5
March 5, 1979	Evening Twilight	0.5	13.5	10.2
6	Morning Twilight	6.2	17.8	15.8
6	Noon	5.2	17.2	15.5
April 9, 1979	Evening Twilight	3.2	-	12.5
10	Morning Twilight	3.2	-	11.8
10	Noon	3.5	-	12.3
May 7, 1979	Evening Twilight	10.0	-	20.8
8	Morning Twilight	10.1	-	20.9
8	Noon	10.8	-	21.2
July 10, 1979	Evening Twilight	16.7	-	25.8
10	Morning Twilight	17.0	-	25.8
10	Noon	18.0	-	26.6
August 6, 1979	Evening Twilight	24.5	35.0	34.0
7	Morning Twilight	24.0	34.2	34.0
7	Noon	24.3	35.5	34.0
September 10, 1979	Evening Twilight	19.8	broken pump	29.2
11	Morning Twilight	19.8	31.0	29.6
11	Noon	21.0	31.1	30.2
October 8, 1979	Evening Twilight	16.0	27.2	25.0
9	Morning Twilight	16.0	27.0	24.5
9	Noon	15.0	26.0	24.0
November 12, 1979	Evening Twilight	9.5	19.8	-
13	Morning Twilight	9.3	19.9	-
13	Noon	9.3	20.2	-
December 10, 1979	Evening Twilight	4.0	18.0	-
11	Morning Twilight	4.1	17.5	-
11	Noon	4.1	17.2	-

(continued)

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[1] Dashes appear when a unit was not operating. Blanks are for missing data.

Table 2 (continued)

Date	Time	Intake, °C	Discharge #1, °C	Discharge #2, °C
January 21, 1980	Evening Twilight	-0.2	12.0	6.6
22	Morning Twilight	-0.3	12.0	6.5
22	Noon	-0.3	12.0	6.5
February 4, 1980	Evening Twilight	0.6	12.2	12.4
5	Morning Twilight	3.2	14.5	11.9
5	Noon	2.4	14.5	14.3
March 10, 1980	Evening Twilight	5.5	17.2	14.0
11	Morning Twilight	6.3	17.8	15.1
11	Noon	6.0	17.2	14.0
April 7, 1980	Evening Twilight	3.8	15.6	13.2
8	Morning Twilight	7.3	8.3	15.4
8	Noon	6.1	7.6	15.2
May 12, 1980	Evening Twilight	11.9	23.0	21.4
13	Morning Twilight	12.5	23.8	22.2
13	Noon	12.5	24.0	22.4
June 9, 1980	Evening Twilight	14.7	-	24.1
10	Morning Twilight	14.0	-	25.5
10	Noon	13.9	-	23.1
July 14, 1980	Evening Twilight	22.5	-	31.3
15	Morning Twilight	22.3	-	31.8
15	Noon	23.6	-	32.8
August 11, 1980	Evening Twilight	23.8	31.1	33.5
12	Morning Twilight	24.2	31.9	34.0
12	Noon	23.0	31.1	33.0
September 8, 1980	Evening Twilight	20.1	29.3	29.5
9	Morning Twilight	22.9	31.5	31.0
9	Noon	22.5	33.2	32.2
October 13, 1980	Evening Twilight	16.0	26.2	24.6
14	Morning Twilight	14.0	25.1	22.9
14	Noon	15.2	25.4	23.7
November 10, 1980	Evening Twilight	10.5	20.6	-
11	Morning Twilight	9.2	19.5	-
11	Noon	9.3	19.5	-
December 8, 1980	Evening Twilight	6.4	16.9	-
9	Morning Twilight	7.7	17.9	-
9	Noon	6.8	16.0	-

(continued)

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[1] Dashes appear when a unit was not operating. Blanks are for missing data.

Table 2 (continued)

Date	Time	Intake, °C	Discharge #1, °C	Discharge #2, °C
January 12, 1981	Evening Twilight	1.2	12.8	10.3
13	Morning Twilight	3.2	14.6	14.3
13	Noon	4.2	15.9	13.4
February 9, 1981	Evening Twilight	3.8	14.6	12.8
10	Morning Twilight	4.1	15.4	13.1
10	Noon	4.2	14.9	15.2
March 16, 1981	Evening Twilight	3.7	14.8	
17	Morning Twilight	3.2	14.4	
17	Noon	4.1	15.3	
April 6, 1981	Evening Twilight	7.9	18.2	
7	Morning Twilight	7.6	18.0	
7	Noon	7.7	18.2	
May 11, 1981	Evening Twilight	9.2	19.6	
12	Morning Twilight	10.1	19.7	
12	Noon	8.9	19.5	
June 9, 1981	Evening Twilight	17.7	-	26.8
10	Morning Twilight	17.4	-	25.3
10	Noon	17.9	-	26.8
July 13, 1981	Evening Twilight	23.7	-	29.3
14	Morning Twilight	23.5	-	29.9
14	Noon	23.2	-	33.8
August 10, 1981	Evening Twilight	25.0	31.9	33.9
11	Morning Twilight	25.7	31.9	35.2
11	Noon	25.3	31.84	33.2
September 14, 1981	Evening Twilight	22.0	33.4	31.6
15	Morning Twilight	22.5	34.0	32.8
15	Noon	23.2	34.7	32.1
October 12, 1981	Evening Twilight	14.5	25.4	-
13	Morning Twilight	14.3	25.0	-
13	Noon	14.4	25.2	-
November 9, 1981	Evening Twilight	10.1	-	19.2
10	Morning Twilight	10.1	-	21.0
10	Noon	10.9	-	19.7

(continued)

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[1] Dashes appear when a unit was not operating. Blanks are for missing data.

Table 2 (continued)

Date	Time	Intake, °C	Discharge #1, °C	Discharge #2, °C
December 7, 1981	Evening Twilight	9.1	21.0	18.5
8	Morning Twilight	6.0	15.7	17.7
8	Noon	5.2	14.9	16.8
January 12, 1982	Evening Twilight	9.8	21.0	19.3
13	Morning Twilight	10.3	19.8	20.0
13	Noon	10.1	20.6	19.7
February 8, 1982	Evening Twilight	1.2	-	10.2
9	Morning Twilight	1.8	-	11.0
9	Noon	1.4	-	10.8
March 8, 1982	Evening Twilight	1.0	11.0	12.0
9	Morning Twilight	1.0	11.8	10.4
9	Noon	0.2	11.3	10.2
April 12, 1982	Evening Twilight	7.9	19.7	17.2
13	Morning Twilight	3.6	16.0	14.9
13	Noon	3.8	15.4	13.9
May 10, 1982	Evening Twilight	13.2	22.3	24.2
11	Morning Twilight	13.1	24.4	22.9
11	Noon	14.8	29.0	23.7

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[1] Dashes appear when a unit was not operating. Blanks are for missing data.

RESULTS AND DISCUSSION

Variation of Major Phytoplankton Groups

For the purpose of contrasting changes in abundance and in species diversity, comparisons between phytoplankton assemblages from 1975 through 1980 are made. The phytoplankton assemblages are divided into nine major groups. These groups are filamentous blue-green, coccoid blue-green, filamentous green, coccoid green, flagellates, centric diatoms, pennate diatoms, desmids, and other algae. Other algae are those not belonging to the other major groups. Major group abundances (cells/mL) are tabulated monthly for each year. The annual means, for those years for which the counts are complete, are included in this tabulation.

Coccoid blue-green algae were least abundant in 1976 (Table 3). Since then, the abundance of coccoid blue-green algae increased for 1977 and 1978, decreased for 1979, and increased again for 1980. In 1980, the highest coccoid blue-green abundances in entrained monthly samples occurred between August and December. In general, this time of peak abundance has occurred in all years.

Filamentous blue-green algae were less abundant in 1980 than 1975 or 1976, but they were more abundant than in 1977, 1978, and 1979 (Table 4). In 1980, peak abundances were reached in June and July.

Coccoid green algae were less abundant in 1980 than in 1975 and 1976, but they were more abundant than in 1977, 1978, and 1979 (Table 5). This may be attributed to the natural variability in the phytoplankton population in the nearshore of Lake Michigan. In 1980, peak concentrations occurred from July through September.

Table 3. Monthly variation of coccoid blue-green algae from 1975 through 1980 (cells/mL).

Month	1975'	1976'	1977'	1978'	1979'	1980'
January		461.(149.)		296.(91.9)	275.(44.5)	501.(143.)
February	109.(59.7)	254.(71.7)		95.0(50.0)	120.(24.3)	130(19.1)
March	257.(186.)	347.(110.)	137.(57.2)	28.7(12.6)	209.(43.8)	102.(37.2)
April	312.(125.)	143.(63.6)	110.(76.2)	78.8(30.7)	30.(27.6)	132.(34.6)
May	689.(169.)	87.1(46.6)	47.3(27.3)	142.(54.6)	171.(137.)	18.4(12.9)
June	235.(155.)	33.6(25.1)	114(45.6)	521.(166.)		311.(110.)
July	1050.(155.)	57.8(26.5)	133.(28.5)	244.(75.7)	117.(27.6)	313.(63.7)
August	286.(53.2)	439.(93.8)	1210.(254.)	149.(35.4)	376.(53.1)	1513.(240.)
September	1220.(169.)	339.(118.)	917.(93.6)	660.(80.4)	845.(138.)	1103.(191.)
October	945.(212.)	560.(196.)	727.(145.)	2353.(365.)	1209.(142.)	1832.(243.)
November	600.(166.)	422.(121.)	1320.(289.)	1992.(278)	1013.(119.)	1668.(213.)
December	176.(106.)	275.(73.4)	872.(124.)	3642.(363.)	1282.(174.)	1321.(319.)
Yearly Mean	535.(117.)	285.(50.1)	599.(159.)	850.(134.)	513.(144.)	745.(199.)

'Mean is followed by the standard error.

Table 4. Monthly variation of filamentous blue-green algae from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		22.0(8.06)		15.2(5.61)	7.91(1.33)	9.16(2.61)
February	28.2(8.10)	16.4(3.53)		6.22(2.46)	3.78(0.60)	5.10(1.02)
March	59.7(17.6)	13.4(2.53)	16.7(3.19)	3.60(.921)	4.57(0.86)	7.73(1.55)
April	27.6(5.40)	57.9(5.16)	110.(76.2)	2.63(.919)	3.58(1.71)	3.37(0.86)
May	103.(37.0)	457.(52.8)	17.5(4.09)	14.4(4.53)		54.5(15.3)
June	314.(38.1)	81.1(16.1)	24.3(8.29)	111.(51.9)		312.(110.)
July	95.1(25.5)	72.1(12.7)	59.9(14.3)	65.0(12.6)	201.(29.3)	211.(65.1)
August	8.90(2.70)	9.24(3.08)	17.6(6.37)	111.(26.5)	20.1(5.09)	62.1(18.7)
September	17.3(9.20)	46.8(15.8)	25.0(8.84)	8.89(2.68)	41.8(5.81)	26.4(5.94)
October	98.8(34.0)	45.9(23.8)	21.4(7.61)	87.0(18.9)	115.(18.2)	50.7(19.0)
November	21.6(17.8)	6.35(4.31)	12.7(3.13)	82.9(18.7)	38.3(9.60)	69.9(23.3)
December	15.4(7.70)	74.5(44.3)	45.2(18.6)	67.9(13.5)	5.38(1.91)	14.9(8.17)
Yearly Mean	71.8(26.5)	75.2(35.6)	35.0(9.54)	48.0(13.3)	41.5(18.7)	68.9(27.6)

[1] Mean is followed by the standard error.

Table 5. Monthly variation of coccoid green algae from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		42.2(12.2)		56.8(17.4)	39.6(4.87)	70.5(32.9)
February	39.3(14.2)	29.5(11.1)		10.7(2.57)	18.5(3.53)	24.3(5.37)
March	55.2(24.7)	22.9(7.63)	21.1(4.43)	16.6(4.54)	79.4(43.5)	50.6(10.4)
April	49.7(14.8)	57.9(12.3)	51.4(8.31)	108.(25.2)	69.9(22.5)	48.3(6.90)
May	47.1(19.7)	145.(30.6)	15.3(4.89)	145.(23.6)	125.(18.1)	86.2(33.6)
June	141.(23.2)	98.4(26.9)	39.2(15.8)	150.(45.3)		111.(31.9)
July	1000.(107.)	689.(123.)	152.(19.2)	103.(36.0)	54.9(15.2)	443.(35.2)
August	197.(37.1)	494.(46.8)	115.(16.5)	166.(33.0)	153.(21.6)	407.(63.9)
September	176.(24.2)	755.(129.)	54.4(8.31)	174.(24.1)	95.6(19.6)	433.(66.8)
October	116.(16.1)	242.(37.1)	232.(85.4)	256.(26.9)	132.(12.9)	146.(23.9)
November	138.(66.9)	134.(36.1)	65.1(18.2)	159.(18.1)	77.9(15.0)	159.(41.6)
December	110.(47.8)	240.(54.4)	49.5(11.4)	194.(15.1)	133.(29.9)	62.6(14.5)
Yearly Mean	188.(82.8)	246.(74.6)	79.5(21.5)	128.(22.6)	89.0(12.9)	170.(46.2)

[1] Mean is followed by the standard error.

For the years 1975 through 1980, filamentous green algae were least abundant in 1980 (Table 6). In 1980, the primary peak abundances were reached during May and September.

Flagellates showed no marked variation in abundance from 1975 to 1977 (Table 7), but they exhibited a decrease in abundance in 1978, 1979, and 1980. The 1979 yearly average of abundance was unduly low due to the absence of June samples, which were often high. During 1980, peak abundances occurred during April and July.

Centric diatoms showed a marked reduction in population density during 1977 compared to the previous years (Table 8) but increased during 1978, 1979, and 1980 compared to 1977. Even the 1979 yearly average represents an increase compared to the value for 1977. The 1979 yearly average may be unduly low because no June sample was collected that year, and the June abundance is usually large for centric diatoms. The 1980 yearly average abundance was markedly higher than that of 1979. The 1980 peak abundance in May is the second highest concentration observed for centric diatoms in the monthly samples since 1976. The highest concentration occurred in June of 1976. In 1980, population density peaks occurred in April, May, and September. Peak concentrations of this group of diatoms usually occur in the spring. The population density reduction in 1977 can be attributed to the natural long-term variation of the phytoplankton community.

Pennate diatoms occurred in reduced numbers in 1980 compared to 1975 and 1976, but in a greater abundance compared to 1977, 1978, and 1979 (Table 9). The 1979 yearly average may be unduly low. In 1980, peak abundance was reached in May and June with a secondary peak in October and November. The reason for the low counts in 1979 may be the absence of June samples, when the abundance is usually high.

Table 6. Monthly variation of filamentous green algae from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		31.6(17.4)		2.26(1.35)	2.49(0.89)	1.46(0.85)
February	18.0(9.70)	2.00(1.20)		.350(.241)	0.278(0.280)	0.0(0.0)
March	34.8(12.6)	16.4(6.62)	6.63(4.37)	3.04(1.82)	0.600(0.330)	0.550(0.40)
April	0.0(0.0)	18.1(10.5)	18.2(12.3)	2.21(1.70)	0.00(0.00)	0.094(0.09)
May	1.50(1.50)	57.8(23.0)	4.63(2.32)	1.70(1.15)	0.00(0.0)	8.66(3.55)
June	29.5(20.6)	55.0(14.0)	.417(.417)	2.62(1.03)		1.37(0.75)
July	0.3(0.3)	37.3(11.1)	22.9(4.79)	11.2(2.82)	4.34(1.40)	0.0(0.0)
August	0.8(0.6)	4.28(2.52)	0.0(0.0)	8.15(2.83)	.228(0.228)	2.94(1.04)
September	0.2(0.2)	13.7(6.13)	1.86(.888)	1.12(.401)	.700(0.523)	5.57(2.55)
October	2.8(1.1)	9.67(2.47)	6.63(4.02)	8.19(2.16)	5.53(1.61)	1.93(0.85)
November	1.5(1.2)	6.35(5.48)	26.8(6.92)	18.4(4.37)	0.0(0.0)	0.275(0.27)
December	14.4(7.3)	5.52(2.39)	14.0(6.97)	35.4(4.55)	12.3(7.81)	3.04(1.30)
Yearly Mean	9.44(3.87)	21.5(5.64)	10.2(3.06)	7.92(2.03)	2.41(1.14)	2.16(0.76)

[1] Mean is followed by the standard error.

Table 7. Monthly variation of flagellated algae from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		110.(18.7)		156.(44.0)	277.(53.2)	446.(69.4)
February	90.8(20.8)	252.(32.1)		109.(21.7)	242.(46.7)	264.(21.0)
March	272.(56.6)	268.(25.5)	628.(60.2)	97.5(24.6)	392.(37.1)	291.(25.5)
April	857.(190.)	351.(36.6)	1010.(116.)	435.(69.9)	379.(44.4)	775.(59.5)
May	641.(82.3)	1350.(220.)	1200.(160.)	728.(153.)	625.(80.5)	499.(66.8)
June	802.(148.)	633.(70.5)	235.(30.6)	2840.(275.)		513.(79.5)
July	561.(94.6)	452.(31.6)	267.(33.9)	395.(77.7)	534.(51.4)	635.(63.2)
August	504.(56.7)	482.(86.6)	376.(31.9)	191.(18.9)	227.(34.9)	494.(52.7)
September	587.(71.6)	426.(70.3)	302.(57.8)	75.7(11.5)	274.(38.7)	422.(99.5)
October	696.(85.4)	559.(91.7)	550.(91.8)	108.(15.9)	249.(34.9)	113.(26.7)
November	417.(51.9)	524.(47.6)	754.(156.)	52.0(12.4)	444.(29.4)	127.(36.7)
December	368.(59.9)	415.(84.2)	78.9(19.3)	261.(88.0)	486.(66.0)	66.0(13.2)
Yearly Mean	527.(69.0)	485.(89.0)	540.(114.)	454.(68.9)	375.(40.5)	387.(63.2)

[1] Mean is followed by the standard error.

Table 8. Monthly variation of centric diatoms from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		1810.(191.)		310.(46.7)	193.(11.8)	253.(23.7)
February	1040.(130.)	560.(45.0)		125.(12.8)	169.(8.96)	205.(11.9)
March	1290.(111.)	807.(56.8)	463.(57.7)	423.(37.8)	352.(22.2)	337.(28.8)
April	2550.(427.)	930.(51.1)	779.(83.9)	592.(74.5)	2590.(199.)	310.(17.7)
May	1190.(170.)	1400.(189.)	139.(23.1)	1800.(168.)	428.(28.4)	2334.(176.)
June	817.(64.3)	212.(18.3)	451.(91.5)	1450.(141.)		1802.(163.)
July	914.(108.)	3370.(361.)	967.(65.9)	1100.(99.6)	78.8(6.89)	148.(12.1)
August	132.(23.9)	272.(25.9)	175.(12.0)	200.0(30.0)	96.3(9.88)	547.(92.9)
September	69.2(8.3)	1060.(157.)	183.(14.8)	225.(40.5)	247.(28.2)	1876.(101.)
October	286.(21.2)	644.(50.9)	140.(18.1)	904.(88.7)	511.(53.0)	806.(40.1)
November	404.(64.5)	1090.(69.4)	194.(24.2)	195.(21.3)	240.(14.3)	527.(74.1)
December	1700.(132.)	503.(58.8)	165.(18.5)	160.(9.63)	368.(.34.1)	578.(58.5)
Yearly Mean	945.(224.)	1050.(249.)	366.(93.7)	623.(64.0)	479.(214.)	810.(217.)

[1] Mean is followed by the standard error.

Table 9. Monthly variation of pennate diatoms from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		991.(186.)		598.(79.0)	213.(16.4)	605.(54.0)
February	1640.(196.)	265.(43.0)		62.2(8.27)	43.8(4.30)	153.(16.0)
March	1340.(146.)	329.(46.3)	1210.(90.6)	41.7(4.68)	200.(17.9)	222.(26.8)
April	1160.(306.)	1340.(123.)	1710.(187.)	226.(37.1)	748.(67.9)	376.(24.7)
May	3040.(278.)	864.(158.)	383.(45.0)	1910.(162.)	2492.(142.)	2868.(215.)
June	1220.(102.)	332.(29.9)	743.(129.)	1750.(134.)		2025.(209.)
July	90.8(12.8)	2900.(459.)	487.(44.8)	1450.(160.)	156.(26.7)	284.(44.0)
August	84.8(16.8)	1250.(207.)	73.2(10.1)	514.1(17.2)	267.(37.2)	68.7(14.4)
September	270.(52.7)	1920.(411.)	146.(15.5)	120.(23.2)	133.(25.6)	326.(31.6)
October	295.(34.6)	498.(36.6)	822.(45.2)	570.(63.1)	381.(22.8)	1388.(131.)
November	501.(74.2)	842.(100.)	724.(100.)	963.(107.)	638.(57.0)	1571.(231.)
December	333.(43.4)	1320.(148.)	548.(50.2)	572.(45.5)	1759.(131.)	810.(84.5)
Yearly Mean	907.(271.)	1070.(220.)	685.(155.)	731.(74.6)	639.(236.)	891.(255.)

[1] Mean is followed by the standard error.

Desmid numbers were lowest in 1976 (Table 10). The yearly mean for 1980 is the second highest for the period of 1976 to 1980. In 1980, peak abundance occurred in June.

The group of other algae was least abundant in 1979 in the period from 1975 through 1980 (Table 11). The 1980 yearly average showed a marked increase over that of 1979. In 1980, peak abundance occurred in September. Of the six years, mean total algae concentration was lowest in 1979 (Table 12). The reason for this low count may be the absence of data for June. The 1980 yearly average is higher than those observed for 1979, 1978, and 1977 but lower than those observed in 1975 and 1976. In 1980, peak abundance occurred in May. For all years, peak abundances usually occurred in the spring. However, peak abundances of any of the major phytoplankton groups (especially diatoms) may occur during any of the months of thermal stratification. Increased numbers during these months were generally related to upwelling along the eastern shore of Lake Michigan in the vicinity of the Donald C. Cook Nuclear Plant.

Changes noted for each major group are either unexplained at this time or are attributable to natural long-term variations of the phytoplankton community in Lake Michigan.

Numbers of Forms, Diversity, and Redundancy

The quantitative measures of the number of species (forms), the diversity index, and redundancy were used to evaluate various assemblages of phytoplankton which appeared in entrainment samples. The diversity index is calculated using the formula presented by Wilhm and Dorris (1968):

$$\overline{d} = -\sum_{i=1}^{S} (n_i/n) \log_2 (n_i/n)$$

Table 10. Monthly variation of desmids from 1975 through 1980 (cells/mL).

Month	1975[1]	1976[1]	1977[1]	1978[1]	1979[1]	1980[1]
January		0.0(0.0)		1.05(.640)	0.461(0.290)	1.46(0.37)
February	0.8(0.5)	.238(.191)		.275(.207)	0.339(0.120)	0.133(0.072)
March	0.8(0.5)	.417(.298)	.142(.142)	.208(.151)	0.322(0.140)	1.10(0.306)
April	1.2(1.2)	.825(.592)	.275(.275)	0.0(0.0)	0.0(0.0)	0.606(0.23)
May	3.0(0.0)	1.65(.642)	1.52(.583)	0.83(0.44)	2.75(1.06)	1.10(0.805)
June	2.5(0.9)	.142(.142)	1.25(.580)	0.83(0.43)		2.20(0.938)
July	2.2(1.2)	1.25(.843)	1.47(.325)	2.22(0.70)	0.833(0.308)	1.60(0.387)
August	0.4(0.2)	.550(.371)	1.11(.587)	0.51(0.22)	0.278(0.166)	0.594(0.41)
September	0.3(0.3)	.275(.275)	.0667(.0667)	0.022(0.022)	0.231(0.115)	0.839(0.337)
October	0.8(0.4)	0.0(0.0)	0.0(0.0)	1.20(0.439)	0.511(0.225)	0.550(0.298)
November	0.5(0.3)	0.0(0.0)	.825(.431)	1.94(0.561)	1.11(0.424)	0.558(0.313)
December	0.0(0.0)	.447(.298)	1.38(.604)	1.98(0.397)	1.25(0.506)	1.10(0.74)
Yearly Mean	1.14(.298)	.484(.150)	.804(.197)	0.935(0.329)	0.731(0.233)	0.987(0.164)

[1] Mean is followed by the standard error.

Table 11. Monthly variation of other algae from 1975 through 1980 (cells/mL).

Month	1975'	1976'	1977'	1978'	1979'	1980'
January		62.4(18.1)		50.8(11.2)	84.4(9.25)	64.4(13.2)
February	7.0(3.2)	58.3(30.4)		53.9(8.07)	94.4(9.4)	76.9(11.6)
March	29.4(4.4)	39.9(5.93)	16.7(5.49)	66.2(7.79)	92.0(13.9)	92.2(12.7)
April	70.0(16.9)	91.1(42.8)	167.(20.8)	57.6(10.9)	29.8(6.58)	46.9(6.30)
May	84.0(17.2)	148.(27.8)	55.6(10.5)	104.(11.3)	111.(30.5)	106.(18.6)
June	148.(29.0)	104.(12.1)	37.9(7.65)	400.(44.3)		204.(32.8)
July	480.(57.1)	361.(52.3)	193.(22.0)	514.(63.9)	40.8(6.97)	200.(25.2)
August	55.0(22.1)	192.(19.8)	206.(26.7)	119.(23.4)	114.(11.7)	333.(54.0)
September	31.6(6.2)	481.(54.7)	62.0(7.15)	86.6(10.3)	91.(10.6)	399.(61.0)
October	44.0(5.0)	166.(23.7)	183.(21.4)	245.(23.7)	179.(18.4)	149.(15.4)
November	65.7(13.0)	84.7(14.5)	119.(15.6)	112.(18.5)	93.3(9.22)	152.(42.2)
December	71.0(13.1)	42.0(7.67)	63.4(15.1)	124.(13.0)	96.9(10.5)	66.6(15.9)
Yearly Mean	98.7(39.7)	153.(39.5)	110.(22.6)	161.(20.3)	93.3(11.7)	157.(32.0)

'Mean is followed by the standard error.

Table 12. Monthly variation of total algae from 1975 through 1980 (cells/mL).

Month	1975'	1976'	1977'	1978'	1979'	1980'
January		3530.(429.)		1490.(210.)	1090.(92.5)	1953.(195.)
February	2970.(318.)	1410.(147.)		465.(81.7)	691.(62.9)	833.(57.3)
March	3340.(421.)	1840.(182.)	2500.(206.)	681.(63.9)	1330.(121.)	1105.(90.2)
April	5020.(816.)	2990.(200.)	3890.(336.)	1500.(170.)	3850.(243.)	1693.(86.5)
May	5800.(413.)	4520.(396.)	1860.(214.)	4840.(397.)	3972.(224.)	5977.(372.)
June	3710.(302.)	1550.(132.)	1650.(249.)	7220.(461.)		5032.(352.)
July	4200.(243.)	7940.(836.)	2280.(156.)	3880.(321.)	1187.(92.3)	2237.(180.)
August	1270.(92.8)	3140.(292.)	2170.(296.)	1460.(172.)	1256.(82.0)	3430.(409.)
September	2380.(208.)	5050.(675.)	1690.(140.)	1350.(113.)	1729.(198.)	4684.(338.)
October	2490.(286.)	2720.(291.)	2680.(285.)	4530.(450.)	2783.(157.)	4618.(358.)
November	2150.(259.)	3090.(237.)	3210.(428.)	3580.(407.)	2547.(150.)	4337.(464.)
December	2790.(170.)	2870.(312.)	1840.(189.)	5060.(414.)	4146.(308.)	2924.(390.)
Yearly Mean	3280.(399.)	3390.(519.)	2380.(228.)	3000.(272.)	2235.(387.)	3235.(488.)

'Mean is followed by the standard error.

where S is the number of species, n is the total number of phytoplankton in cells/mL, and n_i is the number of phytoplankton of the i_{th} species. Since not all forms encountered can be identified to the species level, the diversity index presented may differ somewhat from the true diversity.

Redundancy is a measure of the dominance of one or a few species within population assemblages. As presented by Wilhm and Dorris (1968), it is:

$$r = \frac{\overline{d}_{max} - \overline{d}}{\overline{d}_{max} - \overline{d}_{min}}$$

where $\overline{d}$ is the diversity of a community as calculated above, $\overline{d}_{max}$ is the maximum diversity for the community, and $\overline{d}_{min}$ is the minimum diversity for the community. $\overline{d}_{max}$ and $\overline{d}_{min}$ are computed as follows:

$$\overline{d}_{max} = (1/n)(\log_2 n! - S\log_2 [n/S]!)$$

$$\overline{d}_{min} = (1/n)(\log_2 n! - S\log_2 [n/S-1]!)$$

The possible values of r vary in a range between 0 and 1. When an r equals 0, it indicates that all the species encountered in a community have the same abundance, whereas when an r equals 1, it implies that one species dominates a community. As shown in the formula, the value is derived from the measures of species number, abundance and diversity.

For the period between 1975 and 1980, the number of forms of phytoplankton was lowest in 1975 (Table 13). The number of forms in 1980 is the second lowest in the six years of observation. Because of the absence of June data when the number of forms is usually high, the mean number of forms for 1979 may be unduly low.

Table 13. Comparison of the number of forms of phytoplankton for the years 1975 through 1980. Standard errors are included in the first set of parentheses and sample size is shown in the second set of parentheses.

Month	1975	1976	1977	1978	1979	1980
January	---[1]	59.4(2.79)(11)	---[1]	62.9(2.47)(11)	59.7(3.03)(18)	46.8(2.07)(17)
February	51.1(1.90)(9)	57.3(1.64)(12)	---	48.9(1.01)(12)	46.6(1.37)(18)	43.8(1.26)(18)
March	51.7(1.89)(9)	59.3(1.59)(12)	52.9(2.36)(12)	40.3(1.16)(12)	56.7(1.80)(18)	44.2(1.15)(18)
April	48.3(1.38)(9)	56.1(1.43)(12)	55.5(3.37)(12)	55.1(3.24)(12)	44.8(1.97)(12)	48.3(1.43)(18)
May	47.4(1.78)(9)	60.3(2.84)(12)	46.4(2.91)(12)	81.9(2.07)(12)	38.8(1.39)(12)	44.1(1.29)(18)
June	49.2(1.77)(12)	65.8(1.77)(12)	64.1(3.59)(12)	85.3(4.17)(12)		53.2(2.02)(12)
July	51.6(.892)(12)	87.3(3.78)(12)	57.7(2.64)(12)	69.7(2.73)(18)	32.0(1.35)(12)	40.6(2.03)(12)
August	44.5(2.32)(12)	53.4(3.31)(12)	46.9(2.26)(12)	49.9(1.93)(18)	48.8(1.88)(18)	55.5(5.43)(18)
September	44.1(3.12)(10)	84.8(4.30)(12)	60.3(2.75)(12)	67.1(2.53)(18)	64.6(3.75)(16)	69.9(2.39)(18)
October	54.9(2.18)(12)	58.8(2.77)(12)	52.3(2.60)(12)	78.2(3.02)(18)	67.4(1.92)(18)	58.2(2.40)(18)
November	50.3(2.11)(12)	57.2(1.74)(12)	46.6(1.85)(12)	72.6(3.47)(18)	56.5(1.95)(12)	52.8(2.22)(12)
December	50.8(1.74)(11)	56.5(1.81)(12)	56.4(2.52)(12)	55.1(2.19)(18)	61.0(2.87)(12)	51.4(1.94)(12)
Yearly Mean	49.4(.969)	63.1(3.25)	53.9(1.92)	63.9(2.50)	52.4(3.36)	50.7(2.33)

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[1] Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.

Though no trend is apparent in diversity, 1976 diversities are higher than those of 1975, 1977, 1978, 1979, and 1980 (Table 14). The increase in diversity in 1976 may in part be due to upwelling and mixing events which enriched the nearshore region with nutrients and a different phytoplankton community. The mean yearly diversity for 1980 was high compared to that of 1977, lower than those for 1975, 1976, and 1978, and equal to the 1979 average. The monthly average of diversity in 1980 reached a peak in June.

Redundancy variation during 1975 through 1980 shows no distinct trend (Table 15). Though highest in 1977, the difference between the 1980 and 1977 redundancies does not vary greatly from the difference between any other two years.

All phytoplankton cell counts and their derived community descriptions do not, at this time, indicate any observable plant impact.

Phytoplankton Viability

Because the phaeophytin *a* / chlorophyll *a* ratio is relatively insensitive to changes in viability, all chlorophyll data are presented as in the reports of the 1975, 1976, 1977, 1978, and 1979 data (Rossmann *et al*. 1977, Rossmann *et al*. 1979, Rossmann *et al*. 1980, Chang *et al*. 1981, Rossmann *et al*. 1982). Of the chlorophylls, chlorophyll *a* is the most sensitive for detecting changes in viability. A considerably more sensitive means of assessing changes in phytoplankton viability is productivity as measured by the uptake of C^{14}.

Table 14. Comparison of phytoplankton form diversities for the years 1975 through 1980. Standard errors are included in the first set of parentheses and sample size is shown in the second set of parentheses.

Month	1975	1976	1977	1978	1979	1980
January	---[1]	4.29(.055)(11)	---[1]	4.53(.092)(11)	4.34(0.102)(18)	3.79(0.087)(17)
February	4.35(.047) (9)	4.47(.059)(12)	---	4.37(.103)(12)	4.00(0.110)(18)	3.90(0.048)(18)
March	4.30(.054) (9)	4.34(.063)(12)	3.85(.068)(12)	3.69(.108)(12)	4.30(0.066)(18)	4.13(0.048)(18)
April	4.21(0.57) (9)	4.30(.047)(12)	4.36(.087)(12)	4.21(.119)(12)	3.82(0.078)(12)	3.72(0.060)(18)
May	3.76(.228) (9)	4.37(.112)(12)	2.98(.186)(12)	4.96(0.03)(12)	3.48(0.074)(12)	3.94(0.035)(18)
June	4.17(.081) (12)	4.67(.062)(12)	4.62(.084)(12)	4.31(0.10)(12)		4.16(0.055)(12)
July	3.93(.065) (12)	5.08(.038)(12)	4.00(.056)(12)	4.86(0.05)(18)	3.24(0.089)(12)	3.87(0.051)(12)
August	3.58(.163) (12)	3.50(.114)(12)	3.29(.161)(12)	4.07(0.97)(18)	3.82(0.061)(18)	3.58(0.125)(18)
September	3.36(.189) (10)	4.92(.097)(12)	3.29(.109)(12)	4.40(0.15)(18)	3.55(0.084)(16)	4.00(0.060)(18)
October	3.96(.138) (12)	4.48(.082)(12)	4.00(.076)(12)	3.77(0.11)(18)	4.15(0.083)(18)	3.79(0.102)(18)
November	4.02(.119) (12)	3.97(.061)(12)	3.69(.094)(12)	3.58(0.11)(18)	3.81(0.046)(12)	3.76(0.076)(12)
December	3.83(.0982)(11)	3.96(.096)(12)	3.82(.113)(12)	2.91(0.08)(18)	3.89(0.069)(18)	3.71(0.155)(12)
Yearly Mean	3.95(.092)	4.36(.124)	3.79(.159)	4.15(0.09)	3.86(0.103)	3.86(0.05)

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[1] Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.

Table 15. Comparison of phytoplankton redundancies for the years 1975 through 1980. Standard errors are included in the first set of parentheses and sample size is shown in the second set of parentheses.

Month	1975	1976	1977	1978	1979	1980
January	---[1]	.270(.011)(11)	---[1]	.238(.016)(11)	.262(0.015)(18)	0.318(0.012)(17)
February	.230(.009)(9)	.231(.011)(12)	---	.207(.024)(12)	.278(0.020)(18)	0.286(0.012)(18)
March	.243(.008)(9)	.263(.011)(12)	.329(.008)(12)	.317(.021)(12)	.261(0.010)(18)	0.240(0.010)(18)
April	.246(.009)(9)	.260(.007)(12)	.244(.006)(12)	.272(.013)(12)	.303(0.012)(12)	0.337(0.013)(18)
May	.327(.054)(9)	.259(.015)(12)	.474(.030)(12)	.217(.007)(12)	.340(0.015)(12)	0.270(0.006)(18)
June	.258(.010)(12)	.223(.010)(12)	.223(.010)(12)	.329(.013)(12)		0.274(0.005)(12)
July	.310(.011)(12)	.210(.008)(12)	.318(.011)(12)	.201(.006)(18)	.358(0.014)(12)	0.270(0.010)(12)
August	.353(.026)(12)	.393(.017)(12)	.411(.034)(12)	.280(.009)(18)	.318(0.014)(18)	0.396(0.013)(18)
September	.389(.029)(10)	.227(.013)(12)	.457(.021)(12)	.447(.026)(18)	.422(0.012)(16)	0.394(0.008)(18)
October	.317(.021)(12)	.232(.014)(12)	.299(.011)(12)	.405(.017)(18)	.317(0.016)(18)	0.354(0.017)(18)
November	.289(.020)(12)	.322(.011)(12)	.335(.015)(12)	.427(.019)(18)	.348(0.011)(12)	0.334(0.016)(12)
December	.325(.017)(11)	.322(.018)(12)	.348(.019)(12)	.502(.017)(18)	.345(0.011)(12)	0.349(0.030)(12)
Yearly Mean	.299(.0152)	.268(.0154)	.344(.0262)	.320(0.030)	0.323(0.014)	0.316(0.014)

[1] Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.

Viability based on Chlorophylls

During the period of 1975 through May 1982, the occurrence of increase or decrease exceeded 10% twice (Table 16). These were in 1977 when there was a 16% occurrence of decreases in viability compared to only a 1% occurrence of increases, and in 1982 when there was an 11% occurrence of increases in viability compared to a 7% occurrence of decreases.

Since chlorophyll a is the most sensitive of the chlorophyll variables for detecting changes in viability, it will be discussed in detail. Table 17 contains a summary of the occurrences of statistically significant (0.05 level of significance) changes in viability between the intake and discharge. The table lists those percent occurrences for both non-incubated and incubated samples. The data are derived from Tables 18-27 which present all of the comparisons betwen intake and discharge. Except for 1979, the occurrence of viability decreases was greater than the number of increases. This suggests that a small negative plant impact on phytoplankton viability is occurring. The mean percent occurrence of decreases for all years is 15.9, while that for increases is 6.4.

Viability based on Productivity (C^{14})

Beginning in March of 1980, viability experiments on primary productivity were carried out at monthly intervals (Table 28). Using the C-14 fixation method for measuring production on the waters taken from the intake and discharge pipes, the experiments showed a large reduction in primary productivity in the discharge water, ranging from 16% to 80% as compared to the intake water. This occurred at times when no apparent difference was found

Table 16. Changes in viability noted by comparison of chlorophyll data from the intake with those from the discharges.

Year	Percent of Comparisons Showing Increase	Percent of Comparisons Showing Decrease
1975	2	4
1976	4	5
1977	1	16
1978	9	9
1979	9	5
1980	3	2
1981	8	5
1982 (through May)	11	7
	$\overline{X}$ = 5.9	6.6
	σ = 3.8	4.3

Table 17. Percent occurrence of statistically significant (0.05 level of significance) changes in viability (chlorophyll a) between the intake and discharge.

	Decrease		Increase	
Year	Non-incubated	Incubated	Non-incubated	Incubated
1975	0	5	0	0
1976	8	8	6	0
1977	30	60	0	0
1978	22	17	5	17
1979	15	12	16	30
1980	17	8	3	8
1981	15	25	8	17
1982 (through May)	20	0	13	20
$\overline{X}$ =	15.9	16.9	6.4	11.5
σ =	9.0	19.0	5.8	11.2

TABLE 18. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/81	2020	I5	0	4	0.419E+01	0.153E+00			
01/12/81	2027	D1	0	5	0.411E+01	0.454E-01			
01/12/81	2033	D2	0	5	0.406E+01	0.124E+00	INTAKE VS DISCHARGE	0.349E+00	0.713E+00
01/12/81	2020	I5	37	4	0.428E+01	0.148E+00			
01/12/81	2027	D1	37	5	0.435E+01	0.626E-01			
01/12/81	2033	D2	37	5	0.425E+01	0.119E+00	INTAKE VS DISCHARGE	0.219E+00	0.804E+00
01/13/81	0635	I5	0	5	0.417E+01	0.150E+00			
01/13/81	0642	DI	0	4	0.399E+01	0.912E-01			
01/13/81	0650	D2	0	5	0.391E+01	0.878E-01	INTAKE VS DISCHARGE	0.143E+01	0.281E+00
01/13/81	1222	I5	0	5	0.392E+01	0.171E+00			
01/13/81	1227	D1	0	5	0.361E+01	0.626E-01			
01/13/81	1233	D2	0	5	0.379E+01	0.101E+00	INTAKE VS DISCHARGE	0.168E+01	0.228E+00
02/09/81	1931	I5	0	5	0.231E+01	0.144E+00			
02/09/81	1937	D1	0	5	0.246E+01	0.292E-01			
02/09/81	1932	D2	0	5	0.239E+01	0.568E-01	INTAKE VS DISCHARGE	0.683E+00	0.526E+00
02/09/81	1931	I5	37	4	0.246E+01	0.691E-01			
02/09/81	1937	D1	37	5	0.236E+01	0.520E-01			
02/09/81	1932	D2	37	5	0.236E+01	0.120E+00	INTAKE VS DISCHARGE	0.361E+00	0.706E+00
02/10/81	0642	I5	0	5	0.245E+01	0.122E+00			
02/10/81	0637	D1	0	5	0.258E+01	0.136E+00			
02/10/81	0637	D2	0	5	0.256E+01	0.702E-01	INTAKE VS DISCHARGE	0.434E+00	0.659E+00
02/10/81	1212	I5	0	5	0.272E+01	0.111E+00			
02/10/81	1213	D1	0	3	0.256E+01	0.134E+00			
02/10/81	1221	D2	0	4	0.248E+01	0.999E-01	INTAKE VS DISCHARGE	0.127E+01	0.329E+00
03/16/81	2055	I5	0	5	0.720E+01	0.882E-01			
03/16/81	2050	D1	0	4	0.757E+01	0.104E+00	INTAKE VS DISCHARGE	0.746E+01	0.300E-01
03/16/81	2055	I5	35	5	0.730E+01	0.131E+00			
03/16/81	2050	D1	35	3	0.662E+01	0.156E+00	INTAKE VS DISCHARGE	0.105E+02	0.189E-01
03/17/81	0537	I5	0	4	0.768E+01	0.143E+00			
03/17/81	0543	D1	0	5	0.775E+01	0.232E+00	INTAKE VS DISCHARGE	0.690E-01	0.789E+00
03/17/81	1208	I5	0	4	0.813E+01	0.129E+00			
03/17/81	1217	D1	0	5	0.733E+01	0.699E-01	INTAKE VS DISCHARGE	0.339E+02	0.118E-02

TABLE 18. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/06/81	2117	I5 0	4	0.858E+01	0.889E-01			
04/06/81	2115	D1 0	5	0.837E+01	0.878E-01	INTAKE VS DISCHARGE	0.277E+01	0.140E+00
04/06/81	2117	I5 36	5	0.877E+01	0.129E+00			
04/06/81	2115	D1 36	2	0.889E+01	0.300E-01	INTAKE VS DISCHARGE	0.317E+00	0.598E+00
04/07/81	0448	I5 0	5	0.689E+01	0.899E-01			
04/07/81	0449	D1 0	4	0.625E+01	0.146E+00	INTAKE VS DISCHARGE	0.153E+02	0.680E-02
04/07/81	1204	I5 0	5	0.714E+01	0.662E-01			
04/07/81	1203	D1 0	5	0.623E+01	0.137E+00	INTAKE VS DISCHARGE	0.358E+02	0.691E-03
05/11/81	2127	I5 0	5	0.182E+02	0.388E+00			
05/11/81	2124	D1 0	5	0.184E+02	0.198E+00	INTAKE VS DISCHARGE	0.135E+00	0.718E+00
05/11/81	2127	I5 35	5	0.190E+02	0.253E+00			
05/11/81	2124	D1 35	5	0.188E+02	0.220E+00	INTAKE VS DISCHARGE	0.512E+00	0.499E+00
05/12/81	0342	I5 0	5	0.188E+02	0.136E+00			
05/12/81	0339	D1 0	4	0.182E+02	0.193E+00	INTAKE VS DISCHARGE	0.650E+01	0.388E-01
05/12/81	1216	I5 0	5	0.213E+02	0.446E+00			
05/12/81	1217	D1 0	5	0.211E+02	0.286E+00	INTAKE VS DISCHARGE	0.143E+00	0.711E+00
06/08/81	2235	I5 0	5	0.401E+01	0.745E-01			
06/08/81	2221	D2 0	5	0.377E+01	0.951E-01	INTAKE VS DISCHARGE	0.408E+01	0.780E-01
06/08/81	2235	I5 35	4	0.336E+01	0.157E+00			
06/08/81	2221	D2 35	4	0.335E+01	0.106E+00	INTAKE VS DISCHARGE	0.434E-02	0.938E+00
06/09/81	0248	I5 0	5	0.436E+01	0.210E+00			
06/09/81	0255	D2 0	5	0.404E+01	0.237E+00	INTAKE VS DISCHARGE	0.101E+01	0.347E+00
06/09/81	1153	I5 0	5	0.357E+01	0.865E-01			
06/09/81	1144	D2 0	5	0.323E+01	0.197E+00	INTAKE VS DISCHARGE	0.250E+01	0.152E+00
07/13/81	2232	I5 0	4	0.0	0.0			
07/13/81	2248	D2 0	5	0.918E+00	0.345E+00	INTAKE VS DISCHARGE	0.549E+01	0.520E-01
07/13/81	2232	I5 36	5	0.906E+00	0.164E+00			
07/13/81	2248	D2 36	5	0.124E+01	0.996E-01	INTAKE VS DISCHARGE	0.303E+01	0.120E+00
07/14/81	0315	I5 0	5	0.162E+01	0.791E-01			
07/14/81	0327	D2 0	5	0.192E+01	0.121E+00	INTAKE VS DISCHARGE	0.434E+01	0.708E-01
07/14/81	1205	I5 0	5	0.158E+01	0.979E-01			
07/14/81	1218	D2 0	5	0.159E+01	0.115E+00	INTAKE VS DISCHARGE	0.436E-02	0.938E+00

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DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
08/10/81	2200	I5	0	4	0.203E+01	0.125E+00			
08/10/81	2212	D1	0	3	0.210E+01	0.125E+00			
08/10/81	2147	D2	0	5	0.206E+01	0.140E+00	INTAKE VS DISCHARGE	0.660E-01	0.932E+00
08/10/81	2200	I5	36	5	0.127E+01	0.104E+00			
08/10/81	2212	D1	36	4	0.164E+01	0.497E-01			
08/10/81	2147	D2	36	5	0.141E+01	0.765E-01	INTAKE VS DISCHARGE	0.478E+01	0.331E-01
08/11/81	0435	I5	0	4	0.236E+01	0.696E-01			
08/11/81	0428	D1	0	5	0.231E+01	0.106E+00			
08/11/81	0426	D2	0	4	0.209E+01	0.914E-01	INTAKE VS DISCHARGE	0.228E+01	0.154E+00
08/11/81	1108	I5	0	5	0.249E+01	0.111E+00			
08/11/81	1123	D1	0	4	0.247E+01	0.103E+00			
08/11/81	1105	D2	0	4	0.240E+01	0.781E-01	INTAKE VS DISCHARGE	0.200E+00	0.818E+00
09/14/81	2116	I4	0	5	0.361E+01	0.232E+00			
09/14/81	2058	D1	0	5	0.421E+01	0.860E-01			
09/14/81	2129	D2	0	5	0.340E+01	0.970E-01	INTAKE VS DISCHARGE	0.756E+01	0.839E-02
09/14/81	2116	I4	35	4	0.323E+01	0.111E+00			
09/14/81	2058	D1	35	4	0.378E+01	0.127E+00			
09/14/81	2129	D2	35	3	0.340E+01	0.200E-01	INTAKE VS DISCHARGE	0.725E+01	0.173E-01
09/15/81	0514	I4	0	5	0.391E+01	0.157E+00			
09/15/81	0501	D1	0	4	0.373E+01	0.484E-01			
09/15/81	0522	D2	0	4	0.453E+01	0.696E-01	INTAKE VS DISCHARGE	0.122E+02	0.277E-02
09/15/81	1208	I4	0	5	0.375E+01	0.204E+00			
09/15/81	1155	D1	0	4	0.350E+01	0.155E+00			
09/15/81	1219	D2	0	5	0.340E+01	0.713E-01	INTAKE VS DISCHARGE	0.147E+01	0.274E+00
10/12/81	1952	I5	0	4	0.432E+01	0.117E+00			
10/12/81	2000	D1	0	4	0.454E+01	0.960E-01	INTAKE VS DISCHARGE	0.203E+01	0.205E+00
10/12/81	1952	I5	38	4	0.454E+01	0.929E-01			
10/12/81	2000	D1	38	5	0.399E+01	0.348E-01	INTAKE VS DISCHARGE	0.362E+02	0.102E-02
10/13/81	0516	I5	0	5	0.411E+01	0.147E+00			
10/13/81	0523	D1	0	2	0.406E+01	0.160E+00	INTAKE VS DISCHARGE	0.368E-01	0.841E+00
10/13/81	1202	I5	0	5	0.393E+01	0.314E-01			
10/13/81	1209	D1	0	5	0.367E+01	0.699E-01	INTAKE VS DISCHARGE	0.110E+02	0.114E-01

TABLE 18. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
11/09/81	1907	I5 0	5	0.108E+02	0.281E+00			
11/09/81	1915	D2 0	5	0.109E+02	0.187E+00	INTAKE VS DISCHARGE	0.877E-01	0.765E+00
11/09/81	1907	I5 37	5	0.112E+02	0.252E+00			
11/09/81	1915	D2 37	4	0.110E+02	0.303E+00	INTAKE VS DISCHARGE	0.213E+00	0.657E+00
11/10/81	0610	I5 0	5	0.929E+01	0.379E+00			
11/10/81	0620	D2 0	5	0.878E+01	0.166E+00	INTAKE VS DISCHARGE	0.152E+01	0.253E+00
11/10/81	1212	I5 0	5	0.980E+01	0.302E+00			
11/10/81	1228	D2 0	5	0.997E+01	0.184E+00	INTAKE VS DISCHARGE	0.242E+00	0.636E+00
12/07/81	1956	I5 0	5	0.625E+01	0.408E+00			
12/07/81	1942	D1 0	4	0.575E+01	0.109E+00			
12/07/81	1910	D2 0	5	0.650E+01	0.545E-01	INTAKE VS DISCHARGE	0.198E+01	0.185E+00
12/07/81	1956	I5 36	5	0.660E+01	0.825E-01			
12/07/81	1942	D1 36	4	0.578E+01	0.101E+00			
12/07/81	1910	D2 36	5	0.569E+01	0.299E+00	INTAKE VS DISCHARGE	0.655E+01	0.144E-01
12/08/81	0632	I5 0	4	0.651E+01	0.838E-01			
12/08/81	0645	D1 0	5	0.641E+01	0.136E+00			
12/08/81	0659	D2 0	4	0.636E+01	0.135E+00	INTAKE VS DISCHARGE	0.348E+00	0.715E+00
12/08/81	1229	I5 0	4	0.689E+01	0.232E+00			
12/08/81	1242	D1 0	5	0.560E+01	0.138E+00			
12/08/81	1255	D2 0	5	0.554E+01	0.132E+00	INTAKE VS DISCHARGE	0.199E+02	0.493E-03

TABLE 19. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/81	2020	I5 0	4	0.0	0.0			
01/12/81	2027	D1 0	5	0.0	0.0			
01/12/81	2033	D2 0	5	0.105E-01	0.597E-02	INTAKE VS DISCHARGE	0.276E+01	0.108E+00
01/12/81	2020	I5 37	4	0.0	0.0			
01/12/81	2027	D1 37	5	0.344E-03	0.344E-03			
01/12/81	2033	D2 37	5	0.651E-02	0.562E-02	INTAKE VS DISCHARGE	0.111E+01	0.364E+00
01/13/81	0635	I5 0	5	0.209E-01	0.131E-01			
01/13/81	0642	DI 0	4	0.455E-01	0.178E-01			
01/13/81	0650	D2 0	5	0.964E-02	0.964E-02	INTAKE VS DISCHARGE	0.177E+01	0.217E+00
01/13/81	1222	I5 0	5	0.245E-01	0.166E-01			
01/13/81	1227	D1 0	5	0.184E-01	0.184E-01			
01/13/81	1233	D2 0	5	0.378E-01	0.165E-01	INTAKE VS DISCHARGE	0.331E+00	0.725E+00
02/09/81	1931	I5 0	5	0.442E-01	0.984E-02			
02/09/81	1937	D1 0	5	0.602E-01	0.152E-01			
02/09/81	1932	D2 0	5	0.385E-01	0.587E-02	INTAKE VS DISCHARGE	0.105E+01	0.382E+00
02/09/81	1931	I5 37	4	0.116E+00	0.109E-01			
02/09/81	1937	D1 37	5	0.801E-01	0.155E-01			
02/09/81	1932	D2 37	5	0.807E-01	0.170E-01	INTAKE VS DISCHARGE	0.169E+01	0.229E+00
02/10/81	0642	I5 0	5	0.479E-01	0.134E-01			
02/10/81	0637	D1 0	5	0.943E-01	0.271E-01			
02/10/81	0637	D2 0	5	0.505E-01	0.835E-02	INTAKE VS DISCHARGE	0.208E+01	0.169E+00
02/10/81	1212	I5 0	5	0.102E+00	0.284E-01			
02/10/81	1213	D1 0	3	0.694E-01	0.205E-01			
02/10/81	1221	D2 0	4	0.211E-01	0.116E-01	INTAKE VS DISCHARGE	0.326E+01	0.877E-01
03/16/81	2055	I5 0	5	0.678E-02	0.678E-02	INTAKE VS DISCHARGE	0.778E+00	0.410E+00
03/16/81	2050	D1 0	4	0.0	0.0			
03/16/81	2055	I5 35	5	0.489E-01	0.338E-01	INTAKE VS DISCHARGE	0.561E+00	0.486E+00
03/16/81	2050	D1 35	3	0.142E-01	0.142E-01			
03/17/81	0537	I5 0	4	0.0	0.0	INTAKE VS DISCHARGE	0.136E+01	0.282E+00
03/17/81	0543	D1 0	5	0.247E-01	0.187E-01			
03/17/81	1208	I5 0	4	0.486E-01	0.301E-01	INTAKE VS DISCHARGE	0.338E+01	0.109E+00
03/17/81	1217	D1 0	5	0.0	0.0			

TABLE 19. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/06/81	2117	I5	0	4	0.0	0.0			
04/06/81	2115	D1	0	5	0.114E-01	0.114E-01	INTAKE VS DISCHARGE	0.778E+00	0.410E+00
04/06/81	2117	I5	36	5	0.0	0.0			
04/06/81	2115	D1	36	2	0.500E-06	0.500E-06	INTAKE VS DISCHARGE	0.357E+01	0.118E+00
04/07/81	0448	I5	0	5	0.0	0.0			
04/07/81	0449	D1	0	4	0.115E-01	0.957E-02	INTAKE VS DISCHARGE	0.189E+01	0.212E+00
04/07/81	1204	I5	0	5	0.0	0.0			
04/07/81	1203	D1	0	5	0.826E-02	0.826E-02	INTAKE VS DISCHARGE	0.100E+01	0.348E+00
05/11/81	2127	I5	0	5	0.249E+00	0.825E-01			
05/11/81	2124	D1	0	5	0.291E+00	0.629E-01	INTAKE VS DISCHARGE	0.161E+00	0.696E+00
05/11/81	2127	I5	35	5	0.189E+00	0.391E-01			
05/11/81	2124	D1	35	5	0.176E+00	0.910E-01	INTAKE VS DISCHARGE	0.176E-01	0.884E+00
05/12/81	0342	I5	0	5	0.176E+00	0.808E-01			
05/12/81	0339	D1	0	4	0.755E+00	0.463E+00	INTAKE VS DISCHARGE	0.193E+01	0.207E+00
05/12/81	1216	I5	0	5	0.797E-01	0.469E-01			
05/12/81	1217	D1	0	5	0.495E+00	0.144E+00	INTAKE VS DISCHARGE	0.753E+01	0.259E-01
06/08/81	2235	I5	0	5	0.0	0.0			
06/08/81	2221	D2	0	5	0.377E-01	0.260E-01	INTAKE VS DISCHARGE	0.210E+01	0.185E+00
06/08/81	2235	I5	35	4	0.927E-01	0.604E-01			
06/08/81	2221	D2	35	4	0.652E-01	0.186E-01	INTAKE VS DISCHARGE	0.190E+00	0.675E+00
06/09/81	0248	I5	0	5	0.156E-01	0.156E-01			
06/09/81	0255	D2	0	5	0.124E+00	0.961E-01	INTAKE VS DISCHARGE	0.124E+01	0.299E+00
06/09/81	1153	I5	0	5	0.351E-01	0.206E-01			
06/09/81	1144	D2	0	5	0.382E-01	0.232E-01	INTAKE VS DISCHARGE	0.101E-01	0.910E+00
07/13/81	2232	I5	0	4	0.875E-02	0.513E-02			
07/13/81	2248	D2	0	5	0.506E-02	0.506E-02	INTAKE VS DISCHARGE	0.256E+00	0.629E+00
07/13/81	2232	I5	36	5	0.660E-01	0.323E-01			
07/13/81	2248	D2	36	5	0.441E-01	0.212E-01	INTAKE VS DISCHARGE	0.320E+00	0.589E+00
07/14/81	0315	I5	0	5	0.636E-01	0.660E-02			
07/14/81	0327	D2	0	5	0.300E-01	0.160E-01	INTAKE VS DISCHARGE	0.376E+01	0.885E-01
07/14/81	1205	I5	0	5	0.339E-01	0.174E-01			
07/14/81	1218	D2	0	5	0.289E-01	0.137E-01	INTAKE VS DISCHARGE	0.511E-01	0.814E+00

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DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
08/10/81	2200	I5	0	4	0.327E-01	0.166E-01			
08/10/81	2212	D1	0	3	0.218E-01	0.218E-01			
08/10/81	2147	D2	0	5	0.111E-01	0.717E-02	INTAKE VS DISCHARGE	0.646E+00	0.549E+00
08/10/81	2200	I5	36	5	0.523E-01	0.234E-01			
08/10/81	2212	D1	36	4	0.0	0.0			
08/10/81	2147	D2	36	5	0.0	0.0	INTAKE VS DISCHARGE	0.443E+01	0.399E-01
08/11/81	0435	I5	0	4	0.343E-01	0.198E-01			
08/11/81	0428	D1	0	5	0.109E+00	0.137E-01			
08/11/81	0426	D2	0	4	0.132E+00	0.307E-01	INTAKE VS DISCHARGE	0.533E+01	0.277E-01
08/11/81	1108	I5	0	5	0.152E-02	0.137E-02			
08/11/81	1123	D1	0	4	0.188E-01	0.188E-01			
08/11/81	1105	D2	0	4	0.676E-01	0.856E-02	INTAKE VS DISCHARGE	0.979E+01	0.527E-02
09/14/81	2116	I4	0	5	0.324E-01	0.219E-01			
09/14/81	2058	D1	0	5	0.820E-01	0.500E-01			
09/14/81	2129	D2	0	5	0.100E+00	0.151E-01	INTAKE VS DISCHARGE	0.115E+01	0.349E+00
09/14/81	2116	I4	35	4	0.677E-01	0.346E-01			
09/14/81	2058	D1	35	4	0.131E+00	0.296E-01			
09/14/81	2129	D2	35	3	0.175E-01	0.175E-01	INTAKE VS DISCHARGE	0.342E+01	0.861E-01
09/15/81	0514	I4	0	5	0.546E-02	0.546E-02			
09/15/81	0501	D1	0	4	0.0	0.0			
09/15/81	0522	D2	0	4	0.249E-01	0.134E-01	INTAKE VS DISCHARGE	0.254E+01	0.130E+00
09/15/81	1208	I4	0	5	0.544E-01	0.270E-01			
09/15/81	1155	D1	0	4	0.552E-01	0.160E-01			
09/15/81	1219	D2	0	5	0.758E-01	0.264E-01	INTAKE VS DISCHARGE	0.249E+00	0.782E+00
10/12/81	1952	I5	0	4	0.250E-06	0.250E-06			
10/12/81	2000	D1	0	4	0.0	0.0	INTAKE VS DISCHARGE	0.100E+01	0.358E+00
10/12/81	1952	I5	38	4	0.0	0.0			
10/12/81	2000	D1	38	5	0.974E-02	0.974E-02	INTAKE VS DISCHARGE	0.778E+00	0.410E+00
10/13/81	0516	I5	0	5	0.0	0.0			
10/13/81	0523	D1	0	2	0.102E-01	0.102E-01	INTAKE VS DISCHARGE	0.357E+01	0.118E+00
10/13/81	1202	I5	0	5	0.536E-02	0.536E-02			
10/13/81	1209	D1	0	5	0.460E-02	0.372E-02	INTAKE VS DISCHARGE	0.136E-01	0.897E+00

TABLE 19. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
11/09/81	1907	I5 0	5	0.226E-02	0.226E-02	INTAKE VS DISCHARGE	0.100E+01	0.348E+00
11/09/81	1915	D2 0	5	0.0	0.0			
11/09/81	1907	I5 37	5	0.0	0.0	INTAKE VS DISCHARGE	0.130E+01	0.293E+00
11/09/81	1915	D2 37	4	0.230E-01	0.230E-01			
11/10/81	0610	I5 0	5	0.584E-02	0.584E-02	INTAKE VS DISCHARGE	0.112E+01	0.322E+00
11/10/81	0620	D2 0	5	0.267E-01	0.189E-01			
11/10/81	1212	I5 0	5	0.351E-01	0.245E-01	INTAKE VS DISCHARGE	0.159E+00	0.697E+00
11/10/81	1228	D2 0	5	0.220E-01	0.220E-01			
12/07/81	1956	I5 0	5	0.120E-01	0.924E-02	INTAKE VS DISCHARGE	0.235E+01	0.142E+00
12/07/81	1942	D1 0	4	0.0	0.0			
12/07/81	1910	D2 0	5	0.673E-01	0.365E-01			
12/07/81	1956	I5 36	5	0.743E-01	0.667E-01	INTAKE VS DISCHARGE	0.601E+00	0.568E+00
12/07/81	1942	D1 36	4	0.0	0.0			
12/07/81	1910	D2 36	5	0.350E-01	0.350E-01			
12/08/81	0632	I5 0	4	0.450E-01	0.450E-01	INTAKE VS DISCHARGE	0.151E+01	0.268E+00
12/08/81	0645	D1 0	5	0.183E+00	0.730E-01			
12/08/81	0659	D2 0	4	0.165E+00	0.470E-01			
12/08/81	1229	I5 0	4	0.300E-01	0.191E-01	INTAKE VS DISCHARGE	0.196E+01	0.188E+00
12/08/81	1242	D1 0	5	0.852E-02	0.852E-02			
12/08/81	1255	D2 0	5	0.0	0.0			

TABLE 20. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/81	2020	I5 0	4	0.729E+00	0.350E-01			
01/12/81	2027	D1 0	5	0.832E+00	0.600E-01			
01/12/81	2033	D2 0	5	0.817E+00	0.488E-01	INTAKE VS DISCHARGE	0.108E+01	0.375E+00
01/12/81	2020	I5 37	4	0.893E+00	0.521E-01			
01/12/81	2027	D1 37	5	0.710E+00	0.239E-01			
01/12/81	2033	D2 37	5	0.842E+00	0.580E-01	INTAKE VS DISCHARGE	0.408E+01	0.483E-01
01/13/81	0635	I5 0	5	0.887E+00	0.648E-01			
01/13/81	0642	DI 0	4	0.856E+00	0.692E-01			
01/13/81	0650	D2 0	5	0.771E+00	0.716E-01	INTAKE VS DISCHARGE	0.807E+00	0.474E+00
01/13/81	1222	I5 0	5	0.690E+00	0.702E-01			
01/13/81	1227	D1 0	5	0.657E+00	0.476E-01			
01/13/81	1233	D2 0	5	0.918E+00	0.842E-01	INTAKE VS DISCHARGE	0.424E+01	0.414E-01
02/09/81	1931	I5 0	5	0.577E+00	0.439E-01			
02/09/81	1937	D1 0	5	0.609E+00	0.151E-01			
02/09/81	1932	D2 0	5	0.576E+00	0.183E-01	INTAKE VS DISCHARGE	0.435E+00	0.659E+00
02/09/81	1931	I5 37	4	0.759E+00	0.176E-01			
02/09/81	1937	D1 37	5	0.575E+00	0.149E-01			
02/09/81	1932	D2 37	5	0.471E+00	0.795E-01	INTAKE VS DISCHARGE	0.757E+01	0.947E-02
02/10/81	0642	I5 0	5	0.498E+00	0.285E-01			
02/10/81	0637	D1 0	5	0.698E+00	0.895E-01			
02/10/81	0637	D2 0	5	0.608E+00	0.624E-01	INTAKE VS DISCHARGE	0.235E+01	0.139E+00
02/10/81	1212	I5 0	5	0.784E+00	0.777E-01			
02/10/81	1213	D1 0	3	0.663E+00	0.107E-01			
02/10/81	1221	D2 0	4	0.550E+00	0.603E-01	INTAKE VS DISCHARGE	0.331E+01	0.u52E-01
03/16/81	2055	I5 0	5	0.128E+01	0.378E-01			
03/16/81	2050	D1 0	4	0.141E+01	0.825E-01	INTAKE VS DISCHARGE	0.244E+01	0.162E+00
03/16/81	2055	I5 35	5	0.120E+01	0.114E+00			
03/16/81	2050	D1 35	3	0.100E+01	0.646E-01	INTAKE VS DISCHARGE	0.151E+01	0.265E+00
03/17/81	0537	I5 0	4	0.152E+01	0.333E-01			
03/17/81	0543	D1 0	5	0.150E+01	0.136E+00	INTAKE VS DISCHARGE	0.285E-01	0.857E+00
03/17/81	1208	I5 0	4	0.148E+01	0.884E-01			
03/17/81	1217	D1 0	5	0.890E+00	0.224E+00	INTAKE VS DISCHARGE	0.493E+01	0.623E-01

TABLE 20. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/06/81	2117	I5	0	4	0.142E+01	0.133E+00			
04/06/81	2115	D1	0	5	0.151E+01	0.651E-01	INTAKE VS DISCHARGE	0.387E+00	0.556E+00
04/06/81	2117	I5	36	5	0.149E+01	0.297E-01			
04/06/81	2115	D1	36	2	0.147E+01	0.550E-01	INTAKE VS DISCHARGE	0.680E-01	0.793E+00
04/07/81	0448	I5	0	5	0.116E+01	0.356E-01			
04/07/81	0449	D1	0	4	0.127E+01	0.738E-01	INTAKE VS DISCHARGE	0.191E+01	0.209E+00
04/07/81	1204	I5	0	5	0.126E+01	0.708E-01			
04/07/81	1203	D1	0	5	0.118E+01	0.331E-01	INTAKE VS DISCHARGE	0.996E+00	0.349E+00
05/11/81	2127	I5	0	5	0.323E+01	0.187E+00			
05/11/81	2124	D1	0	5	0.380E+01	0.218E+00	INTAKE VS DISCHARGE	0.395E+01	0.819E-01
05/11/81	2127	I5	35	5	0.372E+01	0.412E+00			
05/11/81	2124	D1	35	5	0.377E+01	0.121E+00	INTAKE VS DISCHARGE	0.136E-01	0.897E+00
05/12/81	0342	I5	0	5	0.395E+01	0.324E+00			
05/12/81	0339	D1	0	4	0.311E+01	0.346E+00	INTAKE VS DISCHARGE	0.304E+01	0.125E+00
05/12/81	1216	I5	0	5	0.394E+01	0.265E+00			
05/12/81	1217	D1	0	5	0.457E+01	0.166E+00	INTAKE VS DISCHARGE	0.397E+01	0.814E-01
06/08/81	2235	I5	0	5	0.679E+00	0.521E-01			
06/08/81	2221	D2	0	5	0.684E+00	0.294E-01	INTAKE VS DISCHARGE	0.815E-02	0.918E+00
06/08/81	2235	I5	35	4	0.662E+00	0.162E+00			
06/08/81	2221	D2	35	4	0.472E+00	0.353E-01	INTAKE VS DISCHARGE	0.131E+01	0.298E+00
06/09/81	0248	I5	0	5	0.599E+00	0.697E-01			
06/09/81	0255	D2	0	5	0.598E+00	0.134E+00	INTAKE VS DISCHARGE	0.386E-04	0.983E+00
06/09/81	1153	I5	0	5	0.675E+00	0.834E-01			
06/09/81	1144	D2	0	5	0.611E+00	0.157E+00	INTAKE VS DISCHARGE	0.130E+00	0.722E+00
07/13/81	2232	I5	0	4	0.926E-01	0.460E-01			
07/13/81	2248	D2	0	5	0.172E+00	0.470E-01	INTAKE VS DISCHARGE	0.142E+01	0.272E+00
07/13/81	2232	I5	36	5	0.345E+00	0.779E-01			
07/13/81	2248	D2	36	5	0.207E+00	0.888E-01	INTAKE VS DISCHARGE	0.137E+01	0.276E+00
07/14/81	0315	I5	0	5	0.356E+00	0.474E-01			
07/14/81	0327	D2	0	5	0.302E+00	0.656E-01	INTAKE VS DISCHARGE	0.459E+00	0.521E+00
07/14/81	1205	I5	0	5	0.357E+00	0.224E-01			
07/14/81	1218	D2	0	5	0.319E+00	0.796E-01	INTAKE VS DISCHARGE	0.213E+00	0.656E+00

TABLE 20. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
08/10/81	2200	I5	0	4	0.319E+00	0.598E-01			
08/10/81	2212	D1	0	3	0.426E+00	0.603E-01			
08/10/81	2147	D2	0	5	0.505E+00	0.392E-01	INTAKE VS DISCHARGE	0.361E+01	0.720E-01
08/10/81	2200	I5	36	5	0.314E+00	0.606E-01			
08/10/81	2212	D1	36	4	0.0	0.0			
08/10/81	2147	D2	36	5	0.0	0.0	INTAKE VS DISCHARGE	0.237E+02	0.293E-03
08/11/81	0435	I5	0	4	0.521E+00	0.554E-01			
08/11/81	0428	D1	0	5	0.790E+00	0.608E-01			
08/11/81	0426	D2	0	4	0.616E+00	0.671E-01	INTAKE VS DISCHARGE	0.512E+01	0.306E-01
08/11/81	1108	I5	0	5	0.247E+00	0.624E-01			
08/11/81	1123	D1	0	4	0.202E+00	0.169E+00			
08/11/81	1105	D2	0	4	0.482E+00	0.878E-01	INTAKE VS DISCHARGE	0.179E+01	0.218E+00
09/14/81	2116	I4	0	5	0.326E+00	0.974E-01			
09/14/81	2058	D1	0	5	0.504E+00	0.614E-01			
09/14/81	2129	D2	0	5	0.664E+00	0.104E+00	INTAKE VS DISCHARGE	0.357E+01	0.620E-01
09/14/81	2116	I4	35	4	0.394E+00	0.125E+00			
09/14/81	2058	D1	35	4	0.646E+00	0.384E-01			
09/14/81	2129	D2	35	3	0.268E+00	0.751E-01	INTAKE VS DISCHARGE	0.443E+01	0.524E-01
09/15/81	0514	I4	0	5	0.229E+00	0.933E-01			
09/15/81	0501	D1	0	4	0.104E+00	0.104E+00			
09/15/81	0522	D2	0	4	0.374E+00	0.347E-01	INTAKE VS DISCHARGE	0.228E+01	0.155E+00
09/15/81	1208	I4	0	5	0.599E+00	0.126E+00			
09/15/31	1155	D1	0	4	0.558E+00	0.872E-01			
09/15/81	1219	D2	0	5	0.597E+00	0.877E-01	INTAKE VS DISCHARGE	0.435E-01	0.954E+00
10/12/81	1952	I5	0	4	0.397E+00	0.799E-01	INTAKE VS DISCHARGE	0.701E-01	0.788E+00
10/12/81	2000	D1	0	4	0.418E+00	0.143E-01			
10/12/81	1952	I5	38	4	0.561E+00	0.634E-01	INTAKE VS DISCHARGE	0.147E-01	0.893E+00
10/12/81	2000	D1	38	5	0.552E+00	0.356E-01			
10/13/81	0516	I5	0	5	0.547E+00	0.350E-01	INTAKE VS DISCHARGE	0.137E+01	0.295E+00
10/13/81	0523	D1	0	2	0.471E+00	0.530E-01			
10/13/81	1202	I5	0	5	0.646E+00	0.501E-01	INTAKE VS DISCHARGE	0.260E+00	0.625E+00
10/13/81	1209	D1	0	5	0.680E+00	0.457E-01			

TABLE 20. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
11/09/81	1907	I5 0	5	0.134E+01	0.113E+00			
11/09/81	1915	D2 0	5	0.137E+01	0.606E-01	INTAKE VS DISCHARGE	0.637E-01	0.795E+00
11/09/81	1907	I5 37	5	0.121E+01	0.178E+00			
11/09/81	1915	D2 37	4	0.197E+01	0.612E+00	INTAKE VS DISCHARGE	0.178E+01	0.224E+00
11/10/81	0610	I5 0	5	0.137E+01	0.141E+00			
11/10/81	0620	D2 0	5	0.150E+01	0.558E-01	INTAKE VS DISCHARGE	0.667E+00	0.442E+00
11/10/81	1212	I5 0	5	0.160E+01	0.461E-01			
11/10/81	1228	D2 0	5	0.127E+01	0.201E+00	INTAKE VS DISCHARGE	0.268E+01	0.140E+00
12/07/81	1956	I5 0	5	0.989E+00	0.114E+00			
12/07/81	1942	D1 0	4	0.868E+00	0.325E-01			
12/07/81	1910	D2 0	5	0.116E+01	0.780E-01	INTAKE VS DISCHARGE	0.267E+01	0.115E+00
12/07/81	1956	I5 36	5	0.127E+01	0.201E+00			
12/07/81	1942	D1 36	4	0.779E+00	0.202E+00			
12/07/81	1910	D2 36	5	0.111E+01	0.159E+00	INTAKE VS DISCHARGE	0.166E+01	0.236E+00
12/08/81	0632	I5 0	4	0.126E+01	0.184E+00			
12/08/81	0645	D1 0	5	0.174E+01	0.350E+00			
12/08/81	0659	D2 0	4	0.133E+01	0.171E+00	INTAKE VS DISCHARGE	0.985E+00	0.409E+00
12/08/81	1229	I5 0	4	0.121E+01	0.175E+00			
12/08/81	1242	D1 0	5	0.723E+00	0.492E-01			
12/08/81	1255	D2 0	5	0.708E+00	0.509E-01	INTAKE VS DISCHARGE	0.814E+01	0.766E-02

TABLE 21. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/81	2020	I5 0	4	0.229E+00	0.148E+00	INTAKE VS DISCHARGE	0.845E-02	0.990E+00
01/12/81	2027	D1 0	5	0.2[illegible]E+00	0.825E-01			
01/12/81	2033	D2 0	5	0.229E+00	0.145E+00			
01/12/81	2020	I5 37	4	0.162E+00	0.110E+00	INTAKE VS DISCHARGE	0.182E+01	0.208E+00
01/12/81	2027	D1 37	5	0.0	0.0			
01/12/81	2033	D2 37	5	0.438E-01	0.438E-01			
01/13/81	0635	I5 0	5	0.534E-01	0.534E-01	INTAKE VS DISCHARGE	0.540E+00	0.599E+00
01/13/81	0642	DI 0	4	0.111E+00	0.100E+00			
01/13/81	0650	D2 0	5	0.167E+00	0.864E-01			
01/13/81	1222	I5 0	5	0.834E-01	0.500E-01	INTAKE VS DISCHARGE	0.148E+01	0.268E+00
01/13/81	1227	D1 0	5	0.218E+00	0.924E-01			
01/13/81	1233	D2 0	5	0.299E+00	0.114E+00			
02/09/81	1931	I5 0	5	0.248E+00	0.148E+00	INTAKE VS DISCHARGE	0.280E+01	0.101E+00
02/09/81	1937	D1 0	5	0.0	0.0			
02/09/81	1932	D2 0	5	0.0	0.0			
02/09/81	.931	I5 37	4	0.0	0.0	INTAKE VS DISCHARGE	0.505E+00	0.619E+00
02/09/81	1937	D1 37	5	0.192E-01	0.145E-01			
02/09/81	1932	D2 37	5	0.310E-01	0.310E-01			
02/10/81	0642	I5 0	5	0.576E-01	0.576E-01	INTAKE VS DISCHARGE	0.649E+00	0.542E+00
02/10/81	0637	D1 0	5	0.417E-01	0.278E-01			
02/10/81	0637	D2 0	5	0.0	0.0			
02/10/81	1212	I5 0	5	0.0	0.0	INTAKE VS DISCHARGE	0.186E+01	0.213E+00
02/10/81	1213	D1 0	3	0.0	0.0			
02/10/81	1221	D2 0	4	0.720E-01	0.529E-01			
03/16/81	2055	I5 0	5	0.354E+00	0.107E+00	INTAKE VS DISCHARGE	0.832E+01	0.243E-01
03/16/81	2050	D1 0	4	0.400E-02	0.400E-02			
03/16/81	2055	I5 35	5	0.512E-01	0.512E-01	INTAKE VS DISCHARGE	0.557E+01	0.571E-01
03/16/81	2050	D1 35	3	0.770E+00	0.406E+00			
03/17/81	0537	I5 0	4	0.115E+00	0.115E+00	INTAKE VS DISCHARGE	0.348E+00	0.576E+00
03/17/81	0543	D1 0	5	0.224E+00	0.137E+00			
03/17/81	1208	I5 0	4	0.116E+00	0.673E-01	INTAKE VS DISCHARGE	0.136E-02	0.961E+00
03/17/81	1217	D1 0	5	0.122E+00	0.120E+00			

TABLE 21. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/06/81	2117	I5	0	4	0.748E-01	0.555E-01			
04/06/81	2115	D1	0	5	0.128E-01	0.128E-01	INTAKE VS DISCHARGE	0.148E+01	0.263E+00
04/06/81	2117	I5	36	5	0.175E+00	0.101E+00			
04/06/81	2115	D1	36	2	0.500E-06	0.500E-06	INTAKE VS DISCHARGE	0.106E+01	0.351E+00
04/07/81	0448	I5	0	5	0.120E+00	0.120E+00			
04/07/81	0449	D1	0	4	0.370E+00	0.214E+00	INTAKE VS DISCHARGE	0.117E+01	0.317E+00
04/07/81	1204	I5	0	5	0.498E+00	0.221E+00			
04/07/81	1203	D1	0	5	0.416E+00	0.115E+00	INTAKE VS DISCHARGE	0.108E+00	0.743E+00
05/11/81	2127	I5	0	5	0.479E+01	0.405E+00			
05/11/81	2124	D1	0	5	0.512E+01	0.327E+00	INTAKE VS DISCHARGE	0.391E+00	0.552E+00
05/11/81	2127	I5	35	5	0.303E+01	0.628E+00			
05/11/81	2124	D1	35	5	0.363E+01	0.193E+00	INTAKE VS DISCHARGE	0.819E+00	0.395E+00
05/12/81	0342	I5	0	5	0.441E+01	0.299E+00			
05/12/81	0339	D1	0	4	0.409E+01	0.250E+00	INTAKE VS DISCHARGE	0.594E+00	0.470E+00
05/12/81	1216	I5	0	5	0.400E+01	0.490E+00			
05/12/81	1217	D1	0	5	0.517E+01	0.382E+00	INTAKE VS DISCHARGE	0.352E+01	0.972E-01
06/08/81	2235	I5	0	5	0.248E+00	0.857E-01			
06/08/81	2221	D2	0	5	0.158E+00	0.657E-01	INTAKE VS DISCHARGE	0.694E+00	0.433E+00
06/08/81	2235	I5	35	4	0.523E+00	0.159E+00			
06/08/81	2221	D2	35	4	0.814E-01	0.470E-01	INTAKE VS DISCHARGE	0.714E+01	0.379E-01
06/09/81	0248	I5	0	5	0.124E+00	0.912E-01			
06/09/81	0255	D2	0	5	0.447E+00	0.189E+00	INTAKE VS DISCHARGE	0.236E+01	0.163E+00
06/09/81	1153	I5	0	5	0.350E+00	0.112E+00			
06/09/81	1144	D2	0	5	0.588E+00	0.201E+00	INTAKE VS DISCHARGE	0.107E+01	0.333E+00
07/13/81	2232	I5	0	4	0.213E+01	0.294E+00			
07/13/81	2248	D2	0	5	0.937E+00	0.497E+00	INTAKE VS DISCHARGE	0.367E+01	0.971E-01
07/13/81	2232	I5	36	5	0.496E+00	0.168E+00			
07/13/81	2248	D2	36	5	0.117E+00	0.722E-01	INTAKE VS DISCHARGE	0.427E+01	0.727E-01
07/14/81	0315	I5	0	5	0.232E+00	0.131E+00			
07/14/81	0327	D2	0	5	0.449E-01	0.197E-01	INTAKE VS DISCHARGE	0.199E+01	0.195E+00
07/14/81	1205	I5	0	5	0.273E+00	0.134E+00			
07/14/81	1218	D2	0	5	0.140E+00	0.793E-01	INTAKE VS DISCHARGE	0.735E+00	0.420E+00

TABLE 21. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
08/10/81	2200	I5	0	4	0.148E+00	0.148E+00			
08/10/81	2212	D1	0	3	0.873E-01	0.873E-01			
08/10/81	2147	D2	0	5	0.694E-01	0.694E-01	INTAKE VS DISCHARGE	0.161E+00	0.850E+00
08/10/81	2200	I5	36	5	0.313E+00	0.111E+00			
08/10/81	2212	D1	36	4	0.0	0.0			
08/10/81	2147	D2	36	5	0.0	0.0	INTAKE VS DISCHARGE	0.699E+01	0.119E-01
08/11/81	0435	I5	0	4	0.292E-01	0.292E-01			
08/11/81	0428	D1	0	5	0.230E+00	0.120E+00			
08/11/81	0426	D2	0	4	0.169E+00	0.781E-01	INTAKE VS DISCHARGE	0.124E+01	0.332E+00
08/11/81	1108	I5	0	5	0.172E+00	0.112E+00			
08/11/81	1123	D1	0	4	0.108E+00	0.108E+00			
08/11/81	1105	D2	0	4	0.187E+00	0.115E+00	INTAKE VS DISCHARGE	0.128E+00	0.876E+00
09/14/81	2116	I4	0	5	0.748E+00	0.301E+00			
09/14/81	2058	D1	0	5	0.637E+00	0.141E+00			
09/14/81	2129	D2	0	5	0.134E+01	0.152E+00	INTAKE VS DISCHARGE	0.325E+01	0.757E-01
09/14/81	2116	I4	35	4	0.108E+01	0.801E-01			
09/14/81	2058	D1	35	4	0.737E+00	0.136E+00			
09/14/81	2129	D2	35	[illegible]	0.475E+00	0.721E-01	INTAKE VS DISCHARGE	0.777E+01	0.146E-01
09/15/81	0514	I4	0	[illegible]	0.907E+00	0.176E+00			
09/15/81	0501	D1	0	[illegible]	0.598E+00	0.787E-01			
09/15/81	0522	D2	0	[illegible]	0.614E+00	0.123E+00	INTAKE VS DISCHARGE	0.160E+01	0.251F+00
09/15/81	1208	I4	0	[illegible]	0.318E+00	0.223E+00			
09/15/81	1155	D1	0	[illegible]	0.645E+00	0.327E+00			
09/15/81	1219	D2	0	[illegible]	0.596E+00	0.129E+00	INTAKE VS DISCHARGE	0.620E+00	0.558E+00
10/12/81	1952	I5	0	[illegible]	0.250E-06	0.250E-06			
10/12/81	2000	D1	0	4	0.0	0.0	INTAKE VS DISCHARGE	0.100E+01	0.358E+00
10/12/81	1952	I5	38	4	0.440E-01	0.440E-01			
10/12/81	2000	D1	38	5	0.0	0.0	INTAKE VS DISCHARGE	0.130E+01	0.293E+00
10/13/81	0516	I5	0	5	0.278E+00	0.115E+00			
10/13/81	0523	D1	0	2	0.0	0.0	INTAKE VS DISCHARGE	0.209E+01	0.208E+00
10/13/81	1202	I5	0	5	0.295E+00	0.108E+00			
10/13/81	1209	D1	0	5	0.124E+00	0.767E-01	INTAKE VS DISCHARGE	0.167E+01	0.232E+00

TABLE 21. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
11/09/81	1907	I5	0	5	0.172E+01	0.308E+00			
11/09/81	1915	D2	0	5	0.583E+00	0.819E-01	INTAKE VS DISCHARGE	0.128E+02	0.805E-02
11/09/81	1907	I5	37	5	0.217E+00	0.102E+00			
11/09/81	1915	D2	37	4	0.216E+00	0.130E+00	INTAKE VS DISCHARGE	0.214E-04	0.984E+00
11/10/81	0610	I5	0	5	0.599E+00	0.158E+00			
11/10/81	0620	D2	0	5	0.454E+00	0.198E+00	INTAKE VS DISCHARGE	0.328E+00	0.585E+00
11/10/81	1212	I5	0	5	0.703E+00	0.216E+00			
11/10/81	1228	D2	0	5	0.446E+00	0.161E+00	INTAKE VS DISCHARGE	0.906E+00	0.371E+00
12/07/81	1956	I5	0	5	0.546E+00	0.359E+00			
12/07/81	1942	D1	0	4	0.975E+00	0.130E+00			
12/07/81	1910	D2	0	5	0.401E+00	0.174E+00	INTAKE VS DISCHARGE	0.125E+01	0.325E+00
12/07/81	1956	I5	36	5	0.331E+00	0.177E+00			
12/07/81	1942	D1	36	4	0.236E+00	0.175E+00			
12/07/81	1910	D2	36	5	0.897E+00	0.273E+00	INTAKE VS DISCHARGE	0.267E+01	0.115E+00
12/08/81	0632	I5	0	4	0.105E+01	0.144E+00			
12/08/81	0645	D1	0	5	0.754E+00	0.234E+00			
12/08/81	0659	D2	0	4	0.649E+00	0.245E+00	INTAKE VS DISCHARGE	0.825E+00	0.469E+00
12/08/81	1229	I5	0	4	0.858E+00	0.290E+00			
12/08/81	1242	D1	0	5	0.549E+00	0.145E+00			
12/08/81	1255	D2	0	5	0.759E+00	0.989E-01	INTAKE VS DISCHARGE	0.773E+00	0.488E+00

TABLE 22. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/81	2020	I5	0	4	0.589E-01	0.387E-01	INTAKE VS DISCHARGE	0.235E-01	0.974E+00
01/12/81	2027	D1	0	5	0.516E-01	0.207E-01			
01/12/81	2033	D2	0	5	0.610E-01	0.389E-01			
01/12/81	2020	I5	37	4	0.398E-01	0.269E-01	INTAKE VS DISCHARGE	0.191E+01	0.195E+00
01/12/81	2027	D1	37	5	0.0	0.0			
01/12/81	2033	D2	37	5	0.100E-01	0.100E-01			
01/13/81	0635	I5	0	5	0.139E-01	0.139E-01	INTAKE VS DISCHARGE	0.541E+00	0.599E+00
01/13/81	0642	DI	0	4	0.295E-01	0.269E-01			
01/13/81	0650	D2	0	5	0.443E-01	0.234E-01			
01/13/81	1222	I5	0	5	0.226E-01	0.134E-01	INTAKE VS DISCHARGE	0.143E+01	0.278E+00
01/13/81	1227	D1	0	5	0.621E-01	0.268E-01			
01/13/81	1233	D2	0	5	0.812E-01	0.313E-01			
02/09/81	1931	I5	0	5	0.121E+00	0.737E-01	INTAKE VS DISCHARGE	0.269E+01	0.109E+00
02/09/81	1937	D1	0	5	0.0	0.0			
02/09/81	1932	D2	0	5	0.0	0.0			
02/09/81	1931	I5	37	4	0.0	0.0	INTAKE VS DISCHARGE	0.523E+00	0.609E+00
02/09/81	1937	D1	37	5	0.852E-02	0.645E-02			
02/09/81	1932	D2	37	5	0.157E-01	0.157E-01			
02/10/81	0642	I5	0	5	0.284E-01	0.284E-01	INTAKE VS DISCHARGE	0.656E+00	0.539E+00
02/10/81	0637	D1	0	5	0.181E-01	0.118E-01			
02/10/81	0637	D2	0	5	0.0	0.0			
02/10/81	1212	I5	0	5	0.0	0.0	INTAKE VS DISCHARGE	0.180E+01	0.222E+00
02/10/81	1213	D1	0	3	0.0	0.0			
02/10/81	1221	D2	0	4	0.317E-01	0.236E-01			
03/16/81	2055	I5	0	5	0.497E-01	0.152E-01	INTAKE VS DISCHARGE	0.809E+01	0.257E-01
03/16/81	2050	D1	0	4	0.540E-03	0.540E-03			
03/16/81	2055	I5	35	5	0.696E-02	0.696E-02	INTAKE VS DISCHARGE	0.560E+01	0.566E-01
03/16/81	2050	D1	35	3	0.119E+00	0.638E-01			
03/17/81	0537	I5	0	4	0.157E-01	0.157E-01	INTAKE VS DISCHARGE	0.351E+00	0.575E+00
03/17/81	0543	D1	0	5	0.308E-01	0.188E-01			
03/17/81	1208	I5	0	4	0.145E-01	0.852E-02	INTAKE VS DISCHARGE	0.140E-01	0.896E+00
03/17/81	1217	D1	0	5	0.169E-01	0.167E-01			

TABLE 22. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/06/81	2117	I5	0	4	0.858E-02	0.630E-02	INTAKE VS DISCHARGE	0.148E+01	0.264E+00
04/06/81	2115	D1	0	5	0.153E-02	0.153E-02			
04/06/81	2117	I5	36	5	0.203E-01	0.117E-01	INTAKE VS DISCHARGE	0.108E+01	0.348E+00
04/06/81	2115	D1	36	2	0.100E-05	0.0			
04/07/81	0448	I5	0	5	0.178E-01	0.178E-01	INTAKE VS DISCHARGE	0.139E+01	0.278E+00
04/07/81	0449	D1	0	4	0.617E-01	0.357E-01			
04/07/81	1204	I5	0	5	0.711E-01	0.316E-01	INTAKE VS DISCHARGE	0.557E-02	0.931E+00
04/07/81	1203	D1	0	5	0.684E-01	0.191E-01			
05/11/81	2127	I5	0	5	0.265E+00	0.283E-01	INTAKE VS DISCHARGE	0.155E+00	0.700E+00
05/11/81	2124	D1	0	5	0.278E+00	0.189E-01			
05/11/81	2127	I5	35	5	0.161E+00	0.336E-01	INTAKE VS DISCHARGE	0.847E+00	0.387E+00
05/11/81	2124	D1	35	5	0.193E+00	0.104E-01			
05/12/81	0342	I5	0	5	0.235E+00	0.169E-01	INTAKE VS DISCHARGE	0.193E+00	0.672E+00
05/12/81	0339	D1	0	4	0.225E+00	0.146E-01			
05/12/81	1216	I5	0	5	0.190E+00	0.263E-01	INTAKE VS DISCHARGE	0.304E+01	0.119E+00
05/12/81	1217	D1	0	5	0.246E+00	0.182E-01			
06/08/81	2235	I5	0	5	0.632E-01	0.222E-01	INTAKE VS DISCHARGE	0.468E+00	0.517E+00
06/08/81	2221	D2	0	5	0.435E-01	0.183E-01			
06/08/81	2235	I5	35	4	0.161E+00	0.513E-01	INTAKE VS DISCHARGE	0.653E+01	0.441E-01
06/08/81	2221	D2	35	4	0.247E-01	0.139E-01			
06/09/81	0248	I5	0	5	0.321E-01	0.240E-01	INTAKE VS DISCHARGE	0.244E+01	0.156E+00
06/09/81	0255	D2	0	5	0.123E+00	0.527E-01			
06/09/81	1153	I5	0	5	0.101E+00	0.340E-01	INTAKE VS DISCHARGE	0.134E+01	0.281E+00
06/09/81	1144	D2	0	5	0.201E+00	0.788E-01			
07/13/81	2232	I5	0	4	0.100E+03	0.0	INTAKE VS DISCHARGE	0.124E+02	0.107E-01
07/13/81	2248	D2	0	5	0.215E+02	0.197E+02			
07/13/81	2232	I5	36	5	0.739E+00	0.276E+00	INTAKE VS DISCHARGE	0.481E+01	0.597E-01
07/13/81	2248	D2	36	5	0.116E+00	0.708E-01			
07/14/81	0315	I5	0	5	0.162E+00	0.990E-01	INTAKE VS DISCHARGE	0.187E+01	0.209E+00
07/14/81	0327	D2	0	5	0.256E-01	0.112E-01			
07/14/81	1205	I5	0	5	0.192E+00	0.974E-01	INTAKE VS DISCHARGE	0.595E+00	0.467E+00
07/14/81	1218	D2	0	5	0.104E+00	0.598E-01			

TABLE 22. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
08/10/81	2200	I5	0	4	0.840E-01	0.840E-01			
08/10/81	2212	D1	0	3	0.467E-01	0.467E-01			
08/10/81	2147	D2	0	5	0.406E-01	0.406E-01	INTAKE VS DISCHARGE	0.158E+00	0.852E+00
08/10/81	2200	I5	36	5	0.280E+00	0.106E+00			
08/10/81	2212	D1	36	4	0.0	0.0			
08/10/81	2147	D2	36	5	0.0	0.0	INTAKE VS DISCHARGE	0.611E+01	0.174E-01
08/11/81	0435	I5	0	4	0.125E-01	0.125E-01			
08/11/81	0428	D1	0	5	0.109E+00	0.598E-01			
08/11/81	0426	D2	0	4	0.835E-01	0.373E-01	INTAKE VS DISCHARGE	0.120E+01	0.344E+00
08/11/81	1108	I5	0	5	0.780E-01	0.520E-01			
08/11/81	1123	D1	0	4	0.470E-01	0.470E-01			
08/11/81	1105	D2	0	4	0.816E-01	0.519E-01	INTAKE VS DISCHARGE	0.132E+00	0.873E+00
09/14/81	2116	I4	0	5	0.233E+00	0.102E+00			
09/14/81	2058	D1	0	5	0.150E+00	0.315E-01			
09/14/81	2129	D2	0	5	0.400E+00	0.493E-01	INTAKE VS DISCHARGE	0.351E+01	0.643E-01
09/14/81	2116	I4	35	4	0.337E+00	0.354E-01			
09/14/81	2058	D1	35	4	0.197E+00	0.383E-01			
09/14/81	2129	D2	35	3	0.140E+00	0.207E-01	INTAKE VS DISCHARGE	0.850E+01	0.117E-01
09/15/81	0514	I4	0	5	0.240E+00	0.537E-01			
09/15/81	0501	D1	0	4	0.160E+00	0.211E-01			
09/15/81	0522	D2	0	4	0.137E+00	0.293E-01	INTAKE VS DISCHARGE	0.182E+01	0.213E+00
09/15/81	1208	I4	0	5	0.954E-01	0.673E-01			
09/15/81	1155	D1	0	4	0.197E+00	0.103E+00			
09/15/81	1219	D2	0	5	0.179E+00	0.422E-01	INTAKE VS DISCHARGE	0.601E+00	0.568E+00
10/12/81	1952	I5	0	4	0.250E-06	0.250E-06			
10/12/81	2000	D1	0	4	0.0	0.0	INTAKE VS DISCHARGE	0.100E+01	0.358E+00
10/12/81	1952	I5	38	4	0.103E-01	0.103E-01			
10/12/81	2000	D1	38	5	0.0	0.0	INTAKE VS DISCHARGE	0.130E+01	0.293E+00
10/13/81	0516	I5	0	5	0.714E-01	0.296E-01			
10/13/81	0523	D1	0	2	0.0	0.0	INTAKE VS DISCHARGE	0.208E+01	0.210E+00
10/13/81	1202	I5	0	5	0.753E-01	0.275E-01			
10/13/81	1209	D1	0	5	0.346E-01	0.215E-01	INTAKE VS DISCHARGE	0.136E+01	0.278E+00

TABLE 22. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
11/09/81	1907	I5 0	5	0.163E+00	0.320E-01			
11/09/81	1915	D2 0	5	0.539E-01	0.801E-02	INTAKE VS DISCHARGE	0.109E+02	0.117E-01
11/09/81	1907	I5 37	5	0.194E-01	0.896E-02			
11/09/81	1915	D2 37	4	0.203E-01	0.123E-01	INTAKE VS DISCHARGE	0.375E-02	0.942E+00
11/10/81	0610	I5 0	5	0.670E-01	0.187E-01			
11/10/81	0620	D2 0	5	0.533E-01	0.235E-01	INTAKE VS DISCHARGE	0.209E+00	0.659E+00
11/10/81	1212	I5 0	5	0.744E-01	0.233E-01			
11/10/81	1228	D2 0	5	0.455E-01	0.165E-01	INTAKE VS DISCHARGE	0.102E+01	0.343E+00
12/07/81	1956	I5 0	5	0.992E-01	0.668E-01			
12/07/81	1942	D1 0	4	0.169E+00	0.214E-01			
12/07/81	1910	D2 0	5	0.619E-01	0.270E-01	INTAKE VS DISCHARGE	0.130E+01	0.313E+00
12/07/81	1956	I5 36	5	0.507E-01	0.273E-01			
12/07/81	1942	D1 36	4	0.423E-01	0.319E-01			
12/07/81	1910	D2 36	5	0.168E+00	0.536E-01	INTAKE VS DISCHARGE	0.307E+01	0.883E-01
12/08/81	0632	I5 0	4	0.161E+00	0.217E-01			
12/08/81	0645	D1 0	5	0.120E+00	0.378E-01			
12/08/81	0659	D2 0	4	0.103E+00	0.396E-01	INTAKE VS DISCHARGE	0.663E+00	0.539E+00
12/08/81	1229	I5 0	4	0.129E+00	0.435E-01			
12/08/81	1242	D1 0	5	0.100E+00	0.274E-01			
12/08/81	1255	D2 0	5	0.139E+00	0.197E-01	INTAKE VS DISCHARGE	0.467E+00	0.641E+00

TABLE 23. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/82	1936	I5 0	5	0.283E+01	0.179E+00			
01/12/82	1950	D1 0	5	0.264E+01	0.938E-01			
01/12/82	2000	D2 0	5	0.282E+01	0.271E+00	INTAKE VS DISCHARGE	0.297E+00	0.748E+00
01/12/82	1936	I5 37	4	0.270E+01	0.145E+00			
01/12/82	1950	D1 37	5	0.287E+01	0.176E+00			
01/12/82	2000	D2 37	4	0.276E+01	0.147E+00	INTAKE VS DISCHARGE	0.313E+00	0.738E+00
01/13/82	0634	I5 0	5	0.285E+01	0.159E+00			
01/13/82	0648	D1 0	5	0.262E+01	0.146E+00			
01/13/82	0701	D2 0	5	0.253E+01	0.157E+00	INTAKE VS DISCHARGE	0.116E+01	0.349E+00
01/13/82	1210	I5 0	4	0.208E+01	0.429E-01			
01/13/82	1223	D1 0	4	0.228E+01	0.735E-01			
01/13/82	1233	D2 0	4	0.223E+01	0.675E-01	INTAKE VS DISCHARGE	0.281E+01	0.115E+00
02/08/82	1951	I5 0	4	0.313E+01	0.191E+00			
02/08/82	1938	D2 0	5	0.301E+01	0.988E-01	INTAKE VS DISCHARGE	0.373E+00	0.563E+00
02/08/82	1951	I5 36	5	0.310E+01	0.122E+00			
02/08/82	1938	D2 36	4	0.314E+01	0.166E+00	INTAKE VS DISCHARGE	0.427E-01	0.829E+00
02/09/82	0648	I5 0	5	0.323E+01	0.167E+00			
02/09/82	0638	D2 0	5	0.277E+01	0.115E+00	INTAKE VS DISCHARGE	0.527E+01	0.510E-01
02/09/82	1223	I5 0	5	0.293E+01	0.119E+00			
02/09/82	1226	D2 0	5	0.283E+01	0.130E+00	INTAKE VS DISCHARGE	0.283E+00	0.611E+00
03/08/82	2041	I5 0	4	0.398E+01	0.103E+00			
03/08/82	2052	D1 0	4	0.403E+01	0.127E+00			
03/08/82	2106	D2 0	5	0.354E+01	0.105E+00	INTAKE VS DISCHARGE	0.611E+01	0.196E-01
03/08/82	2041	I5 36	4	0.372E+01	0.135E+00			
03/08/82	2052	D1 36	5	0.371E+01	0.160E+00			
03/08/82	2106	D2 36	4	0.359E+01	0.101E+00	INTAKE VS DISCHARGE	0.282E+00	0.759E+00
03/09/82	0535	I5 0	4	0.371E+01	0.111E+00			
03/09/82	0546	D1 0	4	0.442E+01	0.229E+00			
03/09/82	0555	D2 0	4	0.441E+01	0.900E-01	INTAKE VS DISCHARGE	0.672E+01	0.175E-01
03/09/82	1211	I5 0	5	0.398E+01	0.125E+00			
03/09/82	1225	D1 0	4	0.400E+01	0.149E+00			
03/09/82	1235	D2 0	4	0.403E+01	0.999E-01	INTAKE VS DISCHARGE	0.439E-01	0.953E+00

TABLE 23. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/12/82	2110	I5	0	4	0.102E+02	0.311E+00			
04/12/82	2120	D1	0	4	0.108E+02	0.132E+00			
04/12/82	2120	D2	0	5	0.106E+02	0.140E+00	INTAKE VS DISCHARGE	0.243E+01	0.139E+00
04/12/82	2110	I5	35	5	0.106E+02	0.206E+00			
04/12/82	2120	D1	35	4	0.107E+02	0.233E+00			
04/12/82	2120	D2	35	5	0.109E+02	0.289E+00	INTAKE VS DISCHARGE	0.294E+00	0.750E+00
04/13/82	0432	I5	0	4	0.106E+02	0.913E-01			
04/13/82	0444	D1	0	3	0.111E+02	0.300E+00			
04/13/82	0447	D2	0	3	0.918E+01	0.132E+00	INTAKE VS DISCHARGE	0.282E+02	0.969E-03
04/13/82	1212	I5	0	5	0.861E+01	0.121E+00			
04/13/82	1237	D1	0	4	0.866E+01	0.197E+00			
04/13/82	1225	D2	0	5	0.901E+01	0.257E+00	INTAKE VS DISCHARGE	0.120E+01	0.338E+00
05/10/82	2140	I5	0	4	0.614E+01	0.191E+00			
05/10/82	2153	D1	0	5	0.586E+01	0.237E+00			
05/10/82	2207	D2	0	5	0.582E+01	0.811E-01	INTAKE VS DISCHARGE	0.841E+00	0.460E+00
05/10/82	2140	I5	36	4	0.539E+01	0.142E+00			
05/10/82	2153	D1	36	4	0.577E+01	0.691E-01			
05/10/82	2207	D2	36	3	0.514E+01	0.633E-01	INTAKE VS DISCHARGE	0.860E+01	0.114E-01
05/11/82	0347	I5	0	5	0.311E+01	0.806E-01			
05/11/82	0406	D1	0	5	0.324E+01	0.793E-01			
05/11/82	0353	D2	0	5	0.328E+01	0.621E-01	INTAKE VS DISCHARGE	0.139E+01	0.288E+00
05/11/82	1207	I5	0	5	0.388E+01	0.109E+00			
05/11/82	1226	D1	0	5	0.342E+01	0.662E-01			
05/11/82	1216	D2	0	4	0.360E+01	0.641E-01	INTAKE VS DISCHARGE	0.788E+01	0.842E-02

TABLE 24. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/82	1936	I5	0	5	0.325E+00	0.727E-01			
01/12/82	1950	D1	0	5	0.529E+00	0.595E-01			
01/12/82	2000	D2	0	5	0.551E+00	0.648E-01	INTAKE VS DISCHARGE	0.358E+01	0.614E-01
01/12/82	1936	I5	37	4	0.408E+00	0.549E-01			
01/12/82	1950	D1	37	5	0.434E+00	0.595E-01			
01/12/82	2000	D2	37	4	0.310E+00	0.584E-01	INTAKE VS DISCHARGE	0.123E+01	0.335E+00
01/13/82	0634	I5	0	5	0.271E+00	0.130E+00			
01/13/82	0648	D1	0	5	0.100E+00	0.100E+00			
01/13/82	0701	D2	0	5	0.247E+00	0.893E-01	INTAKE VS DISCHARGE	0.728E+00	0.506E+00
01/13/82	1210	I5	0	4	0.0	0.0			
01/13/82	1223	D1	0	4	0.445E-02	0.445E-02			
01/13/82	1233	D2	0	4	0.285E-01	0.285E-01	INTAKE VS DISCHARGE	0.848E+00	0.462E+00
02/08/82	1951	I5	0	4	0.0	0.0			
02/08/82	1938	D2	0	5	0.252E-01	0.252E-01	INTAKE VS DISCHARGE	0.778E+00	0.410E+00
02/08/82	1951	I5	36	5	0.0	0.0			
02/08/82	1938	D2	36	4	0.250E-06	0.250E-06	INTAKE VS DISCHARGE	0.130E+01	0.293E+00
02/09/82	0648	I5	0	5	0.191E-01	0.191E-01			
02/09/82	0638	D2	0	5	0.0	0.0	INTAKE VS DISCHARGE	0.100E+01	0.348E+00
02/09/82	1223	I5	0	5	0.200E-06	0.200E-06			
02/09/82	1226	D2	0	5	0.0	0.0	INTAKE VS DISCHARGE	0.100E+01	0.348E+00
03/08/82	2041	I5	0	4	0.0	0.0			
03/08/82	2052	D1	0	4	0.0	0.0			
03/08/82	2106	D2	0	5	0.379E-01	0.298E-01	INTAKE VS DISCHARGE	0.124E+01	0.331E+00
03/08/82	2041	I5	36	4	0.0	0.0			
03/08/82	2052	D1	36	5	0.445E-01	0.201E-01			
03/08/82	2106	D2	36	4	0.777E-01	0.778E-01	INTAKE VS DISCHARGE	0.756E+00	0.497E+00
03/09/82	0535	I5	0	4	0.285E-01	0.278E-01			
03/09/82	0546	D1	0	4	0.0	0.0			
03/09/82	0555	D2	0	4	0.0	0.0	INTAKE VS DISCHARGE	0.105E+01	0.392E+00
03/09/82	1211	I5	0	5	0.200E-06	0.200E-06			
03/09/82	1225	D1	0	4	0.0	0.0			
03/09/82	1235	D2	0	4	0.0	0.0	INTAKE VS DISCHARGE	0.769E+00	0.491E+00

TABLE 24. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/12/82	2110	I5 0	4	0.0	0.0			
04/12/82	2120	D1 0	4	0.171E-02	0.171E-02			
04/12/82	2120	D2 0	5	0.892E-02	0.892E-02	INTAKE VS DISCHARGE	0.633E+00	0.553E+00
04/12/82	2110	I5 35	5	0.200E-06	0.200E-06			
04/12/82	2120	D1 35	4	0.0	0.0			
04/12/82	2120	D2 35	5	0.0	0.0	INTAKE VS DISCHARGE	0.884E+00	0.443E+00
04/13/82	0432	I5 0	4	0.250E-06	0.250E-06			
04/13/82	0444	D1 0	3	0.0	0.0			
04/13/82	0447	D2 0	3	0.0	0.0	INTAKE VS DISCHARGE	0.700E+00	0.530E+00
04/13/82	1212	I5 0	5	0.413E-01	0.189E-01			
04/13/82	1237	D1 0	4	0.0	0.0			
04/13/82	1225	D2 0	5	0.0	0.0	INTAKE VS DISCHARGE	0.424E+01	0.442E-01
05/10/82	2140	I5 0	4	0.250E-06	0.250E-06			
05/10/82	2153	D1 0	5	0.0	0.0			
05/10/82	2207	D2 0	5	0.0	0.0	INTAKE VS DISCHARGE	0.131E+01	0.310E+00
05/10/82	2140	I5 36	4	0.0	0.0			
05/10/82	2153	D1 36	4	0.0	0.0			
05/10/82	2207	D2 36	3	0.433E-02	0.433E-02	INTAKE VS DISCHARGE	0.145E+01	0.290E+00
05/11/82	0347	I5 0	5	0.0	0.0			
05/11/82	0406	D1 0	5	0.242E-01	0.242E-01			
05/11/82	0353	D2 0	5	0.482E-02	0.482E-02	INTAKE VS DISCHARGE	0.808E+00	0.471E+00
05/11/82	1207	I5 0	5	0.200E-06	0.200E-06			
05/11/82	1226	D1 0	5	0.0	0.0			
05/11/82	1216	D2 0	4	0.0	0.0	INTAKE VS DISCHARGE	0.884E+00	0.443E+00

TABLE 25. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/82	1936	I5	0	5	0.188E+01	0.215E+00			
01/12/82	1950	D1	0	5	0.248E+01	0.194E+00			
01/12/82	2000	D2	0	5	0.270E+01	0.227E+00	INTAKE VS DISCHARGE	0.400E+01	0.479E-01
01/12/82	1936	I5	37	4	0.224E+01	0.139E+00			
01/12/82	1950	D1	37	5	0.203E+01	0.176E+00			
01/12/82	2000	D2	37	4	0.180E+01	0.230E+00	INTAKE VS DISCHARGE	0.137E+01	0.300E+00
01/13/82	0634	I5	0	5	0.150E+01	0.540E+00			
01/13/82	0648	D1	0	5	0.768E+00	0.469E+00			
01/13/82	0701	D2	0	5	0.131E+01	0.427E+00	INTAKE VS DISCHARGE	0.623E+00	0.555E+00
01/13/82	1210	I5	0	4	0.435E+00	0.100E+00			
01/13/82	1223	D1	0	4	0.304E+00	0.629E-01			
01/13/82	1233	D2	0	4	0.416E+00	0.134E+00	INTAKE VS DISCHARGE	0.468E+00	0.642E+00
02/08/82	1951	I5	0	4	0.597E+00	0.871E-01			
02/08/82	1938	D2	0	5	0.643E+00	0.171E+00	INTAKE VS DISCHARGE	0.495E-01	0.817E+00
02/08/82	1951	I5	36	5	0.456E+00	0.338E-01			
02/08/82	1938	D2	36	4	0.412E+00	0.671E-01	INTAKE VS DISCHARGE	0.399E+00	0.551E+00
02/09/82	0648	I5	0	5	0.662E+00	0.247E+00			
02/09/82	0638	D2	0	5	0.459E+00	0.686E-01	INTAKE VS DISCHARGE	0.630E+00	0.454E+00
02/09/82	1223	I5	0	5	0.438E+00	0.460E-01			
02/09/82	1226	D2	0	5	0.412E+00	0.526E-01	INTAKE VS DISCHARGE	0.141E+00	0.712E+00
03/08/82	2041	I5	0	4	0.664E+00	0.471E-01			
03/08/82	2052	D1	0	4	0.600E+00	0.686E-01			
03/08/82	2106	D2	0	5	0.408E+00	0.117E+00	INTAKE VS DISCHARGE	0.229E+01	0.153E+00
03/08/82	2041	I5	36	4	0.268E+00	0.101E+00			
03/08/82	2052	D1	36	5	0.439E+00	0.860E-01			
03/08/82	2106	D2	36	4	0.213E+00	0.540E-01	INTAKE VS DISCHARGE	0.208E+01	0.177E+00
03/09/82	0535	I5	0	4	0.544E+00	0.120E+00			
03/09/82	0546	D1	0	4	0.633E+00	0.672E-01			
03/09/82	0555	D2	0	4	0.387E+00	0.403E-01	INTAKE VS DISCHARGE	0.227E+01	0.160E+00
03/09/82	1211	I5	0	5	0.544E+00	0.527E-01			
03/09/82	1225	D1	0	4	0.262E+00	0.498E-01			
03/09/82	1235	D2	0	4	0.304E+00	0.475E-01	INTAKE VS DISCHARGE	0.947E+01	0.581E-02

TABLE 25. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/12/82	2110	I5 0	4	0.115E+01	0.109E+00			
04/12/82	2120	D1 0	4	0.108E+01	0.340E-01			
04/12/82	2120	D2 0	5	0.111E+01	0.943E-01	INTAKE VS DISCHARGE	0.135E+00	0.870E+00
04/12/82	2110	I5 35	5	0.139E+01	0.206E+00			
04/12/82	2120	D1 35	4	0.109E+01	0.268E-01			
04/12/82	2120	D2 35	5	0.108E+01	0.111E-01	INTAKE VS DISCHARGE	0.191E+01	0.196E+00
04/13/82	0432	I5 0	4	0.119E+01	0.474E-01			
04/13/82	0444	D1 0	3	0.113E+01	0.132E+00			
04/13/82	0447	D2 0	3	0.106E+01	0.693E-01	INTAKE VS DISCHARGE	0.595E+00	0.579E+00
04/13/82	1212	I5 0	5	0.141E+01	0.129E+00			
04/13/82	1237	D1 0	4	0.111E+01	0.114E+00			
04/13/82	1225	D2 0	5	0.117E+01	0.556E-01	INTAKE VS DISCHARGE	0.247E+01	0.131E+00
05/10/82	2140	I5 0	4	0.726E+00	0.998E-01			
05/10/82	2153	D1 0	5	0.667E+00	0.579E-01			
05/10/82	2207	D2 0	5	0.657E+00	0.352E-01	INTAKE VS DISCHARGE	0.306E+00	0.742E+00
05/10/82	2140	I5 36	4	0.624E+00	0.419E-01			
05/10/82	2153	D1 36	4	0.945E+00	0.699E-01			
05/10/82	2207	D2 36	3	0.803E+00	0.374E-01	INTAKE VS DISCHARGE	0.943E+01	0.903E-02
05/11/82	0347	I5 0	5	0.352E+00	0.425E-01			
05/11/82	0406	D1 0	5	0.762E+00	0.128E+00			
05/11/82	0353	D2 0	5	0.425E+00	0.149E+00	INTAKE VS DISCHARGE	0.355E+01	0.627E-01
05/11/82	1207	I5 0	5	0.344E+00	0.525E-01			
05/11/82	1226	D1 0	5	0.341E+00	0.472E-01			
05/11/82	1216	D2 0	4	0.328E+00	0.183E-01	INTAKE VS DISCHARGE	0.304E-01	0.967E+00

TABLE 26. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/82	1936	I5 0	5	0.520E+00	0.242E+00	INTAKE VS DISCHARGE	0.198E+01	0.182E+00
01/12/82	1950	D1 0	5	0.118E+01	0.208E+00			
01/12/82	2000	D2 0	5	0.108E+01	0.303E+00			
01/12/82	1936	I5 37	4	0.593E+00	0.264E+00	INTAKE VS DISCHARGE	0.165E+01	0.241E+00
01/12/82	1950	D1 37	5	0.230E+00	0.125E+00			
01/12/82	2000	D2 37	4	0.183E+00	0.926E-01			
01/13/82	0634	I5 0	5	0.181E+00	0.161E+00	INTAKE VS DISCHARGE	0.999E+00	0.399E+00
01/13/82	0648	D1 0	5	0.201E+00	0.123E+00			
01/13/82	0701	D2 0	5	0.443E+00	0.151E+00			
01/13/82	1210	I5 0	4	0.384E+00	0.129E+00	INTAKE VS DISCHARGE	0.686E+01	0.166E-01
01/13/82	1223	D1 0	4	0.400E-02	0.400E-02			
01/13/82	1233	D2 0	4	0.587E-01	0.415E-01			
02/08/82	1951	I5 0	4	0.464E+00	0.312E+00	INTAKE VS DISCHARGE	0.174E+01	0.228E+00
02/08/82	1938	D2 0	5	0.898E-01	0.637E-01			
02/08/82	1951	I5 36	5	0.172E+00	0.682E-01	INTAKE VS DISCHARGE	0.495E+01	0.619E-01
02/08/82	1938	D2 36	4	0.0	0.0			
02/09/82	0648	I5 0	5	0.128E+00	0.791E-01	INTAKE VS DISCHARGE	0.855E+00	0.385E+00
02/09/82	0638	D2 0	5	0.249E+00	0.104E+00			
02/09/82	1223	I5 0	5	0.588E-01	0.326E-01	INTAKE VS DISCHARGE	0.824E+00	0.394E+00
02/09/82	1226	D2 0	5	0.124E+00	0.638E-01			
03/08/82	2041	I5 0	4	0.694E-01	0.479E-01	INTAKE VS DISCHARGE	0.768E+00	0.492E+00
03/08/82	2052	D1 0	4	0.0	0.0			
03/08/82	2106	D2 0	5	0.428E-01	0.428E-01			
03/08/82	2041	I5 36	4	0.284E+00	0.997E-01	INTAKE VS DISCHARGE	0.334E+01	0.789E-01
03/08/82	2052	D1 36	5	0.171E-01	0.171E-01			
03/08/82	2106	D2 36	4	0.139E+00	0.969E-01			
03/09/82	0535	I5 0	4	0.782E+00	0.191E+00	INTAKE VS DISCHARGE	0.802E+01	0.111E-01
03/09/82	0546	D1 0	4	0.292E-01	0.292E-01			
03/09/82	0555	D2 0	4	0.164E+00	0.152E+00			
03/09/82	1211	I5 0	5	0.259E+00	0.126E+00	INTAKE VS DISCHARGE	0.613E+00	0.563E+00
03/09/82	1225	D1 0	4	0.127E+00	0.740E-01			
03/09/82	1235	D2 0	4	0.105E+00	0.105E+00			

TABLE 26. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/12/82	2110	I5 0	4	0.600E-01	0.600E-01			
04/12/82	2120	D1 0	4	0.104E+00	0.602E-01			
04/12/82	2120	D2 0	5	0.0	0.0	INTAKE VS DISCHARGE	0.142E+01	0.287E+00
04/12/82	2110	I5 35	5	0.812E-01	0.773E-01			
04/12/82	2120	D1 35	4	0.0	0.0			
04/12/82	2120	D2 35	5	0.694E-01	0.694E-01	INTAKE VS DISCHARGE	0.422E+00	0.667E+00
04/13/82	0432	I5 0	4	0.153E+00	0.921E-01			
04/13/82	0444	D1 0	3	0.0	0.0			
04/13/82	0447	D2 0	3	0.0	0.0	INTAKE VS DISCHARGE	0.195E+01	0.214E+00
04/13/82	1212	I5 0	5	0.573E+00	0.181E+00			
04/13/82	1237	D1 0	4	0.0	0.0			
04/13/82	1225	D2 0	5	0.332E-01	0.332E-01	INTAKE VS DISCHARGE	0.802E+01	0.800E-02
05/10/82	2140	I5 0	4	0.481E-01	0.221E-01			
05/10/82	2153	D1 0	5	0.151E+00	0.924E-01			
05/10/82	2207	D2 0	5	0.112E+00	0.970E-01	INTAKE VS DISCHARGE	0.355E+00	0.710E+00
05/10/82	2140	I5 36	4	0.494E+00	0.154E+00			
05/10/82	2153	D1 36	4	0.625E+00	0.191E+00			
05/10/82	2207	D2 36	3	0.107E+01	0.140E+00	INTAKE VS DISCHARGE	0.292E+01	0.114E+00
05/11/82	0347	I5 0	5	0.376E+00	0.802E-01			
05/11/82	0406	D1 0	5	0.845E+00	0.139E+00			
05/11/82	0353	D2 0	5	0.235E+00	0.533E-01	INTAKE VS DISCHARGE	0.107E+02	0.280E-02
05/11/82	1207	I5 0	5	0.620E-01	0.620E-01			
05/11/82	1226	D1 0	5	0.694E-01	0.527E-01			
05/11/82	1216	D2 0	4	0.148E+00	0.677E-01	INTAKE VS DISCHARGE	0.576E+00	0.581E+00

TABLE 27. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/12/82	1936	I5 0	5	0.208E+00	0.102E+00			
01/12/82	1950	D1 0	5	0.458E+00	0.918E-01			
01/12/82	2000	D2 0	5	0.445E+00	0.159E+00	INTAKE VS DISCHARGE	0.134E+01	0.298E+00
01/12/82	1936	I5 37	4	0.236E+00	0.111E+00			
01/12/82	1950	D1 37	5	0.890E-01	0.497E-01			
01/12/82	2000	D2 37	4	0.684E-01	0.340E-01	INTAKE VS DISCHARGE	0.163E+01	0.244E+00
01/13/82	0634	I5 0	5	0.603E-01	0.539E-01			
01/13/82	0648	D1 0	5	0.810E-01	0.512E-01			
01/13/82	0701	D2 0	5	0.183E+00	0.693E-01	INTAKE VS DISCHARGE	0.126E+01	0.320E+00
01/13/82	1210	I5 0	4	0.188E+00	0.654E-01			
01/13/82	1223	D1 0	4	0.183E-02	0.183E-02			
01/13/82	1233	D2 0	4	0.281E-01	0.205E-01	INTAKE VS DISCHARGE	0.647E+01	0.193E-01
02/08/82	1951	I5 0	4	0.168E+00	0.118E+00			
02/08/82	1938	D2 0	5	0.321E-01	0.228E-01	INTAKE VS DISCHARGE	0.161E+01	0.245E+00
02/08/82	1951	I5 36	5	0.588E-01	0.234E-01			
02/08/82	1938	D2 36	4	0.0	0.0	INTAKE VS DISCHARGE	0.493E+01	0.621E-01
02/09/82	0648	I5 0	5	0.426E-01	0.278E-01			
02/09/82	0638	D2 0	5	0.951E-01	0.403E-01	INTAKE VS DISCHARGE	0.115E+01	0.316E+00
02/09/82	1223	I5 0	5	0.203E-01	0.111E-01			
02/09/82	1226	D2 0	5	0.480E-01	0.251E-01	INTAKE VS DISCHARGE	0.103E+01	0.342E+00
03/08/82	2041	I5 0	4	0.175E-01	0.118E-01			
03/08/82	2052	D1 0	4	0.0	0.0			
03/08/82	2106	D2 0	5	0.121E-01	0.121E-01	INTAKE VS DISCHARGE	0.702E+00	0.521E+00
03/08/82	2041	I5 36	4	0.767E-01	0.255E-01			
03/08/82	2052	D1 36	5	0.534E-02	0.534E-02			
03/08/82	2106	D2 36	4	0.404E-01	0.288E-01	INTAKE VS DISCHARGE	0.310E+01	0.912E-01
03/09/82	0535	I5 0	4	0.215E+00	0.562E-01			
03/09/82	0546	D1 0	4	0.765E-02	0.765E-02			
03/09/82	0555	D2 0	4	0.393E-01	0.366E-01	INTAKE VS DISCHARGE	0.823E+01	0.104E-01
03/09/82	1211	I5 0	5	0.675E-01	0.333E-01			
03/09/82	1225	D1 0	4	0.338E-01	0.198E-01			
03/09/82	1235	D2 0	4	0.267E-01	0.267E-01	INTAKE VS DISCHARGE	0.614E+00	0.562E+00

TABLE 27. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
04/12/82	2110	I5	0	4	0.647E-02	0.647E-02			
04/12/82	2120	D1	0	4	0.957E-02	0.554E-02			
04/12/82	2120	D2	0	5	0.0	0.0	INTAKE VS DISCHARGE	0.125E+01	0.330E+00
04/12/82	2110	I5	35	5	0.780E-02	0.741E-02			
04/12/82	2120	D1	35	4	0.0	0.0			
04/12/82	2120	D2	35	5	0.674E-02	0.674E-02	INTAKE VS DISCHARGE	0.422E+00	0.668E+00
04/13/82	0432	I5	0	4	0.144E-01	0.861E-02			
04/13/82	0444	D1	0	3	0.0	0.0			
04/13/82	0447	D2	0	3	0.0	0.0	INTAKE VS DISCHARGE	0.196E+01	0.213E+00
04/13/82	1212	I5	0	5	0.673E-01	0.216E-01			
04/13/82	1237	D1	0	4	0.0	0.0			
04/13/82	1225	D2	0	5	0.342E-02	0.342E-02	INTAKE VS DISCHARGE	0.789E+01	0.840E-02
05/10/82	2140	I5	0	4	0.816E-02	0.382E-02			
05/10/82	2153	D1	0	5	0.285E-01	0.175E-01			
05/10/82	2207	D2	0	5	0.193E-01	0.166E-01	INTAKE VS DISCHARGE	0.427E+00	0.664E+00
05/10/82	2140	I5	36	4	0.917E-01	0.282E-01			
05/10/82	2153	D1	36	4	0.109E+00	0.335E-01			
05/10/82	2207	D2	36	3	0.208E+00	0.250E-01	INTAKE VS DISCHARGE	0.385E+01	0.691E-01
05/11/82	0347	I5	0	5	0.123E+00	0.270E-01			
05/11/82	0406	D1	0	5	0.265E+00	0.487E-01			
05/11/82	0353	D2	0	5	0.718E-01	0.166E-01	INTAKE VS DISCHARGE	0.892E+01	0.501E-02
05/11/82	1207	I5	0	5	0.173E-01	0.173E-01			
05/11/82	1226	D1	0	5	0.214E-01	0.165E-01			
05/11/82	1216	D2	0	4	0.417E-01	0.193E-01	INTAKE VS DISCHARGE	0.510E+00	0.616E+00

Table 28. Comparison of primary productivity (C-14 fixation) between the intake and discharge waters ($^{mg}C/L/hr$).

Date	Intake	Discharge	D/I ratio
March 20, 1980	1.50 ± 0.15	0.63 ± 0.06	0.42
April 08, 1980	4.40 ± 0.26	2.97 ± 0.11	0.68
May 20, 1980	11.59 ± 1.42	6.64 ± 0.24	0.57
June 10, 1980	7.03 ± 0.24	3.63 ± 0.22	0.52
July 16, 1980	4.22 ± 0.76	2.28 ± 0.30	0.54
August 06, 1980	1.70 ± 0.31	0.56 ± 0.18	0.33
August 13, 1980	5.20 ± 0.51	2.72 ± 0.35	0.52
September 13, 1980	4.12 ± 0.22	1.59 ± 0.32	0.39
October 17, 1980	7.05 ± 0.24	2.03 ± 0.50	0.29
October 22, 1980	6.26 ± 0.72	1.25 ± 0.24	0.20
November 11, 1980	12.49 ± 0.65	3.40 ± 0.08	0.27
December 16, 1980	9.48 ± 0.83	6.00 ± 0.27	0.63
January 13, 1981	3.79 ± 0.19	2.26 ± 0.25	0.60
February 10, 1981	2.62 ± 0.01	1.35 ± 0.05	0.52
March 19, 1981	6.05 ± 0.43	4.12 ± 0.07	0.68
May 12, 1981	6.93 ± 0.37	2.27 ± 0.10	0.33
June 9, 1981	2.55 ± 0.10	1.60 ± 0.04	0.63
July 16, 1981	4.49 ± 0.27	2.32 ± 0.11	0.52
August 11, 1981	3.79 ± 0.31	1.25 ± 0.07	0.33
September 18, 1981	7.39 ± 0.61	3.85 ± 0.22	0.52
October 14, 1981	8.79 ± 0.87	3.37 ± 0.07	0.38
November 11, 1981	10.500 ± 0.14	4.47 ± 0.66	0.43
November 13, 1981	10.12 ± 0.229	4.44 ± 0.24	0.44
December 9, 1981	8.20 ± 0.57	4.87 ± 0.15	0.59
January 14, 1982	1.19 ± 0.11	0.89 ± 0.42	0.75
February 9, 1982	3.32 ± 0.07	1.05 ± 0.31	0.32
March 10, 1982	4.62 ± 0.29	3.87 ± 0.23	0.84
April 3, 1982	14.89 ± 0.49	10.60 ± 0.86	0.71
May 11, 1982	3.27 ± 0.03	1.45 ± 0.26	0.44

between the intake and the discharge chlorophyll a concentrations. The level of reduction of primary productivity in the discharge water for all the experiments is statistically significant (≤ 0.05). When a follow-up experiment using a different mixture of water from the intake and discharge pipes was carried out, the results showed that the higher the percentage of discharge water in the mixture, the lower the primary productivity rate (Figure 1). This suggested that the cause of this reduction in primary productivity is the passage of the water through the condenser cooling system. The significant level of reduction, however, was not apparent for comparisons between the discharge plume and the ambient water (Figure 2). This may be attributed to the rapid mixing of plume water with ambient lake water. Even after two days of continuous incubation with the enrichment of 2 μgL^{-1} of orthophosphate, the rate of primary productivity in the discharge water did not show a recovery to the levels observed in the intake water. During the entire experiment, the chlorophyll a concentration in the discharge water showed no significant difference from that of the intake water (Table 29). The data to date indicate that there is little significant observed impact on the photosynthetic mechanism (chlorophyll a) resulting from the passage of water through the condenser cooling system, but there is a reduction in photosynthetic rate (primary productivity). The factors causing this reduction are not yet clear. Based on the experiments conducted in 1980, 1981, and 1982, inhibition from heat or microelements are the plausible factors producing this reduction.

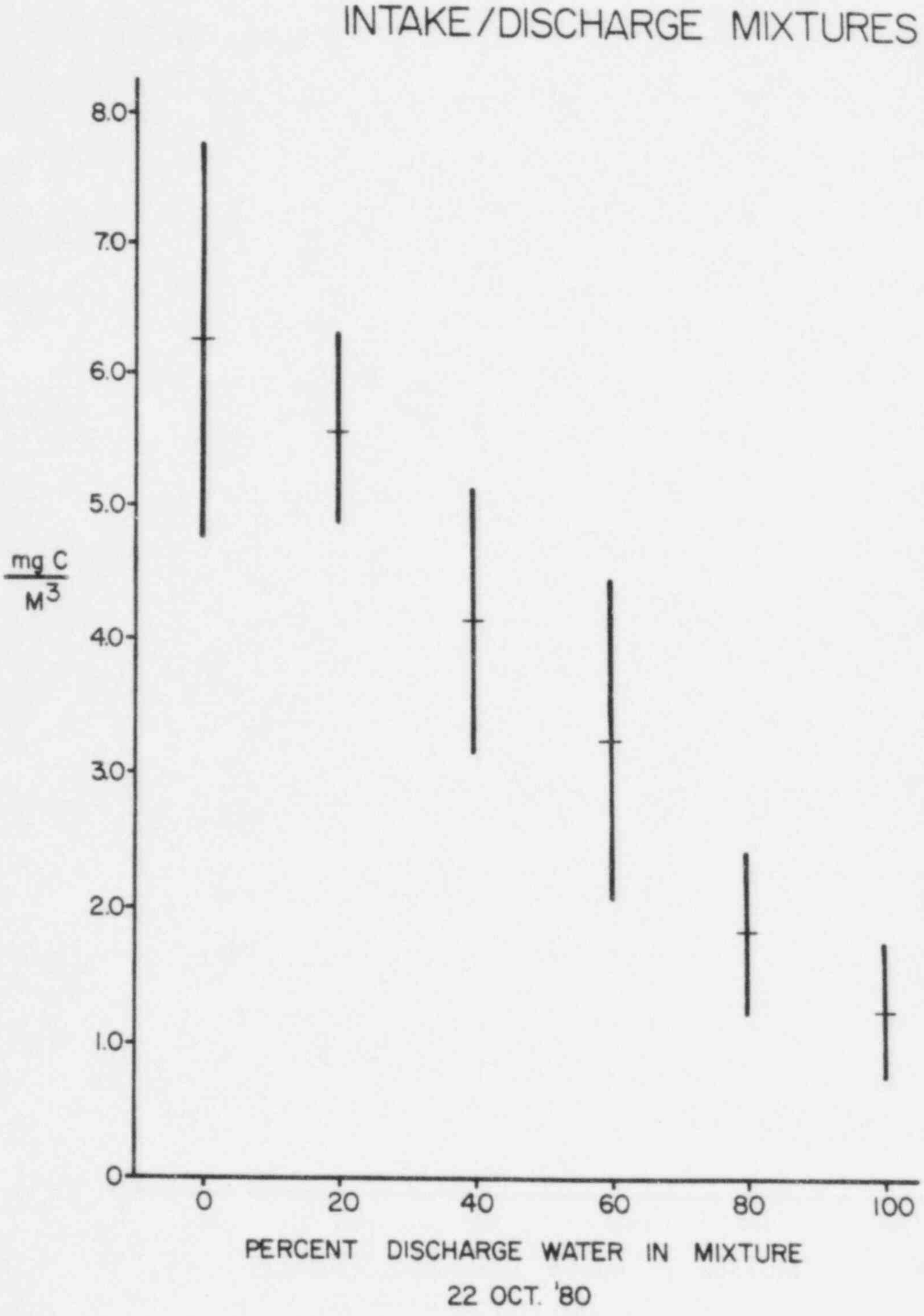

Figure 1. The relationship between the rate of primary productivity (C^{14}) in mgC/m^3 and the percent discharge water in the culture mixture.

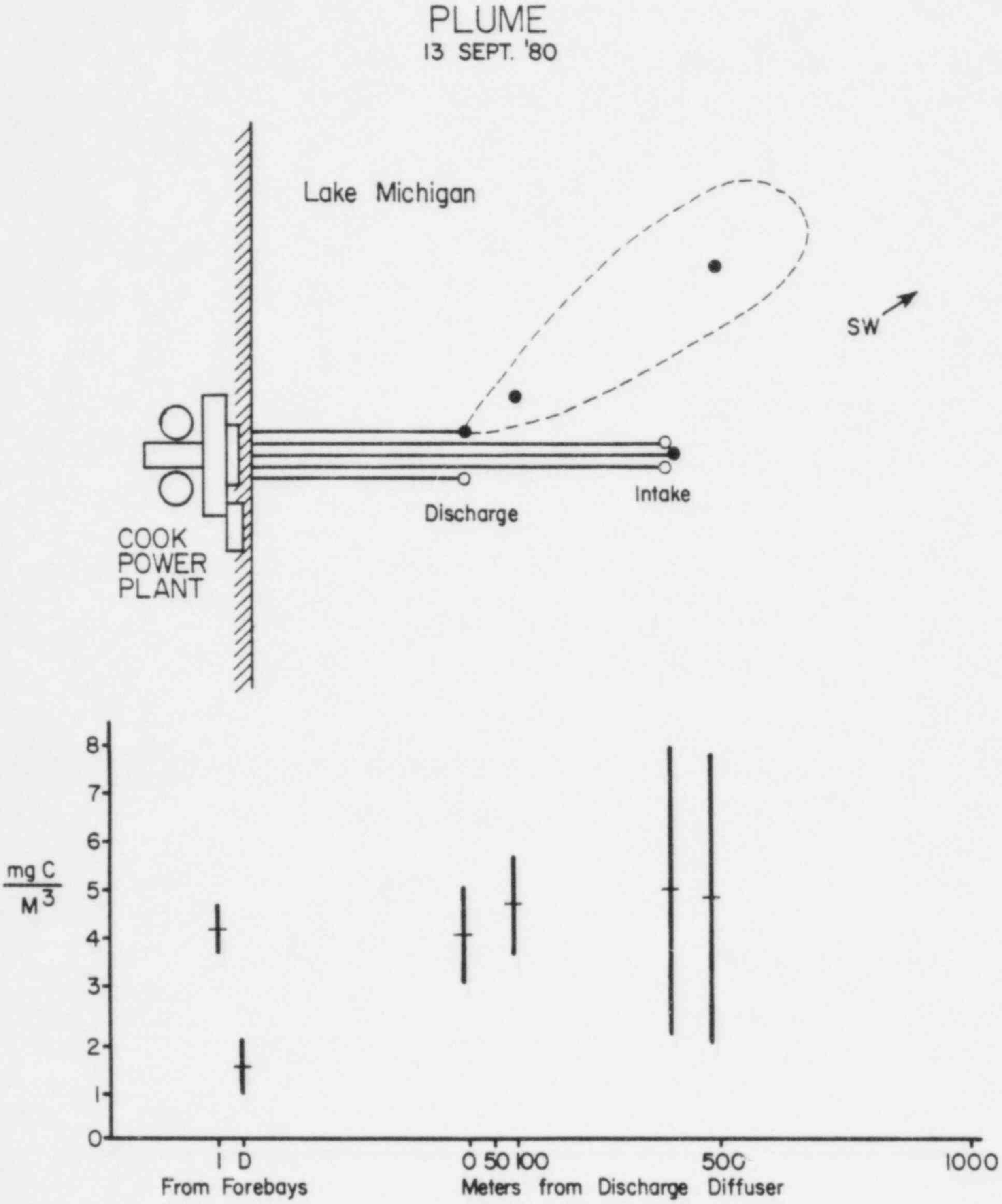

Figure 2. The rate of primary productivity (C^{14}) in mgC/m^3 versus the distance from the discharge diffuser.

Table 29. Productivity/Chlorophyll a ratio.

	Intake	Discharge	I/O Ratio
1st Day	0.93 ± 0.01	0.36 ± 0.15	2.58
2nd Day	0.44 ± 0.13	0.23 ± 0.12	1.91
1st/2nd	2.11	1.57	

CONCLUSIONS

Comparison of phytoplankton major group mean concentrations for 1975 through 1980 gave the following general observations: 1) coccoid blue-green algae and desmids were least abundant during 1976; 2) flagellates were most abundant during 1977; 3) filamentous blue-green algae, coccoid green algae, and centric diatoms were least abundant in 1977; 4) other algae were most abundant in 1978; 5) filamentous green algae were most abundant in 1976; and 6) pennate diatoms and total algae were least abundant in 1979. Low abundances in 1979 may result from the absence of June samples, a time when abundances are usually high. Therefore, the 1979 abundances may be low-biased.

The number of forms of phytoplankton was relatively high in 1976 and 1978, redundancy was highest in 1977, and diversity was relatively high in 1976 and 1978 and lowest in 1977. These changes in community structure statistics mimic changes noted in the major groups, especially for 1977. Decreases in filamentous blue-green algae, coccoid green algae, centric diatoms, pennate diatoms, and total algae in 1977, the increased redundancy in 1977, and the decreased diversity in 1977 describe a phytoplankton community considerably different from those of 1975, 1976, and 1978.

With the exception of 1977 when the character of the entrained phytoplankton community was such that a relatively large negative impact on viability was noted, no consistent long-term statistically significant alteration in viability based on chlorophyll concentrations has been observed that can be attributed to the plant. Using chlorophyll a intake/discharge comparisons, there is a greater occurrence of viability decreases in all years except 1975 and 1979.

Viability based on primary productivity showed a large reduction in the discharge water ranging from 16% to 80% as compared to the intake water. The cause of this reduction can be directly attributed to the passage of the water through the condenser cooling system. However, the level of reduction is not observed when comparing the discharge plume to ambient lake water. The factors causing this reduction are not yet clear. Based on the experiments conducted, inhibition from heat or microelements are the most plausible explanation for this reduction.

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APPENDIX B-3

BENTHOS COLLECTED AT THE DONALD C. COOK NUCLEAR PLANT

BENTHOS COLLECTED FROM 1971 THROUGH MAY 1982 IN THE VICINITY OF THE D. C. COOK NUCLEAR POWER PLANT, SOUTHEASTERN LAKE MICHIGAN

LAKE SURVEYS

Technical Specifications for environmental monitoring are designed to determine if benthic animal populations have changed significantly in the lake after the establishment of the thermal plume and chemical discharges. Benthos populations are examined in detail by three "seasonal" surveys in April, July, and October of each year. "Inner" areas (within 1.6 km of the plant) and "Outer" areas (3.2-11 km from the plant) are analyzed by depth zones, with the Outer areas acting as a reference. The depths encompassed are Zone 0 (0-8 m), Zone 1 (8-16 m), and Zone 2 (16-24 m). Five stations are sampled per zone in both the Inner and Outer areas for a total of 30 stations. Four replicate Ponar grabs are collected at each of the 10 shallow stations of Zone 0 and two at each of the 20 deeper stations of Zones 1 and 2.

This report contains April 1982 data and comparisons of these data with the 1971-1981 surveys. A summary of the 1982 data is presented in Table 1, and Inner and Outer comparisons of the major taxa from 1971-1982 are shown in Figures 1-18. In addition to the April 1982 lake survey, seven years of operational monitoring have been completed, allowing statistical tests for Inner/Outer regional differences. The test design uses Zone mean densities of the major taxa in a two-sample $\underline{t}$-test for each survey date and the faunal parameters of Figures 1-18. All mean station densities are transformed by the equation

$$y=\log10(x)$$

Table 1. Mean density (number m^{-2}) of major benthic taxa in April, 1982. The standard error (S E) is given in each case. The number of Inner and Outer stations in each zone for which data were available is given in parentheses following the Total Animals entry.

Taxon	Region	Zone 0 (0-8 m)		Zone 1 (8-16 m)		Zone 2 (16-24 m)	
		Mean	S E	Mean	S E	Mean	S E
Pontoporeia hoyi	INNER	0.0	0.0	1133.2	542.0	1605.9	761.5
	OUTER	12.1	12.1	424.2	213.6	1363.5	713.4
Tubificidae	INNER	12.1	12.1	2193.7	1249.1	4708.6	4083.5
	OUTER	6.1	6.1	484.8	152.1	2448.2	1409.6
Naididae	INNER	6.1	3.7	181.8	127.5	60.6	21.4
	OUTER	0.0	0.0	48.5	18.2	24.2	11.3
Stylodrilus heringianus	INNER	3.0	3.0	54.5	20.1	563.6	345.2
	OUTER	0.0	0.0	97.0	53.7	1872.5	836.7
Sphaerium nitidum	INNER	0.0	0.0	0.0	0.0	109.1	109.1
	OUTER	0.0	0.0	0.0	0.0	90.9	76.7
Sphaerium striatinum	INNER	0.0	0.0	6.1	6.1	0.0	0.0
	OUTER	0.0	0.0	0.0	0.0	12.1	7.4
Pisidium	INNER	0.0	0.0	151.5	108.0	1145.3	815.4
	OUTER	3.0	3.0	90.9	41.8	2702.8	1679.0
Chironomidae	INNER	33.3	11.1	163.6	87.1	363.6	139.8
	OUTER	45.4	19.8	193.9	58.8	254.5	96.1
Hirudinea	INNER	0.0	0.0	0.0	0.0	60.6	60.6
	OUTER	0.0	0.0	6.1	6.1	36.4	22.3
Operculata	INNER	0.0	0.0	6.1	6.1	60.6	46.0
	OUTER	0.0	0.0	0.0	0.0	72.7	51.2
Pulmonata	INNER	0.0	0.0	0.0	0.0	6.1	6.1
	OUTER	0.0	0.0	0.0	0.0	6.1	6.1
Other	INNER	84.8	52.2	66.7	33.7	315.1	277.8
	OUTER	18.2	18.2	97.0	46.4	127.3	57.0
Total Animals	INNER	139.4	56.0(5)	3963.2	2075.5(5)	9017.3	5641.2(5)
	OUTER	84.8	20.7(5)	1442.3	226.5(5)	9035.5	3887.7(5)

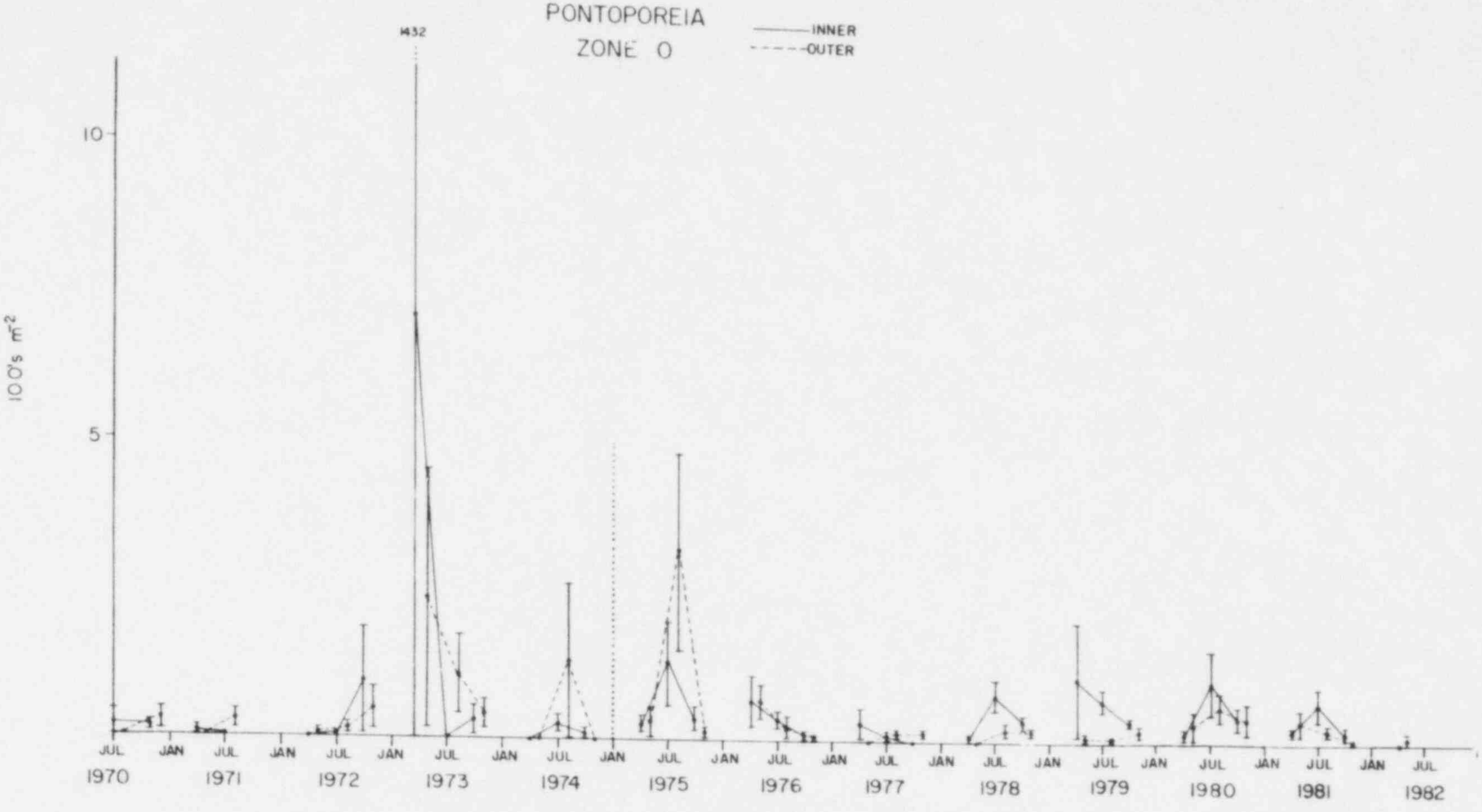

FIGURE 1. Density (animals m^{-2}) of Pontoporeia hoyi in the Inner and Outer regions of Zone 0 (0-8 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

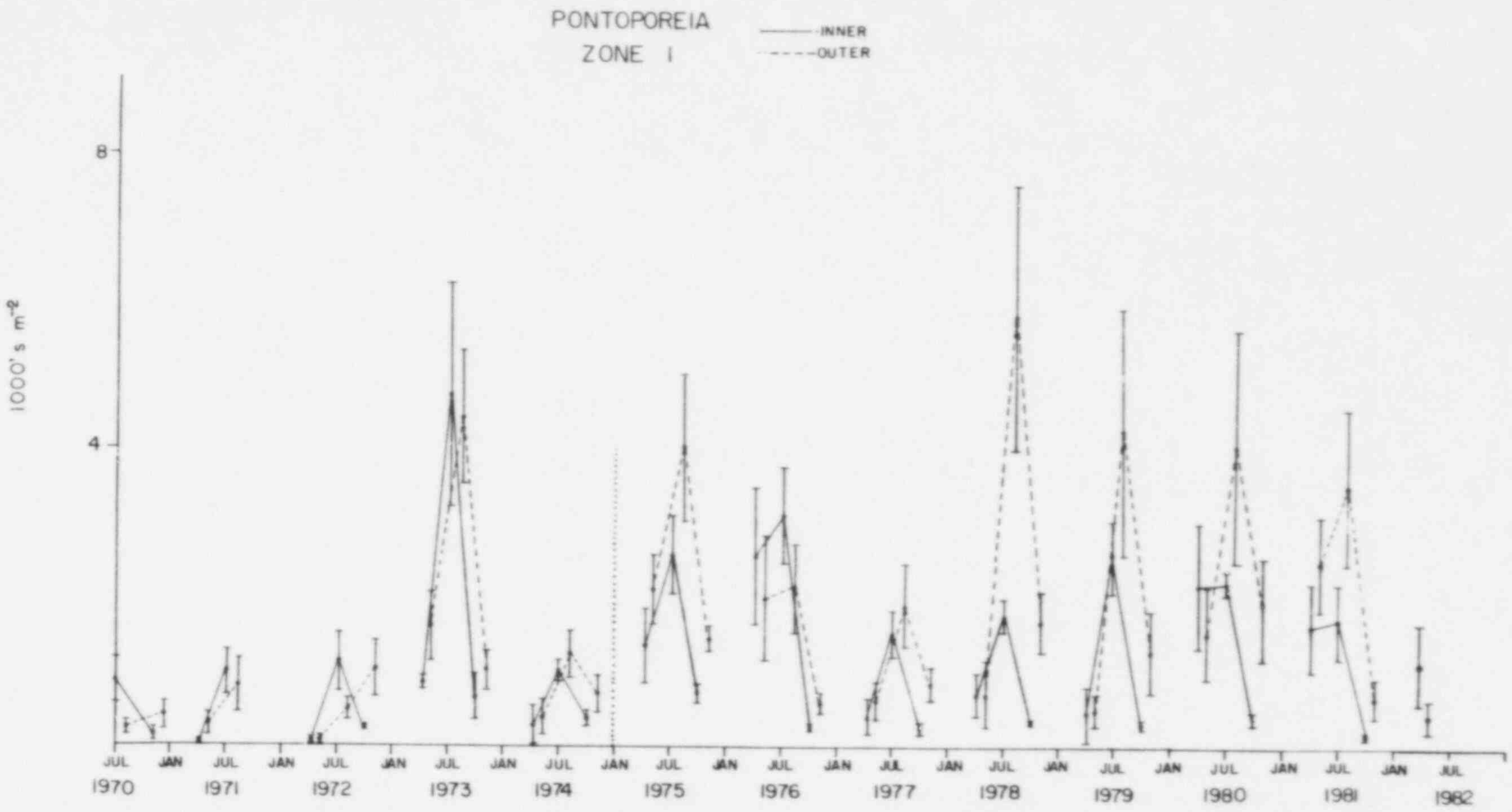

FIGURE 2. Density (animals m^{-2}) of Pontoporeia hoyi in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

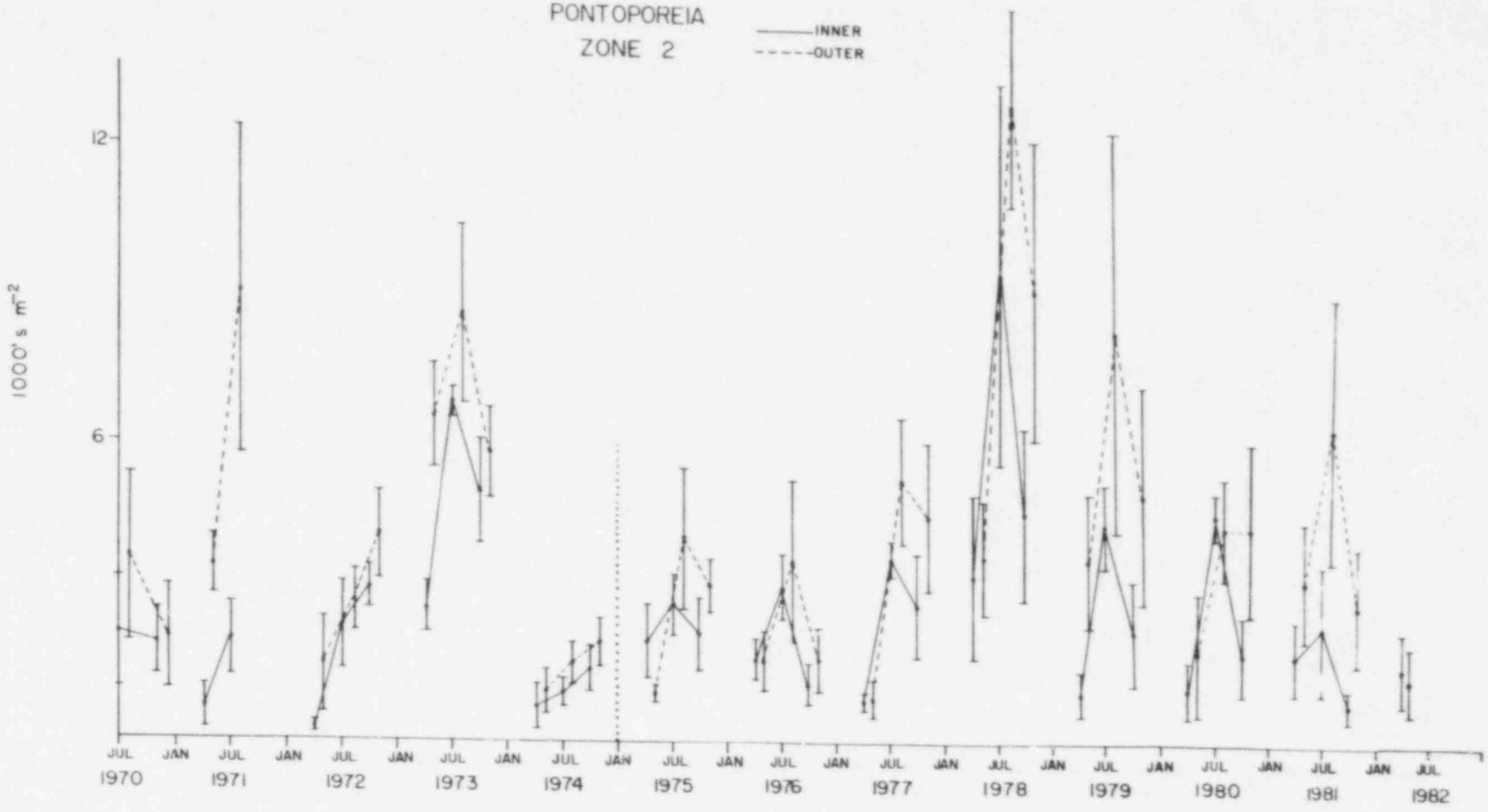

FIGURE 3. Density (animals m^{-2}) of Pontoporeia hoyi in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

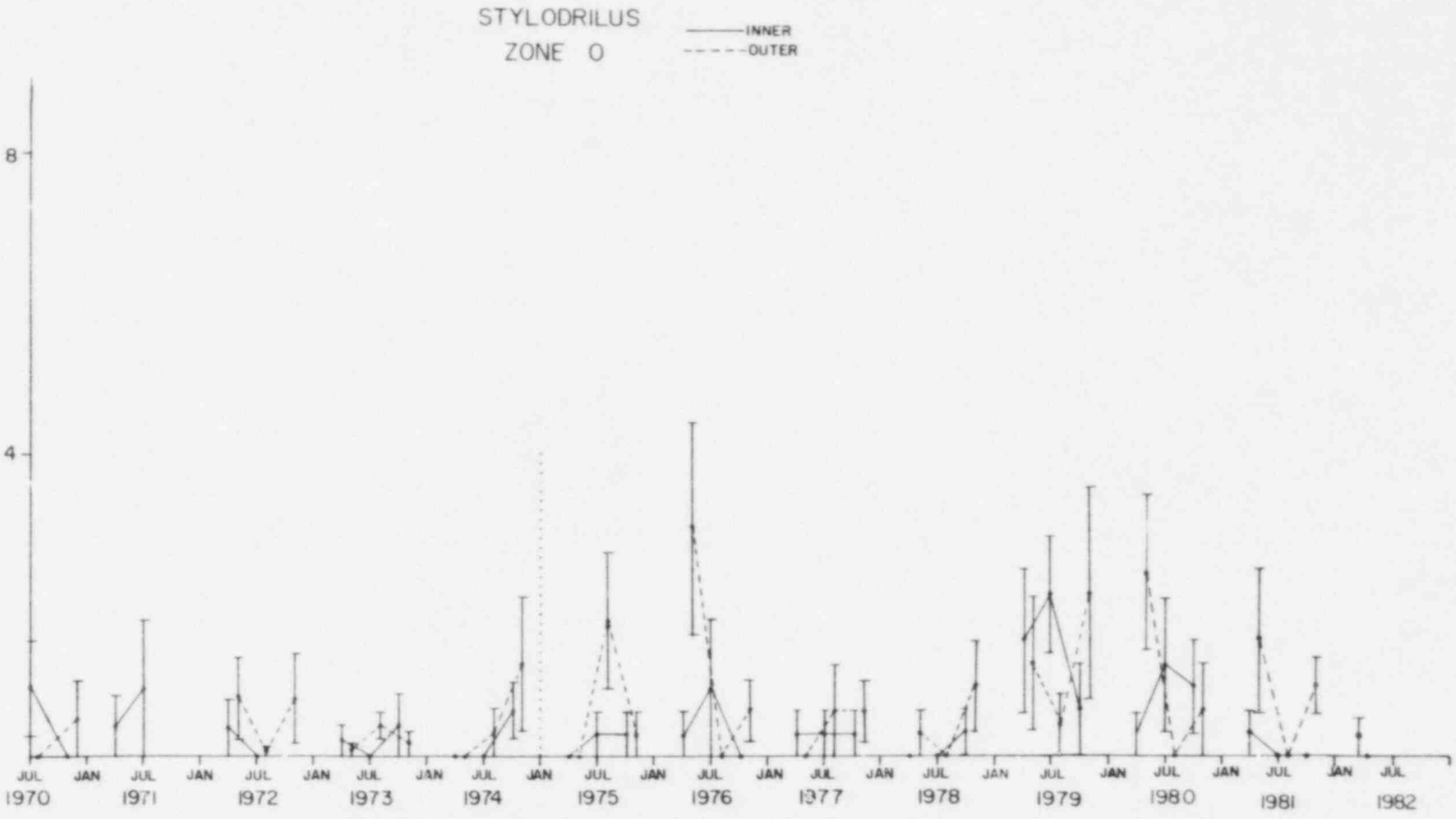

FIGURE 4. Density (animals m^{-2}) of <u>Stylodrilus heringianus</u> in the Inner and Outer regions of Zone 0 (0-8 depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

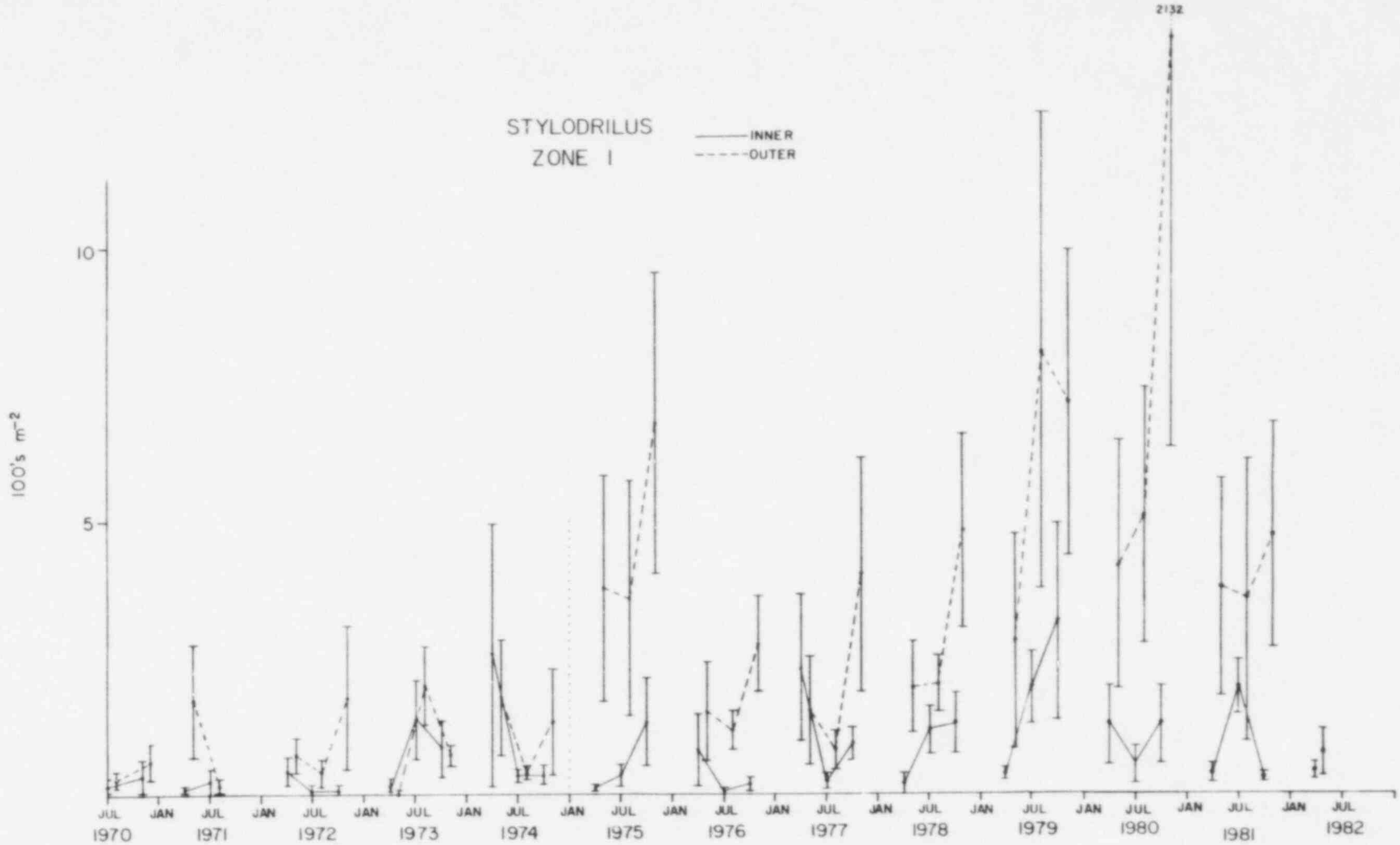

FIGURE 5. Density (animals m^{-2}) of Stylodrilus heringianus in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

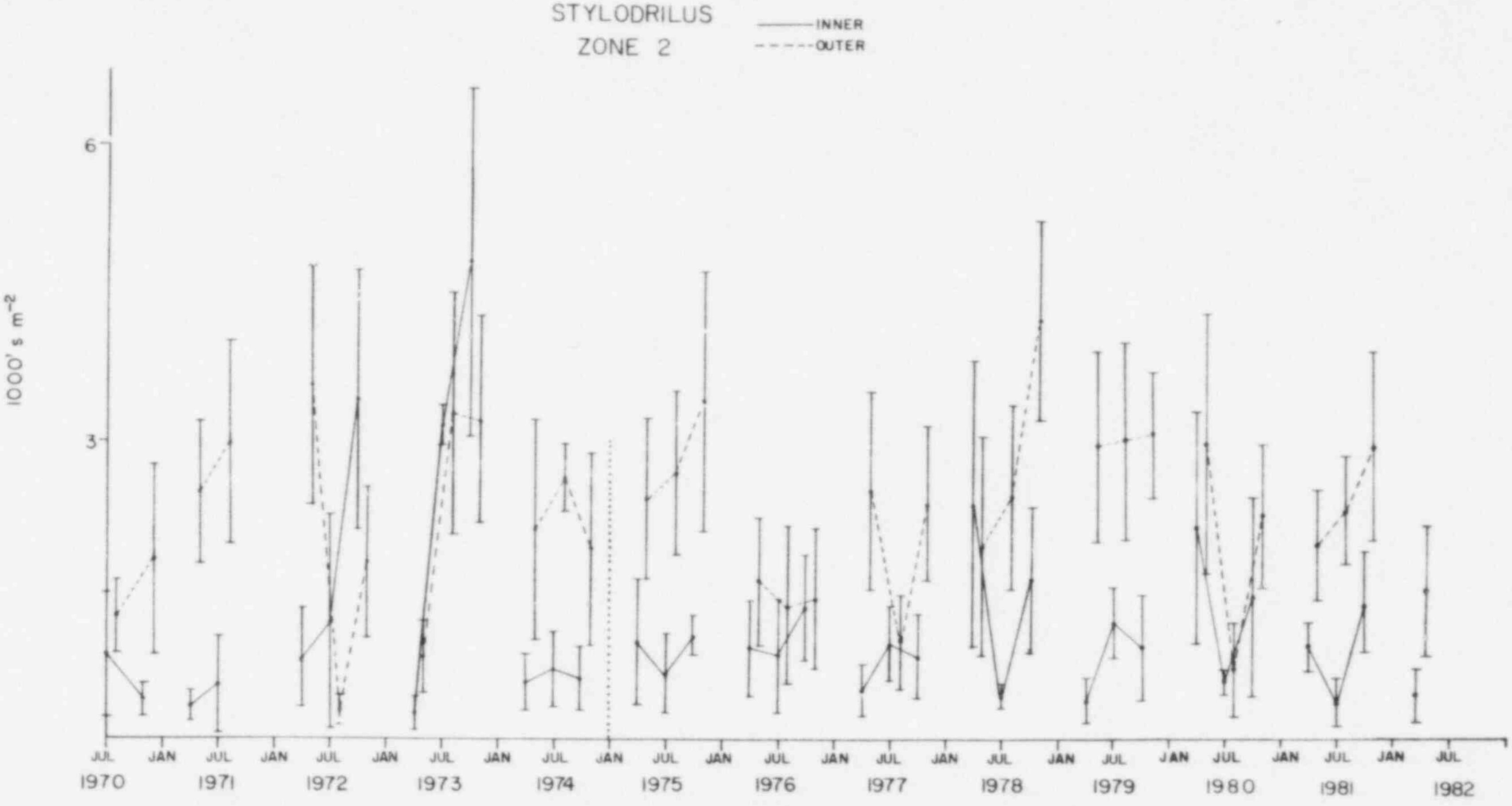

FIGURE 6. Density (animals m^{-2}) of <u>Stylodrilus heringianus</u> in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

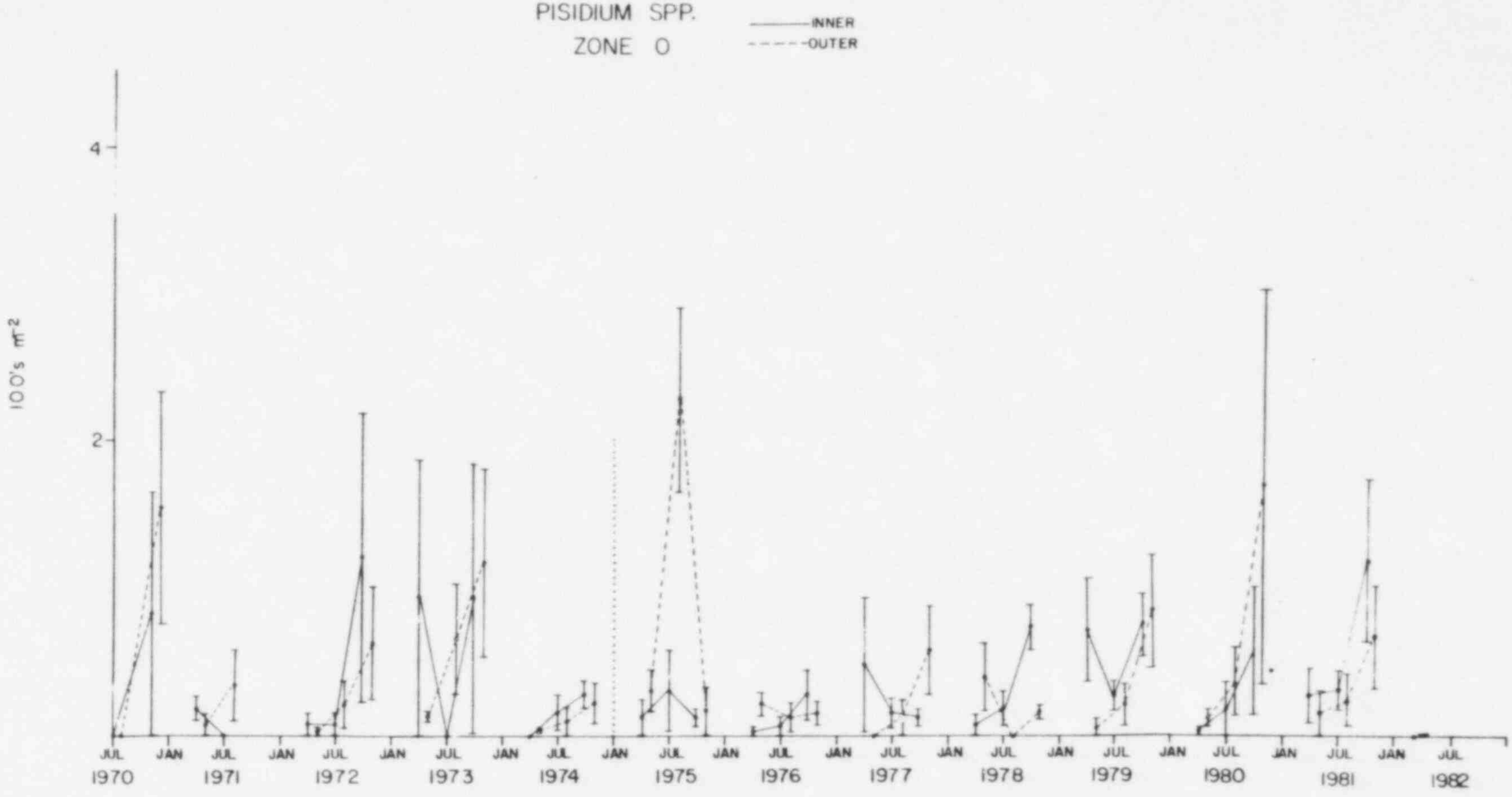

FIGURE 7. Density (animals m^{-2}) of Pisidium spp. in the Inner and Outer regions of Zone 0 (0-8 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

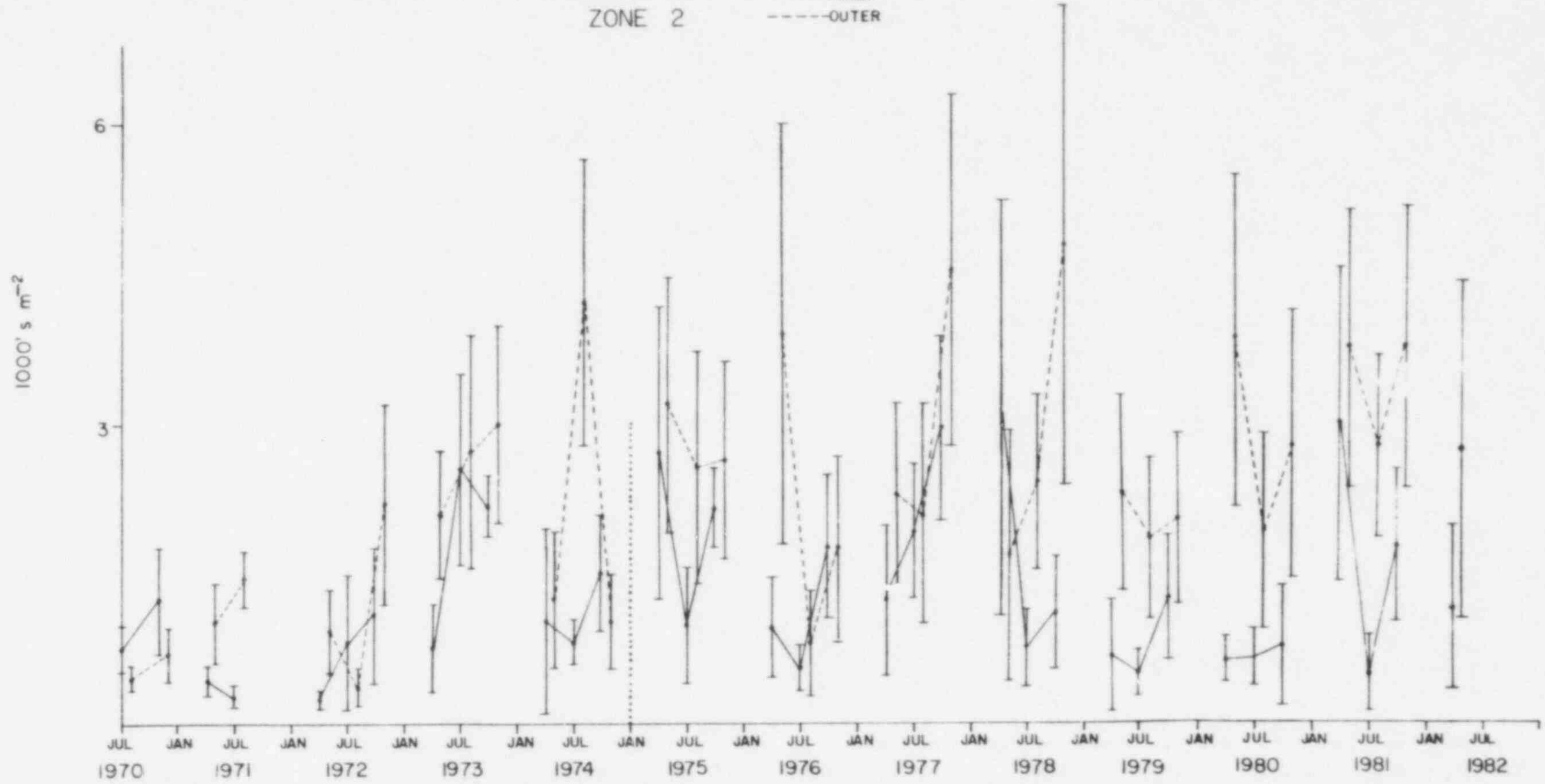

FIGURE 8. Density (animals m^{-2}) of *Pisidium* spp. in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

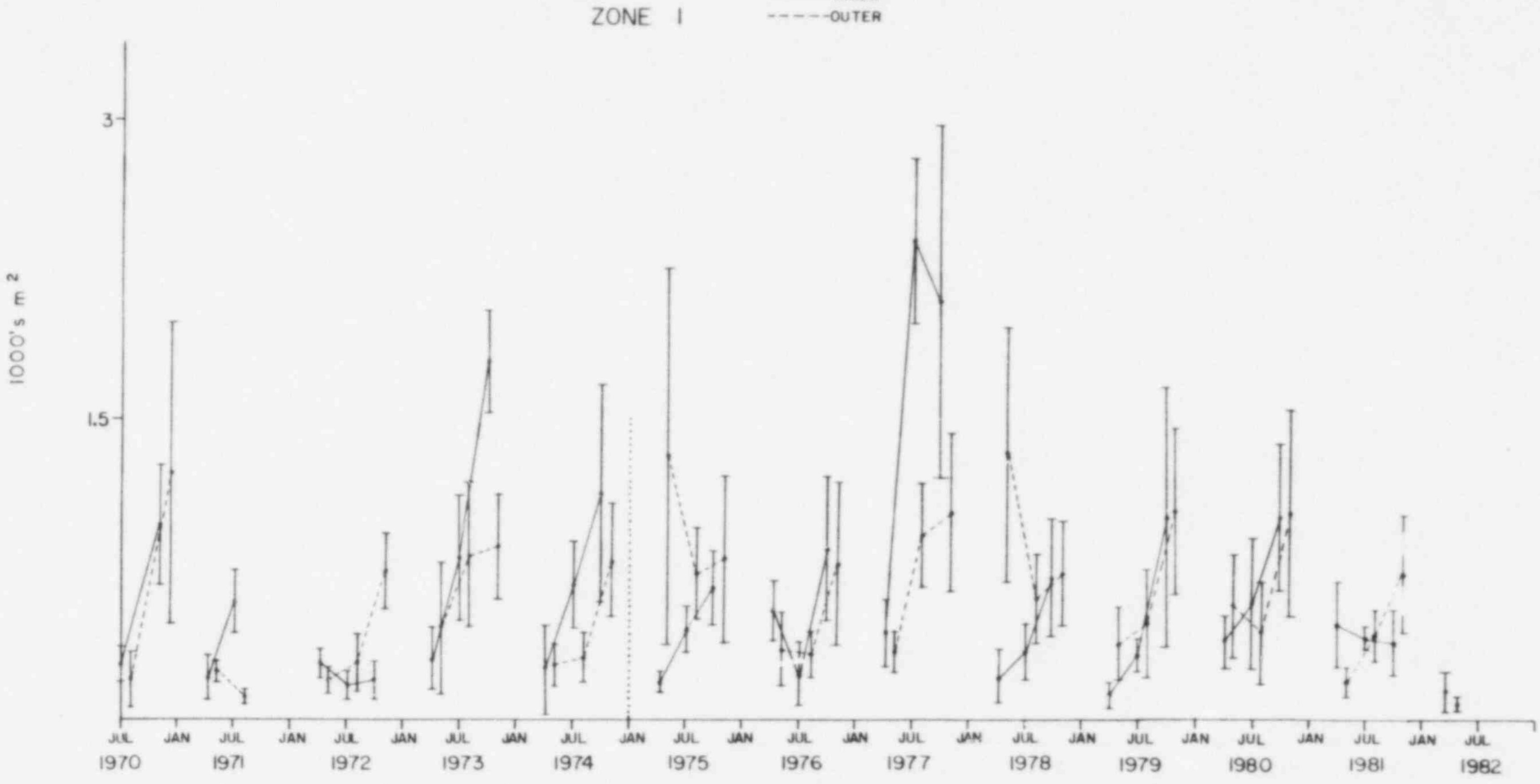

FIGURE 9. Density (animals m^{-2}) of Pisidium spp. in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

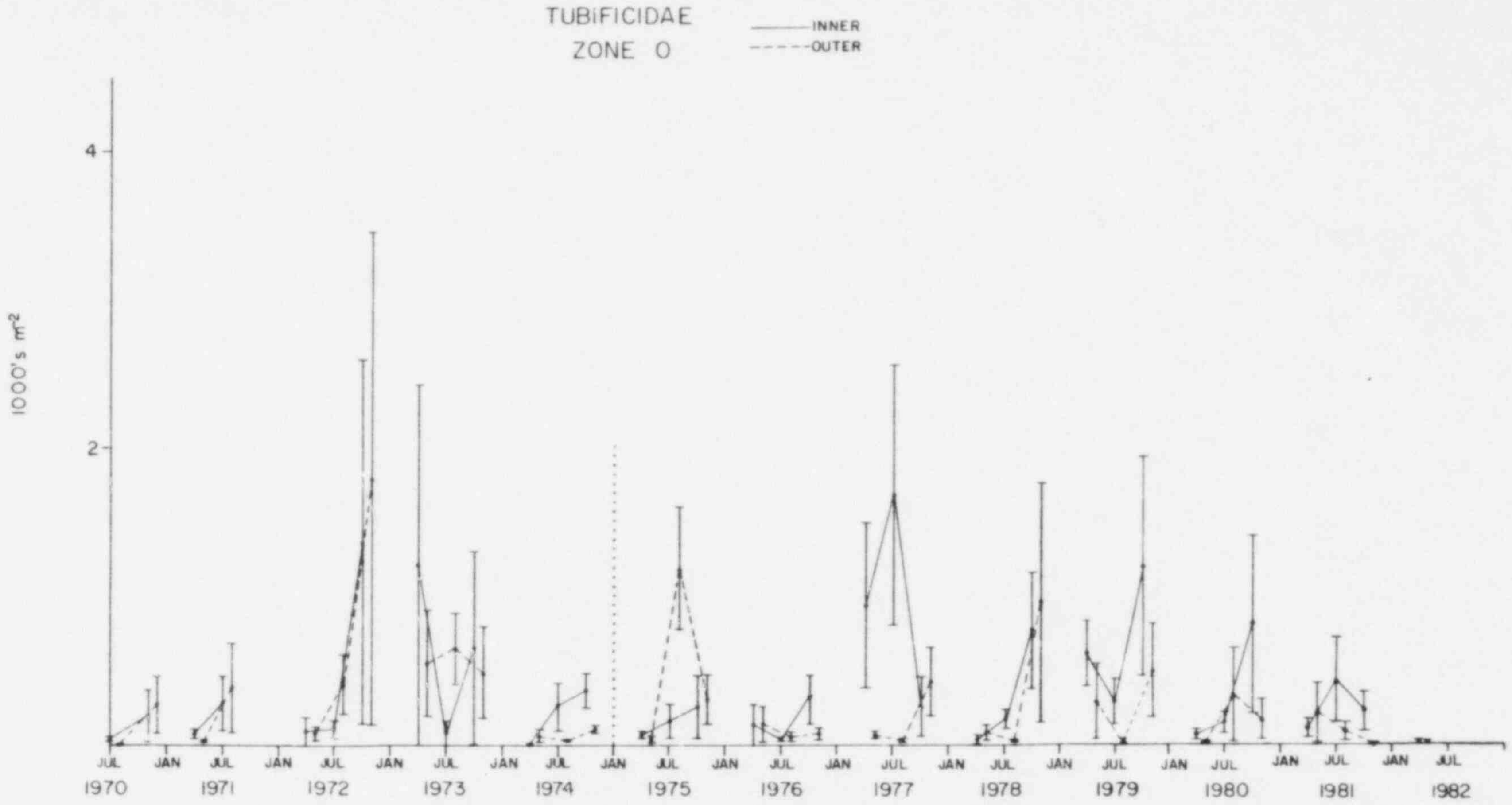

FIGURE 10. Density (animals m^{-2}) of Tubificidae in the Inner and Outer regions of Zone 0 (0-8 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

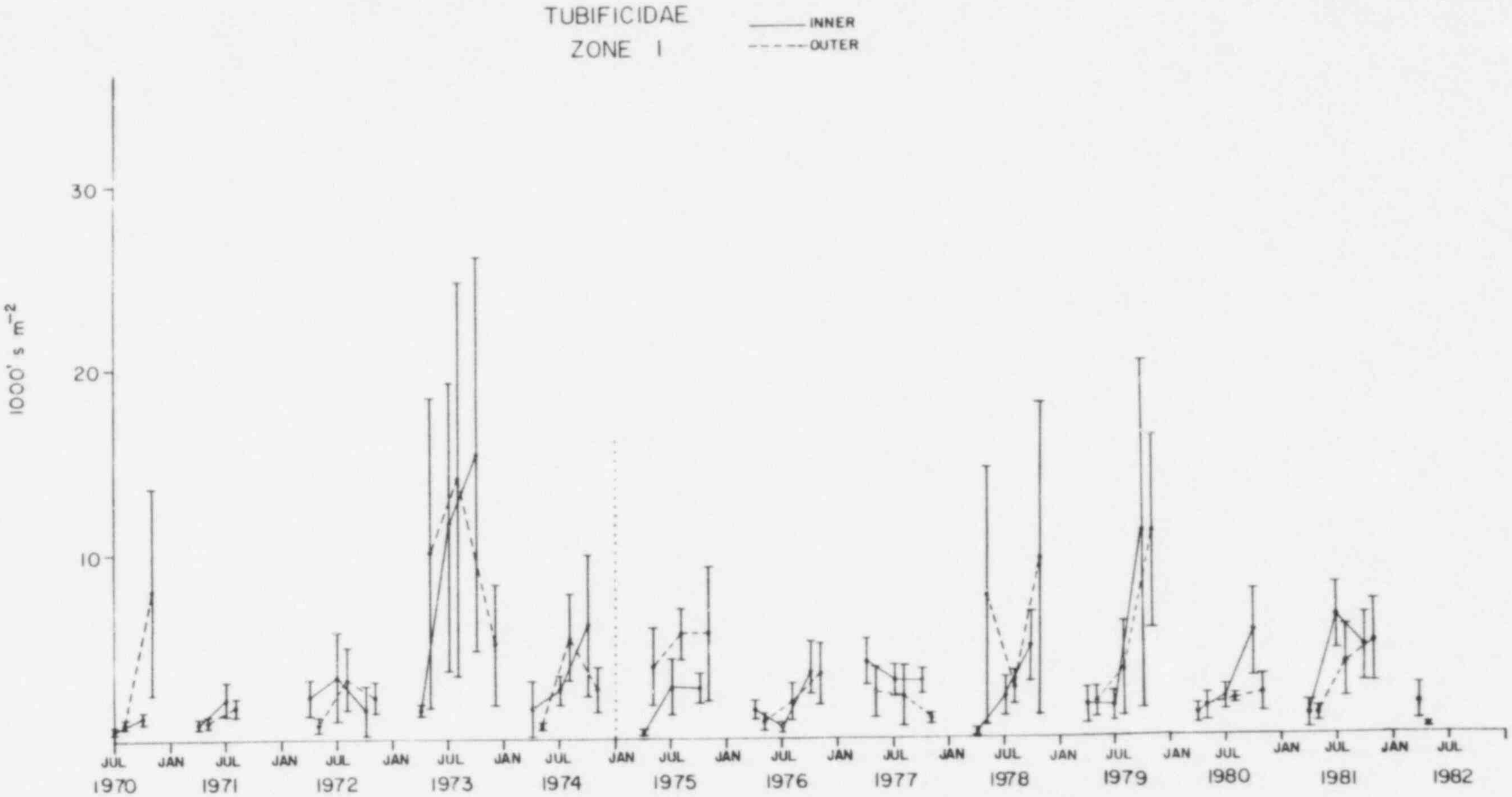

FIGURE 11. Density (animals m^{-2}) of Tubificidae in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

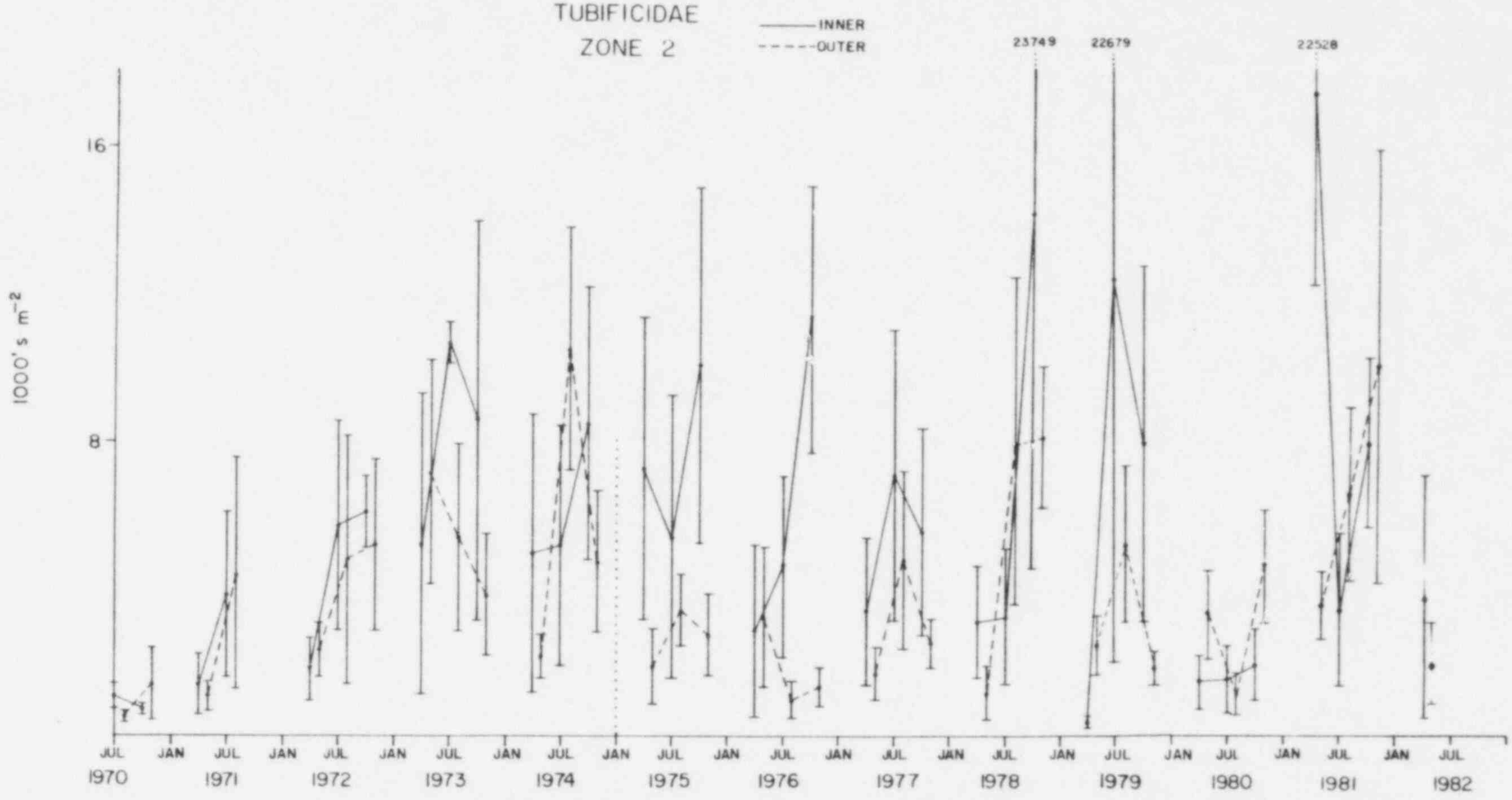

FIGURE 12. Density (animals m^{-2}) of Tubificidae in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

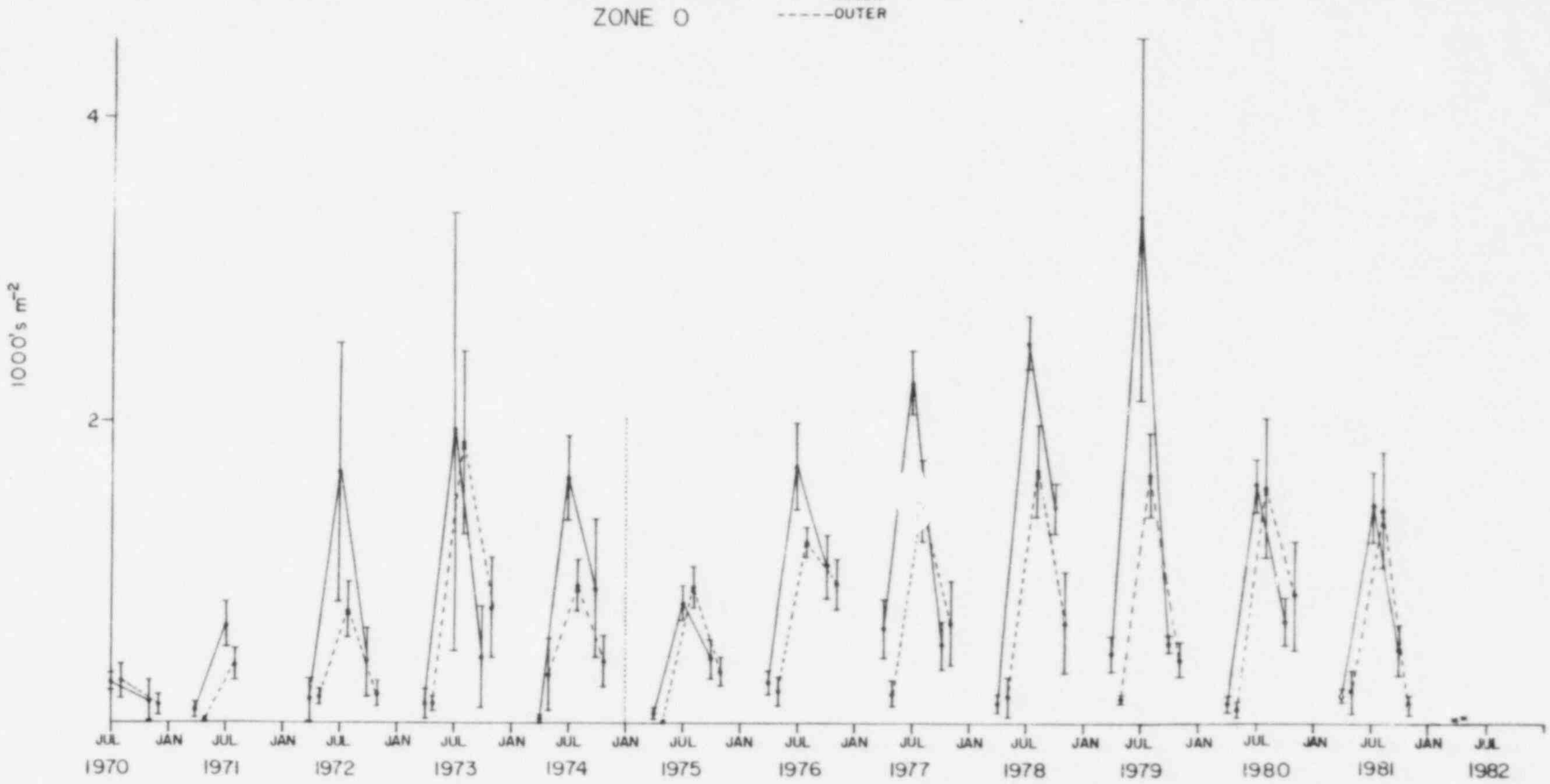

FIGURE 13. Density (animals m^{-2}) of Chironomidae in the Inner and Outer regions of Zone 0 (0-8 m depth), vertical bars are standard errors, vertical dotted line indecates the start of plant operation. For April 1982, Inner given at left, Outer at right.

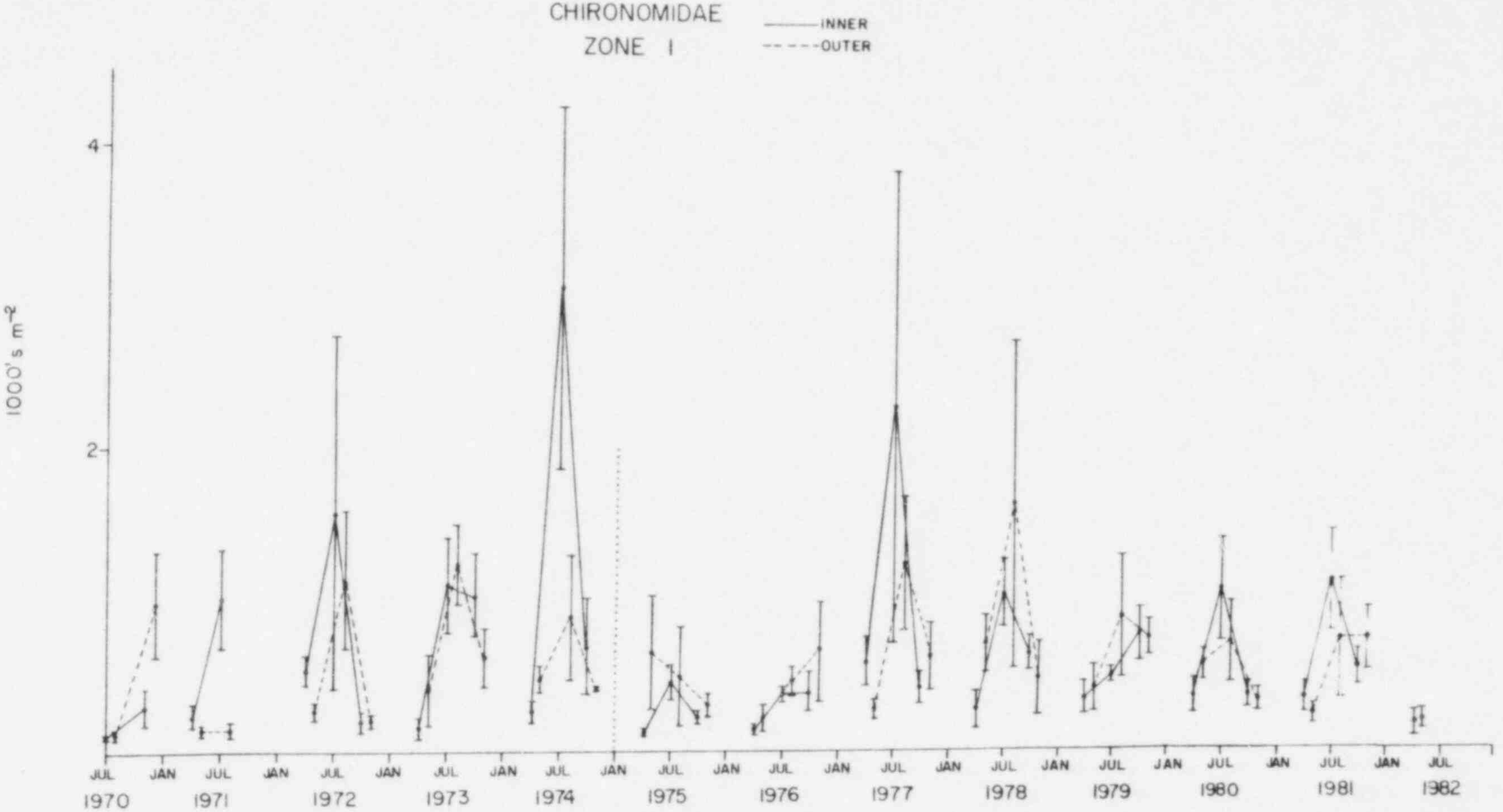

FIGURE 14. Density (animals m^{-2}) of Chironomidae in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operations. For April 1982, Inner given at left, Outer at right.

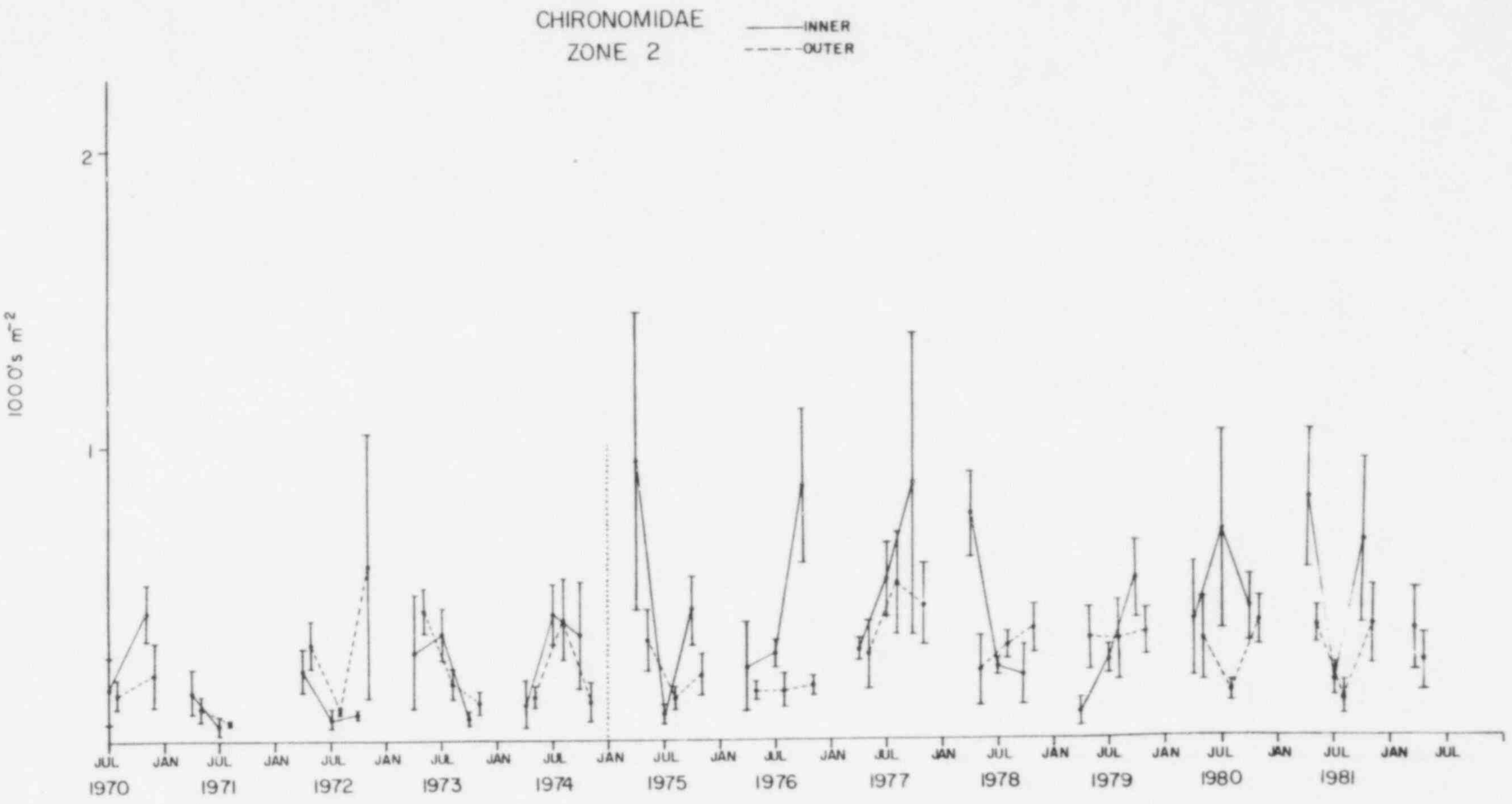

FIGURE 15. Density (animals m^{-2}) of Chironomidae in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

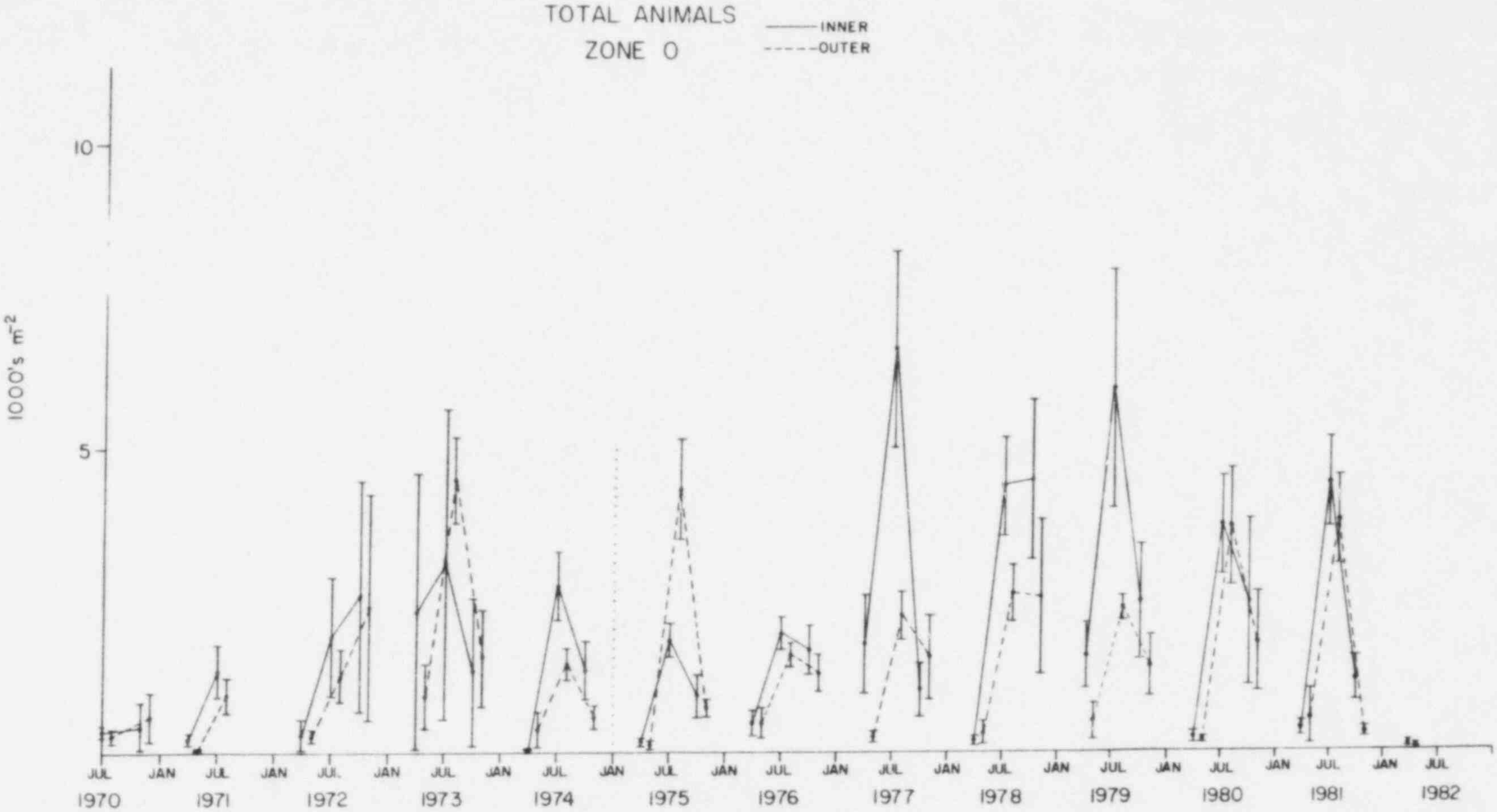

FIGURE 16. Density (animals m^{-2}) of Total Animals in the Inner and Outer regions of Zone 0 (0-8 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

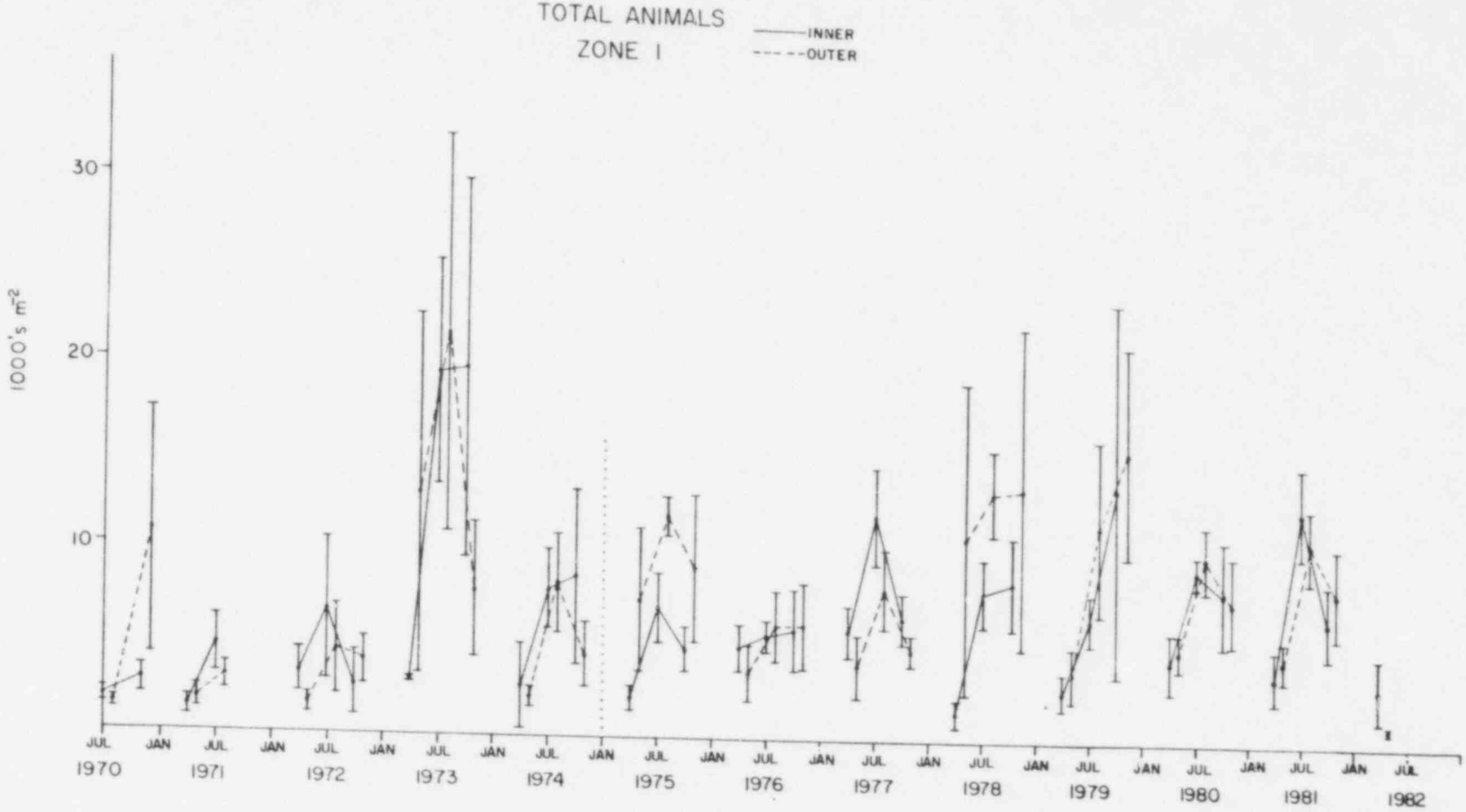

FIGURE 17. Density (animals m^{-2}) of Total Animals in the Inner and Outer regions of Zone 1 (8-16 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

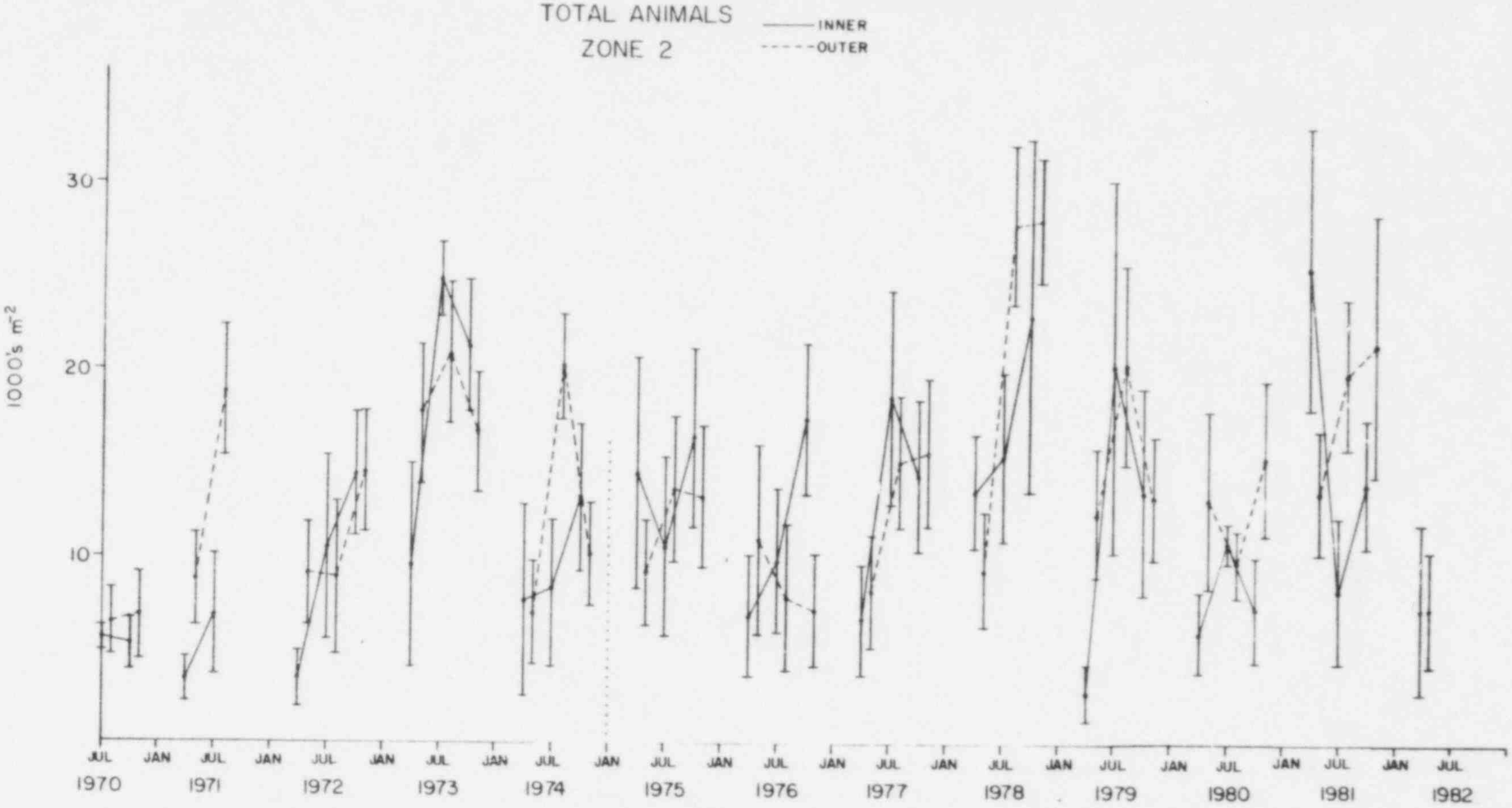

FIGURE 18. Density (animals m^{-2}) of Total Animals in the Inner and Outer regions of Zone 2 (16-24 m depth), vertical bars are standard errors, vertical dotted line indicates the start of plant operation. For April 1982, Inner given at left, Outer at right.

however, if one or more of the means of a set are 0.0, then all means for that set are transformed by

$$y=\log10(x+1)$$

Transformed values for the Outer areas of each Zone are subtracted from corresponding values for Inner areas, providing a logarithmic equivalent of Inner to Outer mean ratios. Ratios are determined for each of the major taxa in Zones 0, 1, and 2 for each seasonal survey of April 1971 to April 1982. The pre-operational ratios for each season, 1971-1974, are compared with operational year ratios, 1975-1982. Significance of differences between the two sets of ratios are tested at the 0.05 level.

Of the total 18 statistical tests performed on the April 1971-1982 data (Tables 2-7) (3 depth zones x 1 seasonal survey x 6 major benthic animal categories), only one Inner/Outer ratio produced a t-test statistic with a probability less than 0.05 but greater than 0.02. When compared with the same period during 1981, the number of significant differences among Inner/Outer ratios was the same. A significant difference was found between the Inner/Outer *Pontoporeia hoyi* ratios for Zone 2 during April surveys (Table 2). The significance of April Inner/Outer ratios for all other taxa remained unchanged with the inclusion of 1982 data.

Statistical differences noted in Zone 2 for past April surveys tend to confirm our previous observation that the Outer region naturally supports a greater number of *Pontoporeia* than the Inner region. Temporally, this difference may vary depending upon the specific year or month as was the case during April 1982, where the Inner region density was slightly higher than Outer region density. Regardless, the trend supported by April survey density

TABLE 2. Logarithms of ratios of Inner to Outer mean population densities for *Pontoporeia hoyi* by year, month and depth zone. The value of Student's *t* is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation ($p < .05$), NS = no significance, ND = no data.

Month	Depth Zone	Year													
		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Student's *t*	Significance
April	0	0.38	-0.26	0.48	-0.30	-0.04	0.00	1.49	0.95	1.03	-0.29	-0.23	-1.11	0.33	NS
	1	-0.67	-0.06	-0.27	-0.15	-0.20	0.11	-0.19	0.00	-0.05	0.15	-0.18	0.43	2.07	NS
	2	-0.74	-0.77	-0.39	-0.17	0.33	0.01	-0.03	-0.05	-0.57	-0.21	-0.27	0.07	2.56	*
July	0	-0.82	-0.41	-1.56	0.32	-0.39	0.18	-0.10	0.58	1.07	0.23	0.45	ND	2.42	*
	1	0.09	0.36	0.03	-0.08	-0.19	0.17	-0.10	-0.52	-0.22	-0.26	-0.31	ND	2.39	*
	2	-0.65	-0.09	-0.10	-0.21	-0.17	-0.07	-0.16	-0.13	-0.28	0.02	-0.43	ND	0.73	NS
October	0	--	0.28	-0.11	1.11	0.39	0.27	-1.20	0.29	0.25	0.01	0.43	ND	0.90	NS
	1	--	-0.61	-0.18	-0.28	-0.31	-0.37	-0.57	-0.73	-0.67	-0.68	-0.59	ND	1.65	NS
	2	--	-0.13	-0.06	-0.13	-0.17	-0.16	-0.22	-0.29	-0.35	-0.38	-0.54	ND	2.38	*

TABLE 3. Logarithms of ratios of Inner to Outer mean population densities for Stylodrilus (Lumbriculidae) by year, month and depth zone. The value of Student's t is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation ($p < .05$), NS = no significance, ND = no data.

Month	Depth Zone	Year												Student's t	Significance
		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982		
April	0	0.70	-0.26	0.18	0.00	0.00	-0.89	0.60	0.60	0.09	-0.80	-0.60	0.60	0.58	NS
	1	-1.24	-0.21	0.82	0.16	-1.50	-0.28	0.18	-1.03	-0.89	-0.52	-1.02	-0.25	1.36	NS
	2	-0.88	-0.64	-0.51	-0.57	-0.39	-0.24	-0.74	0.09	-0.88	-0.15	-0.32	-0.52	1.56	NS
July	0	1.00	-0.30	-0.70	-0.60	-0.68	1.00	-0.24	0.00	0.64	1.11	0.00	ND	0.92	NS
	1	0.11	-0.80	-0.16	-0.70	-1.00	-1.28	-0.52	-0.24	-0.62	-0.97	-0.27	ND	1.90	NS
	2	-0.74	0.61	-0.02	-0.58	-0.60	-0.20	-0.01	-0.74	-0.40	-0.08	-0.79	ND	0.80	NS
October	0	--	-0.95	0.22	-0.27	0.00	-0.85	-0.24	-0.40	-0.50	0.15	-1.00	ND	0.22	NS
	1	--	-1.36	0.12	-0.57	-0.71	-1.18	-0.64	-0.58	-0.36	-1.04	-1.20	ND	0.66	NS
	2	--	0.28	0.18	-0.49	-0.51	-0.03	-0.45	-0.42	-0.52	-0.19	-0.34	ND	1.89	NS

TABLE 4. Logarithms of ratios of Inner to Outer mean population densities for Pisidium spp. by year, month and depth zone. The value of Student's t is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation (p < .05), NS = no significance, ND = no data.

		Year													
Month	Depth Zone	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Student's t	Significance
April	0	0.38	0.30	0.83	-0.60	-0.36	-0.74	1.69	-0.70	1.02	-0.51	0.24	-0.60	0.44	NS
	1	-0.05	0.17	-0.18	-0.02	-0.83	0.19	0.10	-0.78	-0.51	-0.16	0.40	0.22	0.61	NS
	2	-0.36	-0.57	-0.44	-0.09	-0.07	-0.61	-0.27	0.27	-0.53	-0.78	-0.10	-0.37	0.31	NS
July	0	-1.53	-0.42	-1.82	0.20	-0.87	-0.27	0.09	1.28	0.10	-0.29	0.09	ND	1.90	NS
	1	0.72	-0.23	-0.01	0.34	-0.21	-0.15	0.41	-0.25	-0.18	0.13	-0.01	ND	1.25	NS
	2	-0.71	0.34	-0.03	-0.71	-0.41	-0.16	-0.04	-0.50	-0.58	-0.47	-0.75	ND	0.61	NS
October	0	--	0.29	-0.10	0.11	-0.12	0.26	-0.68	0.69	-0.05	-0.46	0.25	ND	0.40	NS
	1	--	-0.58	0.31	0.15	-0.08	0.04	0.30	-0.01	-0.01	-0.01	-0.28	ND	0.17	NS
	2	--	-0.30	-0.14	0.17	-0.09	0.01	-0.19	-0.64	-0.21	-0.56	-0.33	ND	1.19	NS

TABLE 5. Logarithms of ratios of Inner to Outer mean population densities for Tubificidae by year, month and depth zone. The value of Student's t is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation ($p < .05$), NS = no significance, ND = no data.

		Year													
Month	Depth Zone	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Student's t	Significance
April	0	0.58	0.08	0.35	-0.90	0.25	0.00	1.16	-0.36	0.33	0.75	-0.28	0.30	0.71	NS
	1	-0.04	0.45	-0.80	0.36	-1.02	0.24	0.22	-1.41	-0.04	-0.14	0.01	0.66	0.44	NS
	2	0.12	-0.10	-0.14	0.37	0.59	-0.05	0.30	0.43	-0.80	-0.35	0.69	0.28	0.27	NS
July	0	-0.13	-0.58	-0.89	0.98	-0.88	-0.24	1.79	0.90	1.19	-0.35	0.72	ND	1.05	NS
	1	0.11	0.02	0.09	-0.32	-0.30	-0.52	0.14	-0.08	-0.35	0.02	0.21	ND	0.36	NS
	2	-0.06	0.08	0.30	-0.31	0.20	0.67	0.28	-0.39	0.38	0.13	-0.28	ND	0.66	NS
October	0	--	-0.12	0.12	0.56	-0.08	0.67	-0.22	-0.10	0.38	0.67	1.57	ND	0.57	NS
	1	--	-0.16	0.48	0.36	-0.32	0.01	0.45	-0.29	0.00	0.40	-0.03	ND	0.91	NS
	2	--	0.07	0.35	0.26	0.57	0.93	0.34	0.24	0.64	-0.37	-0.10	ND	0.35	NS

TABLE 6. Logarithms of ratios of Inner to Outer mean population densities for Chironomidae by year, month and depth zone. The value of Student's t is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation ($p < .05$), NS = no significance, ND = no data.

Month	Depth Zone	Year												Student's t	Significance
		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982		
April	0	0.56	-0.04	-0.02	-1.07	1.31	0.11	0.52	-0.12	0.45	0.14	-0.05	-0.13	1.25	NS
	1	0.21	0.30	-0.40	-0.25	-0.67	-0.17	0.34	-0.42	-0.07	0.19	0.17	-0.08	0.51	NS
	2	0.17	-0.14	-0.17	-0.09	0.45	0.18	0.03	0.52	-0.59	0.08	0.33	0.15	1.10	NS
July	0	0.23	0.35	0.02	0.25	-0.05	0.15	0.19	0.18	0.31	0.00	0.01	ND	1.20	NS
	1	0.81	0.14	-0.05	0.54	-0.03	-0.09	0.26	-0.20	-0.25	0.17	0.19	ND	2.03	NS
	2	-0.08	-0.14	0.28	0.02	-0.21	0.25	0.01	-0.11	-0.10	0.66	0.17	ND	0.46	NS
October	0	--	0.32	-0.24	0.34	0.09	0.05	-0.11	0.33	0.09	-0.09	0.60	ND	0.02	NS
	1	--	-0.01	0.22	0.22	-0.14	-0.22	-0.18	0.13	0.01	0.04	-0.13	ND	2.36	*
	2	--	-0.83	-0.23	0.44	0.31	-0.67	0.28	0.24	0.18	0.04	0.24	ND	1.52	NS

TABLE 7. Logarithms of ratios of Inner to Outer mean population densities for Total Animals by year, month and depth zone. The value of Student's t is shown for each season and depth zone. The vertical dotted line indicates the start of plant operation. An asterisk (*) indicates that the ratio was significantly different after the start of plant operation (p < .05), NS = no significance, ND = no data.

Month	Depth Zone	Year												Student's t	Significance
		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982		
April	0	0.61	0.00	0.39	-1.04	0.13	0.00	0.83	-0.22	0.50	0.08	-0.17	0.21	0.59	NS
	1	-0.11	0.33	-0.64	0.11	-0.55	0.15	0.17	-0.86	-0.12	-0.05	-0.09	0.44	0.14	NS
	2	-0.42	-0.41	-0.27	0.04	0.20	-0.20	-0.09	0.16	-0.65	-0.34	0.28	0.00	1.06	NS
July	0	0.14	0.18	-0.16	0.27	-0.37	0.08	0.47	0.22	0.40	0.00	0.07	ND	0.11	NS
	1	0.19	0.08	-0.04	-0.01	-0.23	-0.04	0.17	-0.22	-0.24	-0.03	0.07	ND	1.42	NS
	2	-0.44	0.07	0.08	-0.39	-0.11	0.10	0.09	-0.26	0.00	0.05	-0.38	ND	0.69	NS
October	0	--	0.04	-0.06	0.37	0.09	0.12	-0.19	0.26	0.24	0.13	0.59	ND	0.38	NS
	1	--	-0.26	0.40	0.24	-0.28	-0.02	0.13	-0.20	-0.06	0.02	-0.09	ND	1.37	NS
	2	--	0.00	0.11	0.11	0.09	0.39	-0.04	-0.09	0.01	0.33	-0.19	ND	0.01	NS

estimates, as well as during July and October, shows the existence of an inherent regional density difference which favors greater Pontoporeia densities in the Outer region.

Noting the large degree of natural variability associated with benthic macroinvertebrates in Lake Michigan (Figs. 1-18), we are hesitant to attribute much importance to the observed significant differences. This is largely the case because all test statistics lie near the border between acceptance and rejection of $p = 0.05$ in the range $0.02 < P < 0.05$. We feel that probabilities in this range are subject to oscillation from significance to non-significance given their inherent variability.

ENTRAINMENT STUDIES

Technical Specifications require that the samples collected for fish egg and larvae entrainment be "inspected for entrainable benthos". Samples are collected from the intake and discharge forebays four times monthly during June, July and August and twice monthly during the remaining months of the year. Specifications require at least one sample be collected from the intake and discharge during each of three consecutive 8-hr periods. To better define the effects of entrainment, two replicates are taken at the intake forebay, and four consecutive collection periods are used corresponding to midnight-sunrise, sunrise-noon, noon-sunset and sunset-midnight.

It is of interest to determine if large quantities of the more important fish-food organisms are being entrained by the plant's cooling system, because it is assumed that entrained organisms are killed or are in some manner lost from the lake populations. In particular, the monitoring is designed to determine entrained densities of the larger benthic crustaceans which are of known food value to many fish species. Densities (number m^{-3}) of the four most commonly entrained crustacean genera are tabulated for each approximately quarter-day period using the discharge sample and mean of the two intake samples. No suitable definition of a significant impact has been developed for entrained benthos, but the data reported may permit future comparisons with similar studies and other sources of data.

Included in this report are the entrainment data for November through December 1981 and January through May 1982. Densities of the four groups of entrained crustaceans are listed in Tables 8-11.

The larger crustaceans such as *Pontoporeia hoyi* and *Mysis relicta* are night active with greatest densities being entrained between sunset and sunrise (Tables 8-9). Numbers of *Pontoporeia* entrained from January through May 1982 were very similar to those reported during the same months of previous years, excepting April 1982. *Pontoporeia* densities entrained during April 1982 (0.302 m^{-3} for intake only) were greater than usual for this month. However, most of those entrained were recently released young *Pontoporeia*. Because release of young *Pontoporeia* occurs in April and May, occasional large densities may be entrained, but this appears to present no immediate problem to the lake population of *Pontoporeia* at the levels routinely entrained by the Cook Plant.

Entrainment of *Mysis relicta* during the last two months of 1981 and the first five months of 1982 was negligible. This pattern most closely approximated those of 1975 and 1980. The greatest observed *M. relicta* density in 1982 samples was 0.126 m^{-3} (Table 9). It is not possible to assess the effects of entrainment on lake populations of *M. relicta*. Collection methodology for benthos does not adequately sample this pelagic species, and it is well known

TABLE 8. Benthos entrainment data, November-December 1981 and January-May 1982: *Pontoporeia hoyi*, number m^{-3}. I = intake, D = discharge, * = based on one intake sample, -- = missing data.

Sampling Date	SAMPLE PERIOD MIDN---->SUNR I	D	SUNR---->NOON I	D	NOON---->SUNS I	D	SUNS---->MIDN I	D
Nov. 9-10	0.078	0.013	0	0	0.020	0	0.127	0.034
Nov. 23-24	0	0	0	0	0	0	0.030	0
Dec. 7- 8	0.088	0.053	0.033	0.083	0.185	0.019	0	0.050
Dec. 15	0	0	0	0	0	0	--	0.014
Jan. 12-13	0.618	--	--	--	0.080	--	0.619	0.699
Jan. 20-21	0.324	0.094	0.179	--	0.026	--	0.309	--
Feb. 8-9	0	0.014	0.019	0	0.021	0	0.037	0.023
Feb. 23-24	0.009	0	0	0	0	0.027	0.018	0.029
Mar. 8-9	0.015	0	0	0.018	0	0	0	0
Mar. 24-25	0	0	0	0	0	0	0	0
Apr. 12-13	0	0	0	0	0	0	0	0
Apr. 26-27	0.711	0.451	0.279	0.079	0.191	0.124	1.229	0.609
May 10-11	0	0	0	0	0	0	0	0
May 25-26	0	0	0	0	0	0	0	0

TABLE 9. Benthos entrainment data, November-December 1981 and January-May 1982: Mysis relicta, number m^{-3}. I = intake, D = discharge, * = based on one intake sample, -- = missing data.

	SAMPLE PERIOD							
Sampling Date	MIDN---->SUNR		SUNR---->NOON		NOON---->SUNS		SUNS---->MIDN	
	I	D	I	D	I	D	I	D
Nov. 9-10	0.005	0.013	0	0	0	0	0	0
Nov. 23-24	0.057	0.070	0	0	0	0	0.057	0.069
Dec. 7- 8	0.033	0.013	0	0	0	0	0.025	0.017
Dec. 15	0.008	0.021	0	0	0	0	--	0.041
Jan. 12-13	0.013	--	--	--	0	--	0	0.017
Jan. 20-21	0	0	0	--	0	--	0.018	--
Feb. 8-9	0	0	0	0	0	0	0	0
Feb. 23-24	0.055	0.126	0	0	0.010	0.055	0.063	0.086
Mar. 8-9	0.015	0	0	0	0	0	0	0
Mar. 24-25	0.007	0	0	0	0	0	0.020	0
Apr. 12-13	0.008	0.028	0.017	0.029	0	0	0.011	0
Apr. 26-27	0.009	0	0	0.014	0.006	0	0.016	0
May 10-11	0	0	0	0	0	0	0	0
May 25-26	0	0	0	0	0	0	0	0

that the great bulk of the population occurs far offshore in deep water. Inspection of the November and December 1981 and the January through May 1982 *M. relicta* entrainment data revealed no unique trends compared with previous years.

Entrainment of *Gammarus* sp. during the last two months of 1981 and the first five months of 1982 followed a pattern similar to that for all previous years (Table 10). The majority of individuals were entrained from June through December, with few entrained prior to June. Overall, entrainment of *Gammarus* sp. during 1982 was very similar to that of previous years.

Entrainment of *Asellus* sp. always is sporadic but generally greater from June through October (Table 11). The large numbers of *Asellus* entrained in December 1981 were linked with storm activity. Wave action from the storm can strip individuals from the riprap or import them along shore from another locality.

Neither *Gammarus* sp. nor *Asellus* sp. are taxa of the open lake, and originally they were rare in the survey area. Present populations are associated with the riprap, and variation in entrainment reflects population dynamics occurring there but not on the lake bottom. While entrainment of *Pontoporeia hoyi*, *Mysis relicta*, *Gammarus* sp., and *Asellus* sp. shows year to year variation, numbers in general remain fairly consistent. Lake population trends as influenced by the entrainment for the latter three species cannot be predicted by our sampling regimen. Thus we simply present the data at this time.

TABLE 10. Benthos entrainment data, November-December 1981 and January-May 1982: Gammarus, number m^{-3}. I = intake, D = discharge, * = based on one intake sample,-- = missing data.

	SAMPLE PERIOD							
Sampling Date	MIDN---->SUNR		SUNR---->NOON		NOON---->SUNS		SUNS---->MIDN	
	I	D	I	D	I	D	I	D
Nov. 9-10	0.036	0	0.068	0.058	0	0.041	0.045	0
Nov. 23-24	0	0	0	0.017	0.063	0.038	0	0.014
Dec. 7- 8	0.051	0.040	0.130	0.206	0.013	0.097	0.029	0
Dec. 15	0.051	0.062	0	0	0	0.019	--	0
Jan. 12-13	0.039	--	--	--	0	--	0	0.050
Jan. 20-21	0	0.012	0	--	0	--	0	--
Feb. 8-9	0	0	0	0	0	0	0	0
Feb. 23-24	0.009	0	0	0.036	0	0	0	0
Mar. 8-9	0.007	0	0	0	0	0	0	0
Mar. 24-25	0	0	0	0	0	0	0	0
Apr. 12-13	0	0	0	0	0	0	0	0
Apr. 26-27	0	0	0	0	0	0.014	0.016	0
May 10-11	0	0	0	0	0	0	0	0
May 25-26	0	0	0	0	0.006	0	0	0

TABLE 11. Benthos entrainment data, November-December 1981 and January-May 1982: Asellus, number m^{-3}. I = intake, D = discharge, * = based on one intake sample,-- = missing data.

Sampling Date	SAMPLE PERIOD							
	MIDN---->SUNR		SUNR---->NOON		NOON---->SUNS		SUNS---->MIDN	
	I	D	I	D	I	D	I	D
Nov. 9-10	0	0	0	0	0	0	0.019	0
Nov. 23-24	0	0	0	0	0	0	0	0
Dec. 7- 8	0.062	0.053	0.325	0.413	0.169	0.156	0	0
Dec. 15	0.011	0	0.024	0.035	0	0	--	0
Jan. 12-13	0	--	--	--	0	--	0.035	0
Jan. 20-21	0	0	0	--	0	--	0	--
Feb. 8-9	0	0	0	0	0	0	0	0
Feb. 23-24	0 9	0	0	0	0	0	0	0
Mar. 8-9	0	0	0	0	0	0	0	0
Mar. 24-25	0	0	0	0	0	0	0	0
Apr. 12-13	0	0	0	0	0	0	0	0
Apr. 26-27	0	0.017	0	0	0	0	1	0
May 10-11	0	0	0	0	0	0	0	0
May 25-26	0	0	0	0	0	0	0	0

IMPINGEMENT STUDIES

Although impingement studies of benthic macroinvertebrates are not required by Technical Specifications, we have been maintaining records of the species, numbers and weights of crayfish (Astacidae) collected on travelling screens at the Cook Plant. Other benthic macroinvertebrates should pass through the screens by virtue of their small size. These studies are an adjunct to collection of data on fish impingement. As stated in previous reports, all evidence indicates that impinged crayfish originate from colonies recently established on or near the riprap apron around the discharge and intake structures which were installed to protect the bottom from scour. From fish trawling and diving records, crayfish populations appear to be very small outside the immediate vicinity of the riprap, particularly on smooth or sandy bottoms. Consequently, impingement of seemingly large quantities of crayfish has not been considered a negative impact on the ecology of the lake.

November and December 1981 data, not available for the 1981 report, have been included here (Table 12). Additional samples collected during October 1981, not previously available, also are included. No 1982 data were collected for impinged crayfish. All specimens recovered since 1978 have been Orconectes propinquus with the exception of a single Cambarus diogenes. Species other than O. propinquus are rare and may represent occasional immigrants from nearby ponds and streams (e.g., C. diogenes and Orconectes rusticus).

Because of collection methods which are not wholly reliable and from partial decomposition of some specimens, total impingement is, at best, a rough estimate. Numbers and weights from samples (column A, Table 12) are multiplied by the number of days in each semi-monthly period, then divided by the number of

TABLE 12. Numbers and weights of crayfish (*Orconectes propinquus*) impinged on the travelling screens of the Donald C. Cook Nuclear Plant in 1981. The number of 24-hour samples processed for crayfish from each period is given in parentheses. A = sampled quantities. B = estimated totals.

INCLUSIVE DATES		A		B	
		NUMBER	WEIGHT (kg)	NUMBER	WEIGHT (kg)
January	1-16 (4)	32	0.23	128	0.94
	17-31 (4)	30	0.17	113	0.64
February	1-14 (2)	13	0.14	91	0.96
	15-28 (2)	11	0.09	77	0.62
March	1-16 (5)	92	0.71	294	2.26
	17-31 (4)	23	0.20	86	0.77
April	1-15 (3)	109	0.93	545	4.66
	16-30 (4)	9	0.06	34	0.24
May	1-16 (0)	0	0	0	0
	17-31 (0)	0	0	0	0
June	1-15 (1)	14	0.08	210	1.25
	16-30 (1)	3	0.01	45	0.21
July	1-16 (3)	58	0.40	309	2.11
	17-31 (4)	123	0.89	461	3.35
August	1-16 (4)	176	1.37	704	5.35
	17-31 (3)	59	1.41	295	2.07
September	1-15 (2)	17	0.12	128	0.89
	16-30 (3)	17	0.09	85	0.46
October	1-16 (7)	11	0.07	25	0.16
	17-31 (1)	1	0.01	15	0.06
November	1-15 (1)	8	0.05	120	0.79
	16-30 (3)	7	0.06	35	0.28
December	1-16 (3)	7	0.04	37	0.21
	17-31 (3)	8	0.05	40	0.25
	TOTAL			3,877	28.53

24-hr samples for which crayfish were processed in the corresponding period (column B, Tables 12).

Inclusion of the November and December data for 1981 brings that year's impingement totals to 3877 specimens and 28.53 kg (Table 12). This is less than the 4575 specimens and 33.96 kg projected for 1981 given in the last report.

Through the first five years that the plant has been operational, there was a general decrease in numbers and total mass of impinged crayfish: 1975 = 90 kg, 1976 = 92 kg, 1977 = 70 kg, 1978 = 33 kg, and 1979 = 17 kg. Following a marked increase during 1980 (48 kg), the total annual weight impinged again has declined in 1981 to 29 kg. The average weight per crayfish impinged varies annually, ranging 5.5-7.4 gm. Average annual weight per crayfish was lowest in 1978 and highest in 1981. We do not know the age structure, density, or seasonal and yearly fluctuations of the crayfish populations on the riprap; therefore, it is not possible to determine if impingement is a factor in apparent population changes.

CORBICULA STUDIES

Corbicula fluminea (Muller) (Corbicula manilensis) was introduced into the Columbia River of Washington State most likely in the late 1930s and by 1960 had spread through the Mississippi River drainage (for review of Corbicula biology and distribution see Sinclair and Isom 1970 Corbicula was not recorded from the St. Lawrence drainage or any of the Laurentian Great Lakes until 1980 when a few specimens were taken from Lake Erie (Clarke 1981). Its great reproductive rate, method of attachment, and possible impact on service water systems are of concern to power plants. Corbicula attaches to the power plant tubes not as veligers or pediveligers (non-motile, planktonic larvae) as originally thought but as small clams. The small clams attach to the surface of the tubes even in extremely fast flow situations; and, as densities increase, discharge through the tubes is reduced. Complete blockage may occur. It is speculated that Corbicula presently could not survive in the nearshore areas of Lake Erie or Michigan because of winter freezing and ice scour. However, if specimens did exist in deeper waters or nearby rivers, they most likely would survive and eventually could cause damage to water intakes.

The reproductive cycle is triggered by temperatures near 10°C , and, depending on the annual temperature cycle, more than one generation may be produced per year. At the 4°C year around bottom temperatures of Lake Michigan, Corbicula should not survive; or, if introduced larvae have developed into clams, they should not be capable of reproduction. It cannot be discounted that over several generations, a population may develop that will be capable of existence and reproduction in the Great Lakes. Further, it would not be unlikely for thermal effluents from power plants located along the Great Lakes to provide year around temperatures that would permit establishment of a Corbicula population. If either of the latter does occur, then problems may exist.

The lake area around the D. C. Cook Plant needs to be monitored (possibly several times each year) for Corbicula so that appropriate control methods will be implemented if a population is noted. Under conditions favorable for Corbicula, populations can become quite dense in a fairly short period of time (possibly less than one year, White 1979)

No Corbicula has been detected in the regular benthic surveys from 1971-1982. As this portion of the biological studies at the D. C. Cook Plant was discontinued in May 1982, we have begun a special monitoring program specifically designed to detect Corbicula. Monitoring consists of two parts: 1) microscopic analysis of forebay entrainment samples for the veliger, and water borne clams, and 2) analysis of shell collections made along the beach in the vicinity of the plant. Detection of Corbicula as a clam is not difficult but caution must be taken to examine each shell as this species closely resembles the related Sphaeriidae which naturally occur in the lake.

Because it is uncertain when and how many times Corbicula might produce veligers, entrainment was examined from three dates, 25-26 May, 18-19 August, and 5-6 October. Additionally, both the intake and discharge samples were examined from each six hour period (see Entrainment section of this report). The planktonic veliger ranges in size from 0.20-0.22 mm. All materials collected were scanned at 40-100X.

No veligers, pediveligers or small clams were detected in any of the entrainment samples.

Beach walks were conducted on 21 September and 26 October 1982. Two areas were examined. The first was directly in front of the D. C. Cook plant to approximately 300 m south. The second area was located directly south of the St. Joseph River mouth pier and contains about 150 m of beach. All shells in or just above the wave zone were collected and returned to the laboratory.

More than 400 shells and shell fragments were examined for both sites. Only Sphaeriidae and a few small Unionidae were found. Both taxa are native and are not involved in biofouling problems. No Corbicula were collected, and, to date, there have been no validated records of Corbicula in Lake Michigan.

CONCLUSIONS

Lake Surveys

Of the 18 statistical tests performed on species distributions, only the difference between Inner and Outer densities of Pontoporeia hoyi in Zone 2 had a t-test probability less than 0.05 but greater than 0.01. While not ignoring that the result of the test was significant, interpretive caution should be applied given the inherent variability associated with Lake Michigan benthos. Pontoporeia in the Outer region of Zone 2 consistently has occurred in greater densities than in the Inner region. Annual fluctuations in population densities make tentative the acceptance of significant density differences at probabilities greater than the 0.01 level. If test statistics were supporting probabilities less than 0.01, it would likely negate the effect of annual population fluctuations and would lead to a firm conclusion about differences observed.

Entrainment Studies

From January through May 1982, entrainment of Pontoporeia hoyi was very similar to that observed for previous years. Average annual density Mysis relicta was less than several other years and the seasonal entrainment pattern was most similar to that observed during 1975 and 1980. There were no unique distribution patterns or abundances attributable to 1982 entrained Mysis. Entrainment densities of Gammarus sp. during 1982 were very similar to the low densities observed during the same months of previous years. Generally, greatest numbers of entrained Gammarus sp. have been observed during the latter half of the year. Asellus sp. remained rare in entrainment samples during 1982. Except for the large number entrained during December 1981, which was attributable to storm activity, entrained Asellus densities were either zero or very low on a monthly or yearly bases. No effect of plant operation has been detected on lake populations of Pontoporeia. The reasons behind yearly fluctuations of Mysis, Gammarus sp., and Asellus sp. are not known. Our collection methods do not adequately sample their lake populations.

Impingement Studies

Projected impingement of the crayfish Orconectes propinquus for 1981 (29 kg) was most similar to that of 1978 (33 kg) but was lower than that observed in 1980 (48 kg). However, the average weight per individual (7.4 gm) was the highest observed over the years 1975-1980. Since we presently have no way of examining lake populations, it is not possible to determine if the changes are significant or if there is an effect of plant operation.

Corbicula Studies

Entrainment samples were microscopically examined from May, August, and October for the veliger larvae and small adults of Corbicula. No larvae have been detected to date. There were no Corbicula adults collected in the April Benthos survey, and two beach walks (September and October) produced no empty shells. To our best knowledge, Corbicula is neither incidental nor established in Lake Michigan near the plant.

LITERATURE CITED

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APPENDIX B-4

PERIPHYTON COLLECTED AT
THE DONALD C. COOK NUCLEAR PLANT

Periphyton

INTRODUCTION

In accordance with the Technical Specifications, periphyton are collected from the Cook Plant underwater installations by Scuba divers in each month from April through October. The preserved collections are examined in wet-mount for species identification; the species list thus accumulated is taken to be the periphyton community on the underwater installations. These species are watched for in six replicate intake entrainment samples taken each month, as a measure of the periphyton community during the months when diving is not feasible.

The Technical Specifications provide that diving operations shall be dependent upon favorable weather conditions. Periphyton samples could not be taken due to bad weather in April and September 1975, October 1976, and October 1977. Samples of April 1977 were lost in the capsizing of a small boat; samples of May 1977 were accidentally omitted.

Periphyton require attachment to solid substrata during all or part of their life cycles. The plant's offshore riprap bed and submerged intake and discharge structures provide solid substrata in an area naturally devoid of them, and becoming inhabited by periphyton and animal organisms, they constitute a small ecosystem atypical of the surrounding area.

The discharge structures function in, and the intake structures and riprap are reasonably near, the discharge of the plant's waste heat. The organisms supported by these installations are, then, presumably subject to temperature perturbations due to exposure to the plant's discharged heat. Other things being equal, study of the abundance and species composition of the periphyton over time becomes a means of telling whether plant operation has affected this resident (but not indigenous) population.

Newly placed underwater installations undergo periods of surface modifications (rusting, slime formation) before they become colonized by periphyton and subsequently by animal organisms. Our diving records show that 1974 was the first field season when the Cook Plant underwater installations were complete; 1974 was the last preoperational year; and at that time the installations were being colonized rapidly by periphyton, snails, bryozoa, freshwater sponges, and crayfish, but the numbers of periphyte taxa in June and October were low (8 green algae, 1 blue-green, and 30 diatoms). The one preoperational year was insufficient for the installations to become fully colonized; additional colonization and ecological succession changes since 1974 have rendered pre- vs post-operational comparisons of periphyton abundances and species compositions invalid.

Periphyton samples are collected underwater by scraping the substrate with a putty knife and gently transferring the scrapings into a widemouth plastic bottle. After surfacing, the diver disperses the scrapings by gentle stirring and preserves the sample with 5% buffered formalin.

In the laboratory a subsample from each sample of scrapings is removed for wet-mounting in water for species identification at 400-600X on a Leitz-Wetzlar Ortholux microscope. Species identified in the wet mounts of the diver-collected samples taken during April-October become the yearly list of periphyton taxa.

Entrainment sampling is carried out in the intake forebay of the plant screenhouse. Duplicate samples are pumped by nominal 80 gpm diaphragm pumps from 18 feet below the water surface at each of morning twilight, noon, and evening twilight. Samples are one liter each, taken in plastic bottles, preserved with Lugol's fixative, and taken to the laboratory where a permanent slide is made from each sample by the settle-freeze method used in our lake phytoplankton studies. Each sample is settled in a one liter graduated cylinder for two days, 900 mL of supernatant are then siphoned off and the remaining 100 mL swirled and gently shaken to resuspend the settled material. Eighteen mL of the suspension is pipetted to a plexiglass chamber clamped to a microscope slide and allowed two days of secondary settling. Leakage of water at the chamber bottom is prevented by a light ring of stopcock grease. Groups of chambers and slides rest on an aluminum plate during settling. After the second day, freezing is done by setting the plate on a flat block of dry ice until the bottom 1.5 mm is frozen; the supernatant is then decanted and the chamber removed, leaving a wafer of ice on the slide. The slide is placed for two days in an anhydrous alcohol vapor chamber for dehydration, and then for two days in a toluene vapor chamber to prepare for the toluene-based Permount mounting medium and a cover slip. Newly prepared slides are allowed to dry at least two days before identifications and counting are carried out under oil immersion at 1000X. A horizontal and a vertical row across each slide are counted and identified.

The author makes no apology for departing from scientific practice in the presentation of scientific names in the tables; to require the typist to switch to italics for each of the great mass of scientific names was adjudged an avoidable waste of time.

RESULTS AND DISCUSSIONS

Table 1 lists the taxa that were collected by our divers in periphyton samples from the Cook Plant underwater installations during the diving season of 1980 and gives the abundances of these taxa in cells per mL in intake entrainment samples each month.

Ninety-seven periphyte taxa were diver-collected in each of 1975 and 1977, 67 were taken in 1976, 117 in 1978, 131 in 1979, and 141 were taken in 1980. These numbers are substantially higher than the 39 that were collected in preoperational 1974. They indicate that the underwater installations were not fully colonized during 1974, and that valid pre- vs post-operational comparisons cannot be made for Cook Plant periphyton.

The diver-collected periphyton show increasing numbers of taxa (diversity) and decreasing numbers of dominant forms. In 1977, eight of 97 taxa occurred in all the divers' samples; in 1978, three of 117 taxa were present in all their samples; in 1979, no taxon was present in all the samples; and in 1980, only one taxon was present in all their samples. These are expectable characteristics of ecological succession.

In the periphyton samples collected from the underwater installations, there have been (of the 1980 taxa list):

39 taxa that have been present in each of the years 1975-1980 inclusive,
13 were present in five of the six years,
11 were present in four of the six years,
15 were present in three of the six years,
25 were present in two of the six years, and
38 were present in 1980 only.

Table 1. Taxa taken in diver-collected periphyton samples, and their mean abundances in cells/mL in monthly intake entrainment samples during 1980. Abundance values are the means of six replicate samples. Abundances have been computed as cells per liter and divided by 1000.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BACILLARIOPHYTA												
Achnanthes sp.	1.1	0	0	0	0	0	0	0	0.6	0	0.6	0
Amphipleura pellucida	0.6	0	0	0.3	1.1	0	0	0	0	6.6	1.1	0.3
Amphora calumetica	0	0	0	0	0	0	0.1	0	0	0.6	0.3	0
A. sp	8.3	0.1	0	0	0	1.7	0	0.7	0.8	1.1	1.1	4.4
Asterionella formosa	21.8	12.7	20.3	183.3	1345.3	452.1	65.1	1.7	2.2	68.5	384.9	111.1
Caloneis amphisbaena	0	0	0	0	0	0	0	0	0	0	0	0
Centrics (undetermined)	39.5	35.8	91.6	8.9	335.5	145.4	25.0	83.6	133.8	72.4	107.8	129.4
Cocconeis pediculis	0	0	0	0	0	0	0	0	0	0	0	0
C. placentula	0	0	0	0	0	0	0	0	0	0	0	0
C. placentula v. euglypta	0	0	0	0	0	0	0	0	0	0.6	0	0.6
C. sp	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella comensis	18.8	5.0	1.1	1.7	3.3	2.8	75.0	50.2	444.5	423.4	88.2	33.2
C. comta	3.3	0.1	0	0	0	0	6.2	1.3	2.5	10.5	8.0	0.8
C. kuetzingiana	1.9	0	0	0	5.5	0	1.1	2.4	3.9	7.2	13.8	1.1
C. meneghiniana	0	0	0	0	24.3	10.5	0	7.9	468.1	42.6	30.7	27.9
C. ocellata	5.5	3.0	0.8	0.1	0	0	0.1	0.4	1.4	0.6	0.8	1.9
C. sp.	6.6	4.2	4.8	0.3	35.9	1.7	15.2	24.3	78.5	42.6	48.7	47.0
Cymatopleura elliptica	0	0	0	0	0	0	0	0	0	0	0	0
C. solea	0	0	0.3	0	0	1.1	0	0	0	0	1.1	0.6
Cymbella cistula	0	0	0	0	0	0	0	0	0	0	0	0
C. microcephala	0	0	0	0	0	0	0	0	0	0	0	0
C. minuta	0	0	0	0	0.6	1.1	0.3	0	0	0	0.6	0.6
C. minuta f. latens	0	0	0	0	0	0	0	0	0	0.6	0	0
C. prostrata	0	0	0	0	0	0	0	0	0	0	0	0
C. prostrata v. auerswaldii	0	0	0	0	0	0	0	0	0	0	0	0
C. sinuata	0	0	0	0	0	0	0	0	0	0	0	0
C. tumida	0	0	0	0	0	0	0	0	0	0	0	0
C. sp.	0	0	0	0	1.1	0	0	0	0	0	0	0
Diatoma tenue	0	0	0	0	5.0	1.1	0.4	0.3	0	0	0	0.6
D. tenue v. elongatum	10.2	4.3	2.7	5.3	207.8	118.3	0	0.1	0	1.1	3.3	5.0
D. vulgare	0	0	0	0.6	0	0	0	0	0	0	0	0
Diploneis sp.	0	0	0	0	0	0	0	0	0	0	0	0
Entomoneis ornata	0	0	0	0.3	1.1	1.7	0	0	0	1.1	0.3	0
Fragilaria capucina	0	0	0	14.1	8.9	86.2	0	0	11.9	0	0.8	0
F. construens	0	0	0	0.3	0	2.8	0.3	0.1	2.5	12.7	21.6	17.4
F. crotonensis	439.4	81.3	82.9	78.9	458.7	567.1	182.1	20.7	89.0	313.4	385.8	108.6
F. intermedia v. fallax	12.7	6.6	7.3	25.7	32.6	69.1	0	0	16.0	21.0	19.9	1.1
F. pinnata	7.7	0	1.1	0.6	3.3	5.5	1.8	5.8	24.6	17.7	43.1	32.9
F. spinosa	0	0	0	0	0	0	0	0	0	0	0	0
F. vaucheriae	0	0	0.3	0	0	1.1	0.9	0.3	1.1	2.8	0.6	1.7
F. sp.	60.3	7.2	0.4	5.4	18.8	1.1	0.3	0	1.1	4.4	8.6	9.4
Gomphonema olivaceum	0	0	0.3	0	0	0.6	0	0	0	0	0	0.6
G. spp.	0	0	0	0	0	0	0.6	0	0	0	1.1	0.6
Gyrosigma sp.	0	0	0	0	0	0	0	0	0	0	0	0
Melosira granulata	1.1	4.7	9.4	11.6	1182.8	1134.1	3.0	284.6	636.2	752.8	51.7	169.7
M. islandica	5.5	11.6	21.3	78.8	149.8	23.2	0.6	0.6	0	0	1.1	0.6
M. italica	6.9	6.1	24.9	33.2	42.6	30.4	0	0.6	9.7	4.4	0	1.7
M. varians	0	0	0	0.1	0	0	0	0	0	1.7	3.0	0.6
M. spp.	0	0.3	2.5	0	38.7	2.8	0.6	0.8	7.5	3.9	1.1	0

Table 1 continued. BACILLARIOPHYTA continued.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Meridion circulare	0	0	0	0	0	0	0	0	0	0	0	0
Navicula aurora	0	0	0	0	0	0	0	0	0	0	0	0
N. capitata v. luneburgensis	0	0	0	0.1	0	0	0.3	0.3	0	0	0.6	0.8
N. cryptocephala	0	0.1	0	0	1.1	0	0.3	0.3	6.9	0	2.8	1.1
N. decussis	0	0	0	0	0	0	0.6	0.4	0.3	0.6	0	0.6
N. gregaria	0	0.1	0	0.3	1.1	2.8	0.1	0	0	0.6	0	1.7
N. menisculus v. upsaliensis	0.6	0	0	0	0	0	0	0.1	0.3	0	1.7	1.1
N. radiosa	0	0	0	0	0	0	0.3	0	2.2	0	1.1	1.1
N. tripunctata	0	0	0.3	0.1	0	1.1	0.3	0.4	0.3	0	0.6	0.8
N. viridula	0	0	0	0	0	0	0	0	0	0	0	0
N. spp.	0.6	0	0	0.4	3.3	5.5	1.7	1.0	4.2	2.2	0	5.8
Neidium sp.	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia acicularioides	4.1	0.6	0.3	0.3	37.6	74.1	0.3	0.5	5.3	9.9	6.1	4.1
N. acicularis	0.8	0.3	0	0	0	3.3	0.3	0	0	0	0.6	0.6
N. capitellata	0	0	0	0	0	0.6	0	0	5.3	1.7	0	0
N. dissipata	0	0	0	0.1	1.1	0	0.8	0.7	0.8	2.8	0	1.1
N. lauenburgiana	0.6	0	4.1	3.2	3.3	3.3	0	0.7	1.4	0	1.7	1.9
N. palea	0.6	0	0	0	0	7.7	0.7	2.4	4.4	4.4	0.8	1.1
N. recta	0	0	0	0	2.2	0	0	0	0	0	0	0
N. sp.	11.3	1.6	5.5	6.6	43.1	87.3	4.0	5.7	32.6	53.6	32.3	23.8
Pennates (undetermined)	5.3	1.0	2.9	1.4	44.8	35.9	2.1	2.1	6.6	10.5	18.2	11.3
Plagiotropis lepidoptera v. proboscidea	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia eriensis	36.5	16.9	18.5	4.9	20.5	34.3	0	0	3.1	9.4	0.6	0.8
R. gracilis	1.9	8.7	16.6	41.5	374.2	281.3	0.3	0	2.5	2.2	0.6	0.5
Rhoicosphenia curvata	0	0	0	0	0	0	0	0	0	0	0	0.8
Stephanodiscus alpinus	25.1	5.1	17.5	22.0	19.4	29.3	1.5	1.5	2.2	32.6	9.4	19.9
S. astraea	0	0	0	0	0	0	0	0	0	0	0	0
S. binderanus	0	0.4	0	1.4	0	0	0	0	0	0	0	0
S. hantzschii	15.5	19.8	61.0	37.5	0.6	2.2	0.3	0.1	1.7	0	0	32.6
S. minutus	63.6	29.2	29.0	53.1	69.6	38.1	1.1	2.2	1.4	31.5	2.5	79.0
S. subtilis	24.0	2.5	4.7	2.8	41.5	11.1	0.7	5.4	10.0	14.9	37.3	8.6
S. tenuis	4.6	0.7	0	7.3	43.7	11.1	0	0.8	4.7	1.1	77.1	9.4
S. transilvanicus	1.7	0.7	0	4.0	6.1	0	0.3	0	0	0.6	0	0.3
S. spp.	42.0	54.6	113.3	31.2	43.7	22.7	0.3	2.9	3.9	7.7	12.4	21.5
Surirella angusta	0.3	0	0.6	0.3	0	1.1	0.6	0	0	2.2	0.3	0.6
S. ovata	0	0	0	0	0	0	0	0	0	1.1	0	0
Synedra filiformis	10.8	5.8	12.0	5.5	509.6	126.0	1.4	4.3	4.7	7.7	8.3	1.4
S. ostenfeldii	7.7	8.1	7.6	17.6	173.0	178.5	0.3	2.8	3.3	1.1	1.1	1.9
S. ulna	0	0	0	0	0.6	0	0	0	0	0	0	0
S. ulna v. chaseana	0.6	1.1	3.1	2.2	52.0	35.9	0	0	0	1.1	0.3	0
S. sp.	1.1	0.8	0.3	0.3	7.7	0	0	0	0	5.5	0.3	0.6
Tabellaria fenestrata v. intermedia	131.0	25.3	48.4	23.6	175.7	157.0	13.1	2.8	103.9	546.1	522.8	415.9
CHLOROPHYTA												
Ankistrodesmus gracilis	3.3	31.0	40.2	17.4	18.2	2.2	0	3.0	6.6	1.1	2.2	0.6
A. sp.	0	2.2	0	0.8	0	2.2	4.7	1.4	8.9	2.8	1.9	1.1
Chara sp.	0	0	0	0	0	0	0	0	0	0	0	0
Cladophora sp.	0	0	0	0	0	0	0	0	0	0	0	0
Coelastrum cambricum	0	0	0	0	0	0	0	9.7	0	0	0	0
C. sp.	0	0	0	0	0	0	0	0	0	6.1	0	0
Cosmarium sp.	0	0	0	0	0	0	1.9	0	0	0	0.6	0

Table 1 continued. CHLOROPHYTA continued.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crucigenia irregularis	0	0	0	0	0	0	0	0	0	0	0	0
C. quadrata	8.9	8.9	4.4	5.5	13.3	6.6	4.3	38.7	27.6	0	2.2	11.1
Dictyosphaerium sp.	0	0	0	0	0	0	0	0	0	0	0	0
Gloeocystis planctonica	6.1	5.7	39.5	16.3	0	10.0	63.8	64.2	18.8	15.5	8.9	0
G. sp.	2.2	0	0	1.1	0	0	32.6	5.5	0	0	0	0
Golenkinia sp.	0	0	0	0	0	0	0	0	0.6	0	0	0
Green cells (undetermined)	18.5	5.4	8.0	8.8	3.3	23.2	152.4	145.0	150.4	39.2	119.7	45.3
Green coccoids (undetermined)	6.6	10.9	17.1	24.7	11.1	23.8	41.5	146.5	144.3	24.3	16.6	1.4
Green colonies (undetermined)	110.3	3.9	0	1.1	27.6	28.8	54.2	162.6	368.9	101.2	83.7	39.8
Kirchneriella sp.	0	0	0	0	2.2	1.1	0.3	0.1	3.0	0	1.4	0
Micractinium pusillum	0	0	0	0	0	0	0	0	0	0	0	0
Mougeotia sp.	3.3	0	0.6	0	0	0	0	1.4	0	0	0	1.1
Oocystis sp.	3.3	2.8	0	2.2	0	0	284.0	11.7	3.3	4.4	13.8	0
Pediastrum biradiatum	0	0	0	0	0	0	0	1.0	0	0	22.1	0
P. boryanum	0	0	0	0	0	0	0	5.3	7.2	8.9	0	0
P. duplex	0	0	0	0	0	0	0	1.9	20.7	0	0	0
P. simplex	0	0	0	0	0	0	2.2	0.4	8.0	0	0	0
P. sp.	0	0	0	0	10.0	0	0	1.4	4.4	13.8	0	0
Scenedesmus acuminatus	0	0	0	0.6	0	4.4	0	14.2	23.5	2.2	5.5	0
S. acuminatus f. maximus	0	0	0	0	0	0	0	0	0	0	0	0
S. armatus v. boglariensis	0	0	0	0	0	0	0	0	0	0	0	0
S. denticulatus	0	0	0	0	0	0	0	7.9	12.2	2.2	0	0
S. dimorphus	0	0	0	0	0	0	0	0	0	0	0	0
S. quadricauda	0	0	0	0	2.2	6.6	0	16.0	16.3	5.5	1.1	2.2
S. quadricauda v. longispina	0	0	0	1.1	0	9.4	5.5	12.6	11.6	2.2	2.2	1.1
S. spinosus	0	0	0	0	8.8	5.5	3.3	6.1	19.3	1.1	1.1	0
S. spp.	5.0	7.1	22.5	13.0	32.1	85.1	22.4	78.5	121.6	33.7	13.8	23.5
Spirogyra sp.	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum sp.	0	0	0	0	0	0	0	0	0	0	0.3	0
Tetraedron caudatum	0	0	0	0	0	0	0	1.4	2.2	0	0	0.6
CHRYSOPHYTA												
Dinobryon divergens	0	0.1	1.7	0	0	0	68.8	0.6	6.6	23.2	7.5	0
CYANOPHYTA												
Agmenellum quadruplicatum	0	0	0	0	0	0	0	0	66.9	35.4	0	0
Anabaena flos-aquae	0	0	0	0	32.1	0	186.0	63.7	13.5	3.3	30.2	13.8
Anacystis cyanea	0	0	0	0	0	0	0	15.3	94.0	0	0	0
A. incerta	179.6	65.0	81.5	179.7	0	126.0	144.3	1304.8	1078.0	839.0	1139.7	1036.3
A. thermalis	18.3	5.4	1.9	2.5	0	0	16.1	152.3	35.4	218.3	270.8	197.6
Blue-green filament (undetermined)	0	0.1	0	0	0	0	0	0	0	0	0	0
Chamaesiphon sp.	0	0	0	0	0	0	0	0	0	0	0	0
Gomphosphaeria lacustris	34.6	28.3	96.7	0	0	165.8	166.4	528.1	315.1	519.5	118.3	304.0
Oscillatoria sp.	12.7	2.9	5.9	0.1	24.3	19.9	0	1.7	8.0	5.0	3.9	4.1
Schizothrix calcicola	0.8	0.8	0	3.2	35.4	38.1	0	0	0.8	0	0.3	0
S. sp.	0	0	3.6	0	0	0	0	0	0	0	0	0
PYRROPHYTA												
Peridinium sp.	0	0	0	0	0	0	0	0	0	0	0	0
RHODOPHYTA												
Asterocystis sp.	0	0	0	0	0	0	0	0	0	0	0	0

Successive comparisons of yearly periphyte lists to a cumulative master list show that:

20 taxa were new in 1975,
1 taxon was new in 1976,
34 taxa were new in 1977,
43 taxa were new in 1978,
45 taxa were new in 1979, and
38 taxa were new in 1980.

These figures bespeak the presence in each year of substantial numbers of rare taxa on the underwater installations; that some of them have become established is indicated by the above numbers of taxa that have been present in two, three, four, and five years of the six years' study.

On the basis of their frequencies of occurrence in the diver-collected periphyton samples, the dominant periphytes on the underwater installations have been:

1975

Oscillatoria sp. (blue-green)
Cladophora sp. (green)
Diatoms of the genera *Cymbella*, *Diatoma*, *Fragilaria*, *Navicula*, *Nitzschia*, *Stephanodiscus*, *Synedra*, and *Tabellaria*

1976

Oscillatoria sp.
Cladophora sp.
Diatoms of the genera *Cymbella*, *Navicula*, and *Tabellaria*

1977

Phormidium sp. (blue-green)
Cladophora sp.
Dinobryon spp. (golden brown)
Diatoms of the genera *Asterionella*, *Amphora*, *Cymbella*, *Fragilaria*, *Melosira*, *Navicula*, *Nitzschia*, *Stephanodiscus*, *Synedra*, and *Tabellaria*.

1978

Oscillatoria sp.
Cladophora sp.
Diatoms of the genera Asterionella, Fragilaria, Melosira,
Navicula, Nitzschia, Stephanodiscus, and
Tabellaria

1979

Cladophora sp.
Oscillatoria sp.
Diatoms of the genera Asterionella, Cymbella, Fragilaria,
Melosira, Navicula, Nitzschia, Stephanodiscus,
Synedra, and Tabellaria.

1980

Cladophora sp.
Oscillatoria sp.
Scenedesmus quadricauda (green)
Diatoms of the genera Amphora, Fragilaria, Melosira,
Navicula, Nitzschia, and Stephanodiscus.

It is worthy of note that 1980 was the second year in which Cladophora sp. and Oscillatoria sp. were not taken by the divers in each month of the diving season:

Cladophora, not taken in May or September 1979
not taken in April, May, or August 1980

Oscillatoria, not taken in April, August, or September 1979
not taken in July or August 1980.

As in 1979, the dominant diatom genera of 1980 were diver-collected in each month of the diving season, but only one was present in all their samples.

In the combined years 1975 and 1976 when the periphyte lists were fairly similar, intake entrainment sampling captured 89% of the taxa resident on the underwater structures. In 1977, intake entrainment took 74% of the taxa resident in that year. Intake entrainment in 1978 captured 81% of that year's resident taxa. In 1979 intake entrainment took 79% of the resident taxa of that year. Intake entrainment in 1980 caught 78% of that year's resident taxa. Intake entrainment sampling is considered an adequate means of monitoring the periphyton community during the months when diving is not feasible.

CONCLUSIONS

The Cook Plant's underwater intake and discharge structures plus the associated riprap field constitute an artifical reef, providing shelter and solid substrates in a region naturally devoid of them.

After their completions, the underwater installations underwent a period of modifications of surfaces followed by colonization by periphytic algal and animal species. The single pre-operational year, 1974, was insufficient for the installations to become fully colonized. Valid pre- vs post-operational comparisons of periphyton abundances and constituent taxa cannot be made because of additional colonization and changes due to natural ecological succession which took place after 1974.

This study uses diver-collected periphyton samples from the underwater installations to determine the taxa living there, and it examines intake entrainment samples for these taxa as means of assessing the efficiency of entrainment as a monitor of the offshore periphyton community.

The numbers of periphyte taxa taken by the divers have been: 1975, 97; 1976, 67; 1977, 97; 1978, 117; 1979, 131; and 1980, 141. Of the 1980 taxa list, there have been 39 that were present in each of the six years; 14 that were present in five of the six; 11 that were present in four of the six; 15 that were present in three of the six; 25 that were present in two of the six; and 38 that were present in 1980 only.

Dominant periphyte taxa in 1980 were: the green, Cladophora sp., the blue-green, Oscillatoria sp., the green, Scenedesmus quadricauda, and diatoms of the genera Amphora, Fragilaria, Melosira, Navicula, Nitzschia, and Stephanodiscus. Nineteen seventy nine and 1980 were the first two years in which the divers did not collect Cladophora and Oscillatoria in each month of the diving season; the diatom genera were diver-collected in each month of the season, but only one, Navicula tripunctata, was present in all their samples. Increased numbers of taxa and decreased abundances are characteristic of the post-pioneer stages of ecological succession.

With capture rates in intake entrainment sampling ranging from 74% to 89% of the resident offshore taxa, intake entrainment sampling is considered adequate to monitor the periphyton community in months when diving is not possible.

The changes observed in the periphyton community are consistent with advancing stages of "artificial reef" ecological succession, not with any effect of Cook Plant operation.

APPENDIX B-5

FISHERIES STUDIES AT THE DONALD C. COOK NUCLEAR PLANT

FISH

INTRODUCTION

In this section, the 1973 through 1982 fishery data collected are examined. Due to varying degrees of analysis, the actual time period covered varies by area of research. Most effort is devoted to compiling and analyzing data not presented in past Environmental Operating Reports. The extensive data analyses done for past reports were not repeated, but will be referenced and integrated with 1982 data. Sampling after May 1982 was reduced by not trawling at station R (6 m, north Cook) or gillnetting at stations R and Q (9 m, north Cook) or sampling for larvae at stations E (21 m, south Cook) and W (21 m, Warren Dunes); other reductions included no open water larvae tows in September and no trawling in November. Fish species are identified by common names according to Robbins *et al*. (1980).

Field data for three larval fish species were analyzed *via* ANOVA in an attempt to document any potential plant effects. Preoperational data (1973-1974) were compared with operational data (1975-1981). The first year of full operation of both units was 1979.

Entrainment data are presented for 1981. Numbers were extrapolated based on densities observed in entrainment samples for each period sampled (dawn, day, dusk, night) and reported condenser flow through the plant.

Visual inspections of the intake forebay continued through 1982. Fish were seldom observed, except during summer when either one or both units were not operating.

Data on 1982 field catches of abundant juvenile and adult fish were analyzed and compared with 1973-1981 data. ANOVA results from 1973-1981 data were used to determine if variation in fish abundance and distribution was the result of plant operation. Abundance and distribution data on species commonly caught in 1982 and in previous years were also examined.

Only one unit was operating for extended periods in spring and summer 1982, which probably contributed to the lower number of fish impinged in 1982 compared with 1980 and 1981. However, the 886,183 fish impinged through August 1982 was still high relative to impingement rates prior to 1980, an increase we attribute to two-unit operation.

FISH LARVAE - FIELD

INTRODUCTION

Spatial and temporal distributions of larval fish were examined to determine if plant-related differences in densities of larvae between the Cook Plant study area and the Warren Dunes reference area were evident. Analyses in this section of the report include 1973-1974 preoperational and 1975-1981 operational data and incorporate a third full season of two-unit operation.

The following discussion will focus primarily on new information generated by the addition of 1981 data. Further discussion of 1973-1980 results can be found in the 1981 Environmental Operating Report. Sampling methods are described in detail in earlier reports (Jude _et_ _al_. 1975, 1979). Sampling station locations are illustrated in Fig. 1.

METHODS

Statistical Analysis

To guide our interpretation of patterns of larval fish abundance in 1981, we relied greatly on ANOVA results from the previous eight years. ANOVA was applied to larval fish abundance data of three species (alewife, yellow perch, spottail shiner) over the years 1973-1980. All statistical designs were Model I, full factorial, balanced analysis of variance calculated with statistical package BMD8V (Statistical Research Laboratory 1975). To meet the assumptions of the model more closely, densities were transformed using log(density + 1), and mean densities were computed as geometric means. Two zones, beach and open water, were analyzed separately. Details of the ANOVA method appear in the 1981 Environmental Operating Report.

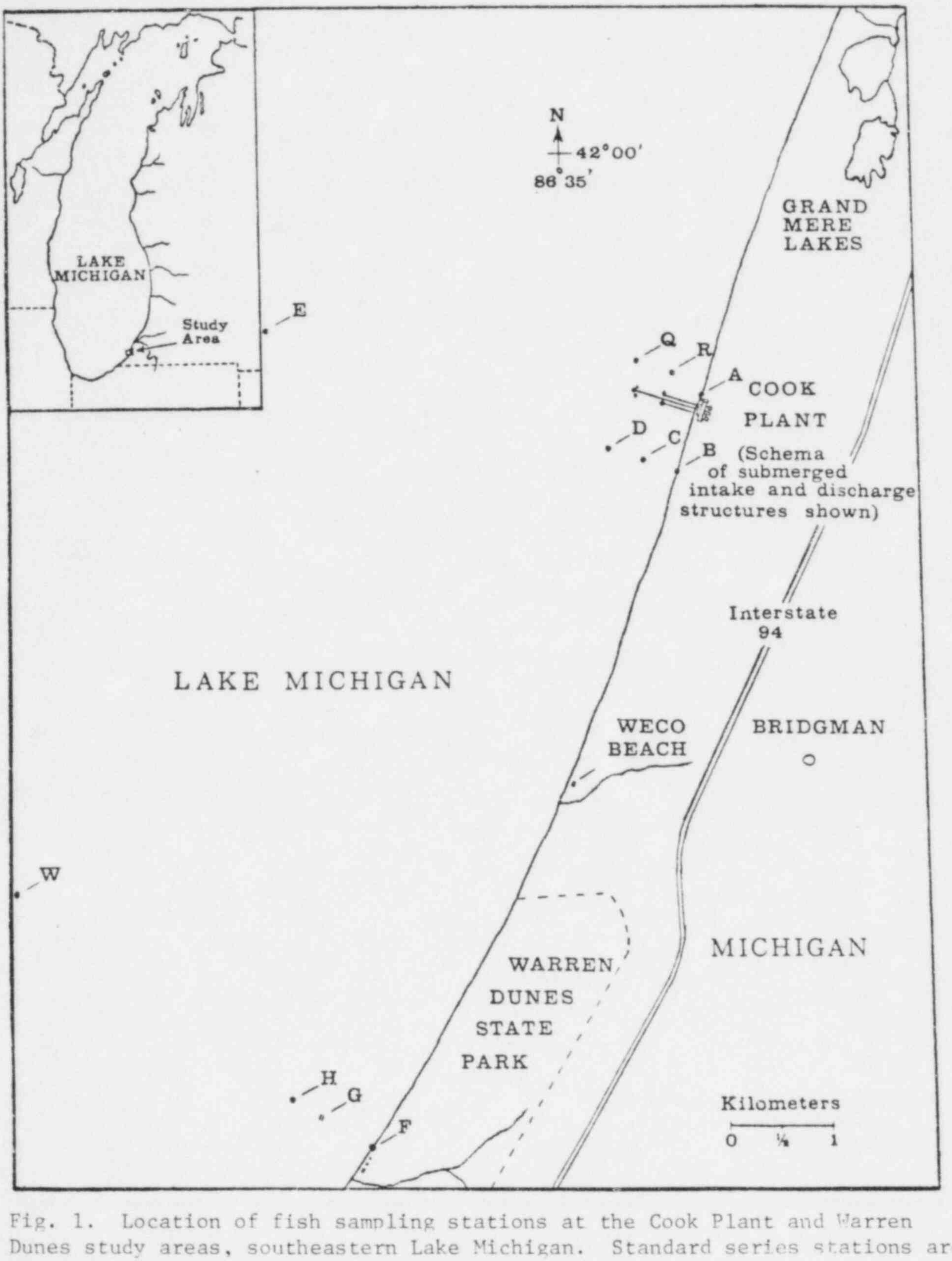

Fig. 1. Location of fish sampling stations at the Cook Plant and Warren Dunes study areas, southeastern Lake Michigan. Standard series stations are A, B, C, D, F, G and H. Stations R and Q are at 6- and 9-m depths, respectively; stations E and W are at 21-m depths.

RESULTS AND DISCUSSION

Alewife

Introduction -- The most abundant larval fish in Cook Plant study areas is alewife, which normally occurs from June through August or September in both beach and open water zones. Both zones were analyzed for plant impact by applying ANOVA to transformed data.

Beach Zone -- Analysis of alewife density data included 9 yr (1973-1981), 3 mo (June-August), three stations (A, north Cook; B, south Cook; and F, Warren Dunes), and two diel periods (day and night) (Table 1). Data from 1981 generally confirmed ANOVA results from 1973-1980 (Table 2). Mean abundance of larval alewives in the beach zone varied significantly from year to year. Geometric means of density + 1 showed 1973 to be the year of highest abundance (3,343 larvae/1000 m^3), while 1980 was the year of lowest abundance (38 larvae/1000 m^3). Geometric means of density + 1 from 1973 to 1980 (respectively) were 3,343, 182, 498, 327, 190, 273, 39, and 38, while arithmetic mean density in 1981 was 406. The intermediate level of density found in 1981 breaks the 8-yr trend of population declines of larval alewives in the Cook Plant study areas.

Highest densities of larval alewives were most often observed in July (1973, 1977, 1979, and 1980), and less often in June (1974, 1975 and 1976). During 1978 and again in 1981, larvae were abundant in both July and August, with lower densities in June. The differences among years are not surprising, because peak spawning periods vary from year to year with seasonal water temperatures and weather conditions. More larval alewives were caught at night than during the day ($P = 0.0056$), though the reverse was true in 1973, 1977, and again in 1981.

Table 1. Summary of factors used in analysis of larval fish density data from Cook Plant study areas, southeastern Lake Michigan.

Species	Factors			
	Beach			
	Year	Month	Station	Time
Alewife	1973-1981	Jun-Aug	A, B, F	day, night
Spottail Shiner	1973-1981	Jun-Aug	A, B, F	night

	Open Water				
	Year	Month	Area	Depth	Time
Alewife	1973-1981	Jun-Aug	Warren Dunes, Cook	6 m, 9 m	day, night
Yellow perch	1973-1974; 1977-1981	Jun	Warren Dunes, Cook	6 m, 9 m	day, night

Table 2. Analysis of variance summary for log(density + 1) of larval alewives. Larvae were netted in the beach zone from June to August, 1973-1980 at Cook Plant study areas, southeastern Lake Michigan.

Source of variation	df	mean square	F-statistic	Attained significance level
Year	7	13.9790	29.2440	0.0000**
Month	2	43.0686	90.0991	0.0000**
Station	2	0.4534	0.9487	0.3896
Time	1	3.7666	7.8797	0.0056*
Y x M	14	13.8925	29.0631	0.0000**
Y x S	14	1.5461	3.2345	0.0001**
M x S	4	0.2096	0.4386	0.7805
Y x T	7	1.4884	3.1138	0.0043*
M x T	2	2.0625	4.3147	0.0151**
S x T	2	0.4131	0.8643	0.4234
Y x M x S	28	1.1987	2.5076	0.0002**
Y x M x T	14	2.8515	5.9654	0.0000**
Y x S x T	14	1.3311	2.7848	0.0010**
M x S x T	4	0.3412	0.7139	0.5836
Y x M x S x T	28	0.7348	1.5373	0.0544
Within cell error	44	0.4780		

** Highly significant (P < 0.001).
* Significant (P < 0.01).

Although there was no significant Station effect in ANOVA, the Year x Station interaction was significant. The significant interaction arose partly from high densities at stations B (south Cook) and F (Warren Dunes) during 1975, while densities at station A (north Cook) were low. The opposite occurred in 1976 and again in 1981, with high densities at station A (north Cook) and low densities at stations B (south Cook) and F (Warren Dunes). No plant impact was apparent from examination of the significant factors of the beach ANOVA.

Open Water Zone -- Analysis of open water alewife data included 9 yr (1973-1981), 3 mo (June through August), two areas (Cook and Warren Dunes), two depths (6- and 9-m contours) and two diel periods (day and night) (Table 1). Abundance of alewives differed significantly from year to year ($P = 0.0000$) (Table 3) and was highest in 1974. Geometric means of density + 1 were 117, 525, 213, 125, 32, 5, 40, and 22 respectively for 1973 to 1980 sampling. Arithmetic mean in 1981 was 103. As in the beach zone, the intermediate level of abundance in 1981 broke a trend of population decline in the open water zone of the Cook Plant study areas.

July was most often the month of largest catches of alewife larvae (1975, 1976, and 1980). In 1974, June and July catches were virtually equal. During 1973, highest catches occurred in June, while during 1977 and 1978, August geometric means were highest. In 1981, arithmetic mean density was highest in August.

More larval alewives were generally caught at night than during the day, and 1981 was no exception. In June and July 1977 and August 1978, more were caught during the day. These reversals produced the significant interactions of Year x Time and Year x Month x Time.

Table 3. Analysis of variance summary for log(density + 1) of larval alewives. Larvae were netted in the open water zone from June to August, 1973-1980 at Cook Plant study areas, southeastern Lake Michigan.

Source of variation	df#	mean square+	F-statistic	Attained significance level
Year	7	40.8325	69.2973	0.0000**
Month	2	57.7430	97.9962	0.0000**
Area	1	0.4660	0.7909	0.3741
Depth	1	20.0098	33.9589	0.0000**
Time	1	18.1650	30.8281	0.0000**
Y x M	14	28.8363	48.9384	0.0000**
Y x A	7	0.5374	0.9121	0.4963
M x A	2	0.5755	0.9767	0.3770
Y x D	7	0.6162	1.0458	0.3974
M x D	2	0.1106	0.1877	0.8288
A x D	1	0.0054	0.0092	0.9234
Y x T	7	3.4974	5.9355	0.0000**
M x T	2	0.1950	0.3309	0.7183
A x T	1	1.4044	2.3834	0.1231
D x T	1	1.0421	1.7687	0.1840
Y x M x A	14	1.6144	2.7399	0.0005**
Y x M x D	14	0.4841	0.8217	0.6457
Y x A x D	7	0.1955	0.3319	0.9394
M x A x D	2	0.4515	0.7662	0.4651
Y x M x T	14	3.1850	5.4053	0.0000**
Y x A x T	7	0.6388	1.0841	0.3716
M x A x T	2	0.0673	0.1142	0.8920
Y x D x T	7	0.8190	1.3900	0.2065
M x D x T	2	1.2064	2.0474	0.1298
A x D x T	1	0.2640	0.4481	0.5034
Y x M x A x D	14	0.6324	1.0732	0.3787
Y x M x A x T	14	0.8952	1.5194	0.0984
Y x M x D x T	14	0.6924	1.1751	0.2897
Y x A x D x T	7	0.5911	1.0031	0.4276
2 x A x D x T	2	1.2660	2.1485	0.1174
Y x M x A x D x T	14	0.5565	0.9444	0.5100
Within cell error	653	0.5842		

One hundred fifteen degrees of freedom were subtracted from the error term to correct for 115 missing observations where cell means were substituted.

+ Mean squares were multiplied by harmonic mean cell size/maximum cell size (nh/n = 0.8767) to correct for two missing observations where cell means were substituted.

** Highly significant (P < 0.001).

Larval alewives were more abundant at the 6-m contour than at the 9-m contour in every year except 1981. In that year mean densities were greater at 9 m at both Cook and Warren Dunes stations, though August mean densities at both 9-m stations (D and H) exceed those at 6-m stations (C and G).

Two of the most important factors in evaluating plant impact, Area and Year x Area, were not significant. A third-order interaction involving Area (Year x Month x Area) was significant but appeared to be caused by different peak monthly abundances during various years rather than differences between areas during any year.

In summary, the Cook Plant had no effect on the distribution of larval alewives in either the beach zone (stations A, north Cook and B, south Cook) or the open water zone C (6 m, south Cook) and D (9 m, south Cook), as concluded from ANOVA results. An apparent population decline of larval alewives from 1973 to 1980 in both study areas was reversed in 1981. Future analysis of variance including station R (6 m, north Cook) will help to confirm these conclusions.

Spottail Shiner

Beach Zone -- The data set used in the analysis of spottail shiner larvae in the beach zone included 9 yr (1973-1981), 3 mo (June, July, August) and three stations (A, north Cook; B, south Cook; and F, Warren Dunes), with duplicate tows taken at each station (Table 1). Only nighttime sampling data were used because daytime samples too often contained no spottail shiner larvae. Nevertheless, zero catches still comprised 25% of the night data set.

Densities of spottail shiner larvae in the Cook Plant study areas differed significantly among years (Table 4). Geometric mean densities (no./1000 m^3) for 1973-1980 were, respectively, 41, 1142, 518, 177, 41, 36, 487, and 126.

Table 4. Analysis of variance summary for log(density + 1) of larval spottail shiners. Larvae were netted in the beach zone from June to August, 1973-1980 at Cook Plant study areas, southeastern Lake Michigan.

Source of variation	df	mean square	F-statistic	Attained significance level
Year	7	6.0327	8.3127	0.0000**
Month	2	16.1135	22.2035	0.0000**
Station	2	0.3441	0.4742	0.6242
Y x M	14	6.0384	8.3206	0.0000**
Y x S	14	1.2379	1.7058	0.0731
M x S	4	1.7076	2.3530	0.0619
Y x M x S	28	1.2425	1.7122	0.0355
Within cell error	72	0.7257		

** Highly significant ($P < 0.001$).

Arithmetic mean density in 1981 was 766. These results suggest a highly variable yearly recruitment for this species. However, it is also possible that our once-a-month sampling efforts only occasionally sampled the period of peak abundance of spottail shiner larvae.

The Month factor was also significant. This effect stems from the brief spawning peak of this species, which produces a peak month of fish larvae abundance. Furthermore, the Year x Month interaction term was significant, because the month of highest fish larvae density varied among years. June samples had the greatest number of spottail shiner larvae in 1973, 1975, 1976, 1978, and 1981, while July was the peak month in 1974, 1977, 1979, and 1980.

Station was not a significant factor, nor did it enter any significant interactions in the ANOVA based on 1973-1980 data. However, in every month of 1981, mean densities were greater at stations A and B (Cook) than at station F (Warren Dunes). Our tentative conclusion is that no significant plant effects could be detected between densities of spottail shiner larvae at Cook Plant and Warren Dunes beach stations.

Yellow Perch

Open Water Zone -- Because low numbers of perch larvae were caught at most times and stations, an ANOVA was performed for only part of the open water larval yellow perch data. For the years considered in this report, only in 1973, 1974, and 1977-1980 were larval yellow perch caught in sufficient numbers to analyze with ANOVA, and then only in June. Thus, the ANOVA data set consisted of 6 yr, 1 mo, two areas (Cook, Warren Dunes), two depth-stations (6 m, 9 m) and two times (day, night) (Table 1).

Results of the analysis showed only one statistically significant factor, Year (Table 5). Geometric mean densities (no/1000 m^3) of yellow perch larvae in June for 1973, 1974, 1977, 1978, 1979, and 1980 were 3, 17, 16, 4, 2, and 4, respectively. Arithmetic mean density in 1981 was 4, with the highest mean density 7/1000 m^3 at station C (6 m) in daytime samples.

Lack of significance for the factor Area (Cook Plant vs. Warren Dunes) means that open water densities of yellow perch larvae did not differ significantly between plant and reference area. Thus, we concluded that there was no difference in density of perch between Warren Dunes and the Cook Plant, establishing the plant as having no demonstrable effect on larval perch abundance.

Rainbow Smelt

Although rainbow smelt larvae were abundant in May samples in 1974, 1975, and 1980, they were too scarce in other years to be included in the ANOVA. In most years, including 1981, rainbow smelt larvae were not collected in April, peaked in abundance in May, declined steadily thereafter and were absent after July. In 1981 they were last taken in June. The highest May density in 1981 was at Cook open water station R (6 m), where a mean of 152 per 1000 m^3 was found in night samples. Only one beach sample contained rainbow smelt, a night sample at station A (beach) in May, with 106 per 1000 m^3.

Minor Species

Other species of larvae were captured in small numbers during 1980. These included burbot, johnny darter, common carp, slimy sculpin, deepwater sculpin, trout-perch, and an unidentified member of the sculpin family.

Table 5. Analysis of variance summary for log(density + 1) of larval yellow perch. Larvae were netted in the open water during June, 1973-1974 and 1977-1980 at Cook Plant study areas, southeastern Lake Michigan.

Source of variation	df#	mean square+	F-statistic	Attained significance level
Year	5	5.3209	6.1707	0.0000**
Area	1	0.3948	0.4579	0.4995
Depth	1	1.2838	1.4889	0.2241
Time	1	1.1055	1.2821	0.2591
Y x A	5	1.1157	1.2939	0.2690
Y x D	5	0.2030	0.2354	0.9464
A x D	1	0.0848	0.0983	0.7541
Y x T	5	0.8043	0.9328	0.4612
A x T	1	0.2558	0.2966	0.5867
D x T	1	2.0349	2.3599	0.1264
Y x A x D	5	0.7454	0.8644	0.5063
Y x A x T	5	1.2841	1.4892	0.1960
Y x D x T	5	1.1114	1.2889	0.2711
A x D x T	1	1.4539	1.6861	0.1959
Y x A x D x T	5	0.4504	0.5223	0.7590
Within cell error	163	0.8623		

Twenty nine degrees of freedom were subtracted from the error term to correct for 29 missing observations where cell means were substituted.

+ Mean squares were multiplied by harmonic mean cell size/maximum cell size (nh/n = 0.8662) to correct for 29 missing observations where cell means were substituted.

**Highly significant (P < 0.001).

Common carp, quillback, slimy sculpin, and unidentified members of the sucker, minnow, and herring families have also been taken during field larvae sampling. Five of the species, trout-perch, common carp, burbot, johnny darter, and deepwater sculpin have been taken often enough to show regularities in distribution. The most consistent records are for trout-perch larvae, which were taken at beach station A (north Cook) in each of the 5 yr, 1974-1978. Common carp larvae occurred at each of Cook stations A (1 m, north Cook), B (1 m, south Cook), and R (6 m, north Cook) at least twice in the years since 1975, and they were never taken at Warren Dunes. Burbot larvae were found during 3 yr at Cook station E (21 m) and in 2 yr at several other stations. Johnny darter larvae occurred at Warren Dunes station H (9 m) in 1976 and 1977 and at south Cook station D (9 m) in 1976, 1977, and 1980. Deepwater sculpin larvae were collected only at open-water stations, twice in May and seven times in April, including stations E (21 m, south Cook), H (9 m, Warren Dunes), and W (21 m, Warren Dunes) in 1981.

Distribution records of larvae of minor species showed two differences between Cook Plant and Warren Dunes. First, in the period 1973-1981, trout-perch larvae occurred consistently at Cook beach station A, but only once at Warren Dunes in the period 1973-1981. Whether this is a plant effect is unknown. Second, during operation years, common carp spawned at Cook, but not at Warren Dunes, and we attribute this to the warm-water plume and currents produced by the discharge of the Cook Plant.

FISH LARVAE - ENTRAINMENT

INTRODUCTION

Mortality caused by the entrainment of fish eggs and larvae in the once-through cooling system at the Cook Plant could represent an important biological impact on local Lake Michigan fishes by reducing the reproductive potential of important forage or game fish populations. To determine the significance of potential plant impacts, species and estimated numbers of fish larvae and eggs entrained at the plant have been documented.

METHODS

Species and numbers of larvae and eggs entrained at the Cook Plant were documented using standardized sampling in 1981. Samples were collected twice per month, except in June, July and August when sampling was done twice per week to coincide with peak abundance of larvae. Samples were collected for a 24-h period. Each period was partitioned into four diel divisions (noon-sunset, sunset-midnight, midnight-sunrise, sunrise-noon) which varied from 4 to 8 h depending on division and day length. Sixteen samples, four replicates (three intake, one discharge) per division, were collected for each 24-h period. Larvae were identified to species when possible, otherwise to the lowest taxonomic group (Table 6). All fish eggs were counted. When large numbers of eggs were found, estimates were made using a volumetric subsampling technique (Jude *et al*. 1975). Additional details of entrainment sample regimes may be found in previous Environmental Operating Reports and Jude *et al*. (1979).

Numbers of fish eggs and larvae entrained per diel division were estimated by calculating the mean number of fish eggs and larvae entrained per unit volume

Table 6. Ichthyoplankton species and groups entrained at the Cook Plant from 1975 to 1981. Scientific names from Robbins et al. (1980).

Common name or category	Scientific name or category
Alewife	*Alosa pseudoharengus* (Wilson)
Spottail shiner	*Notropis hudsonius* (Clinton)
Rainbow smelt	*Osmerus mordax* (Mitchill)
Yellow perch	*Perca flavescens* (Mitchill)
Trout-perch	*Percopsis omiscomaycus* (Walbaum)
Johnny darter	*Etheostoma nigrum* Rafinesque
Slimy sculpin	*Cottus cognatus* Richardson
Common carp	*Cyprinus carpio* Linnaeus
Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Mottled sculpin	*Cottus bairdi* Girard
Deepwater sculpin	*Myoxocephalus thompsoni* (Girard)
Burbot	*Lota lota* (Linnaeus)
Quillback	*Carpiodes cyprinus* (Lesueur)
Unidentified sculpins	*Cottus* spp.
Unidentified minnows	Cyprinidae
Unidentified coregonids	*Coregonus* spp.
Unidentified darters	*Etheostoma* spp.
Unidentified fish larvae as a result of poor condition	
Unidentified fish larvae	
Fish eggs	

sampled. Standardized mean densities of fish larvae and eggs represent a conversion of number per volume sampled (the amount of water pumped through the plankton net) to number per standardized volume (1000 m^3). Then, the mean number of fish eggs and larvae were expanded to the volume of water circulated by the plant during that diel sample division. Sample period estimates of the number of fish eggs and larvae and the volume of circulating water used by the plant were computed by totaling estimates from each diel sample division during a sample period. Non-overlapping, contiguous time intervals (usually 1-2 wk) were established such that the sampling date was the approximate midpoint of the interval. Entrainment densities determined over a sampling period were assumed to be representative of fish egg and larvae abundance per unit volume of circulating water used during the 1-2 wk sample interval. The estimated number of fish eggs and larvae entrained was expanded accordingly. These data were totaled for each month and then yearly estimates computed.

All these estimates are preliminary. As a result of continuous application of new taxonomic information, some larvae identifications will be reevaluated, reassignments made and our estimates revised. For the most part, taxonomic changes will cause some changes in individual species estimates but should not substantially affect total entrainment estimates in any given year.

RESULTS AND DISCUSSION

General Trends, 1975-1981

An estimated 440 million fish larvae and almost 15 billion fish eggs were entrained in the condenser circulating water system at the Cook Plant from 1975 to 1980 (Table 7). Thirteen species were identified in entrainment samples: alewife (*Alosa pseudoharengus*), spottail shiner (*Notropis hudsonius*), rainbow

Table 7. Estimates (in millions) of annual entrainment losses for fish larvae and fish eggs at the Cook Plant, southeastern Lake Michigan, 1975 to 1981. Calculations use actual reported flow rates of the circulating water system.

Taxon	Year of estimate						
	1975	1976	1977	1978	1979	1980	1981
Alewife	63.708	53.7550	27.3888	31.098	125.6180	49.35	111.54
Spottail shiner	3.41	0.9361	2.760	1.681	1.8228	21.06	7.257
Rainbow smelt	1.3608	0.4145	0.1795	0.3496	0.3726	11.954	2.6265
Yellow perch	0.17554	0.03807	1.3224	3.0655	0.3840	0.8971	2.506
Trout-perch	1.079	0.2509	0.1456	0.0194	0.6288	0.4858	0.5394
Johnny darter	0.0440	0.210	0.707	0.772	0.8105		0.153
Slimy sculpin	0.24[illegible]	0.06092	0.0256	0.130		0.553	1.002
Common carp		0.0912	0.0235	0.175	0.3603	0.0513	0.187
Ninespine stickleback				0.124		0.379	0.156
Mottled sculpin	0.152	0.146	0.0483		0.131		0.143
Deepwater sculpin				0.178	0.0141		
Burbot		0.0202		0.102			
Quillback			0.0628				0.534
Unidentified sculpins	0.1899	0.0892	0.0918	0.175	0.0905	0.667	0.5953
Unidentified minnows			0.1248		0.8138	0.2846	0.1714
Unidentified coregonids			0.0850				
Unidentified darters			0.0276				
Poor condition	6.555	2.8642	0.4274	3.352	5.9935	6.4765	11.859
Unidentified larvae	0.1693	0.0349	0.0887	0.100			
Total larvae	77.08664	58.91119	33.5088	41.3215	137.0399	92.1583	139.2696
Total eggs	743.1879	2269.4543	1320.301	5840.8138	1392.5408	3334.692	995.94

smelt (*Osmerus mordax*), yellow perch (*Perca flavescens*), trout-perch (*Percopsis omiscomaycus*), johnny darter (*Etheostoma nigrum*), slimy sculpin (*Cottus* cognatus), common carp (*Cyprinus carpio*), ninespine stickleback (*Pungitius pungitius*), mottled sculpin (*Cottus bairdi*), deepwater sculpin (*Myoxocephalus thompsoni*), burbot (*Lota lota*) and quillback (*Carpiodes cyprinus*). Additionally, there were four groups which could not be categorized to species including minnows, sculpins, coregonids and darters.

Fifteen ichthyoplankton species/groups were identified in Cook Plant entrainment samples collected in 1981. Almost 140 million fish larvae comprising 11 taxonomic categories and almost 1 billion fish eggs were entrained (Table 8). Alewives comprised 80.1% of all entrained larvae. Remaining species listed in order of decreasing abundance were: spottail shiner (5.2%), rainbow smelt (1.9%), yellow perch (1.8%), slimy sculpin (0.7%), trout-perch (0.4%), quillback (0.4%), common carp (0.13%), ninespine stickleback (0.11%), johnny darter (0.11%) and mottled sculpin (0.1%). Two other groups could not be identified to species: cottids and minnows. Approximately 8.5% of all larvae could not be identified as a result of their poor condition.

Alewife

Alewife was the most abundant species entrained and they accounted for almost 80% (351 million) of the total number of larval fish entrained from 1975 to 1980 (Table 7). Entrainment estimates ranged from 27 million in 1977 to 126 million in 1979. Alewife was entrained in almost every month from early April (1977), May (1975, 1976 and 1978) or June (1979 and 1980) to late September (1975, 1977 and 1980), October (1976), or November (1978 and 1979). Entrainment peaks occurred in June (1975) or July (1976-1980).

Table 8. Estimates (in millions) of entrainment losses for fish larvae and fish eggs during 1981 at the Cook Plant, southeastern Lake Michigan. Calculations use actual reported flow rates of the circulating water system. No fish eggs or larvae were found in entrainment samples between 1 December and 31 December 1981.

Taxon	1 Jan- 2 Feb	3 Feb- 6 Mar	7 Mar- 31 Mar	1 Apr- 1 May	2 May- 29 May	30 May- 1 Jul	2 Jul- 31 Jul	1 Aug- 4 Sep	5 Sep- 5 Oct	6 Oct- 31 Oct	1 Nov- 30 Nov	Total	% Total
Alewife						67.5	6.81	35.6	1.63			111.54	80.09
Spottail shiner					0.453	3.49	0.354	2.96				7.257	5.21
Rainbow smelt				0.0995	1.81	0.717						2.6265	1.89
Yellow perch					0.205	2.21	0.0151	0.0759				2.506	1.80
Slimy sculpin					0.743	0.259						1.002	0.72
Trout-perch						0.154	0.0214	0.364				0.5394	0.39
Quillback					0.534							0.534	0.38
Common carp								0.187				0.187	0.13
Ninespine stickleback								0.156				0.156	0.11
Johnny darter						0.153						0.153	0.11
Mottled sculpin						0.143						0.143	0.10
Unidentified sculpins					0.536	0.0593						0.5953	0.43
Unidentified minnows					0.0965			0.0749				0.1714	0.12
Poor condition					0.569	8.35	1.39	1.55				11.859	8.52
Total larvae				0.0995	4.9465	83.0353	8.5905	40.9678	1.63			139.2696	
Fish eggs	9.89	0.815	1.82	1.41	105.	470.	398.	8.83			0.175	995.94	

During 1981, alewife was the most common species entrained accounting for 80% (111.5 million larvae) of the total estimated annual entrainment loss. Alewives appeared in entrainment samples from early June to late September 1981. Most (61%) alewife entrainment occurred during June and densities peaked during the 15-16 June sampling. Sample means (number per 1000 m^3) for each diel period were 1,723 (dusk-midnight), 1,000 (midnight-dawn), 1,705 (dawn-noon) and 1,282 (noon-dusk) with an overall month period sample mean of 1,437.

Spottail Shiner

Spottail shiner was the second-most abundant larva entrained at the Cook Plant. From 1975 to 1980, over 31 million (7% of total) were entrained ranging from less than 1 million in 1976 to 21 million in 1980 (Table 7). Spottails were entrained as early as late May (1979) or June (1975-1978, 1980) to July (1977, 1980), August (1975, 1978, and 1979) and occasionally as late as October (1976). Spottail entrainment rates were usually greatest in June and July of most years.

During 1981, spottail shiner represented 5.2% (7.3 million) of the total estimated larvae entrainment loss (Table 8). Spottail shiners appeared in entrainment samples from mid-May to late August in 1981. Maximum densities occurred in our 15-16 June sampling and coincided with peak alewife larvae abundance. Sample means (number per 1000 m^3) for each diel period were 60 (dusk-midnight), 356 (midnight-dawn), 57 (dawn-noon) and 41 (noon-dusk) with an overall month period sample mean of 134.

Rainbow Smelt

From 1975 to 1980, rainbow smelt accounted for 3.3% (14.6 million) of larval fish entrainment estimates (Table 7). Estimates ranged from 0.18 million in 1977 to almost 12 million in 1980. Smelt entrainment occurred from April (1976, 1977 and 1979) or May (1975, 1987 and 1980) to July (1976, 1977 and 1980) and occasionally as late as August (1975, 1978 and 1979).

Smelt was the third-most abundant species entrained during 1981; estimated entrainment loss was 2.6 million larvae (Table 8). Smelt larvae were present in entrainment samples from late April through late June 1981. Peak smelt abundance in entrainment samples occurred in June. During our 15-16 June sampling, diel sample means (number per 1000 m^3) were 38 (dusk-midnight), 30 (midnight-dawn), 0 (dawn-noon) and 5 (noon-dusk) with an overall month period sample mean of 19.

Yellow Perch

Approximately 5.9 million yellow perch were entrained at the Cook Plant from 1975 to 1980 (Table 7). Perch entrainment totals ranged from 3.1 million in 1978 to 0.04 million in 1976 and averaged less than 1 million fish per year from 1975 to 1980. Entrainment occurred as early as late April (1975) or May (1977, 1978 and 1980) to July (1975-1977 and 1979-1980) or early August (1978).

Yellow perch was the fourth-most abundant species entrained during 1981 (Table 8). This species was entrained from mid-May to mid-August. Yellow perch represented 1.8% (2.5 million) of the total estimated 1981 entrainment loss. Maximum densities of yellow perch were noted during our 15-16 June sampling. Sample means (number per 1000 m^3) for each diel period were 15 (dusk-midnight), 41 (midnight-dawn), 64 (dawn-noon and 134 (noon-dusk) with an overall month period sample mean of 59.

Sculpins

Sculpins (slimy, mottled, deepwater and unidentified) have been entrained consistently at the Cook Plant since 1975 (Table 7). One million slimy, 0.5 million mottled, 0.2 deepwater and 1.3 million unidentified sculpins were entrained from 1975 to 1980. They comprised less than 0.7% of total entrainment losses over that period. Slimy sculpins were present in all years but 1979, mottled sculpins in all years but 1978 and 1980, and deepwater sculpins were only present in 1978 and 1979. Slimy sculpins were usually found in entrainment samples as early as late May (1977) to early August (1975). Mottled sculpins followed a similar pattern, but were usually absent after mid-June. Deepwater sculpins were only present during two sample periods: late March, 1978 and in early June, 1979.

Slimy sculpin larvae accounted for 0.7% (1.0 million) of the total estimated fish larvae entrainment during 1981 (Table 8). Slimy sculpin larvae were present in late-May to mid-June samples. Mottled sculpin larvae were 0.1% of the 1981 entrainment loss and were found from early to mid-June. Unidentified Cottus specimens may be either slimy or mottled sculpins. The poor condition of these larvae did not permit identification to species.

Trout-perch

Trout-perch have been a consistent but minor component of entrainment during 1975-1980 (Table 7) and have averaged less than 0.4 million larvae per year during the period. They are usually collected in entrainment samples starting in June (1975, 1977 and 1980) or July (1976 and 1978) and are present throughout most of the summer months and occasionally into the fall (November 1976 and October 1979). Trout-perch were noted in entrainment samples from mid-

June to late August 1981 but were a small component (0.4%) of estimated 1981 entrainment losses.

Quillback

Quillback larvae were only collected in late April 19[illegible]8 and mid-May 1981. They represented only 0.13% (0.19 million) of the 1981 estimated entrainment loss.

Common Carp

Carp larvae have been entrained at a mean annual rate of 0.14 million larvae from 1976 to 1980 contributing 0.7 million fish to estimated entrainment totals (Table 7). They appeared as early as June (1976 and 1979) in entrainment samples.

Common carp were present in entrainment samples from early to mid-August and comprised 0.15% (0.187 million) of the total estimated 1981 fish larvae entrainment loss. No carp larvae were observed prior to plant startup and carp were only found at plant stations, confirming the suspicion that adult carp were probably attracted to the warm water discharge area to spawn and will continue to inhabit the Cook Plant vicinity.

Ninespine Stickleback

Ninespine sticklebacks were a minor contributor to 1981 entrainment losses (0.16 million) and were found in mid to late August 1981. They have been noted in entrainment samples in only 2 previous years, 1978 and 1980.

Johnny Darter

Johnny darters have been taken in entrainment samples in all years except 1980 and have accounted for 0.6% (2.5 million larvae) of entrainment totals from 1975 to 1980 (Table 7). Johnny darters were usually entrained in June, July and August of most years with peak entrainment occurring in the month of their first appearance. In 1981 they accounted for 0.15 million entrained larvae and were collected from mid-June to early July.

Unidentified minnows

Unidentified minnows accounted for 0.12% (0.6 million) of 1981 entrainment losses. This category probably represents the occasional occurrence of minnow species rarely taken in the Cook Plant area, or they could be damaged carp or spottail larvae.

Poor Condition Larvae

Undoubtedly, many of the larvae reported as being in poor condition were physically damaged alewives. Peak abundance of larvae in poor condition coincided with peak larval alewife and spottail entrainment rates.

Fish Eggs

Almost 1 billion fish eggs passed throught the Cook Plant during 1981 (Table 8). Fish eggs were entrained in every month except September and October 1981. Egg densities for 1981 peaked during our 13-14 July sampling date. Sample means (number per 1000 m^3) for each diel period were 1,927 (noon-dusk), 6,430 (dusk-midnight), 48,545 (midnight-dawn) and 6,974 (dawn-noon) with an overall month period sample mean of 15,962.

SUMMARY

Potentially important sport or commercial fish and their abundance in Cook Plant entrainment samples in 1981 were: rainbow smelt (2.6 million larvae - 1.9% of the total) and yellow perch (2.5 million - 1.8% of the total). No other major game fish species (lake trout, other trout or salmon, centrarchids, esocids, etc.) were found in entrainment samples.

Total numbers of fish larvae entrained are dependent on plant operation and the biological characteristics of the major species entrained (alewife and spottail shiner). Although circulating water flow rates have a direct relationship to the numbers of larvae entrained, small year classes or large spawning aggregations in combination with extended spawning periods can cause substantial variation in annual entrainment losses at the Cook Plant. Reduction in the water volumes used for the condenser circulating water system in April, May, June and July may have substantialy reduced 1981 entrainment losses at the Cook Plant (Table 9). If plant operation had continued at maximum rates during this period, we estimate that in addition to the record entrainment loss in 1981, an additional 25-50% loss would have been likely. Biological factors, in combination with two-unit operation during periods of peak larvae abundance, indicate that entrainment of larval fish will fluctuate considerably between years with periodic substantial increases in numbers of larvae entrained.

Table 9. Total water flow (in millions of cubic meters) through the condenser circulating water system of the Cook Plant, southeastern Lake Michigan in 1981.

Month	Unit 1	Unit 2	Total	% Total
January	109.0	161.8	270.8	9.8
February	120.4	162.1	282.5	10.3
March	132.6	81.0	213.6	7.8
April	128.8	0	128.8	4.7
May	131.4	65.1	196.5	7.1
June	0	165.0	165.0	6.0
July	11.7	130.7	142.4	5.2
August	120.8	169.8	290.6	10.6
September	135.0	170.0	305.0	11.1
October	139.6	42.8	182.4	6.6
November	83.5	181.8	265.3	9.6
December	119.1	191.1	310.2	11.3
Total	1232.	1521.	2753.	

FOREBAY VISUAL INSPECTION

Inspections to monitor fish presence and behavior in the intake forebay were conducted monthly from January to August 1982 in accordance with technical specifications. On 26 April, a trout or salmon, 50-60 cm long, was noted swimming in front of the trash grates at travelling screen MTR-1. On 27 April, two more unidentified salmonids, 30-40 cm in length, were observed swimming at the trash grates at MTR-4. On 25 May, five common carp were espied in the forebay, one at MTR-1 and four at MTR-4. On 2 June, a carp was seen at MTR-4, and on 29 June an alewife was noted at MTR-1. On July 30, two alewives were seen, one at MTR-1 and one at MTR-3. Scuba divers reported the presence of a burbot in the forebay in July. No fish were observed during the rest of the period covered by this report.

ADULT AND JUVENILE FISH - FIELD

INTRODUCTION

Standard series trawl, gill net, and seine catch data on abundant and common species of adult and juvenile fish are analyzed in this section. Major emphasis is placed on examining 1982 data and comparing them with those for 1973 through 1981. Due to time constraints, only April through August catch data were available. No statistical analyses were performed because of the incomplete data set. Instead, the 1982 data were examined for differences and similarities with previous years' results. Sampling was also reduced after May 1982 by eliminating trawling and gillnetting at north Cook stations R (6 m) and Q (9 m). Therefore, no detailed comparisons were made with the north Cook area.

Analyses are an attempt to document and establish plant operational effects on the local fish populations. Examinations and interpretations are preliminary; comprehensive analyses must wait until a complete year's data with statistical tests and limnological and meteorological data are available.

SAMPLING METHODS

Adult and juvenile fish were collected at stations located north and south of the Cook Plant and at Warren Dunes State Park (Fig. 1). For details of materials and methods, see the 1978 Environmental Operating Report and Jude et al. (1975, 1979). Standard series fish effort from 1973 to 1982 is presented in Table 10. After May 1982, no samples were collected at north Cook stations R (6 m) and Q (9 m); no other changes in sampling methodology occurred from January to August 1982.

Table 10. Standard series fishing effort from 1973 to 1982. A complete standard series sampling each month from April to November consisted of 36 samples (16 trawl tows, 8 gill net sets, and 12 beach seine hauls).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1973	0	6	15	35	36	36	36	36	35	36	16	1	287
1974	5	0	20	36	36	36	36	36	36	36	28	8	313
1975	6	0	6	36	36	36	36	36	36	36	32	16	312
1976	0	12	2	36	36	36	36	36	36	32	20	0	282
1977	0	0	0	36	36	36	36	36	36	36	36	4	292
1978	0	0	0	36	36	36	36	36	36	36	36	0	288
1979	0	0	0	36	36	36	36	36	36	36	36	0	288
1980	0	0	0	36	36	36	36	36	36	36	36	0	288
1981	0	0	0	36	36	36	36	36	36	36	36	0	288
1982	0	0	0	36	36	36	36	36	36	36	20	0	272

RESULTS AND DISCUSSION

Abundant Species

Alewife -- Except for 1980, alewife has been the most abundant species in the study areas. Alewife catches have fluctuated considerably from 1973 to 1981, with a maximum of 148,451 fish in 1973 and a low of 16,452 fish in 1980 (Tables 11-19). Since 1979, abundance has been low, and the April to August 1982 catch of only 5,251 fish indicates this trend is continuing (Table 20). The 1982 total catch was the lowest ever found during April to August (mean catch of 36,815 fish for the 10-yr period from 1973 to 1982). Catches from all three gear types have also shown the recent decline in alewife abundance (Tables 21-50). This suggests that all alewife age-groups, as opposed to one or two weak year classes, are declining in southeastern Lake Michigan.

ANOVA of 1973-1981 trawl data (see 1982 Environmental Operating Report) showed no variation attributable to plant effects, and spring and summer catch data for 1982 appear to substantiate this conclusion. Total trawl catches (April to August) were similar between areas in 1982. The total catch of 624 fish at south Cook 6-m station C was larger than at Warren Dunes 6-m station G (258 fish), but the south Cook 9-m station D catch of 532 fish was smaller than the 768 fish caught at the Warren Dunes 9-m station H (Tables 51-54). The 25 fish caught at north Cook 6-m station R during April and May (Table 55) was also similar to the catches at 6-m stations C and G, 27 and 23 fish, respectively.

Like trawl results, ANOVA on 1973-1981 gill net catch data (see 1981 Environmental Operating Report) showed no variation in year or area catches attributable to plant operation. Gill net catch data for spring and summer 1982 did not refute this conclusion. More alewives were caught at south Cook area stations (826 fish) than at Warren Dunes (400 fish) (Tables 56-59). The April

Table 11. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1973. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	1869	10286	3207	6792	13204	79934	765	32389	5	0	148451	76.58
Spottail shiner	ND	17	439	2687	3374	7416	1819	2514	768	1435	121	1	20591	10.62
Rainbow smelt	ND	4	119	3926	823	957	294	8394	1425	338	14	0	16294	8.41
Yellow perch	ND	6	35	15	41	1458	611	909	243	395	22	0	3735	1.93
Trout-perch	ND	0	2	47	156	1567	703	515	160	339	21	0	3510	1.81
Johnny darter	ND	0	0	13	47	58	17	31	11	30	0	0	207	0.11
White sucker	ND	1	7	7	14	26	22	30	41	26	0	0	174	0.09
Lake trout	ND	0	2	1	2	2	6	19	49	27	54	0	162	0.08
Bloater	ND	0	0	0	2	26	42	35	1	20	0	0	126	0.07
Rainbow trout	ND	1	1	15	30	13	6	11	1	3	5	0	86	0.04
Slimy sculpin	ND	0	0	44	14	3	0	6	4	7	1	0	79	0.04
Brown trout	ND	1	4	2	6	33	18	4	3	7	0	0	78	0.04
Longnose sucker	ND	1	4	9	15	14	27	1	1	1	0	0	73	0.04
Emerald shiner	ND	1	2	1	6	1	2	11	15	8	2	0	49	0.03
Longnose dace	ND	2	0	2	4	3	3	4	22	0	1	0	41	0.02
Northern pike	ND	0	0	0	0	2	0	1	8	10	9	0	30	0.02
Coho salmon	ND	0	5	3	9	7	0	0	3	2	0	0	29	0.01
Carp	ND	0	0	2	2	14	1	2	0	6	0	0	27	0.01
Chinook salmon	ND	0	1	2	5	6	2	2	3	2	0	0	23	0.01
Gizzard shad	ND	0	0	0	0	0	0	0	0	1	22	0	23	0.01
Ninespine stickleback	ND	0	1	1	12	5	0	0	0	0	0	0	19	0.01
Mottled sculpin	ND	0	0	9	3	2	0	0	0	2	0	0	16	0.01
Channel catfish	ND	1	0	0	0	1	0	2	0	2	4	0	10	0.01
Bluegill	ND	0	0	0	1	3	0	1	0	0	5	0	10	0.01
Burbot	ND	0	0	4	0	2	0	0	0	0	0	0	6	<0.01
Lake whitefish	ND	0	0	0	1	1	0	0	0	0	0	0	2	<0.01
Black bullhead	ND	0	0	1	0	0	1	0	0	0	0	0	2	<0.01
Fathead minnow	ND	0	0	0	1	0	1	0	0	0	0	0	2	<0.01
Rock bass	ND	0	0	0	0	1	0	0	0	0	1	0	2	<0.01
Golden shiner	ND	0	0	2	0	0	0	0	0	0	0	0	2	<0.01
Largemouth bass	ND	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Totals	ND	35	2491	17080	7775	18413	16779	92426	3523	35050	287	1	193860	

Table 12. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1974. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	282	4832	13920	3788	4662	36669	8179	2977	724	0	76033	66.69
Spottail shiner	1	ND	167	313	4111	6942	5884	6047	414	476	36	22	24413	21.41
Rainbow smelt	0	ND	55	701	794	59	385	3304	93	345	13	5	5754	5.05
Yellow perch	1	ND	14	35	14	156	2581	1182	453	9	75	16	4536	3.98
Trout-perch	0	ND	0	10	145	55	928	128	106	187	17	2	1578	1.38
Johnny darter	0	ND	0	5	93	86	60	6	7	22	14	0	293	0.26
Slimy sculpin	0	ND	2	155	19	15	14	28	2	18	19	0	272	0.24
Bloater	0	ND	0	0	0	3	199	7	1	15	0	0	225	0.20
Coho salmon	0	ND	8	8	71	13	2	26	0	0	25	0	153	0.13
White sucker	2	ND	2	3	16	19	29	13	16	13	5	8	126	0.11
Lake trout	0	ND	1	1	17	9	0	0	0	12	85	0	125	0.11
Longnose sucker	1	ND	2	4	26	11	39	2	3	3	6	2	99	0.09
Gizzard shad	0	ND	5	4	44	1	0	1	20	9	0	0	84	0.07
Brown trout	0	ND	3	5	14	13	6	5	2	1	2	0	51	0.05
Bluegill	0	ND	1	0	40	5	0	0	0	0	0	0	46	0.04
Longnose dace	0	ND	2	1	3	8	2	1	0	20	6	0	43	0.04
Chinook salmon	0	ND	0	3	6	3	6	6	13	0	3	1	41	0.04
Carp	0	ND	0	2	7	0	1	9	5	3	0	0	27	0.02
Ninespine stickleback	0	ND	0	1	15	4	3	1	0	0	0	0	24	0.02
Channel catfish	0	ND	0	1	0	1	8	0	5	1	1	0	17	0.02
Northern pike	1	ND	3	3	1	2	0	1	0	5	0	0	16	0.01
Burbot	0	ND	1	1	2	1	0	0	0	0	0	10	15	0.01
Emerald shiner	0	ND	2	1	1	3	0	0	0	6	0	0	13	0.01
Rainbow trout	0	ND	5	2	0	0	0	0	0	0	1	0	8	0.01
Green sunfish	0	ND	0	0	5	0	0	0	0	1	0	0	6	0.01
Sand shiner	0	ND	0	0	0	0	0	0	0	3	1	0	4	<0.01
Black bullhead	0	ND	0	1	1	0	0	0	0	0	0	0	2	<0.01
Lake herring	0	ND	0	0	0	0	0	0	0	0	0	1	1	<0.01
Lake whitefish	0	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Golden shiner	0	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Bluntnose minnow	0	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Totals	6	ND	555	6092	19365	11198	14809	47438	9319	4127	1033	67	114009	

Table 13. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	797	176	6974	2718	1096	757	7740	21188	168	42	41656	58.74
Spottail shiner	1	ND	12	103	1740	8483	3076	1583	2022	1535	428	831	19814	27.94
Yellow perch	7	ND	29	12	4	968	2143	560	280	151	103	80	4337	6.12
Rainbow smelt	3	ND	21	255	1233	1032	0	173	94	179	105	14	3109	4.38
Trout-perch	0	ND	0	14	151	221	68	114	150	108	51	28	905	1.28
Gizzard shad	0	ND	0	2	0	0	0	28	18	13	106	26	193	0.27
Johnny darter	0	ND	0	2	35	19	3	5	31	19	19	9	142	0.20
Slimy sculpin	0	ND	0	38	48	12	0	1	1	2	5	4	111	0.16
Longnose sucker	1	ND	50	3	9	22	1	2	1	2	3	0	94	0.13
White sucker	1	ND	7	3	6	37	9	0	17	2	2	5	89	0.13
Lake trout	0	ND	1	3	8	21	0	0	0	4	47	1	85	0.12
Coho salmon	0	ND	6	40	1	12	0	2	0	0	2	0	63	0.09
Chinook salmon	0	ND	0	3	0	11	3	3	2	20	7	1	50	0.07
Carp	0	ND	0	0	1	0	14	14	17	2	2	0	50	0.07
Bloater	0	ND	0	0	2	34	0	11	1	.	0	0	49	0.07
Sand shiner	0	ND	0	0	0	0	0	0	1	1	32	0	34	0.05
Brown trout	0	ND	7	2	1	1	1	1	1	1	10	1	26	0.04
Ninespine stickleback	0	ND	0	2	10	14	0	0	0	0	0	0	26	0.04
Longnose dace	0	ND	0	0	0	1	0	2	2	7	6	0	18	0.03
Rainbow trout	0	ND	1	2	0	0	1	0	1	6	3	1	15	0.02
Burbot	1	ND	0	0	0	0	0	0	0	1	0	13	15	0.02
Channel catfish	0	ND	0	0	0	0	1	1	5	1	1	0	9	0.01
Northern pike	1	ND	0	1	0	1	0	0	0	0	3	0	6	0.01
Shorthead redhorse	0	ND	0	0	0	0	0	0	4	0	0	0	4	0.01
Lake whitefish	0	ND	0	1	0	1	0	0	0	0	0	0	2	<0.01
Bluegill	0	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Logperch	0	ND	0	0	1	1	0	0	0	0	0	0	2	<0.01
Emerald shiner	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Lake herring	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Quillback	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Lake sturgeon	0	ND	0	0	1	0	0	0	0	0	0	0	1	<0.01
Pumpkinseed	0	ND	0	0	0	0	1	0	0	0	0	0	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Silver redhorse	0	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Totals	15	ND	931	664	10225	13612	6417	3257	10389	23244	1103	1056	70913	

Table 14. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	204	2020	7446	3862	2852	43406	74708	2225	20	ND	136743	86.77
Spottail shiner	ND	47	49	967	1708	3307	5309	580	823	1178	147	ND	14115	8.96
Yellow perch	ND	13	5	54	24	318	1242	386	422	30	4	ND	2498	1.59
Trout-perch	ND	2	1	25	118	115	1146	134	261	145	8	ND	1955	1.24
Rainbow smelt	ND	1	21	452	67	143	416	19	11	13	122	ND	1265	0.80
Johnny darter	ND	0	0	2	139	12	25	30	31	59	6	ND	304	0.19
Bloater	ND	0	0	3	2	26	76	0	0	0	0	ND	107	0.07
Brown trout	ND	6	0	2	32	18	10	1	17	4	0	ND	90	0.06
White sucker	ND	4	0	6	24	5	18	5	18	8	1	ND	89	0.06
Slimy sculpin	ND	0	0	55	12	1	0	6	2	5	3	ND	84	0.05
Gizzard shad	ND	1	0	0	0	1	1	20	20	7	1	ND	51	0.03
Coho salmon	ND	0	0	0	27	16	1	0	1	1	0	ND	46	0.03
Longnose sucker	ND	20	3	8	4	3	2	0	0	0	0	ND	40	0.03
Sand shiner	ND	0	0	1	0	0	0	7	0	31	0	ND	39	0.03
Lake trout	ND	0	3	6	8	7	2	0	0	11	0	ND	37	0.02
Carp	ND	0	0	0	10	2	1	14	4	1	0	ND	32	0.02
Longnose dace	ND	0	0	1	3	2	1	5	10	1	4	ND	27	0.02
Chinook salmon	ND	1	0	0	0	9	1	0	3	0	0	ND	14	0.01
Rainbow trout	ND	2	0	2	2	1	1	0	4	2	0	ND	14	0.01
Channel catfish	ND	0	0	0	2	0	1	2	8	0	0	ND	13	0.01
Ninespine stickleback	ND	0	0	0	8	1	0	0	0	0	0	ND	9	0.01
Lake whitefish	ND	0	1	2	1	1	1	0	0	0	0	ND	6	<0.01
Burbot	ND	1	0	2	0	0	1	0	0	2	0	ND	6	<0.01
Bluegill	ND	0	0	0	1	0	1	0	0	0	1	ND	3	<0.01
Silver redhorse	ND	0	0	0	0	0	3	0	0	0	0	ND	3	<0.01
Quillback	ND	0	0	0	0	1	1	0	0	0	0	ND	2	<0.01
Golden shiner	ND	1	0	0	0	0	0	0	0	1	0	ND	2	<0.01
Lake sturgeon	ND	0	0	0	1	0	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Brook silverside	ND	0	0	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	99	287	3609	9639	7851	11112	44617	76341	3724	317	ND	157598	

Table 15. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	66	34	1270	1607	3507	20151	12731	3017	13596	0	55979	63.36
Spottail shiner	ND	ND	54	20	2333	2190	2363	10098	3535	1564	398	0	22555	25.53
Yellow perch	ND	ND	11	28	19	189	1300	897	470	47	416	1	3378	3.82
Trout-perch	ND	ND	1	4	193	317	1919	130	172	501	2	0	3239	3.67
Rainbow smelt	ND	ND	0	113	170	2	669	88	99	148	166	0	1455	1.65
Johnny darter	ND	ND	0	34	171	44	31	41	82	4	16	0	423	0.48
Bloater	ND	ND	0	0	0	24	40	0	7	141	15	0	227	0.28
Lake trout	ND	ND	4	10	6	6	6	0	9	27	119	0	187	0.21
White sucker	ND	ND	0	8	29	18	68	13	23	8	5	1	173	0.20
Gizzard shad	ND	ND	0	0	0	0	1	15	39	41	8	0	104	0.12
Longnose sucker	ND	ND	4	5	3	0	34	9	14	6	24	0	99	0.11
Coho salmon	ND	ND	3	1	83	2	0	0	1	2	4	0	96	0.11
Carp	ND	ND	0	5	30	0	5	22	20	3	7	0	92	0.10
Chinook salmon	ND	ND	11	21	0	43	0	0	0	1	0	0	76	0.09
Brown trout	ND	ND	5	9	8	13	5	0	5	1	9	6	61	0.07
Longnose dace	ND	ND	0	1	0	3	1	0	9	38	8	0	60	0.07
Slimy sculpin	ND	ND	0	15	0	0	7	1	2	0	5	0	30	0.03
Emerald shiner	ND	ND	0	0	0	2	23	0	0	3	0	0	28	0.03
Sand shiner	ND	ND	0	1	0	2	13	5	1	0	1	0	23	0.03
Rainbow trout	ND	ND	0	2	1	0	1	0	6	0	2	0	12	0.01
Channel catfish	ND	ND	0	0	0	0	0	5	2	2	0	0	9	0.01
Golden redhorse	ND	ND	0	0	0	0	0	6	3	0	0	0	9	0.01
Burbot	ND	ND	1	0	0	0	0	1	0	0	0	6	8	0.01
Ninespine stickleback	ND	ND	0	0	5	0	2	0	0	0	0	0	7	0.01
Mottled sculpin	ND	ND	0	0	0	0	0	0	0	3	0	0	3	<0.01
Quillback	ND	ND	0	0	0	0	0	1	2	0	0	0	3	<0.01
Lake sturgeon	ND	ND	0	0	0	0	1	1	0	0	0	0	2	<0.01
Bluegill	ND	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Rock bass	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Golden shiner	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Shorthead redhorse	ND	ND	0	0	0	0	0	0	0	0	0	1	1	<0.01
Freshwater drum	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Silver redhorse	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Bluntnose minnow	ND	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Totals	ND	ND	160	311	4321	4463	9996	31485	17235	5559	14801	15	88346	

Table 16. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	4	294	5498	641	1786	2686	26882	701	ND	38492	41.79
Spottail shiner	ND	ND	ND	108	414	6824	15913	6064	2288	4788	202	ND	36601	39.73
Rainbow smelt	ND	ND	ND	66	1580	59	1844	5446	89	109	68	ND	9261	10.05
Trout-perch	ND	ND	ND	5	80	194	610	310	254	1631	20	ND	3104	3.37
Yellow perch	ND	ND	ND	50	4	181	379	206	609	57	90	ND	1576	1.71
Bloater	ND	ND	ND	0	1	117	269	868	29	52	56	ND	1392	1.51
Johnny darter	ND	ND	ND	1	77	57	82	17	5	112	34	ND	385	0.42
Coho salmon	ND	ND	ND	11	23	224	22	17	4	0	0	ND	301	0.33
Lake trout	ND	ND	ND	9	34	31	18	11	89	53	41	ND	286	0.31
Brown trout	ND	ND	ND	63	12	9	10	11	30	17	10	ND	162	0.18
White sucker	ND	ND	ND	1	6	9	15	9	36	31	11	ND	118	0.13
Gizzard shad	ND	ND	ND	0	0	0	0	0	12	88	8	ND	108	0.12
Chinook salmon	ND	ND	ND	7	6	55	4	2	7	22	4	ND	107	0.12
Longnose sucker	ND	ND	ND	14	2	2	1	7	12	8	25	ND	71	0.08
Carp	ND	ND	ND	0	4	0	1	2	6	16	5	ND	34	0.04
Longnose dace	ND	ND	ND	3	3	2	0	0	5	8	5	ND	26	0.03
Rainbow trout	ND	ND	ND	4	1	2	2	5	1	5	1	ND	21	0.02
Slimy sculpin	ND	ND	ND	5	6	1	1	0	0	1	0	ND	14	0.02
Sand shiner	ND	ND	ND	0	0	0	0	0	12	0	0	ND	12	0.01
Emerald shiner	ND	ND	ND	0	0	0	0	3	0	7	0	ND	10	0.01
Lake whitefish	ND	ND	ND	0	1	3	0	2	2	0	1	ND	9	0.01
Ninespine stickleback	ND	ND	ND	1	2	1	0	0	1	0	0	ND	5	0.01
Channel catfish	ND	ND	ND	0	0	0	1	0	1	2	1	ND	5	0.01
Burbot	ND	ND	ND	2	1	0	0	0	0	1	1	ND	5	0.01
Quillback	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Golden shiner	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Lake herring	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Lake sturgeon	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Totals	ND	ND	ND	355	2551	13270	19815	14766	6182	33895	1285	ND	92119	

Table 17. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	267	71	2248	1178	16700	66560	54607	140	ND	141771	76.28
Spottail shiner	ND	ND	ND	711	834	3475	9796	2147	8582	2080	200	ND	27825	14.97
Rainbow smelt	ND	ND	ND	788	2152	579	146	923	54	150	467	ND	5259	2.83
Yellow perch	ND	ND	ND	41	25	104	511	1031	2733	63	151	ND	4659	2.51
Bloater	ND	ND	ND	0	4	68	1979	3	518	90	347	ND	3009	1.62
Trout-perch	ND	ND	ND	41	27	152	326	376	324	461	23	ND	1730	0.93
Chinook salmon	ND	ND	ND	168	83	61	1	1	7	0	1	ND	322	0.17
Johnny darter	ND	ND	ND	20	52	53	38	1	42	20	7	ND	233	0.13
White sucker	ND	ND	ND	40	19	31	8	41	30	18	1	ND	188	0.10
Lake trout	ND	ND	ND	15	3	4	0	2	0	55	85	ND	164	0.09
Gizzard shad	ND	ND	ND	3	0	1	0	6	124	17	8	ND	159	0.09
Slimy sculpin	ND	ND	ND	89	28	7	1	0	0	1	2	ND	128	0.07
Longnose sucker	ND	ND	ND	2	35	20	5	9	20	7	0	ND	98	0.05
Carp	ND	ND	ND	11	29	7	2	12	3	7	0	ND	71	0.04
Coho salmon	ND	ND	ND	39	26	0	0	0	0	0	0	ND	65	0.03
Brown trout	ND	ND	ND	20	10	9	11	0	1	4	5	ND	60	0.03
Rainbow trout	ND	ND	ND	3	1	1	1	1	2	2	3	ND	14	0.01
Emerald shiner	ND	ND	ND	7	1	3	0	0	0	0	1	ND	12	0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	6	3	0	ND	10	0.01
Channel catfish	ND	ND	ND	1	0	0	0	3	3	1	0	ND	8	<0.01
Ninespine stickleback	ND	ND	ND	0	1	7	0	0	0	0	0	ND	8	<0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	0	7	0	ND	7	<0.01
Lake whitefish	ND	ND	ND	3	3	1	0	0	0	0	0	ND	7	<0.01
Longnose dace	ND	ND	ND	3	0	0	0	0	1	2	0	ND	6	<0.01
Mottled sculpin	ND	ND	ND	2	0	0	0	0	0	0	4	ND	6	<0.01
Burbot	ND	ND	ND	1	0	2	0	2	0	0	0	ND	5	<0.01
Northern pike	ND	ND	ND	0	0	0	0	1	3	0	0	ND	4	<0.01
Shorthead redhorse	ND	ND	ND	1	0	0	1	0	0	2	0	ND	4	<0.01
Golden redhorse	ND	ND	ND	0	0	0	0	0	3	0	0	ND	3	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	2	0	1	0	ND	3	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	1	0	0	0	ND	2	<0.01
Round whitefish	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	<0.01
Central mudminnow	ND	ND	DN	1	0	0	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Green sunfish	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Black crappie	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Lake chub	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	2279	3406	6836	14004	21263	79016	57599	1445	ND	185848	

Table 18. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	157	6349	3621	7923	2699	9416	2119	555	ND	32839	40.32
Alewife	ND	ND	ND	813	4777	4230	2349	2325	1344	301	313	ND	16452	20.20
Yellow perch	ND	ND	ND	6	49	329	2020	1532	7564	1088	182	ND	12770	15.68
Rainbow smelt	ND	ND	ND	517	4676	2389	89	1345	519	2023	888	ND	12446	15.28
Trout-perch	ND	ND	ND	14	483	358	363	674	437	773	20	ND	3122	3.83
Bloater	ND	ND	ND	0	143	1064	754	20	794	68	18	ND	2861	3.51
Johnny darter	ND	ND	ND	3	64	67	4	5	23	29	3	ND	198	0.24
Chinook salmon	ND	ND	ND	2	12	141	11	3	9	1	3	ND	182	0.22
Lake trout	ND	ND	ND	2	17	9	0	11	34	16	32	ND	121	0.15
White sucker	ND	ND	ND	2	31	23	26	3	4	18	6	ND	113	0.14
Slimy sculpin	ND	ND	ND	23	19	7	0	0	2	1	3	ND	55	0.07
Gizzard shad	ND	ND	ND	0	1	9	1	2	7	19	14	ND	53	0.07
Longnose sucker	ND	ND	ND	2	14	9	3	3	8	3	5	ND	47	0.06
Brown trout	ND	ND	ND	15	6	9	0	5	1	1	3	ND	40	0.05
Longnose dace	ND	ND	ND	0	1	2	0	5	2	22	2	ND	34	0.04
Carp	ND	ND	ND	2	3	2	3	4	4	7	3	ND	28	0.03
Rainbow trout	ND	ND	ND	3	0	0	0	0	0	9	10	ND	22	0.03
Mottled sculpin	ND	ND	ND	1	5	3	0	1	2	2	1	ND	15	0.02
Lake whitefish	ND	ND	ND	0	12	0	0	1	0	0	1	ND	14	0.02
Coho salmon	ND	ND	ND	2	6	2	0	0	3	0	0	ND	13	0.02
Sand shiner	ND	ND	ND	0	0	0	1	5	0	3	1	ND	10	0.01
Ninespine stickleback	ND	ND	ND	1	4	3	0	0	0	0	0	ND	8	0.01
Burbot	ND	ND	ND	1	0	1	0	0	2	0	1	ND	5	0.01
Black bullhead	ND	ND	ND	0	0	2	1	0	0	0	0	ND	3	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
White crappie	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Fathead minnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	1567	16672	12281	13548	8644	20175	6503	2064	ND	81454	

Table 19. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	883	5448	2684	596	14939	711	1600	178	ND	26439	26.03
Yellow perch	ND	ND	ND	1183	154	6699	10485	490	1795	4404	640	ND	25850	25.45
Spottail shiner	ND	ND	ND	526	1515	15506	2486	558	355	933	711	ND	22580	22.26
Rainbow smelt	ND	ND	ND	5069	6761	592	565	51	111	272	876	ND	14297	14.08
Bloater	ND	ND	ND	1	34	1428	8140	0	35	219	55	ND	9912	9.74
Trout-perch	ND	ND	ND	31	433	202	516	60	210	102	54	ND	1608	1.58
Johnny darter	ND	ND	ND	11	81	24	10	4	6	7	8	ND	151	0.15
White sucker	ND	ND	ND	5	11	25	45	4	13	19	6	ND	128	0.13
Lake trout	ND	ND	ND	11	18	7	5	0	0	18	46	ND	105	0.10
Gizzard shad	ND	ND	ND	3	0	0	1	23	12	26	15	ND	80	0.08
Slimy sculpin	ND	ND	ND	40	14	5	3	0	0	2	10	ND	74	0.07
Longnose sucker	ND	ND	ND	11	15	32	3	2	1	2	4	ND	70	0.07
Carp	ND	ND	ND	2	0	5	1	17	9	14	0	ND	48	0.05
Chinook salmon	ND	ND	ND	7	16	16	3	0	4	0	0	ND	46	0.05
Sand shiner	ND	ND	ND	0	0	0	0	9	10	8	0	ND	27	0.03
Channel catfish	ND	ND	ND	0	1	0	0	8	3	4	4	ND	20	0.02
Emerald shiner	ND	ND	ND	0	0	0	0	5	10	4	0	ND	19	0.02
Rainbow trout	ND	ND	ND	2	1	11	2	0	2	0	0	ND	18	0.02
Bluegill	ND	ND	ND	0	0	1	0	0	0	9	1	ND	11	0.01
Coho salmon	ND	ND	ND	4	6	0	0	0	1	0	0	ND	11	0.01
Lake whitefish	ND	ND	ND	3	2	2	0	0	0	0	0	ND	7	0.01
Mottled sculpin	ND	ND	ND	0	0	0	2	0	3	1	1	ND	7	0.01
Burbot	ND	ND	ND	1	0	0	1	0	2	0	2	ND	6	0.01
Ninespine stickleback	ND	ND	ND	4	0	0	1	0	0	0	0	ND	5	<0.01
Round whitefish	ND	ND	ND	0	0	0	0	0	0	1	2	ND	3	<0.01
Longnose dace	ND	ND	ND	1	0	0	0	0	0	2	0	ND	3	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	2	0	0	1	ND	3	<0.01
Brown trout	ND	ND	ND	0	0	1	1	0	0	0	1	ND	3	<0.01
Largemouth bass	ND	ND	ND	0	0	1	0	0	0	1	0	ND	2	<0.01
Blacknose dace	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Northern pike	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Shorthead redhorse	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Blacknose shiner	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Black bullhead	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Walleye	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Rock bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Grass pickerel	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	7798	14512	27245	22867	16173	3293	7052	2615	ND	101555	

Table 20. Number of fish caught by standard series trawling, gillnetting and seining in Cook Plant study areas, southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	552	1733	3005	1366	1009	ND	ND	ND	ND	7665	27.54
Rainbow smelt	ND	ND	ND	1619	4594	490	42	521	ND	ND	ND	ND	7266	26.11
Yellow perch	ND	ND	ND	110	27	1101	2339	1778	ND	ND	ND	ND	5355	19.24
Alewife	ND	ND	ND	206	1383	1159	406	2097	ND	ND	ND	ND	5251	18.87
Bloater	ND	ND	ND	0	8	1415	0	0	ND	ND	ND	ND	1423	5.11
Trout-perch	ND	ND	ND	16	10	99	53	33	ND	ND	ND	ND	211	0.76
Slimy sculpin	ND	ND	ND	184	14	1	0	0	ND	ND	ND	ND	199	0.72
White sucker	ND	ND	ND	6	8	44	35	46	ND	ND	ND	ND	139	0.50
Common carp	ND	ND	ND	37	15	12	5	3	ND	ND	ND	ND	72	0.26
Johnny darter	ND	ND	ND	4	23	24	3	4	ND	ND	ND	ND	58	0.21
Gizzard shad	ND	ND	ND	0	0	0	3	37	ND	ND	ND	ND	40	0.14
Longnose sucker	ND	ND	ND	6	6	12	0	13	ND	ND	ND	ND	37	0.13
Chinook salmon	ND	ND	ND	3	4	12	1	2	ND	ND	ND	ND	22	0.08
Brown trout	ND	ND	ND	12	2	4	0	2	ND	ND	ND	ND	20	0.07
Emerald shiner	ND	ND	ND	6	1	2	1	0	ND	ND	ND	ND	10	0.04
Mottled sculpin	ND	ND	ND	6	4	0	0	0	ND	ND	ND	ND	10	0.04
Sand shiner	ND	ND	ND	5	0	1	1	1	ND	ND	ND	ND	8	0.03
Lake trout	ND	ND	ND	5	2	0	0	0	ND	ND	ND	ND	7	0.03
Shorthead redhorse	ND	ND	ND	0	0	3	1	0	ND	ND	ND	ND	4	0.01
Channel catfish	ND	ND	ND	0	0	2	2	0	ND	ND	ND	ND	4	0.01
Freshwater drum	ND	ND	ND	0	0	1	1	2	ND	ND	ND	ND	4	0.01
Rainbow trout	ND	ND	ND	3	0	0	1	0	ND	ND	ND	ND	4	0.01
Silver, redhorse	ND	ND	ND	0	0	0	1	2	ND	ND	ND	ND	3	0.01
Coho salmon	ND	ND	ND	1	2	0	0	0	ND	ND	ND	ND	3	0.01
Longnose dace	ND	ND	ND	1	1	0	0	0	ND	ND	ND	ND	2	0.01
Central mudminnow	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.01
Quillback	ND	ND	ND	0	0	0	0	2	ND	ND	ND	ND	2	0.01
Ninespine stickleback	ND	ND	ND	0	2	0	0	0	ND	ND	ND	ND	2	0.01
Golden shiner	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	<0.01
Burbot	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	<0.01
Round whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	<0.01
Lake whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	<0.01
Golden redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	<0.01
Common shiner	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	<0.01
Largemouth bass	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	<0.01
Totals	ND	ND	ND	2788	7839	7387	4263	5554	ND	ND	ND	ND	27831	

Table 21. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1973. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	1358	722	953	292	8273	1360	326	ND	ND	13284	39.59
Alewife	ND	ND	ND	2946	1627	1579	1963	2611	683	508	ND	ND	11917	35.51
Trout-perch	ND	ND	ND	46	90	1505	588	492	155	294	ND	ND	3170	9.45
Spottail shiner	ND	ND	ND	729	563	167	266	504	632	273	ND	ND	3134	9.34
Yellow perch	ND	ND	ND	5	25	360	264	486	209	315	ND	ND	1664	4.96
Johnny darter	ND	ND	ND	13	47	57	15	31	11	27	ND	ND	201	0.60
Slimy sculpin	ND	ND	ND	37	14	3	0	6	4	7	ND	ND	71	0.21
Bloater	ND	ND	ND	0	0	14	9	21	0	19	ND	ND	63	0.19
Mottled sculpin	ND	ND	ND	6	2	2	0	0	0	2	ND	ND	12	0.04
Ninespine stickleback	ND	ND	ND	0	6	5	0	0	0	0	ND	ND	11	0.03
White sucker	ND	ND	ND	0	0	3	1	4	3	0	ND	ND	11	0.03
Longnose sucker	ND	ND	ND	0	0	3	2	0	0	0	ND	ND	5	0.01
Lake trout	ND	ND	ND	0	1	2	0	1	0	0	ND	ND	4	0.01
Northern pike	ND	ND	ND	0	0	0	0	1	0	2	ND	ND	3	0.01
Lake whitefish	ND	ND	ND	0	1	1	0	0	0	0	ND	ND	2	0.01
Brown trout	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Chinook salmon	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Bluegill	ND	ND	ND	0	1	0	0	0	0	0	ND	ND	1	<0.01
Burbot	ND	ND	ND	0	0	1	0	0	0	0	ND	ND	1	<0.01
Totals	ND	ND	ND	5140	3099	4658	3400	12410	3057	1773	ND	ND	33557	

Table 22. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1974. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	3928	7808	755	1149	131	166	765	723	ND	15425	59.59
Rainbow smelt	ND	ND	ND	308	738	59	373	3274	89	284	13	ND	5138	19.85
Spottail shiner	ND	ND	ND	112	1755	333	181	133	86	338	10	ND	2948	11.39
Trout-perch	ND	ND	ND	8	123	53	786	108	88	137	12	ND	1315	5.08
Yellow perch	ND	ND	ND	19	7	89	23	65	84	7	19	ND	313	1.21
Johnny darter	ND	ND	ND	5	93	82	60	6	7	22	14	ND	289	1.12
Slimy sculpin	ND	ND	ND	137	19	14	14	28	2	17	17	ND	248	0.96
Bloater	ND	ND	ND	0	0	3	140	5	0	15	0	ND	163	0.63
Ninespine stickleback	ND	ND	ND	0	13	4	2	1	0	0	0	ND	20	0.08
White sucker	ND	ND	ND	0	0	1	1	2	2	0	0	ND	6	0.02
Lake trout	ND	ND	ND	1	1	0	0	0	0	0	2	ND	4	0.02
Chinook salmon	ND	ND	ND	0	0	0	1	3	0	0	0	ND	4	0.02
Bluegill	ND	ND	ND	0	1	2	0	0	0	0	0	ND	3	0.01
Channel catfish	ND	ND	ND	1	0	0	0	0	0	1	1	ND	3	0.01
Longnose sucker	ND	ND	ND	0	0	0	1	0	0	1	0	ND	2	0.01
Carp	ND	ND	ND	0	0	0	0	0	1	1	0	ND	2	0.01
Brown trout	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	0.01
Burbot	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	4519	10559	1395	2733	3756	525	1588	811	ND	25886	

Table 23. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	9	1889	143	161	16	2119	404	100	32	4873	36.88
Spottail shiner	ND	ND	ND	39	631	342	185	451	749	116	156	797	3466	26.23
Rainbow smelt	ND	ND	ND	159	1093	1026	0	171	92	171	105	13	2830	21.42
Yellow perch	ND	ND	ND	4	2	108	573	132	24	19	4	77	943	7.14
Trout-perch	ND	ND	ND	12	134	204	68	103	89	78	49	28	765	5.79
Johnny darter	ND	ND	ND	2	35	16	3	3	11	19	10	9	128	0.97
Slimy sculpin	ND	ND	ND	37	31	12	0	1	1	2	5	4	93	0.70
Bloater	ND	ND	ND	0	2	33	0	9	1	1	0	0	46	0.35
Gizzard shad	ND	ND	ND	0	0	0	0	0	1	0	0	26	27	0.20
Ninespine stickleback	ND	ND	ND	0	5	14	0	0	0	0	0	0	19	0.14
Lake trout	ND	ND	ND	1	3	3	0	0	0	0	0	0	7	0.05
Longnose sucker	ND	ND	ND	0	1	2	1	2	0	0	0	0	6	0.05
Carp	ND	ND	ND	0	0	0	2	1	0	0	0	0	3	0.02
White sucker	ND	ND	ND	0	0	0	0	0	0	1	1	1	3	0.02
Logperch	ND	ND	ND	0	1	1	0	0	0	0	0	0	2	0.02
Chinook salmon	ND	ND	ND	0	0	0	1	0	0	0	0	0	1	0.01
Burbot	ND	ND	ND	0	0	0	0	0	0	1	0	0	1	0.01
Totals	ND	ND	ND	263	3827	1904	994	889	3107	812	430	987	13213	

Table 24. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	748	4405	130	381	398	78	2164	20	ND	8324	54.99
Spottail shiner	ND	ND	ND	503	576	324	68	134	434	1144	146	ND	3329	21.99
Trout-perch	ND	ND	ND	15	106	62	1088	92	179	143	7	ND	1692	11.18
Rainbow smelt	ND	ND	ND	136	37	0	415	14	3	12	121	ND	738	4.88
Yellow perch	ND	ND	ND	33	3	58	86	154	242	26	4	ND	606	4.00
Johnny darter	ND	ND	ND	2	139	9	25	26	30	59	6	ND	296	1.96
Bloater	ND	ND	ND	3	1	1	60	0	0	0	0	ND	65	0.43
Slimy sculpin	ND	ND	ND	38	12	0	0	4	1	5	3	ND	63	0.42
Ninespine stickleback	ND	ND	ND	0	7	0	0	0	0	0	0	ND	7	0.05
Lake trout	ND	ND	ND	1	1	0	2	0	0	0	0	ND	4	0.03
Burbot	ND	ND	ND	1	0	0	0	0	0	2	0	ND	3	0.02
White sucker	ND	ND	ND	0	0	0	1	0	1	0	0	ND	2	0.01
Carp	ND	ND	ND	0	0	0	0	0	1	1	0	ND	2	0.01
Longnose sucker	ND	ND	ND	2	0	0	0	0	0	0	0	ND	2	0.01
Channel catfish	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	0.01
Bluegill	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	0.01
Lake whitefish	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	0.01
Gizzard shad	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	0.01
Totals	ND	ND	ND	1482	5289	584	2127	822	969	3556	308	ND	15137	

Table 25. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	7	339	417	68	1437	3177	1157	25	ND	6627	34.59
Alewife	ND	ND	ND	2	364	249	134	37	1242	2794	1780	ND	6602	34.46
Trout-perch	ND	ND	ND	4	171	205	1861	118	75	493	1	ND	2928	15.28
Rainbow smelt	ND	ND	ND	75	168	1	663	87	78	111	104	ND	1287	6.72
Yellow perch	ND	ND	ND	14	7	122	13	464	333	29	120	ND	1102	5.75
Johnny darter	ND	ND	ND	34	167	44	26	6	81	4	15	ND	377	1.97
Bloater	ND	ND	ND	0	0	3	11	0	2	141	12	ND	169	0.88
Slimy sculpin	ND	ND	ND	14	0	0	7	1	2	0	2	ND	26	0.14
Longnose sucker	ND	ND	ND	0	0	0	0	8	9	0	1	ND	18	0.09
White sucker	ND	ND	ND	0	3	0	2	3	0	1	0	ND	9	0.05
Ninespine stickleback	ND	ND	ND	0	5	0	2	0	0	0	0	ND	7	0.04
Mottled sculpin	ND	ND	ND	0	0	0	0	0	0	3	0	ND	3	0.02
Burbot	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	0.01
Chinook salmon	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	0.01
Longnose dace	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	0.01
Totals	ND	ND	ND	150	1224	1042	2787	2162	4999	4734	2060	ND	19158	

Table 26. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	0	0	629	14	18	55	8018	694	ND	9428	30.89
Rainbow smelt	ND	ND	ND	47	1452	20	1532	5138	41	102	66	ND	8598	28.17
Spottail shiner	ND	ND	ND	14	146	1361	3	30	916	4638	166	ND	7274	23.84
Trout-perch	ND	ND	ND	3	54	129	573	300	230	1611	18	ND	2918	9.56
Bloater	ND	ND	ND	0	0	106	257	826	27	52	56	ND	1324	4.34
Yellow perch	ND	ND	ND	21	0	55	85	2	271	57	53	ND	544	1.78
Johnny darter	ND	ND	ND	1	75	56	82	16	4	112	34	ND	380	1.25
Slimy sculpin	ND	ND	ND	5	6	1	1	0	0	1	0	ND	14	0.05
White sucker	ND	ND	ND	0	0	3	0	0	0	10	0	ND	13	0.04
Longnose sucker	ND	ND	ND	0	0	2	0	0	6	1	1	ND	10	0.03
Lake trout	ND	ND	ND	0	0	0	1	1	0	1	2	ND	5	0.02
Ninespine stickleback	ND	ND	ND	1	1	1	0	0	1	0	0	ND	4	0.01
Coho salmon	ND	ND	ND	2	0	0	0	0	0	0	0	ND	2	0.01
Burbot	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Carp	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Brown trout	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
TOTALS	ND	ND	ND	96	1734	2363	2548	6531	1552	14603	1090	ND	30517	

Table 27. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	529	214	1738	343	1803	457	1463	128	ND	6675	30.61
Rainbow smelt	ND	ND	ND	664	1868	576	146	915	48	65	444	ND	4726	21.67
Alewife	ND	ND	ND	22	20	618	226	129	629	1815	132	ND	3591	16.47
Yellow perch	ND	ND	ND	29	7	76	41	613	1546	56	140	ND	2508	11.50
Bloater	ND	ND	ND	0	3	68	1933	2	36	65	346	ND	2453	11.25
Trout-perch	ND	ND	ND	19	19	110	275	338	310	423	20	ND	1514	6.94
Johnny darter	ND	ND	ND	20	52	53	17	1	5	20	7	ND	175	0.80
Slimy sculpin	ND	ND	ND	62	28	7	1	0	0	1	2	ND	101	0.46
Longnose sucker	ND	ND	ND	0	1	3	0	5	16	0	0	ND	25	0.11
White sucker	ND	ND	ND	0	1	4	1	2	1	1	0	ND	10	0.05
Ninespine stickleback	ND	ND	ND	0	1	6	0	0	0	0	0	ND	7	0.03
Chinook salmon	ND	ND	ND	0	4	2	0	0	0	0	0	ND	6	0.03
Mottled sculpin	ND	ND	ND	2	0	0	0	0	0	0	4	ND	6	0.03
Lake trout	ND	ND	ND	0	0	2	0	0	0	0	0	ND	2	0.01
Burbot	ND	ND	ND	1	0	1	0	0	0	0	0	ND	2	0.01
Lake whitefish	ND	ND	ND	0	2	0	0	0	0	0	0	ND	2	0.01
Rainbow trout	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Brown trout	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Carp	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Gizzard shad	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Central mudminnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	1350	2220	3264	2983	1809	3049	3910	1223	ND	21808	

Table 28. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	10	1756	405	1077	1930	3394	1081	299	ND	10752	29.36
Rainbow smelt	ND	ND	ND	506	4256	1070	89	748	387	1939	825	ND	10620	29.00
Yellow perch	ND	ND	ND	1	45	248	161	902	2677	1005	77	ND	5116	13.97
Alewife	ND	ND	ND	1	900	1038	104	33	846	280	221	ND	4303	11.75
Trout-perch	ND	ND	ND	9	353	317	354	649	429	721	18	ND	2850	7.78
Bloater	ND	ND	ND	0	140	1009	787	12	700	65	18	ND	2691	7.35
Johnny darter	ND	ND	ND	3	63	67	4	5	7	29	3	ND	181	0.49
Slimy sculpin	ND	ND	ND	22	15	7	0	0	1	1	3	ND	49	0.13
Mottled sculpin	ND	ND	ND	1	5	3	0	1	2	2	1	ND	15	0.04
Longnose sucker	ND	ND	ND	0	2	1	0	3	5	0	0	ND	11	0.03
White sucker	ND	ND	ND	0	2	0	0	1	3	3	0	ND	9	0.02
Gizzard shad	ND	ND	ND	0	0	0	0	0	0	0	5	ND	5	0.01
Ninespine stickleback	ND	ND	ND	1	2	2	0	0	0	0	0	ND	5	0.01
Lake trout	ND	ND	ND	0	2	2	0	0	0	0	0	ND	4	0.01
Carp	ND	ND	ND	0	0	1	0	1	0	1	1	ND	4	0.01
Lake whitefish	ND	ND	ND	0	2	0	0	1	0	0	0	ND	3	0.01
Chinook salmon	ND	ND	ND	0	1	0	1	0	1	0	0	ND	3	0.01
Burbot	ND	ND	ND	0	0	1	0	0	0	0	1	ND	2	0.01
Fathead minnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
White crappie	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	555	7580	5772	2617	4286	8452	5927	1472	ND	36625	

Table 29. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, 1981. ND = no fish.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Yellow perch	ND	ND	ND	1170	145	5799	3011	396	1719	3807	99	ND	16146	31.01
Rainbow smelt	ND	ND	ND	4957	6708	591	560	49	104	252	822	ND	14043	26.97
Bloater	ND	ND	ND	1	30	1014	7934	0	31	207	55	ND	9672	18.58
Alewife	ND	ND	ND	206	4484	322	447	25	201	331	169	ND	6185	11.88
Spottail shiner	ND	ND	ND	378	1279	949	212	216	42	514	656	ND	4246	8.16
Trout-perch	ND	ND	ND	3	390	198	507	43	199	95	52	ND	1487	2.86
Johnny darter	ND	ND	ND	11	80	16	10	4	6	4	8	ND	139	0.27
Slimy sculpin	ND	ND	ND	33	14	5	3	0	0	2	10	ND	67	0.13
Lake trout	ND	ND	ND	0	5	7	3	0	0	0	0	ND	15	0.03
Gizzard shad	ND	ND	ND	0	0	0	0	0	2	0	10	ND	12	0.02
White sucker	ND	ND	ND	1	1	4	1	0	1	1	0	ND	9	0.02
Longnose sucker	ND	ND	ND	2	2	4	0	1	0	0	0	ND	9	0.02
Mottled sculpin	ND	ND	ND	0	0	0	2	0	3	1	1	ND	7	0.01
Channel catfish	ND	ND	ND	0	1	0	0	1	0	1	3	ND	6	0.01
Lake whitefish	ND	ND	ND	2	2	1	0	0	0	0	0	ND	5	0.01
Carp	ND	ND	ND	1	0	0	0	1	0	2	0	ND	4	0.01
Burbot	ND	ND	ND	1	0	0	1	0	1	0	0	ND	3	0.01
Chinook salmon	ND	ND	ND	0	0	1	1	0	0	0	0	ND	2	<0.01
Ninespine stickleback	ND	ND	ND	1	0	0	1	0	0	0	0	ND	2	<0.01
Rock bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Grass pickerel	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	6767	13141	9311	12694	736	2309	5218	1886	ND	52062	

Table 30. Number of fish caught by standard series trawling in Cook Plant study areas, southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	1541	3313	432	42	344	ND	ND	ND	ND	5672	36.16
Yellow perch	ND	ND	ND	83	25	745	1455	1323	ND	ND	ND	ND	3631	23.15
Spottail shiner	ND	ND	ND	387	306	433	596	819	ND	ND	ND	ND	2541	16.20
Alewife	ND	ND	ND	35	56	129	37	1925	ND	ND	ND	ND	2182	13.91
Bloater	ND	ND	ND	0	8	1343	0	0	ND	ND	ND	ND	1351	8.61
Trout-perch	ND	ND	ND	7	6	25	51	23	ND	ND	ND	ND	112	0.71
Slimy sculpin	ND	ND	ND	89	13	1	0	0	ND	ND	ND	ND	103	0.66
White sucker	ND	ND	ND	0	0	0	6	28	ND	ND	ND	ND	34	0.22
Johnny darter	ND	ND	ND	4	23	0	0	4	ND	ND	ND	ND	31	0.20
Longnose sucker	ND	ND	ND	0	0	0	0	13	ND	ND	ND	ND	13	0.08
Mottled sculpin	ND	ND	ND	1	4	0	0	0	ND	ND	ND	ND	5	0.03
Common carp	ND	ND	ND	0	0	0	1	2	ND	ND	ND	ND	3	0.02
Central mudminnow	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.01
Chinook salmon	ND	ND	ND	0	1	0	0	1	ND	ND	ND	ND	2	0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.01
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.01
Lake whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.01
Totals	ND	ND	ND	2150	3756	3108	2188	4483	ND	ND	ND	ND	15685	

Table 31. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1973. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	1869	2682	1091	4198	854	263	79	68	0	0	11104	63.59
Spottail shiner	ND	12	402	914	799	848	25	300	104	137	96	1	3638	20.83
Yellow perch	ND	6	35	10	15	527	338	422	34	33	22	0	1442	8.26
Rainbow smelt	ND	1	118	180	7	4	1	121	60	8	12	0	512	2.93
Trout-perch	ND	0	2	0	7	62	114	19	5	31	20	0	260	1.49
Lake trout	ND	0	2	1	1	0	6	18	49	23	54	0	158	0.90
White sucker	ND	1	2	6	10	11	13	26	38	26	0	0	133	0.76
Longnose sucker	ND	1	4	9	13	11	24	1	1	1	0	0	65	0.37
Bloater	ND	0	0	0	1	12	33	14	1	1	0	0	62	0.36
Northern pike	ND	0	0	0	0	0	0	0	8	7	8	0	23	0.13
Coho salmon	ND	0	5	0	9	1	0	0	3	2	0	0	20	0.11
Chinook salmon	ND	0	0	2	2	0	1	2	3	2	0	0	12	0.07
Brown trout	ND	0	4	1	2	0	0	2	0	1	0	0	10	0.06
Carp	ND	0	0	0	0	0	0	1	0	6	0	0	7	0.04
Channel catfish	ND	0	0	0	0	0	0	0	0	2	4	0	6	0.03
Burbot	ND	0	0	4	0	1	0	0	0	0	0	0	5	0.03
Rainbow trout	ND	0	0	1	2	0	0	0	0	0	0	0	3	0.02
Rock bass	ND	0	0	0	0	1	0	0	0	0	0	0	1	0.01
Mottled sculpin	ND	0	0	1	0	0	0	0	0	0	0	0	1	0.01
Totals	ND	21	2443	3811	1959	5676	1409	1189	385	352	216	1	17462	

Table 32. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1974. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	279	891	1800	2782	2987	351	174	160	1	0	9425	66.70
Spottail shiner	1	ND	98	162	700	1335	161	39	76	77	17	22	2688	19.02
Yellow perch	1	ND	14	15	7	28	50	315	359	2	56	16	863	6.11
Rainbow smelt	0	ND	18	169	17	0	10	20	3	59	0	5	301	2.13
Trout-perch	0	ND	0	1	21	2	140	17	6	50	3	2	242	1.71
Lake trout	0	ND	0	0	16	9	0	0	0	12	83	0	120	0.85
White sucker	2	ND	1	3	15	18	25	10	13	11	5	8	113	0.80
Coho salmon	0	ND	8	4	40	0	0	26	0	0	25	0	103	0.73
Longnose sucker	1	ND	1	4	26	11	38	1	3	1	6	2	94	0.67
Bloater	0	ND	0	0	0	0	59	0	1	0	0	0	60	0.42
Gizzard shad	0	ND	0	0	1	0	0	1	20	8	0	0	30	0.21
Chinook salmon	0	ND	0	1	1	1	0	3	13	0	3	1	23	0.16
Brown trout	0	ND	1	2	5	1	4	5	2	0	2	0	22	0.16
Burbot	0	ND	1	1	1	1	0	0	0	0	0	10	14	0.10
Carp	0	ND	0	0	0	0	0	7	4	2	0	0	13	0.09
Northern pike	1	ND	2	3	1	0	0	0	0	5	0	0	12	0.08
Channel catfish	0	ND	0	0	0	0	0	0	4	0	0	0	4	0.03
Rainbow trout	0	ND	1	0	0	0	0	0	0	0	0	0	1	0.01
Lake whitefish	0	ND	0	0	0	0	0	1	0	0	0	0	1	0.01
Lake herring	0	ND	0	0	0	0	0	0	0	0	0	1	1	0.01
Slimy sculpin	0	ND	0	1	0	0	0	0	0	0	0	0	1	0.01
Totals	6	ND	424	1257	2651	4188	3474	796	678	389	201	67	14131	

Table 33. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	797	167	310	867	511	201	52	44	50	10	3009	46.67
Spottail shiner	1	ND	12	12	113	545	212	205	154	108	21	34	1437	22.29
Yellow perch	7	ND	29	8	2	138	361	366	255	132	87	3	1388	21.53
Longnose sucker	1	ND	50	1	8	20	0	0	1	2	3	0	88	1.36
White sucker	1	ND	7	1	4	17	8	0	17	1	1	4	81	1.26
Lake trout	0	ND	1	2	5	18	0	0	0	4	47	1	78	1.21
Trout-perch	0	ND	0	1	12	17	0	7	20	15	2	0	74	1.15
Rainbow smelt	3	ND	21	12	11	6	0	2	0	7	0	1	65	1.01
Coho salmon	0	ND	6	40	1	5	0	2	0	0	1	0	55	0.85
Gizzard shad	0	ND	0	0	0	0	0	28	15	1	2	0	46	0.71
Carp	0	ND	0	0	0	0	9	13	17	2	2	0	43	0.67
Chinook salmon	0	ND	0	0	0	0	0	3	2	19	7	1	32	0.50
Burbot	1	ND	0	0	0	0	0	0	0	0	0	13	14	0.22
Brown trout	0	ND	7	2	0	1	0	1	1	1	0	1	14	0.22
Channel catfish	0	ND	0	0	0	0	1	1	4	1	1	0	8	0.12
Shorthead redhorse	0	ND	0	0	0	0	0	0	4	0	0	0	4	0.06
Rainbow trout	0	ND	1	0	0	0	0	0	1	0	0	1	3	0.05
Bloater	0	ND	0	0	0	1	0	1	0	0	0	0	2	0.03
Northern pike	1	ND	0	0	0	1	0	0	0	0	0	0	2	0.03
Lake whitefish	0	ND	0	1	0	1	0	0	0	0	0	0	2	0.03
Lake herring	0	ND	0	1	0	0	0	0	0	0	0	0	1	0.02
Silver redhorse	0	ND	0	0	0	0	0	0	0	1	0	0	1	0.02
Lake sturgeon	0	ND	0	0	1	0	0	0	0	0	0	0	1	0.02
Totals	15	ND	931	250	499	1657	1102	810	543	338	224	69	6448	

Table 34. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	204	1267	1136	2078	1647	89	76	12	ND	ND	6509	67.19
Spottail shiner	ND	40	49	142	259	102	384	103	139	31	ND	ND	1449	14.96
Yellow perch	ND	11	5	21	21	244	406	216	167	4	ND	ND	1097	11.32
Rainbow smelt	ND	1	21	16	17	143	1	0	1	1	ND	ND	201	2.07
Trout-perch	ND	0	1	1	3	52	26	4	57	2	ND	ND	146	1.51
White sucker	ND	3	0	5	11	3	14	5	17	7	ND	ND	65	0.67
Gizzard shad	ND	0	0	0	0	0	1	20	18	6	ND	ND	45	0.46
Bloater	ND	0	0	0	0	25	14	0	0	0	ND	ND	39	0.40
Longnose sucker	ND	20	3	5	4	3	2	0	0	0	ND	ND	37	0.38
Coho salmon	ND	0	0	0	19	6	0	0	0	0	ND	ND	25	0.26
Lake trout	ND	0	3	4	7	7	0	0	0	2	ND	ND	23	0.24
Carp	ND	0	0	0	0	0	1	14	3	0	ND	ND	18	0.19
Brown trout	ND	2	0	1	1	1	2	1	1	1	ND	ND	10	0.10
Channel catfish	ND	0	0	0	0	0	0	2	8	0	ND	ND	10	0.10
Lake whitefish	ND	0	1	2	1	1	0	0	0	0	ND	ND	5	0.05
Chinook salmon	ND	0	0	0	0	0	1	0	3	0	ND	ND	4	0.04
Burbot	ND	1	0	1	0	0	1	0	0	0	ND	ND	3	0.03
Rainbow trout	ND	1	0	0	0	0	0	0	0	0	ND	ND	1	0.01
Lake sturgeon	ND	0	0	0	1	0	0	0	0	0	ND	ND	1	0.01
Totals	ND	81	297	1665	1480	2665	2500	454	490	66	ND	ND	9688	

Table 35. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	66	26	608	785	783	92	38	172	4	0	2574	40.05
Spottail shiner	ND	ND	54	2	684	813	60	208	119	133	17	0	2090	32.52
Yellow perch	ND	ND	11	14	11	66	283	408	134	18	11	1	957	14.89
Lake trout	ND	ND	4	10	6	6	6	0	9	27	118	0	186	2.89
White sucker	ND	ND	0	5	21	4	50	10	21	5	3	1	120	1.87
Trout-perch	ND	ND	1	0	15	13	54	3	6	5	0	0	97	1.51
Longnose sucker	ND	ND	4	5	3	0	34	0	5	6	23	0	80	1.24
Rainbow smelt	ND	ND	0	35	0	0	6	1	6	17	0	0	65	1.01
Gizzard shad	ND	ND	0	0	0	0	0	15	39	1	0	0	55	0.86
Carp	ND	ND	0	2	3	0	1	18	20	2	5	0	51	0.79
Bloater	ND	ND	0	0	0	20	29	0	0	0	0	0	49	0.76
Chinook salmon	ND	ND	11	21	0	0	0	0	0	1	0	0	33	0.51
Brown trout	ND	ND	5	0	5	5	2	0	4	1	3	6	31	0.48
Golden redhorse	ND	ND	0	0	0	0	0	6	3	0	0	0	9	0.14
Channel catfish	ND	ND	0	0	0	0	0	4	2	2	0	0	8	0.12
Coho salmon	ND	ND	3	0	0	0	0	0	1	2	1	0	7	0.11
Burbot	ND	ND	1	0	0	0	0	0	0	0	0	6	7	0.11
Rainbow trout	ND	ND	0	0	0	0	1	0	0	0	2	0	3	0.05
Lake sturgeon	ND	ND	0	0	0	0	1	1	0	0	0	0	2	0.03
Shorthead redhorse	ND	ND	0	0	0	0	0	0	0	0	0	1	1	0.02
Quillback	ND	ND	0	0	0	0	0	0	1	0	0	0	1	0.02
Silver redhorse	ND	ND	0	0	0	0	0	0	1	0	0	0	1	0.02
Totals	ND	ND	160	120	1356	1712	1310	766	409	392	187	15	6427	

Table 36. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	4	294	1152	537	138	78	25	1	ND	2229	44.37
Spottail shiner	ND	ND	ND	61	244	25	5	204	126	148	24	ND	837	16.66
Yellow perch	ND	ND	ND	28	4	126	31	197	318	0	36	ND	740	14.73
Rainbow smelt	ND	ND	ND	19	47	27	29	108	48	5	1	ND	284	5.65
Lake trout	ND	ND	ND	8	34	31	17	10	89	51	39	ND	279	5.55
Gizzard shad	ND	ND	ND	0	0	0	0	0	12	88	7	ND	107	2.13
Trout-perch	ND	ND	ND	1	23	26	5	10	19	20	2	ND	106	2.11
White sucker	ND	ND	ND	0	4	5	1	8	36	21	9	ND	84	1.67
Brown trout	ND	ND	ND	4	5	0	3	11	10	16	10	ND	79	1.57
Bloater	ND	ND	ND	0	1	8	9	42	2	0	0	ND	62	1.23
Longnose sucker	ND	ND	ND	14	2	0	1	6	6	7	24	ND	60	1.19
Chinook salmon	ND	ND	ND	7	6	0	4	2	7	22	4	ND	52	1.04
Coho salmon	ND	ND	ND	7	8	4	11	17	4	0	0	ND	51	1.02
Carp	ND	ND	ND	0	2	0	0	2	3	10	5	ND	28	0.56
Lake whitefish	ND	ND	ND	0	1	3	0	2	2	0	1	ND	9	0.18
Channel catfish	ND	ND	ND	0	0	0	0	0	1	2	1	ND	4	0.08
Rainbow trout	ND	ND	ND	1	0	0	0	1	0	1	0	ND	3	0.06
Burbot	ND	ND	ND	0	1	0	0	0	0	1	1	ND	3	0.06
Northern pike	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	0.04
Quillback	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	0.04
Lake herring	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	0.02
Silver redhorse	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	0.02
Lake sturgeon	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	0.02
TOTALS	ND	ND	ND	155	676	1407	653	758	781	428	166	ND	5024	

Table 37. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	74	210	852	1182	181	251	195	70	ND	3015	38.04
Alewife	ND	ND	ND	243	50	1509	844	190	17	0	6	ND	2859	36.08
Yellow perch	ND	ND	ND	11	18	28	42	389	500	7	11	ND	1006	12.69
Rainbow smelt	ND	ND	ND	98	48	2	0	5	3	18	18	ND	192	2.42
Lake trout	ND	ND	ND	15	3	2	0	2	0	45	85	ND	152	1.92
Gizzard shad	ND	ND	ND	0	0	0	0	6	124	6	0	ND	136	1.72
Trout-perch	ND	ND	ND	0	4	21	25	34	12	37	3	ND	136	1.72
White sucker	ND	ND	ND	2	12	26	0	34	29	16	1	ND	120	1.51
Longnose sucker	ND	ND	ND	2	33	16	3	4	3	7	0	ND	68	0.86
Carp	ND	ND	ND	1	27	4	0	11	3	7	0	ND	53	0.67
Bloater	ND	ND	ND	0	1	0	46	1	0	0	1	ND	49	0.62
Chinook salmon	ND	ND	ND	28	2	1	0	1	7	0	1	ND	40	0.50
Brown trout	ND	ND	ND	14	6	6	3	0	1	1	4	ND	35	0.44
Coho salmon	ND	ND	ND	29	0	0	0	0	0	0	0	ND	29	0.37
Silver redhorse	ND	ND	ND	0	0	0	0	1	6	3	0	ND	10	0.13
Channel catfish	ND	ND	ND	1	0	0	0	3	3	1	0	ND	8	0.10
Lake whitefish	ND	ND	ND	3	1	1	0	0	0	0	0	ND	5	0.06
Shorthead redhorse	ND	ND	ND	0	0	0	1	0	0	2	0	ND	3	0.04
Golden redhorse	ND	ND	ND	0	0	0	0	0	3	0	0	ND	3	0.04
Rainbow trout	ND	ND	ND	1	0	0	1	0	0	0	0	ND	2	0.03
Northern pike	ND	ND	ND	0	0	0	0	1	1	0	0	ND	2	0.03
Round whitefish	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	0.03
Totals	ND	ND	ND	523	415	2460	2147	863	963	346	200	ND	7925	

Table 38. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	136	522	2227	820	61	19	192	246	ND	4223	49.91
Alewife	ND	ND	ND	812	478	421	345	80	55	18	91	ND	2300	27.18
Yellow perch	ND	ND	ND	4	2	81	213	392	360	82	38	ND	1172	13.85
Rainbow smelt	ND	ND	ND	2	39	6	0	27	131	33	55	ND	293	3.46
Trout-perch	ND	ND	ND	0	14	22	6	18	8	43	2	ND	113	1.34
Lake trout	ND	ND	ND	2	15	7	0	11	34	8	32	ND	109	1.29
White sucker	ND	ND	ND	0	22	23	3	2	0	12	6	ND	68	0.80
Bloater	ND	ND	ND	0	3	5	7	8	12	3	0	ND	38	0.45
Longnose sucker	ND	ND	ND	2	10	8	3	0	3	3	5	ND	34	0.40
Chinook salmon	ND	ND	ND	2	9	2	1	3	8	0	2	ND	27	0.32
Gizzard shad	ND	ND	ND	0	0	0	0	1	0	15	9	ND	25	0.30
Brown trout	ND	ND	ND	4	2	7	0	5	1	0	1	ND	20	0.24
Carp	ND	ND	ND	1	0	1	1	3	0	6	2	ND	14	0.17
Lake whitefish	ND	ND	ND	0	10	0	0	0	0	0	1	ND	11	0.13
Coho salmon	ND	ND	ND	1	4	2	0	0	3	0	0	ND	10	0.12
Burbot	ND	ND	ND	1	0	0	0	0	2	0	0	ND	3	0.04
Silver redhorse	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	0.01
Totals	ND	ND	ND	967	1130	2012	1399	612	636	415	490	ND	8461	

Table 39. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	79	215	2087	242	175	230	147	55	ND	3230	36.60
Alewife	ND	ND	ND	677	954	808	142	14	22	0	9	ND	2626	29.58
Yellow perch	ND	ND	ND	9	9	259	610	86	76	574	541	ND	2164	24.37
Bloater	ND	ND	ND	0	4	13	206	0	0	0	0	ND	223	2.29
Rainbow smelt	ND	ND	ND	99	30	0	5	0	5	1	54	ND	194	2.18
Lake trout	ND	ND	ND	11	13	0	2	0	0	11	46	ND	83	0.93
White sucker	ND	ND	ND	4	10	19	9	4	11	18	6	ND	81	0.91
Trout-perch	ND	ND	ND	1	43	2	9	10	2	6	2	ND	75	0.84
Longnose sucker	ND	ND	ND	9	13	28	3	1	1	2	4	ND	61	0.69
Carp	ND	ND	ND	1	0	3	1	16	9	12	0	ND	42	0.47
Gizzard shad	ND	ND	ND	0	0	0	1	22	3	7	5	ND	38	0.43
Chinook salmon	ND	ND	ND	7	6	1	2	0	4	0	0	ND	20	0.23
Channel catfish	ND	ND	ND	0	0	0	0	7	3	3	1	ND	14	0.16
Coho salmon	ND	ND	ND	4	3	0	0	0	1	0	0	ND	8	0.09
Silver redhorse	ND	ND	ND	0	0	0	0	2	0	0	1	ND	3	0.03
Brown trout	ND	ND	ND	0	0	1	1	0	0	0	1	ND	3	0.03
Burbot	ND	ND	ND	0	0	0	0	0	1	0	2	ND	3	0.03
Round whitefish	ND	ND	ND	0	0	0	0	0	0	1	2	ND	3	0.03
Rainbow trout	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	0.02
Lake whitefish	ND	ND	ND	1	0	1	0	0	0	0	0	ND	2	0.02
Slimy sculpin	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	0.01
Shorthead redhorse	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	0.01
Smallmouth bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	0.01
Walleye	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	0.01
Totals	ND	ND	ND	903	1300	3223	1235	337	368	784	729	ND	8879	

Table 40. Number of fish caught by standard series gillnetting in Cook Plant study areas, southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	45	184	1872	662	177	ND	ND	ND	ND	2940	49.92
Yellow perch	ND	ND	ND	27	2	351	882	242	ND	ND	ND	ND	1504	25.53
Alewife	ND	ND	ND	171	193	663	178	21	ND	ND	ND	ND	1226	20.81
White sucker	ND	ND	ND	4	6	13	23	16	ND	ND	ND	ND	62	1.05
Gizzard shad	ND	ND	ND	0	0	0	3	37	ND	ND	ND	ND	40	0.68
Common carp	ND	ND	ND	0	11	12	4	1	ND	ND	ND	ND	28	0.48
Longnose sucker	ND	ND	ND	6	6	12	0	0	ND	ND	ND	ND	24	0.41
Rainbow smelt	ND	ND	ND	9	5	0	0	0	ND	ND	ND	ND	14	0.24
Brown trout	ND	ND	ND	4	1	3	0	1	ND	ND	ND	ND	9	0.15
Chinook salmon	ND	ND	ND	3	3	0	1	1	ND	ND	ND	ND	8	0.14
Bloater	ND	ND	ND	0	0	7	0	0	ND	ND	ND	ND	7	0.12
Trout-perch	ND	ND	ND	1	3	1	2	0	ND	ND	ND	ND	7	0.12
Lake trout	ND	ND	ND	5	2	0	0	0	ND	ND	ND	ND	7	0.12
Shorthead redhorse	ND	ND	ND	0	0	3	1	0	ND	ND	ND	ND	4	0.07
Freshwater drum	ND	ND	ND	0	0	0	0	2	ND	ND	ND	ND	2	0.03
Silver redhorse	ND	ND	ND	0	0	0	1	1	ND	ND	ND	ND	2	0.03
Coho salmon	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.02
Burbot	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.02
Rainbow trout	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.02
Round whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.02
Quillback	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.02
Golden redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.02
Totals	ND	ND	ND	277	417	2937	1758	501	ND	ND	ND	ND	5890	

Table 41. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1973. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	0	4658	489	1015	10387	77060	3	31813	5	ND	125430	87.81
Spottail shiner	ND	5	37	1044	2012	6401	1528	1710	32	1025	25	ND	13819	9.67
Rainbow smelt	ND	3	1	2388	94	0	1	0	5	4	2	ND	2498	1.75
Yellow perch	ND	0	0	0	1	571	9	1	0	47	0	ND	629	0.44
Rainbow trout	ND	1	1	14	28	13	6	11	1	3	5	ND	83	0.06
Trout-perch	ND	0	0	1	59	0	1	4	0	14	1	ND	80	0.06
Brown trout	ND	1	0	1	4	32	18	2	3	6	0	ND	67	0.05
Emerald shiner	ND	1	2	1	6	1	2	11	15	8	2	ND	49	0.03
Longnose dace	ND	2	0	2	4	3	3	4	22	0	1	ND	41	0.03
White sucker	ND	0	5	1	4	12	8	0	0	0	0	ND	30	0.02
Gizzard shad	ND	0	0	0	0	0	0	0	0	1	22	ND	23	0.02
Carp	ND	0	0	2	2	14	1	1	0	0	0	ND	20	0.01
Chinook salmon	ND	0	1	0	3	5	1	0	0	0	0	ND	10	0.01
Bluegill	ND	0	0	0	0	3	0	1	0	0	5	ND	9	0.01
Coho salmon	ND	0	0	3	0	6	0	0	0	0	0	ND	9	0.01
Ninespine stickleback	ND	0	1	1	6	0	0	0	0	0	0	ND	8	0.01
Slimy sculpin	ND	0	0	7	0	0	0	0	0	0	1	ND	8	0.01
Johnny darter	ND	0	0	0	0	1	2	0	0	3	0	ND	6	<0.01
Northern pike	ND	0	0	0	0	2	0	0	0	1	1	ND	4	<0.01
Longnose sucker	ND	0	0	0	2	0	1	0	0	0	0	ND	3	<0.01
Mottled sculpin	ND	0	0	2	1	0	0	0	0	0	0	ND	3	<0.01
Channel catfish	ND	1	0	0	0	0	0	2	0	0	0	ND	3	<0.01
Fathead minnow	ND	0	0	0	1	0	1	0	0	0	0	ND	2	<0.01
Black bullhead	ND	0	0	1	0	0	1	0	0	0	0	ND	2	<0.01
Golden shiner	ND	0	0	2	0	0	0	0	0	0	0	ND	2	<0.01
Bloater	ND	0	0	0	1	0	0	0	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	0	1	0	0	0	0	0	0	0	ND	1	<0.01
Rock bass	ND	0	0	0	0	0	0	0	0	0	1	ND	1	<0.01
Totals	ND	14	48	8129	2717	6079	11970	78807	81	32925	71	ND	142841	

Table 42. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1974. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	3	13	4312	251	526	36187	7839	2052	0	ND	51183	69.17
Spottail shiner	0	ND	69	39	1656	5274	5542	5875	252	61	9	ND	18777	25.38
Yellow perch	0	ND	0	1	0	39	2508	802	10	0	0	ND	3360	4.54
Rainbow smelt	0	ND	37	224	39	0	2	10	1	2	0	ND	315	0.43
Gizzard shad	0	ND	5	4	43	1	0	0	0	1	0	ND	54	0.07
Coho salmon	0	ND	0	4	31	13	2	0	0	0	0	ND	50	0.07
Longnose dace	0	ND	2	1	3	8	2	1	0	20	6	ND	43	0.06
Bluegill	0	ND	1	0	39	3	0	0	0	0	0	ND	43	0.06
Brown trout	0	ND	2	3	9	12	0	0	0	1	0	ND	27	0.04
Slimy sculpin	0	ND	2	17	0	1	0	0	0	1	2	ND	23	0.03
Trout-perch	0	ND	0	1	1	0	2	3	12	0	2	ND	21	0.03
Chinook salmon	0	ND	0	2	5	2	5	0	0	0	0	ND	14	0.02
Emerald shiner	0	ND	2	1	1	3	0	0	0	6	0	ND	13	0.02
Carp	0	ND	0	2	7	0	1	2	0	0	0	ND	12	0.02
Channel catfish	0	ND	0	0	0	1	8	0	1	0	0	ND	10	0.01
White sucker	0	ND	1	0	1	0	3	1	1	0	0	ND	7	0.01
Rainbow trout	0	ND	4	2	0	0	0	0	0	0	1	ND	7	0.01
Green sunfish	0	ND	0	0	5	0	0	0	0	1	0	ND	6	0.01
Johnny darter	0	ND	0	0	0	4	0	0	0	0	0	ND	4	0.01
Ninespine stickleback	0	ND	0	1	2	0	1	0	0	0	0	ND	4	0.01
Northern pike	0	ND	1	0	0	2	0	1	0	0	0	ND	4	0.01
Sand shiner	0	ND	0	0	0	0	0	0	0	3	1	ND	4	0.01
Longnose sucker	0	ND	1	0	0	0	0	1	0	1	0	ND	3	<0.01
Bloater	0	ND	0	0	0	0	0	2	0	0	0	ND	2	<0.01
Black bullhead	0	ND	0	1	1	0	0	0	0	0	0	ND	2	<0.01
Lake trout	0	ND	1	0	0	0	0	0	0	0	0	ND	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	ND	1	<0.01
Golden shiner	0	ND	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Bluntnose minnow	0	ND	0	0	0	0	0	0	0	1	0	ND	1	<0.01
Totals	0	ND	131	316	6155	5615	8602	42886	8116	2150	21	ND	73992	

Table 43. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	0	4775	1708	424	540	5569	20740	18	ND	33774	65.90
Spottail shiner	ND	ND	ND	52	976	7596	2679	927	1119	1311	251	ND	14911	29.09
Yellow perch	ND	ND	ND	0	0	722	1209	62	1	0	12	ND	2006	3.91
Rainbow smelt	ND	ND	ND	84	127	0	0	0	2	1	0	ND	214	0.42
Gizzard shad	ND	ND	ND	2	0	0	0	0	2	12	104	ND	120	0.23
Trout-perch	ND	ND	ND	1	5	0	0	4	41	15	0	ND	66	0.13
Sand shiner	ND	ND	ND	0	0	0	0	0	1	1	32	ND	34	0.07
Longnose dace	ND	ND	ND	0	0	1	0	2	2	7	6	ND	18	0.04
Slimy sculpin	ND	ND	ND	1	17	0	0	0	0	0	0	ND	18	0.04
Chinook salmon	ND	ND	ND	3	0	11	2	0	0	1	0	ND	17	0.03
Johnny darter	ND	ND	ND	0	0	3	0	2	0	0	9	ND	14	0.03
Brown trout	ND	ND	ND	0	1	0	1	0	0	0	10	ND	12	0.02
Rainbow trout	ND	ND	ND	2	0	0	1	0	0	6	3	ND	12	0.02
Coho salmon	ND	ND	ND	0	0	7	0	0	0	0	1	ND	8	0.02
Ninespine stickleback	ND	ND	ND	2	5	0	0	0	0	0	0	ND	7	0.01
White sucker	ND	ND	ND	2	2	0	1	0	0	0	0	ND	5	0.01
Northern pike	ND	ND	ND	1	0	0	0	0	0	0	3	ND	4	0.01
Carp	ND	ND	ND	0	1	0	3	0	0	0	0	ND	4	0.01
Bluegill	ND	ND	ND	0	0	1	0	0	1	0	0	ND	2	<0.01
Emerald shiner	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Bloater	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Quillback	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Largemouth bass	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Pumpkinseed	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	151	5909	10051	4321	1538	6739	22094	449	ND	51252	

Table 44. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	ND	5	1905	1654	824	42919	74554	43	0	ND	121910	91.82
Spottail shiner	ND	7	ND	122	873	2881	4857	343	250	3	1	ND	9337	7.03
Yellow perch	ND	0	ND	0	0	16	750	16	11	0	0	ND	795	0.60
Rainbow smelt	ND	0	ND	300	13	0	0	5	7	0	1	ND	326	0.25
Trout-perch	ND	2	ND	9	9	1	32	38	25	0	1	ND	117	0.09
Brown trout	ND	4	ND	1	31	17	8	0	16	3	0	ND	80	0.06
Sand shiner	ND	0	ND	1	0	0	0	7	0	31	0	ND	39	0.03
Longnose dace	ND	0	ND	1	3	2	1	5	10	1	4	ND	27	0.02
White sucker	ND	1	ND	1	13	2	3	0	0	1	1	ND	22	0.02
Slimy sculpin	ND	0	ND	17	0	1	0	2	1	0	0	ND	21	0.02
Coho salmon	ND	0	ND	0	8	10	1	0	1	1	0	ND	21	0.02
Rainbow trout	ND	1	ND	2	2	1	1	0	4	2	0	ND	13	0.01
Carp	ND	0	ND	0	10	2	0	0	0	0	0	ND	12	0.01
Lake trout	ND	0	ND	1	0	0	0	0	0	9	0	ND	10	0.01
Chinook salmon	ND	1	ND	0	0	9	0	0	0	0	0	ND	10	0.01
Johnny darter	ND	0	ND	0	0	3	0	4	1	0	0	ND	8	0.01
Gizzard shad	ND	1	ND	0	0	1	0	0	2	1	0	ND	5	<0.01
Silver redhorse	ND	0	ND	0	0	0	3	0	0	0	0	ND	3	<0.01
Bloater	ND	0	ND	0	1	0	2	0	0	0	0	ND	3	<0.01
Quillback	ND	0	ND	0	0	1	1	0	0	0	0	ND	2	<0.01
Golden shiner	ND	1	ND	0	0	0	0	0	0	1	0	ND	2	<0.01
Ninespine stickleback	ND	0	ND	0	1	1	0	0	0	0	0	ND	2	<0.01
Bluegill	ND	0	ND	0	0	0	1	0	0	0	1	ND	2	<0.01
Channel catfish	ND	0	ND	0	1	0	1	0	0	0	0	ND	2	<0.01
Longnose sucker	ND	0	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Brook silverside	ND	0	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	0	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Totals	ND	18	ND	462	2870	4602	6485	43341	74884	102	9	ND	132773	

Table 45. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	6	298	573	2590	20022	11451	51	11812	ND	46803	74.57
Spottail shiner	ND	ND	ND	11	1310	960	2235	8453	239	274	356	ND	13838	22.05
Yellow perch	ND	ND	ND	0	1	1	1004	25	3	0	285	ND	1319	2.10
Trout-perch	ND	ND	ND	0	7	99	4	9	91	3	1	ND	214	0.34
Rainbow smelt	ND	ND	ND	3	2	1	0	0	15	20	62	ND	103	0.16
Coho salmon	ND	ND	ND	1	83	2	0	0	0	0	3	ND	89	0.14
Longnose dace	ND	ND	ND	1	0	3	1	0	9	37	8	ND	59	0.09
Gizzard shad	ND	ND	ND	0	0	0	1	0	0	40	8	ND	49	0.08
Johnny darter	ND	ND	ND	0	4	0	5	35	1	0	1	ND	46	0.07
White sucker	ND	ND	ND	3	5	14	16	0	2	2	2	ND	44	0.07
Chinook salmon	ND	ND	ND	0	0	42	0	0	0	0	0	ND	42	0.07
Carp	ND	ND	ND	3	27	0	4	4	0	1	2	ND	41	0.07
Brown trout	ND	ND	ND	9	3	8	3	0	1	0	6	ND	30	0.05
Emerald shiner	ND	ND	ND	0	0	2	23	0	0	3	0	ND	28	0.04
Sand shiner	ND	ND	ND	1	0	2	13	5	1	0	1	ND	23	0.04
Rainbow trout	ND	ND	ND	2	1	0	0	0	6	0	0	ND	9	0.01
Bloater	ND	ND	ND	0	0	1	0	0	5	0	3	ND	9	0.01
Slimy sculpin	ND	ND	ND	1	0	0	0	0	0	0	3	ND	4	0.01
Quillback	ND	ND	ND	0	0	0	0	1	1	0	0	ND	2	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	1	0	0	ND	2	<0.01
Longnose sucker	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Lake trout	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Rock bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Golden shiner	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Freshwater drum	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	41	1741	1709	5899	28557	11827	433	12554	ND	62761	

Table 46. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	33	24	5438	15905	5830	1286	2	12	ND	29490	50.36
Alewife	ND	ND	ND	0	0	3717	90	1630	2553	18839	6	ND	26835	47.43
Rainbow smelt	ND	ND	ND	0	81	12	283	0	0	2	1	ND	379	0.67
Yellow perch	ND	ND	ND	1	0	0	263	7	20	0	1	ND	292	0.52
Coho salmon	ND	ND	ND	2	15	220	11	0	0	0	0	ND	248	0.44
Brown trout	ND	ND	ND	58	7	9	7	0	0	1	0	ND	82	0.14
Trout-perch	ND	ND	ND	1	3	39	32	0	5	0	0	ND	80	0.14
Chinook salmon	ND	ND	ND	0	0	55	0	0	0	0	0	ND	55	0.10
Longnose dace	ND	ND	ND	3	3	2	0	0	5	8	5	ND	26	0.05
White sucker	ND	ND	ND	1	2	1	14	1	0	0	2	ND	21	0.04
Rainbow trout	ND	ND	ND	3	1	2	2	4	1	4	1	ND	18	0.03
Sand shiner	ND	ND	ND	0	0	0	0	0	12	0	0	ND	12	0.02
Emerald shiner	ND	ND	ND	0	0	0	0	3	0	7	0	ND	10	0.02
Bloater	ND	ND	ND	0	0	3	3	0	0	0	0	ND	6	0.01
Johnny darter	ND	ND	ND	0	2	1	0	1	1	0	0	ND	5	0.01
Carp	ND	ND	ND	0	2	0	1	0	2	0	0	ND	5	0.01
Lake trout	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Golden shiner	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	<0.01
Blackchin shiner	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Channel catfish	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Longnose sucker	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Burbot	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Gizzard shad	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
TOTALS	ND	ND	ND	104	141	9500	16614	7477	3849	18864	29	ND	56578	

Table 47. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	2	1	121	108	16381	65914	52792	2	ND	135321	86.68
Spottail shiner	ND	ND	ND	108	410	885	8271	163	7874	422	2	ND	18135	11.62
Yellow perch	ND	ND	ND	1	0	0	428	29	687	0	0	ND	1145	0.73
Bloater	ND	ND	ND	0	0	0	0	0	482	25	0	ND	507	0.32
Rainbow smelt	ND	ND	ND	26	236	1	0	3	3	67	5	ND	341	0.22
Chinook salmon	ND	ND	ND	140	77	58	1	0	0	0	0	ND	276	0.18
Trout-perch	ND	ND	ND	22	4	21	26	4	2	1	0	ND	80	0.05
White sucker	ND	ND	ND	38	6	1	7	5	0	1	0	ND	58	0.04
Johnny darter	ND	ND	ND	0	0	0	21	0	37	0	0	ND	58	0.04
Coho salmon	ND	ND	ND	10	26	0	0	0	0	0	0	ND	36	0.02
Slimy sculpin	ND	ND	ND	27	0	0	0	0	0	0	0	ND	27	0.02
Brown trout	ND	ND	ND	5	4	3	8	0	0	3	1	ND	24	0.02
Gizzard shad	ND	ND	ND	3	0	1	0	0	0	10	8	ND	22	0.01
Carp	ND	ND	ND	10	2	3	2	0	0	0	0	ND	17	0.01
Emerald shiner	ND	ND	ND	7	1	3	0	0	0	0	1	ND	12	0.01
Rainbow trout	ND	ND	ND	2	1	1	0	1	1	2	3	ND	11	0.01
Lake trout	ND	ND	ND	0	0	0	0	0	0	10	0	ND	10	0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	0	7	0	ND	7	<0.01
Longnose dace	ND	ND	ND	3	0	0	0	0	1	2	0	ND	6	<0.01
Longnose sucker	ND	ND	ND	0	1	1	2	0	1	0	0	ND	5	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	2	0	1	0	ND	3	<0.01
Burbot	ND	ND	ND	0	0	1	0	2	0	0	0	ND	3	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	1	0	0	0	ND	2	<0.01
Bluntnose minnow	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Ninespine stickleback	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Black crappie	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Lake chub	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Green sunfish	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Shorthead redhorse	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	406	771	1104	8874	16591	75008	53143	22	ND	156115	

Table 48. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	11	4071	989	6026	708	6003	46	10	ND	17864	49.12
Alewife	ND	ND	ND	0	3359	1971	1820	2212	443	3	1	ND	9849	27.08
Yellow perch	ND	ND	ND	1	2	0	1646	238	4527	1	67	ND	6482	17.82
Rainbow smelt	ND	ND	ND	9	381	513	0	570	1	51	8	ND	1533	4.22
Trout-perch	ND	ND	ND	5	116	19	3	7	0	9	0	ND	159	0.44
Chinook salmon	ND	ND	ND	0	2	139	9	0	0	1	1	ND	152	0.42
Bloater	ND	ND	ND	0	0	50	0	0	82	0	0	ND	132	0.36
White sucker	ND	ND	ND	2	7	0	23	0	1	3	0	ND	36	0.10
Longnose dace	ND	ND	ND	0	1	2	0	5	2	22	2	ND	34	0.09
Gizzard shad	ND	ND	ND	0	1	9	1	1	7	4	0	ND	23	0.06
Rainbow trout	ND	ND	ND	3	0	0	0	0	0	9	10	ND	22	0.06
Brown trout	ND	ND	ND	11	4	2	0	0	0	1	2	ND	20	0.05
Johnny darter	ND	ND	ND	0	1	0	0	0	16	0	0	ND	17	0.05
Sand shiner	ND	ND	ND	0	0	0	1	5	0	3	1	ND	10	0.03
Carp	ND	ND	ND	1	3	0	2	0	4	0	0	ND	10	0.03
Lake trout	ND	ND	ND	0	0	0	0	0	0	8	0	ND	8	0.02
Slimy sculpin	ND	ND	ND	1	4	0	0	0	1	0	0	ND	6	0.02
Coho salmon	ND	ND	ND	1	2	0	0	0	0	0	0	ND	3	0.01
Black bullhead	ND	ND	ND	0	0	2	1	0	0	0	0	ND	3	0.01
Ninespine stickleback	ND	ND	ND	0	2	1	0	0	0	0	0	ND	3	0.01
Longnose sucker	ND	ND	ND	0	2	0	0	0	0	0	0	ND	2	0.01
Totals	ND	ND	ND	45	7998	3697	9532	3746	11087	161	102	ND	36368	

Table 49. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	0	10	1554	7	14900	488	669	0	ND	17628	43.40
Spottail shiner	ND	ND	ND	69	21	12470	2032	167	83	272	0	ND	15114	37.21
Yellow perch	ND	ND	ND	4	0	641	6864	8	0	23	0	ND	7540	18.57
Rainbow smelt	ND	ND	ND	13	23	1	0	2	2	19	0	ND	60	0.15
Trout-perch	ND	ND	ND	27	0	2	0	7	9	1	0	ND	46	0.11
White sucker	ND	ND	ND	0	0	2	35	0	1	0	0	ND	38	0.09
Gizzard shad	ND	ND	ND	3	0	0	0	1	7	19	0	ND	30	0.07
Sand shiner	ND	ND	ND	0	0	0	0	9	10	8	0	ND	27	0.07
Chinook salmon	ND	ND	ND	0	10	14	0	0	0	0	0	ND	24	0.06
Emerald shiner	ND	ND	ND	0	0	0	0	5	10	4	0	ND	19	0.05
Bloater	ND	ND	ND	0	0	1	0	0	4	12	0	ND	17	0.04
Rainbow trout	ND	ND	ND	2	1	11	0	0	2	0	0	ND	16	0.04
Johnny darter	ND	ND	ND	0	1	8	0	0	0	3	0	ND	12	0.03
Bluegill	ND	ND	ND	0	0	1	0	0	0	9	0	ND	10	0.02
Lake trout	ND	ND	ND	0	0	0	0	0	0	7	0	ND	7	0.02
Slimy sculpin	ND	ND	ND	6	0	0	0	0	0	0	0	ND	6	0.01
Longnose dace	ND	ND	ND	1	0	0	0	0	0	2	0	ND	3	0.01
Coho salmon	ND	ND	ND	0	3	0	0	0	0	0	0	ND	3	0.01
Ninespine stickleback	ND	ND	ND	3	0	0	0	0	0	0	0	ND	3	0.01
Carp	ND	ND	ND	0	0	2	0	0	0	0	0	ND	2	<0.01
Largemouth bass	ND	ND	ND	0	0	1	0	0	0	1	0	ND	2	<0.01
Blacknose dace	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Black bullhead	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Northern pike	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Blacknose shiner	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	128	71	14711	8938	15100	616	1050		ND	40614	

Table 50. Number of fish caught by standard series seining in Cook Plant study areas, southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	120	1243	700	108	13	ND	ND	ND	ND	2184	34.91
Alewife	ND	ND	ND	0	1134	367	191	151	ND	ND	ND	ND	1843	29.46
Rainbow smelt	ND	ND	ND	69	1276	58	0	177	ND	ND	ND	ND	1580	25.26
Yellow perch	ND	ND	ND	0	0	5	2	213	ND	ND	ND	ND	220	3.52
Slimy sculpin	ND	ND	ND	95	1	0	0	0	ND	ND	ND	ND	96	1.53
Trout-perch	ND	ND	ND	8	1	73	0	10	ND	ND	ND	ND	92	1.47
Bloater	ND	ND	ND	0	0	65	0	0	ND	ND	ND	ND	65	1.04
White sucker	ND	ND	ND	2	2	31	6	2	ND	ND	ND	ND	43	0.69
Common carp	ND	ND	ND	37	4	0	0	0	ND	ND	ND	ND	41	0.66
Johnny darter	ND	ND	ND	0	0	24	3	0	ND	ND	ND	ND	27	0.43
Chinook salmon	ND	ND	ND	0	0	12	0	0	ND	ND	ND	ND	12	0.19
Brown trout	ND	ND	ND	8	1	1	0	1	ND	ND	ND	ND	11	0.18
Emerald shiner	ND	ND	ND	6	1	2	1	0	ND	ND	ND	ND	10	0.16
Sand shiner	ND	ND	ND	5	0	1	1	1	ND	ND	ND	ND	8	0.13
Mottled sculpin	ND	ND	ND	5	0	0	0	0	ND	ND	ND	ND	5	0.08
Channel catfish	ND	ND	ND	0	0	2	2	0	ND	ND	ND	ND	4	0.06
Rainbow trout	ND	ND	ND	3	0	0	0	0	ND	ND	ND	ND	3	0.05
Freshwater drum	ND	ND	ND	0	0	1	1	0	ND	ND	ND	ND	2	0.03
Longnose dace	ND	ND	ND	1	1	0	0	0	ND	ND	ND	ND	2	0.03
Coho salmon	ND	ND	ND	1	1	0	0	0	ND	ND	ND	ND	2	0.03
Bluegill	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.02
Largemouth bass	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.02
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.02
Golden shiner	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.02
Quillback	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.02
Common shiner	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.02
Totals	ND	ND	ND	361	3666	1342	317	570	ND	ND	ND	ND	6256	

Table 51. Number of fish caught by standard series trawling at station C (6 m, south Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	11	51	271	401	437	ND	ND	ND	ND	1171	31.73
Yellow perch	ND	ND	ND	1	1	293	296	319	ND	ND	ND	ND	910	24.65
Rainbow smelt	ND	ND	ND	316	445	2	0	137	ND	ND	ND	ND	900	24.38
Alewife	ND	ND	ND	10	17	76	11	510	ND	ND	ND	ND	624	16.91
Slimy sculpin	ND	ND	ND	26	8	0	0	0	ND	ND	ND	ND	34	0.92
White sucker	ND	ND	ND	0	0	0	6	20	ND	ND	ND	ND	26	0.70
Trout-perch	ND	ND	ND	1	2	2	2	2	ND	ND	ND	ND	9	0.24
Bloater	ND	ND	ND	0	2	5	0	0	ND	ND	ND	ND	7	0.19
Johnny darter	ND	ND	ND	0	3	0	0	3	ND	ND	ND	ND	6	0.16
Common carp	ND	ND	ND	0	0	0	1	1	ND	ND	ND	ND	2	0.05
Central mudminnow	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.03
Chinook salmon	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.03
Totals	ND	ND	ND	366	529	649	717	1430	ND	ND	ND	ND	3691	

Table 52. Number of fish caught by standard series trawling at station D (9 m, south Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	573	1161	331	4	43	ND	ND	ND	ND	2112	54.60
Yellow perch	ND	ND	ND	3	6	42	114	453	ND	ND	ND	ND	618	15.98
Alewife	ND	ND	ND	6	7	11	20	488	ND	ND	ND	ND	532	13.75
Spottail shiner	ND	ND	ND	70	69	19	71	78	ND	ND	ND	ND	30	7.94
Bloater	ND	ND	ND	0	1	222	0	0	ND	ND	ND	ND	223	5.77
Slimy sculpin	ND	ND	ND	23	5	0	0	0	ND	ND	ND	ND	28	0.72
Trout-perch	ND	ND	ND	1	3	4	3	14	ND	ND	ND	ND	25	0.65
Johnny darter	ND	ND	ND	0	14	0	0	0	ND	ND	ND	ND	14	0.36
Mottled sculpin	ND	ND	ND	1	4	0	0	0	ND	ND	ND	ND	5	0.13
Longnose sucker	ND	ND	ND	0	0	0	0	3	ND	ND	ND	ND	3	0.08
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.03
Totals	ND	ND	ND	677	1271	629	212	1079	ND	ND	ND	ND	3868	

Table 53. Number of fish caught by standard series trawling at station G (6 m, Warren Dunes), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	268	748	0	0	40	ND	ND	ND	ND	1056	33.63
Yellow perch	ND	ND	ND	1	2	253	545	101	ND	ND	ND	ND	902	28.73
Spottail shiner	ND	ND	ND	36	123	126	79	168	ND	ND	ND	ND	532	16.94
Bloater	ND	ND	ND	0	4	327	0	0	ND	ND	ND	ND	331	10.54
Alewife	ND	ND	ND	0	23	8	3	224	ND	ND	ND	ND	258	8.22
Slimy sculpin	ND	ND	ND	29	0	0	0	0	ND	ND	ND	ND	29	0.92
Trout-perch	ND	ND	ND	2	1	4	1	5	ND	ND	ND	ND	13	0.41
Longnose sucker	ND	ND	ND	0	0	0	0	9	ND	ND	ND	ND	9	0.29
White sucker	ND	ND	ND	0	0	0	0	5	ND	ND	ND	ND	5	0.16
Johnny darter	ND	ND	ND	1	1	0	0	0	ND	ND	ND	ND	2	0.06
Silver redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.03
Common carp	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.03
Lake whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.03
Totals	ND	ND	ND	338	902	718	628	554	ND	ND	ND	ND	3140	

Table 54. Number of fish caught by standard series trawling at station H (9 m, Warren Dunes), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	384	959	99	38	124	ND	ND	ND	ND	1604	32.17
Yellow perch	ND	ND	ND	78	16	157	500	450	ND	ND	ND	ND	1201	24.09
Bloater	ND	ND	ND	0	1	789	0	0	ND	ND	ND	ND	790	15.84
Alewife	ND	ND	ND	19	9	34	3	703	ND	ND	ND	ND	768	15.40
Spottail shiner	ND	ND	ND	270	63	17	45	136	ND	ND	ND	ND	531	10.65
Trout-perch	ND	ND	ND	3	0	15	45	2	ND	ND	ND	ND	65	1.30
Slimy sculpin	ND	ND	ND	11	0	1	0	0	ND	ND	ND	ND	12	0.24
Johnny darter	ND	ND	ND	3	5	0	0	1	ND	ND	ND	ND	9	0.18
White sucker	ND	ND	ND	0	0	0	0	3	ND	ND	ND	ND	3	0.06
Central mudminnow	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.02
Chinook salmon	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.02
Longnose sucker	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.02
Totals	ND	ND	ND	769	1054	1112	631	1420	ND	ND	ND	ND	4986	

Table 55. Number of fish caught by trawling at station R (6 m, north Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	343	483	ND	ND	ND	ND	ND	ND	ND	826	82.60
Spottail shiner	ND	ND	ND	79	42	ND	ND	ND	ND	ND	ND	ND	121	12.10
Alewife	ND	ND	ND	3	22	ND	ND	ND	ND	ND	ND	ND	25	2.50
Slimy sculpin	ND	ND	ND	15	2	ND	ND	ND	ND	ND	ND	ND	17	1.70
Yellow perch	ND	ND	ND	1	4	ND	ND	ND	ND	ND	ND	ND	5	0.50
Trout-perch	ND	ND	ND	0	2	ND	ND	ND	ND	ND	ND	ND	2	0.20
Johnny darter	ND	ND	ND	0	2	ND	ND	ND	ND	ND	ND	ND	2	0.20
Central mudminnow	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.10
Bloater	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.10
Totals	ND	ND	ND	443	557	ND	ND	ND	ND	ND	ND	ND	1000	

Table 56. Number of fish caught by standard series gillnetting at station C (6 m, south Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	5	41	372	108	50	ND	ND	ND	ND	576	39.94
Alewife	ND	ND	ND	103	58	235	67	2	ND	ND	ND	ND	465	32.25
Yellow perch	ND	ND	ND	2	2	120	176	27	ND	ND	ND	ND	327	22.68
Common carp	ND	ND	ND	0	10	10	2	1	ND	ND	ND	ND	23	1.60
Gizzard shad	ND	ND	ND	0	0	0	3	17	ND	ND	ND	ND	20	1.39
White sucker	ND	ND	ND	0	0	1	5	2	ND	ND	ND	ND	8	0.55
Brown trout	ND	ND	ND	2	1	3	0	0	ND	ND	ND	ND	6	0.42
Shorthead redhorse	ND	ND	ND	0	0	3	0	0	ND	ND	ND	ND	3	0.21
Rainbow smelt	ND	ND	ND	1	2	0	0	0	ND	ND	ND	ND	3	0.21
Trout-perch	ND	ND	ND	1	0	0	1	0	ND	ND	ND	ND	2	0.14
Silver redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.07
Longnose sucker	ND	ND	ND	0	0	1	0	0	ND	ND	ND	ND	1	0.07
Golden redhorse	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.07
Coho salmon	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.07
Freshwater drum	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.07
Chinook salmon	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.07
Round whitefish	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.07
Lake trout	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.07
Rainbow trout	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.07
Totals	ND	ND	ND	116	116	745	363	102	ND	ND	ND	ND	1442	

Table 57. Number of fish caught by standard series gillnetting at station D (9 m, south Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	13	17	716	107	68	ND	ND	ND	ND	921	53.02
Yellow perch	ND	ND	ND	19	0	47	244	107	ND	ND	ND	ND	417	24.01
Alewife	ND	ND	ND	4	54	249	45	9	ND	ND	ND	ND	361	20.78
Gizzard shad	ND	ND	ND	0	0	0	0	7	ND	ND	ND	ND	7	0.40
White sucker	ND	ND	ND	2	0	0	4	1	ND	ND	ND	ND	7	0.40
Lake trout	ND	ND	ND	4	2	0	0	0	ND	ND	ND	ND	6	0.35
Common carp	ND	ND	ND	0	1	2	2	0	ND	ND	ND	ND	5	0.29
Rainbow smelt	ND	ND	ND	1	2	0	0	0	ND	ND	ND	ND	3	0.17
Chinook salmon	ND	ND	ND	1	1	0	1	0	ND	ND	ND	ND	3	0.17
Trout-perch	ND	ND	ND	0	2	0	1	0	ND	ND	ND	ND	3	0.17
Longnose sucker	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.12
Silver redhorse	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.06
Shorthead redhorse	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.06
Totals	ND	ND	ND	46	79	1014	406	192	ND	ND	ND	ND	1737	

Table 58. Number of fish caught by standard series gillnetting at station G (6 m, Warren Dunes), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	20	49	699	411	25	ND	ND	ND	ND	1204	63.97
Yellow perch	ND	ND	ND	2	0	118	198	35	ND	ND	ND	ND	353	18.76
Alewife	ND	ND	ND	33	60	118	59	4	ND	ND	ND	ND	274	14.56
White sucker	ND	ND	ND	1	5	4	7	10	ND	ND	ND	ND	27	1.43
Longnose sucker	ND	ND	ND	1	4	6	0	0	ND	ND	ND	ND	11	0.58
Gizzard shad	ND	ND	ND	0	0	0	0	7	ND	ND	ND	ND	7	0.37
Chinook salmon	ND	ND	ND	0	1	0	0	1	ND	ND	ND	ND	2	0.11
Brown trout	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.11
Rainbow smelt	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.05
Trout-perch	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.05
Totals	ND	ND	ND	59	121	945	675	82	ND	ND	ND	ND	1882	

Table 59. Number of fish caught by standard series gillnetting at station H (9 m, Warren Dunes), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Yellow perch	ND	ND	ND	4	0	66	264	73	ND	ND	ND	ND	407	49.10
Spottail shiner	ND	ND	ND	7	77	85	36	34	ND	ND	ND	ND	239	28.83
Alewife	ND	ND	ND	31	21	61	7	6	ND	ND	ND	ND	126	15.20
White sucker	ND	ND	ND	1	1	8	7	3	ND	ND	ND	ND	20	2.41
Longnose sucker	ND	ND	ND	3	2	5	0	0	ND	ND	ND	ND	10	1.21
Rainbow smelt	ND	ND	ND	7	0	0	0	0	ND	ND	ND	ND	7	0.84
Bloater	ND	ND	ND	0	0	7	0	0	ND	ND	ND	ND	7	0.84
Gizzard shad	ND	ND	ND	0	0	0	0	6	ND	ND	ND	ND	6	0.72
Chinook salmon	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.24
Trout-perch	ND	ND	ND	0	0	1	0	0	ND	ND	ND	ND	1	0.12
Burbot	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.12
Brown trout	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.12
Freshwater drum	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.12
Quillback	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.12
Totals	ND	ND	ND	56	101	233	314	125	ND	ND	ND	ND	829	

and May catch (246 fish) at the north Cook area was similar to the south Cook area catch of 219 alewives and larger than the 145 fish caught at the Warren Dunes area (Tables 60 and 61). If operation of the Cook Plant was depressing the local alewife population, we would expect smaller catches in the Cook area, but 1982 data, coupled with previous years' data, indicate no plant effect was measured by gill net catches.

ANOVA of 1973-1981 seine catch data showed no significant variation which could be attributed to plant operation (see 1981 Environmental Operating Report). While the 1982 alewife catch at Warren Dunes station F (1,390 fish) was more than 5 times greater than at either of the two Cook stations (Tables 62, 63, and 64), we can not at present identify this substantial difference as a plant effect. Most alewives are seined in the fall, and these data were not available for examination. Also, seine catches of alewives fluctuated considerably in all previous years, but ANOVA results have not shown a significant difference in station catches. A full year's data, plus statistical analysis, will be needed before a conclusion can be drawn from the alewife seine catch in 1982.

Past analyses have shown no plant effects on the alewife population sampled by trawl, gill net, and seine. Addition of 1982 trawl and gill net data did not change this conclusion, but a substantially greater catch at the Warren Dunes seine station in 1982 prevents drawing a similar conclusion for seine data. A full year's data, plus statisical analysis of the 1982 data, should allow a final conclusion. All three gear types have shown and continue to show a decline in 1982 of the southeastern Lake Michigan alewife population.

We believe that the recent decline in the southeastern Lake Michigan alewife population is a result of increasing mortality on this clupeid.

Table 60. Number of fish caught by gillnetting at station R (6 m, north Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	1	96	ND	ND	ND	ND	ND	ND	ND	97	51.87
Spottail shiner	ND	ND	ND	6	66	ND	ND	ND	ND	ND	ND	ND	72	38.50
Rainbow smelt	ND	ND	ND	8	0	ND	ND	ND	ND	ND	ND	ND	8	4.28
Brown trout	ND	ND	ND	3	0	ND	ND	ND	ND	ND	ND	ND	3	1.60
Trout-perch	ND	ND	ND	1	1	ND	ND	ND	ND	ND	ND	ND	2	1.07
Lake trout	ND	ND	ND	0	2	ND	ND	ND	ND	ND	ND	ND	2	1.07
Yellow perch	ND	ND	ND	0	2	ND	ND	ND	ND	ND	ND	ND	2	1.07
White sucker	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.53
Totals	ND	ND	ND	20	167	ND	ND	ND	ND	ND	ND	ND	187	

Table 61. Number of fish caught by gillnetting at station Q (9 m, north Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	3	146	ND	ND	ND	ND	ND	ND	ND	149	69.95
Spottail shiner	ND	ND	ND	25	11	ND	ND	ND	ND	ND	ND	ND	36	16.90
Lake trout	ND	ND	ND	7	3	ND	ND	ND	ND	ND	ND	ND	10	4.69
Yellow perch	ND	ND	ND	5	2	ND	ND	ND	ND	ND	ND	ND	7	3.29
Rainbow smelt	ND	ND	ND	4	0	ND	ND	ND	ND	ND	ND	ND	4	1.88
Longnose sucker	ND	ND	ND	0	2	ND	ND	ND	ND	ND	ND	ND	2	0.94
Trout-perch	ND	ND	ND	0	1	ND	ND	ND	ND	ND	ND	ND	1	0.47
Slimy sculpin	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.47
White sucker	ND	ND	ND	0	1	ND	ND	ND	ND	ND	ND	ND	1	0.47
Chinook salmon	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.47
Brown trout	ND	ND	ND	1	0	ND	ND	ND	ND	ND	ND	ND	1	0.47
Totals	ND	ND	ND	47	166	ND	ND	ND	ND	ND	ND	ND	213	

Table 62. Number of fish caught by standard series seining at station A (north Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	40	105	74	25	5	ND	ND	ND	ND	249	28.62
Alewife	ND	ND	ND	0	2	158	23	27	ND	ND	ND	ND	210	24.14
Yellow perch	ND	ND	ND	0	0	1	0	169	ND	ND	ND	ND	170	19.54
Rainbow smelt	ND	ND	ND	21	8	56	0	6	ND	ND	ND	ND	91	10.46
Trout-perch	ND	ND	ND	4	1	29	0	2	ND	ND	ND	ND	36	4.14
Slimy sculpin	ND	ND	ND	33	0	0	0	0	ND	ND	ND	ND	33	3.79
White sucker	ND	ND	ND	1	0	24	4	0	ND	ND	ND	ND	29	3.33
Bloater	ND	ND	ND	0	0	16	0	0	ND	ND	ND	ND	16	1.84
Johnny darter	ND	ND	ND	0	0	12	1	0	ND	ND	ND	ND	13	1.49
Common carp	ND	ND	ND	0	4	0	0	0	ND	ND	ND	ND	4	0.46
Brown trout	ND	ND	ND	1	1	1	0	0	ND	ND	ND	ND	3	0.34
Chinook salmon	ND	ND	ND	0	0	3	0	0	ND	ND	ND	ND	3	0.34
Sand shiner	ND	ND	ND	0	0	0	1	1	ND	ND	ND	ND	2	0.23
Mottled sculpin	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.23
Emerald shiner	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.23
Coho salmon	ND	ND	ND	1	1	0	0	0	ND	ND	ND	ND	2	0.23
Channel catfish	ND	ND	ND	0	0	1	0	0	ND	ND	ND	ND	1	0.11
Rainbow trout	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.11
Freshwater drum	ND	ND	ND	0	0	1	0	0	ND	ND	ND	ND	1	0.11
Longnose dace	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.11
Quillback	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.11
Totals	ND	ND	ND	107	122	376	54	211	ND	ND	ND	ND	870	

Table 63. Number of fish caught by standard series seining at station B (south Cook), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Rainbow smelt	ND	ND	ND	37	1248	2	0	100	ND	ND	ND	ND	1387	48.63
Spottail shiner	ND	ND	ND	54	680	181	69	8	ND	ND	ND	ND	992	34.78
Alewife	ND	ND	ND	0	2	98	24	119	ND	ND	ND	ND	243	8.52
Slimy sculpin	ND	ND	ND	53	1	0	0	0	ND	ND	ND	ND	54	1.89
Trout-perch	ND	ND	ND	2	0	33	0	6	ND	ND	ND	ND	41	1.44
Common carp	ND	ND	ND	37	0	0	0	0	ND	ND	ND	ND	37	1.30
Bloater	ND	ND	ND	0	0	36	0	0	ND	ND	ND	ND	36	1.26
Yellow perch	ND	ND	ND	0	0	0	2	25	ND	ND	ND	ND	27	0.95
Johnny darter	ND	ND	ND	0	0	5	2	0	ND	ND	ND	ND	7	0.25
Chinook salmon	ND	ND	ND	0	0	6	0	0	ND	ND	ND	ND	6	0.21
White sucker	ND	ND	ND	1	0	1	1	2	ND	ND	ND	ND	5	0.18
Sand shiner	ND	ND	ND	4	0	0	0	0	ND	ND	ND	ND	4	0.14
Mottled sculpin	ND	ND	ND	3	0	0	0	0	ND	ND	ND	ND	3	0.11
Emerald shiner	ND	ND	ND	2	0	1	0	0	ND	ND	ND	ND	3	0.11
Brown trout	ND	ND	ND	3	0	0	0	0	ND	ND	ND	ND	3	0.11
Channel catfish	ND	ND	ND	0	0	1	1	0	ND	ND	ND	ND	2	0.07
Ninespine stickleback	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.04
Golden shiner	ND	ND	ND	0	0	0	0	1	ND	ND	ND	ND	1	0.04
Totals	ND	ND	ND	196	1932	364	99	261	ND	ND	ND	ND	2852	

Table 64. Number of fish caught by standard series seining at station F (Warren Dunes), southeastern Lake Michigan, April-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	0	1130	111	144	5	ND	ND	ND	ND	1390	54.85
Spottail shiner	ND	ND	ND	26	458	445	14	0	ND	ND	ND	ND	943	37.21
Rainbow smelt	ND	ND	ND	11	20	0	0	71	ND	ND	ND	ND	102	4.03
Yellow perch	ND	ND	ND	0	0	4	0	19	ND	ND	ND	ND	23	0.91
Trout-perch	ND	ND	ND	2	0	11	0	2	ND	ND	ND	ND	15	0.59
Bloater	ND	ND	ND	0	0	13	0	0	ND	ND	ND	ND	13	0.51
White sucker	ND	ND	ND	0	2	6	1	0	ND	ND	ND	ND	9	0.36
Slimy sculpin	ND	ND	ND	9	0	0	0	0	ND	ND	ND	ND	9	0.36
Johnny darter	ND	ND	ND	0	0	7	0	0	ND	ND	ND	ND	7	0.28
Emerald shiner	ND	ND	ND	2	1	1	1	0	ND	ND	ND	ND	5	0.20
Brown trout	ND	ND	ND	4	0	0	0	1	ND	ND	ND	ND	5	0.20
Chinook salmon	ND	ND	ND	0	0	3	0	0	ND	ND	ND	ND	3	0.12
Sand shiner	ND	ND	ND	1	0	1	0	0	ND	ND	ND	ND	2	0.08
Rainbow trout	ND	ND	ND	2	0	0	0	0	ND	ND	ND	ND	2	0.08
Common shiner	ND	ND	ND	1	0	0	0	0	ND	ND	ND	ND	1	0.04
Channel catfish	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.04
Freshwater drum	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.04
Longnose dace	ND	ND	ND	0	1	0	0	0	ND	ND	ND	ND	1	0.04
Bluegill	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.04
Largemouth bass	ND	ND	ND	0	0	0	1	0	ND	ND	ND	ND	1	0.04
Totals	ND	ND	ND	58	1612	602	164	98	ND	ND	ND	ND	2534	

The decline has been consistently recorded at all of our sampling stations. Apparently a combination of mortality factors is beginning to substantially reduce alewife abundance. The major factors include predation by increasing populations of salmonids and competition with the increasing bloater population. Another source of mortality, entrapment by all power plants and water intakes on Lake Michigan may also be a factor. Whether the recent declne is a forewarning of a collapse or just a continuation of a downward trend of the Lake Michigan alewife population can not be determined from our data.

Bloater -- All coregonids under approximately 300 mm in total length, except lake whitefish, could not be identified to species because of morphometric changes in Lake Michigan populations and possible hybridization of some species (Smith 1964; Scott and Crossman 1973). We concluded that most small coregonids we caught were bloaters (*Coregonus hoyi*), but some of these fish may have been young lake herring (*C. artedii*) or hybrid coregonids. In previous reports (Jude *et al*. 1975, 1979), we referred to these fish as "unidentified coregonids", but in keeping with present practices of Great Lakes' fishery biologists, we will identify these fish as bloaters. The Michigan Department of Natural Resources lists bloater as a threatened species in Michigan.

The bloater population in Lake Michigan has changed considerably since 1900. After 1900, the population began to increase as the other seven deepwater coregonids began to decline due to overfishing and lamprey predation (Smith 1964). By the late 1960s, however, changes in sex and age composition and growth of bloaters indicated the possible start of a population decline in Lake Michigan (Brown 1970). Brown's prediction proved accurate. The population declined drastically in the early 1970s which resulted in total closure of the commercial fishery in 1976. This action apparently came in time to reverse the population decline, at least in southeastern Lake Michigan, as evidenced by our increased catches in 1978, 1979, 1980, and 1981.

During most months, bloaters are in water deeper than 18 m in Lake Michigan, but some fish move shoreward (to 9 m) during summer (Wells 1968). Therefore, most bloaters are distributed deeper than our study areas, and we are only sampling fringes of the population.

Total standard series catches of bloaters ranged from 49 fish in 1975 to 9,912 fish in 1981 (Tables 11-19). The April to August 1982 catch of 1,423 fish indicates that the bloater population may have declined from the peak abundance year of 1981. However, the population is still larger than in 1973 to 1978. Trawls have produced the majority of bloaters caught in the study areas (Tables 21-50). In 1982, 1,351 bloaters were trawled while only 7 fish were gillnetted and 65 fish were seined (Tables 30, 40, and 50). Small and sporadic gill net and seine catches in 1982, as in previous years, precluded drawing any conclusions on plant effects from these data.

During 1973-1977 when bloater abundance was low, there was no consistent pattern in larger or smaller trawl catches at Warren Dunes compared with the Cook Plant area. However, during high abundance years 1978-1981, catches at Warren Dunes stations were consistently larger than at either south or north Cook stations. The 1982 trawl data also confirm this trend. South Cook stations produced 230 fish while similar Warren Dunes stations produced 1,121 fish (Tables 51-54). Because overall abundance was low in preoperational years, we can not establish a definite plant effect in causing small catches at Cook during high abundance years 1978-1982, but it is possible that impingement (large numbers of bloaters were impinged in 1978 and 1980) at the plant is depressing the bloater population in the Cook area. Further examination with statistical analyses may help establish causes.

In summary, the bloater population in the study areas has shown a dramatic increase since 1977. The April to August 1982 catch indicates a decline from the peak year of 1981, but the population is still substantially higher than it was in years prior to 1978. These population changes reflect a lake-wide increase which is not related to plant operation. However, in recent high abundance years, smaller trawl catches at the Cook Plant compared with Warren Dunes may be related to plant operation.

Spottail Shiner -- Spottail shiner has been one of the three most commonly collected species in all survey years (1973-1981), and catches have averaged 24,593 fish over that period. This species has comprised from 9% (14,115 in 1976) to 40% (32,839 in 1980) of annual catches (Tables 11-19). Spottails were netted and impinged in almost every month. Larvae were collected in both field and entrainment sampling from June to October in most years.

Annual mean catches (April to August) for 1973 to 1981 were 2,740 (14%) in trawls, 2,106 (11%) in gill nets, and 14,332 (75%) in seines. In 1982, during the same months, total catch (7,665) was the lowest of any survey year (1973 - 1981 mean = 18,511) (Table 20). In 1982, trawls accounted for 33% (2,541), gill nets 38% (2,940), and seines 29% (2,184) of standard series catches. The 1982 seine collections were 15% of the annual rate from 1973 to 1981.

Trawl ANOVA for 1973-1981 data (see 1981 Environmental Operating Report) indicated no variation that could be attributed to plant operation. In these analyses, significant statistical effects were noted for Year, Month, Depth, Time, Area, and Station. Significant Year effects were the result of large annual population changes, i.e., the production of large year classes in 1977, 1979, 1980, and a small year class in 1981. Both trawl and gill net catches reflected the variability in year-class strength, and significant Year interactions occurred in those years when either extremely large or small year classes entered the population. Significant Year and Month main effects and associated interactions were probably a result of the seasonal behavior patterns of the species including large-scale movements of adults inshore for spawning, their subsequent exit in late summer, and recruitment of young-of-the-year to our gear in the fall. Area main effect was also significant. A trend of larger catches at Warren Dunes stations was noted in operational years (1975-1979), but differences were not statistically significant until the addition of 1980 and 1981 data (Tables 21-29). A preliminary review of April-August 1982 data indicates that trawl catches appear roughly equivalent to those of previous years (Table 30). Mean area catch at Cook Plant stations (739) was similar to the 1973-1981 mean (734), but the Warren Dunes area catch was lower (532) than previous years (636) suggesting a return to pre-1980 catch levels (Tables 51-59).

Gill net ANOVA (1973-1981) (see 1981 Environmental Operating Report) indicates significant main effects of Year, a result of the previously mentioned variation in year-class strength. Large spawning aggregations of adults from May to June in most years contributed to significant Month effects.
No significant differences occurred from 1973 to 1981 in our gill net catches in either Cook Plant or Warren Dunes areas. In 1982, gill net catches at both areas were greater than previous years (Table 40). Mean catches were 463 (Cook Plant area) and 592 (Warren Dunes area) for 1973-1981 (April-August). During 1982, catches for each area were 749 (Cook) and 722 (Warren Dunes). Both were much greater and disproportionate in view of the catch patterns of

previous years (Tables 56-61). The increase in gill net catch may be the result of contributions of large 1979 and 1980 year-classes to this year's spawning adult population.

ANOVA of 1973-1981 seine data indicated that no differences attributable to plant operation occurred within the segment of the spottail population surveyed by this gear. Year and Month main effects were significant, primarily as a result of variable year-class strength, seasonal use of the beach zone for spawning by adults and recruitment of young-of-the-year spottails to seine catches in July, August or September of most years. Usually, seine catches were greater at Cook Plant stations than at Warren Dunes stations (Tables 41-49). Mean annual seine catches (April-August 1973-1981) were 4,701 (33%) at station A (north Cook), 6,494 (45%) at station B (south Cook), and 3,137 (22%) at station F (Warren Dunes). However, in 1982 catches for the same period were 29 (11%) at station A, 992 (45%) at station B, and 943 (43%) at station F (Tables 62-64). In 1982, station F catch was 30%, station B catch was 15%, and station A catch was 5% of the 1973-1981 annual means. The exact reason for this decline is unknown and will be further examined statistically when a complete annual data set is available. In previous years, abundant young-of-the-year spottails were usually collected in August but occasionally as early as July or as late as September. The 1982 spottail year class has been almost completely absent from our seine catch to date. The dramatic decline in seine catches appeared to affect all stations but was most evident at station A (north Cook). The vicinity of station A was the target of considerable disruption beginning in early August with the deposition of large quantities of dredge materials from above the discharge pipes. This activity may have temporarily reduced the acceptability of this area as a prime young-of-the-year spottail habitat.

Most significant statistical interactions of spottail shiner catch data collected from 1973 to 1982 can be associated with the complex interrelationships of year-class variability, seasonal behavior patterns, and gear selection. These influences appear to overshadow any plant impact on this population. However, the recently noted shifts in spottail distribution and abundance in Cook Plant areas suggest that a more detailed examination of 1982 data is warranted when a complete data set becomes available.

Rainbow Smelt -- Standard series catches have ranged from a high of 16,294 smelt in 1973 to a low of 1,265 fish in 1976 (Tables 11-19). These data reveal that after peak abundance in 1973 the smelt population of southeastern Lake Michigan declined to a low in 1976 and 1977 and then increased to another peak in 1981. The April to August 1982 smelt catch of 7,266 fish is slightly above the 10-yr April to August average of 6,736 fish but considerably below the 13,025 fish caught in 1981. Evidently the smelt population is again beginning to decline after the peak year of 1981. These cyclic changes in yearly abundance are most likely natural population fluctuations rather than being a result of plant operation.

Most rainbow smelt caught in 1982, as in previous years, were trawled (Tables 21-50). Gill net catches were too small and sporadic to draw any conclusions. Seine catches showed that more than 13 times more smelt were caught at the south Cook station than at either the north Cook or Warren Dunes stations. Variation of this type, i.e., substantially larger catches at one station, is not unusual and has been found during all previous years. Statistical analysis (ANOVA) of 1973-1981 data showed no significant differences between station catches. We therefore do not believe that extreme fluctuations in smelt abundance among seine stations is related to plant operation.

ANOVA results from 1973-1981 trawl data showed significant yearly differences in catch, which we attribute to natural population changes, and significantly larger catches of smelt at Warren Dunes than at Cook during all years, including preoperational years. The April to August 1982 trawl data did not refute any of these conclusions. However, there were slightly more smelt caught at Cook Plant stations (3,012 fish) than at the Warren Dunes stations (2,660 fish). Also the April and May catch of 826 fish at the north Cook 6-m station was smaller than at either the south Cook or Warren Dunes 6-m stations (Tables 51, 53, and 55).

In summary, April to August 1982 catch data exhibited no variation in smelt abundance which could be attributed to operation of the Cook Plant. Total catch indicates that the southeastern Lake Michigan smelt population may be declining after peaking in 1981.

Trout-perch -- Annual catches of trout-perch have ranged from a low of 905 fish in 1975 to a high of 3,510 fish in 1973; the 9-yr mean catch was 2,306 fish (Tables 11-19). There has been no consistent trend in abundance fluctuations. The April to August 1982 catch of only 211 fish is considerably below the 10-yr April to August average catch of 1,439 fish and indicates that the trout-perch population may be at an extremely low level.

As in all previous study years, the majority of trout-perch caught in 1982 were trawled (Tables 21-30). The small total catch in 1982, compared to previous years, came mostly from small trawl and gill net catches (Tables 31-40).

Ninety-two trout-perch were seined in 1982 compared to an annual average of 96 fish from 1973 to 1981.

Previous analyses of the trout-perch trawl data (see 1981 Environmental Operating Report) demonstrated no variation attributable to plant operation. There was an overall pattern of greater abundance at Warren Dunes in 1973-1974, a shift to the Cook area in 1975-1976, and then back to Warren Dunes again in 1979-1980. Other years showed generally similar catches between areas. The 1982 trawl data suggest that abundance is again greater at Warren Dunes (Tables 51-54); however, the extremely small size of the catches limits the value of this conclusion. In general, annual fluctuations in abundance have occurred at both study areas; the 1982 trawl data also demonstrated this in that small catches occurred at all stations. These findings, including the addition of 1982 results, demonstrate no variation in trawl catches of trout-perch attributable to plant operation.

Past analyses of the trout-perch gill net catch data showed no variation ascribable to plant operation (see 1981 Environmental Operating Report). The 1982 gill net catch of seven fish was the smallest catch ever recorded (Tables 31-40). Because both study areas produced small catches, the low abundance was not the result of plant operation.

Past analyses of the trout-perch seine catch data showed variation resulting from natural population fluctuations and variable use of the beach zone by trout-perch as seasonal weather patterns change from year to year (see 1981 Environmental Operating Report). April to August 1982 seine catches of 36, 41, and 15 fish at the north Cook, south Cook, and Warren Dunes stations, respectively, demonstrate trout-perch beach zone abundances similar to previous years' abundances. Smallest catch at Warren Dunes was also typical of all previous study years, except 1973, when Warren Dunes produced the largest catch. Thus, seine catch data from 1973 to 1982 have not shown any variation attributable to plant operation.

In summary, trout-perch catch data for 1982 were consistent with patterns and trends established from previous years' data, and major conclusions from past analyses were unchanged. Abundance peaks occurred in 1973, 1977-1978 and 1980 and were unrelated to plant operation. Very low abundance occurred in 1975. Data for 1982 suggest that trout-perch abundance is again at a very low level, possibly the lowest in the past 10 yr.

Yellow Perch -- From 1973 to 1979, the total standard series catches of yellow perch ranged from approximately 1,600 to 4,700 fish (Tables 11-20). In 1980 and 1981, the catch rose dramatically to a high of 25,850 fish in 1981. The April to August 1982 catch of 5,355 perch indicates that the population level is still high, although down from the 1981 peak. The increase in recent years is the result of an extremely abundant 1980 year class. Apparently environmental conditions in 1980 were conducive to survival of yellow perch. Continuing decline of the alewife population in Lake Michigan may also be an ancillary factor in the good perch survival.

Previous analyses of the yellow perch trawl data (see 1981 Environmental Operating Report) demonstrated no variation directly attributable to plant operation. However, in high abundance years 1979 and 1980, more perch were trawled at Warren Dunes than at Cook, a trend possibly resulting from impingement at the plant depressing the perch population at Cook. In 1981 this trend was reversed with greater catches at Cook, thus results were ambiguous regarding plant effects. The April to August 1982 trawl catches were similar at the Cook and Warren Dunes 6-m stations; however, almost twice as many fish were trawled at the Warren Dunes 9-m station than at the comparable Cook station (Tables 51-54). Thus, results from trawl catches are still unclear regarding plant effects, although there is still a trend of greater catches at Warren Dunes in operational years.

Analysis of 1973-1981 gill net catch data, like the trawl analyses, gave ambiguous results regarding plant operation. During preoperational years, and in 1975 there were similar catches at Cook and Warren Dunes, but from 1976-1980 more perch were gillnetted at Cook. This trend, we concluded, resulted from an attraction of large perch to the plant's discharges and riprap. In 1981, however, more fish were gillnetted at Warren Dunes; a change possibly resulting from impingement of perch beginning to depress the perch population at Cook. Notably large numbers of perch were impinged in 1980 and 1981. In 1982 total gill net catches were similar at Cook and Warren Dunes (Tables 56-59). Thus further clarification is necessary to ascertain plant effects on the yellow perch population.

Analysis of 1973-1981 seine catch data showed no variation attributable to plant operation. Yearly variation resulted from strong and weak year classes of perch, while occasional large catches at either the north or south Cook stations indicated contagious distribution and schooling behavior of small perch in the beach zone. Data for 1982 corroborated these conclusions. The seine catch at the north Cook station was more than 6 times greater than at either the south Cook or Warren Dunes stations (Tables 62-64). However, the total seine catch of perch was very small (second smallest catch from April to August of 1973-1981) compared to previous years (Tables 41-50). This may indicate that the 1981 and 1982 year classes will be small.

In summary, April to August 1982 data showed that the total yellow perch population is still high compared to the populations in 1974-1978. However, the perch population may be declining from its peak in 1981. The recent increase is a result of the very large 1980 year class. Trawl and gill net catch data have shown and continue to show in 1982 ambiguous results regarding plant operations. There is a tendency for larger perch to be attracted to the Cook area with a possible depression of the total perch population in the Cook vicinity because of mortality from large numbers of perch being impinged in 1980 and 1981. Past statistical analyses have pointed to this conclusion but not verified the results. Seine catches in 1982 showed no variation resulting from plant operation, but they did indicate small year classes in 1981 and 1982.

Common Species

Brown Trout -- The 1981 total catch of 20 brown trout was below the April to August average catch of 442 fish from 1973-1981. There has been a general decline in brown trout abundance since the peak year of 1978 (Tables 11-20). Causes for the decline are unknown, but it probably is related to differential annual plantings of brown trout by state fishery agencies. Although the data have not been thoroughly analyzed, there are indications that some of the small brown trout collected in the study areas, especially by seining, are planted fish. However. the decline in recent years has been noticed for all sizes of brown trout collected. In 1982, six browns were gillnetted at Cook and three at Warren Dunes, while three fish were seined at each of the Cook stations and five fish at Warren Dunes (Tables 56-64). Thus the 1982 catches were generally similar between the Cook and Warren Dunes areas, as catches have been in all previous years. Also the recent decline has occurred at both study areas. Therefore, we believe these abundance changes are not the result of plant operation.

Chinook Salmon -- Total catches of chinook salmon were low in 1973-1977, high in 1978-1980, and low in 1981 (Tables 11-20). The April to August 1982 catch of 22 chinooks indicates that abundance is continuing at a low level. These changes in abundance are probably the result of variations in annual plantings by state fishery agencies rather than the result of plant operations. Most of the changes in abundance were caused by variation in seine catches of small, presumably planted fish. In 1982, four chinooks were gillnetted at the south Cook area and four at Warren Dunes; three fish each were seined at the north Cook and Warren Dunes stations, while six chinooks were seined at the south Cook station. These data demonstrate, as have previous years' data, that abundances were similar between study areas. Therefore, we believe that variation in chinook abundance is not the result of plant operation.

Coho Salmon -- Coho salmon catches have been declining since the peak year of 1978 (Tables 11-20). The April to August 1982 catch of only three fish indicates that the decline is still progressing. This trend is probably the result of differential plantings of coho salmon by state fishery agencies. Catch data from 1973-1981 showed similar abundances between the Cook and Warren Dunes areas, and thus changes in yearly abundance were not the result of plant operation. The low overall catch prevents drawing any conclusions regarding plant operation affecting the 1982 Cook area coho abundance.

Common Carp -- Catch data from 1973 to 1981 showed that common carp became more abundant during operational years. Average annual catch during preoperational years was 27 fish, while the operational years' average was 51 fish (Tables 11-19). The April to August 1982 catch of 72 carp is the highest catch ever found during similar months from 1973 to 1981 (Table 20). Thus carp abundance was still high during operational year 1982.

Common carp abundance at the Cook area increased in operational years, while abundance at Warren Dunes decreased slightly. Average annual catch during operational years 1975-1981 was 38 fish at south Cook stations, while Warren Dunes stations averaged six fish. During preoperational years, the averages were 11 fish at south Cook and 10 fish at Warren Dunes. Catch data for April to August 1982 also corroborate these findings. Sixty-five carp were caught at south Cook stations and only one fish at Warren Dunes. These data clearly substantiate the attraction of common carp to the Cook Plant area. We believe that carp are attracted to the warm water of the discharge and possibly the currents and suspended particles in the discharge plumes. Scuba divers also observed that carp were more abundant near the discharges than at other areas in the plant vicinity. This attraction has resulted in carp spawning in the Cook area. Common carp larvae were collected at the Cook area during operational years but not during preoperational years and never at Warren Dunes.

In summary, operation of the Cook Plant has affected the distribution and abundance of common carp by attracting fish to the plant vicinity. Catch data for 1982 corroborate this attraction. The discharge plumes have attracted carp in sufficient numbers to result in spawning near the plant. Although carp abundance at the plant area has fluctuated in operational years, there have been no trends in either increasing or decreasing numbers nor substantial changes with the addition of the Unit 2 discharge in 1979.

Emerald Shiner -- Annual emerald shiner catches have ranged from 0 to 49 fish with a 9-yr average of 15 fish per year (Tables 11-19). The April to August 1982 catch of 10 fish is slightly above the 10-yr average of 8 fish for similar months from 1973 to 1982. Thus the emerald shiner population remains low. Whether the recent decline in the southeastern Lake Michigan alewife population (a competing species) will allow an increase in the emerald shiner population remains to be seen. As in all study years, seining accounted for all specimens in 1982 (Tables 62-64). Emerald shiners, when present, have been seined at all three seining stations. Thus no substantial differences have been found between area catches. These data indicate that operation of the Cook Plant has had no detectable effect on emerald shiner abundance.

Gizzard Shad — Past analyses (see 1981 Environmental Operating Report) of seine catches have shown no plant effect on small gizzard shad in the beach zone, but gill net catches have shown a statistically greater abundance of shad at the Cook area in operational years. Gizzard shad are evidently being attracted to the underwater structures, riprap and the warm-water discharge. The gill net catch from April to August 1982 corroborates this finding. Of the 40 gizzard shad caught, 27 were gillnetted from the south Cook area, while only 13 were caught at Warren Dunes (Tables 56-59). No shad were seined from April to August 1982. In most years gizzard shad were seined in the fall. Catch data from 1979 to 1982 have shown that addition of the Unit 2 discharge in 1979 did not substantially increase the attraction of shad to the Cook area.

Johnny Darter -- Catches of johnny darters have shown a continual decline since the peak year of 1977 (Tables 11-19). The April to August 1982 catch of 58 darters is the smallest ever found during similar months from 1973 to 1981 and indicates that the darter population is continuing to decline. This population decrease does not appear to be the result of plant operation since abundance has declined at both the Cook and Warren Dunes areas.

Trawl catch data from 1973 to 1981 showed darters more abundant at the Cook area 6-m stations than at Warren Dunes. Scuba divers have observed that darters are attracted to the plant's riprap, and we believe this attraction has caused greater abundance at Cook 6-m stations. The 1982 trawl catch, although small, also showed greater abundance at the Cook station (six fish at Cook, two fish at Warren Dunes).

Lake Sturgeon -- Lake sturgeon is a rare species in the study area and threatened in Lake Michigan. Five sturgeons were gillnetted between 1975 and 1978 and one fish was impinged in 1980. None was caught in 1982. No effect of plant operation on lake sturgeon numbers was discernible.

Lake Trout -- Recent annual catches of lake trout have shown a continual decline since the peak catch of 286 fish in 1978 (Tables 11-19). In 1973, the catch was about average and declined continually to a low in 1976 and then increased in 1977 and 1978. The April to August 1982 catch of seven lake trout, which was the smallest ever found for similar months from 1973 to 1981 (average catch of

35 fish), indicates that the recent population decline is continuing. However, in all previous years most lake trout were caught during the fall when the fish move shoreward to spawn; fall 1982 catch data were not available for examination. Variation in annual catches is probably not related to plant operation, but is instead the result of natural population changes.

Examination of catches by stations and areas from 1973 to 1981 showed that while lake trout abundance increased in operational years at Warren Dunes, it decreased considerably at 6 m in the Cook area and remained the same at 9 m in the Cook area. This change suggests the possibility that either the discharge plumes were repelling lake trout from the Cook area or that impingement might be depressing the abundance in the Cook area. This finding was not substantiated by the 1982 data because of the small catch obtained, which consisted of seven lake trout all caught in the Cook area. Thus, results are still ambiguous regarding plant effects.

Longnose Dace -- Annual longnose dace catches from 1973 to 1981 have ranged from 3 fish in 1981 to 60 fish in 1977; mean catch was 29 fish per year (Tables 11-19). The two fish caught from April to August 1982 suggest that the dace population is still at a very low level. Both dace were seined, one at the north Cook station and the other at Warren Dunes. The mean catch of 42 fish in preoperational years was greater than the mean catch of 25 fish in operational years 1975-1981. Greater abundance in preoperational years may have resulted from this species being attracted to rubble associated with the safe harbor used in the early stages of plant construction. Seine catches were greater at Cook stations compared with Warren Dunes in preoperational years. Recent declines in abundance probably indicate localized population instability or signal reduction of preferred habitat in the plant area of Lake Michigan. Plant operation apparently has not affected longnose dace abundance, although plant construction affected the distribution of this species.

Longnose Sucker -- Annual longnose sucker catches have ranged from 40 fish in 1976 to 99 fish in 1974 and in 1977 (Tables 11-19). The April to August 1982 catch of 37 longnose suckers was smaller than the 9-yr mean catch of 48 fish for similar months from 1973 to 1981. Overall, these data show a relatively stable population of longnose suckers in the study areas. No substantial changes were evident in preoperational catches compared with operational catches or in catches from one-unit years compared with two-unit years.

Longnose sucker abundance has been greater at Warren Dunes than at the Cook Plant during preoperational years and all operational years. Catch data for 1982 corroborate this finding; 31 suckers were caught at Warren Dunes while only six fish were caught in the south Cook area (Tables 51-59). Causes for either an attraction to Warren Dunes or a repulsion from Cook are undetermined. It is possible that the total disturbance at the plant site from construction and dredging in preoperational years and discharge currents during operational years are repelling this species.

Ninespine Stickleback -- Annual catches of ninespine sticklebacks have been small since the peak catch of 26 fish in 1975 (Tables 11-19). The April to August 1982 catch of only two sticklebacks confirms that the population is still at a low level. While preoperational catches averaged 22 fish and operational catches averaged 10 fish, the abundance decrease has occurred at both the Cook area and at Warren Dunes. Therefore, we attribute the decline to natural causes rather than to plant operation.

Rainbow Trout -- Annual catches of rainbow trout have ranged from 86 fish in 1973 to 8 fish in 1974; average catch for the 9-yr period was 23 fish (Tables 11-19). The four rainbows caught from April to August 1982 suggest that the population in the study areas is at a low level again (Table 20). Most rainbow trout (91%) were collected in seines and in 1982 three of the four fish were seined (Tables 41-50). Because most rainbow trout in the study areas were juveniles (less than 245 mm), we believe that fluctuations in annual catches were the result of differential plantings by state fishery agencies.

Past total catches have been similar between study areas and in 1982 two fish were caught at the Cook area and two fish at Warren Dunes. Because no substantial abundance or distribution changes occurred in operational years or between study areas during operational years, we conclude that plant operation has not affected the rainbow trout population in the plant vicinity.

Slimy Sculpin -- Annual catches of slimy sculpins have ranged from a low of 14 fish in 1978 to a high of 272 fish in 1974; the 9-yr average was 94 fish per year (Tables 11-19). The April to August 1982 catch of 199 sculpins suggests that the population is at a high level again. Apparently, this species exhibits considerable natural population fluctuations. Also, we are only sampling the fringes of the Lake Michigan population, which resides in water much deeper than 9 m (Wells 1968). Water temperature variation can also have a considerable influence on the catch in a given year because sculpins prefer cold water.

Examination of trawl and seine catches at Cook and Warren Dunes stations revealed a tendency for greater abundance in the Cook area. These differences occurred in all study years including 1982. Sixty-two sculpins were trawled at the south Cook area and 41 fish at Warren Dunes in 1982; seining at north Cook, south Cook, and Warren Dunes produced, respectively, 33, 54, and 9 fish. We believe that greater abundance at Cook is a result of sculpins being attracted to the intake and discharge riprap and establishing a localized population there. Scuba divers have documented the attraction of sculpins to the riprap. In conclusion, while the lack of trends between preoperational and operational years' abundance demonstrates no obvious plant operational effects, there has been a distribution change resulting from sculpins being attracted to the riprap.

White Sucker -- Annual white sucker catches ranged from a high of 188 fish in 1979 to a low of 86 fish in 1976; the 9-yr average catch was 133 fish. The April to August 1982 catch of 139 fish was notably larger than the 10-yr April to August average catch of 92 fish and suggests that 1982 will be another peak year for white sucker abundance. Because annual catches remained relatively constant, no obvious changes occurred in operational years compared with preoperational years, and because low and high catches usually occurred simultaneously at both study areas, we believe abundance fluctuations were the result of natural variability rather than plant operation.

White sucker abundance has been substantially greater at Warren Dunes than at the Cook Plant during preoperational years and all operational years. Catch data for 1982 support this finding; 65 white suckers were caught at Warren Dunes and 45 at the south Cook area. Longnose sucker abundance was also notably greater at Warren Dunes. A cause for this difference has not been established, but we suspect that both sucker species are repelled from the Cook area because of construction activities and discharge currents.

ADULT AND JUVENILE FISH - IMPINGEMENT

INTRODUCTION

As explained in the 1980 Environmental Operating Report, estimated monthly impingement of fish at the Cook Plant since 1 March 1976 has been calculated using the average daily weights and numbers of fish impinged from the seven or eight 24-h samples taken every fourth day each month (mean model). Because the frequency distribution of total daily impingement weight has varied from near-normal to extremely skewed, mean monthly weight of impinged fish often yields a very inaccurate estimate of total monthly impingement. To improve our estimate, we developed a new method (ratio model) which incorporates total weight of fish impinged each month (which we measure) in estimating total number and weight of each species of fish impinged each month.

All impingement data for 1976 through 1980 were recalculated using the ratio model which estimates total number and weight of impinged fish. Revised estimates were presented in Tables 69-80 of the 1981 Environmental Operating Report and will be briefly summarized by years of one- and two-unit operation. Data for 1981 and 1982 (January-August) are presented in this report (Tables 65-68).

RESULTS AND DISCUSSION

1975-1977

During 3 yr of one-unit operation, annual volume of cooling water pumped averaged 1.2×10^9 m^3. Annual estimated total number of fish impinged during this period ranged from 6,279 in 1977 to 225,737 in 1975, and averaged 157,945 fish per year. Alewife was the predominate species, averaging 66% of the total

Table 65. Estimated number of fish impinged on Cook Plant traveling screens in 1981.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	39	0	39	37157	543433	606809	186645	17635	5990	2086	18924	2210	1420967	69.22
Yellow perch	13150	323	167	27	4306	340710	4546	2683	987	1370	14030	10260	392559	19.12
Rainbow smelt	11420	645	34	12111	70059	780	11952	846	66	322	956	3737	112928	5.50
Spottail shiner	18630	1135	1561	381	34300	13022	1541	984	2115	1448	4132	6950	86199	4.20
Trout-perch	553	22	25	274	3310	12949	600	364	786	2259	357	2201	23700	1.15
Slimy sculpin	421	124	266	1335	2674	361	18	88	0	10	304	1372	6973	0.34
Bloater	133	0	5	0	277	132	1349	100	66	190	366	520	3138	0.15
Gizzard shad	327	43	34	0	0	0	0	0	13	54	278	932	1681	0.08
Mottled sculpin	55	5	10	27	595	334	48	100	39	44	48	56	1361	0.07
Burbot	101	91	79	33	69	129	60	169	44	41	26	33	875	0.04
Johnny darter	0	0	0	0	220	446	12	0	4	0	0	0	682	0.03
Lake trout	31	16	0	0	116	18	6	0	0	14	189	126	516	0.03
Longnose sucker	125	22	20	0	12	38	6	13	13	3	4	9	265	0.01
Channel catfish	55	22	20	0	38	0	0	0	0	3	4	33	175	0.01
Brown trout	109	5	15	0	9	0	0	19	0	0	0	9	166	0.01
White sucker	23	27	10	2	3	12	0	0	0	34	22	5	138	0.01
Ninespine stickleback	16	0	0	0	84	3	6	0	0	0	0	5	114	0.01
Fourhorn sculpin	16	5	0	0	3	0	0	0	0	0	9	47	80	<0.01
Bluegill	0	0	0	2	40	3	0	0	0	0	0	28	73	<0.01
Coho salmon	16	5	0	0	0	0	0	0	0	0	0	28	49	<0.01
Central mudminnow	8	0	0	0	35	0	0	0	0	0	0	0	43	<0.01
Round whitefish	8	0	0	0	0	0	0	0	0	3	9	19	39	<0.01
Rainbow trout	23	5	0	0	3	0	0	6	0	0	0	0	37	<0.01
Black bullhead	0	0	0	0	9	3	0	13	4	0	0	5	34	<0.01
White crappie	8	0	5	0	0	0	0	0	0	0	0	5	18	<0.01
Common carp	0	0	0	0	0	0	6	0	0	3	4	5	18	<0.01
Northern pike	8	0	0	0	0	0	0	0	0	0	4	5	17	<0.01
Chinook salmon	8	0	5	0	0	0	0	0	0	0	4	0	17	<0.01
Rock bass	0	0	0	0	6	0	0	0	0	3	0	5	14	<0.01
Green sunfish	0	0	0	0	0	0	6	0	0	3	0	5	14	<0.01
Shorthead redhorse	8	0	0	0	0	0	6	0	0	0	0	0	14	<0.01
Longnose dace	8	0	0	0	0	0	0	0	0	0	0	0	8	<0.01
Sea lamprey	8	0	0	0	0	0	0	0	0	0	0	0	8	<0.01
Smallmouth bass	0	0	0	0	0	0	0	0	0	3	0	5	8	<0.01
Brown bullhead	0	0	0	2	0	0	0	0	0	0	0	5	7	<0.01
Lake whitefish	0	0	0	2	0	0	0	0	0	0	0	5	7	<0.01
Black crappie	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Bloater	0	0	0	0	0	0	0	0	0	0	4	0	4	<0.01
Pumpkinseed	0	0	0	0	0	0	0	0	4	0	0	0	4	<0.01
Yellow bullhead	0	0	0	0	0	0	0	0	0	3	0	0	3	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	0	3	0	0	3	<0.01
Spotted sucker	0	0	0	0	3	0	0	0	0	0	0	0	3	<0.01
Totals	45307	2495	2300	51353	659604	975749	206807	23020	10131	7899	39674	28625	2052964	

Table 66. Estimated weight of fish impinged on Cook Plant traveling screens in 1981.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.42	0.0	1.76	842.30	4575.34	2718.85	1413.13	414.55	16.09	48.37	39.27	6.43	10076.52	57.92
Yellow perch	145.70	11.04	22.21	3.05	29.23	2197.33	176.59	111.74	32.35	76.30	280.87	163.49	3249.93	18.68
Lake trout	94.99	39.21	0.0	0.0	22.82	11.38	0.09	0.0	0.0	51.21	674.79	402.52	1297.02	7.46
Spottail shiner	213.61	14.90	21.76	4.27	278.40	88.13	14.07	8.82	21.79	17.15	50.59	82.65	816.14	4.69
Longnose sucker	207.69	26.99	31.99	0.0	19.06	51.46	8.40	13.04	15.43	4.75	5.46	15.57	399.84	2.30
Burbot	34.64	55.06	33.56	12.26	27.84	37.14	20.79	48.98	9.99	7.07	8.30	15.78	311.41	1.79
Rainbow smelt	29.84	9.16	1.09	33.46	149.25	1.59	23.90	2.61	0.71	3.51	12.00	30.39	297.51	1.71
Gizzard shad	114.41	17.81	11.25	0.0	0.0	0.0	0.0	0.0	14.45	9.08	26.60	49.19	242.79	1.40
Trout-perch	6.34	0.28	0.34	2.87	36.65	59.52	4.99	3.42	9.45	31.65	5.81	32.80	194.13	1.12
White sucker	46.15	9.72	1.59	4.46	4.77	9.42	0.0	0.0	0.0	21.20	15.89	10.77	123.96	0.71
Brown trout	26.17	0.41	9.50	0.0	12.40	0.0	0.0	60.97	0.0	0.0	0.0	1.09	110.54	0.64
Slimy sculpin	4.36	1.43	2.72	8.37	14.77	1.31	0.07	0.46	0.0	0.12	3.35	15.05	52.01	0.30
Coho salmon	9.92	3.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.97	35.23	0.20
Channel catfish	12.01	0.55	3.07	0.0	0.09	0.0	0.0	0.0	0.0	0.01	4.29	11.97	32.00	0.18
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	29.08	0.0	0.0	0.14	0.85	0.16	30.23	0.17
Bloater	0.67	0.0	0.02	0.0	3.06	1.32	15.40	0.70	0.35	1.30	1.85	2.67	27.37	0.16
Rainbow trout	3.05	3.60	0.0	0.0	2.15	0.0	0.0	10.81	0.0	0.0	0.0	0.0	19.62	0.11
Round whitefish	3.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	1.64	12.88	18.70	0.11
Chinook salmon	7.41	0.0	9.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.46	0.0	18.48	0.11
Mottled sculpin	0.68	0.09	0.11	0.37	3.39	2.65	0.44	0.93	0.49	0.50	0.41	0.63	10.69	0.06
Shorthead redhorse	2.46	0.0	0.0	0.0	0.0	0.0	3.55	0.0	0.0	0.0	0.0	0.0	6.02	0.03
Bluegill	0.0	0.0	0.0	0.05	5.21	0.01	0.0	0.0	0.0	0.0	0.0	0.38	5.65	0.03
Lake whitefish	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.92	5.00	0.03
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.56	0.0	0.09	3.65	0.02
Northern pike	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.27	0.14	2.41	0.01
Sea lamprey	1.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.91	0.01
Johnny darter	0.0	0.0	0.0	0.0	0.52	0.70	0.02	0.0	0.01	0.0	0.0	0.0	1.25	0.01
Fourhorn sculpin	0.21	0.06	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.11	0.73	1.13	0.01
Black bullhead	0.0	0.0	0.0	0.0	0.30	0.02	0.0	0.38	0.10	0.0	0.0	0.22	1.03	0.01
Rock bass	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.80	0.0	0.06	0.88	0.01
Brown bullhead	0.0	0.0	0.0	0.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.73	<0.01
White crappie	0.02	0.0	0.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.63	<0.01
Yellow bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.46	0.0	0.0	0.46	<0.01
Central mudminnow	0.09	0.0	0.0	0.0	0.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33	<0.01
Ninespine stickleback	0.04	0.0	0.0	0.0	0.24	0.01	0.02	0.0	0.0	0.0	0.0	0.01	0.32	<0.01
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.30	<0.01
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.0	0.0	0.22	<0.01
Black crappie	0.0	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	<0.01
Green sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.06	0.0	0.06	0.15	<0.01
Bloater	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.0	0.11	<0.01
Longnose dace	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	<0.01
Spotted sucker	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	<0.01
Totals	967.83	193.66	151.27	912.09	5185.78	5180.80	1710.58	677.41	121.54	277.71	1134.94	882.90	17396.50	

Table 67. Estimated number of fish impinged on Cook Plant traveling screens, January-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	0	70	86308	107717	531505	85610	1391	ND	ND	ND	ND	812601	91.70
Spottail shiner	630	149	830	27022	794	3280	562	58	ND	ND	ND	ND	33325	3.76
Yellow perch	2193	531	399	1080	624	6050	2900	1077	ND	ND	ND	ND	14854	1.68
Rainbow smelt	46	16	18	12672	318	537	100	0	ND	ND	ND	ND	13707	1.55
Slimy sculpin	348	12	95	4308	454	584	9	0	ND	ND	ND	ND	5810	0.66
Trout-perch	88	34	28	686	113	713	88	36	ND	ND	ND	ND	1786	0.20
Burbot	51	37	49	44	183	306	100	54	ND	ND	ND	ND	824	0.09
White sucker	51	6	11	55	120	324	29	4	ND	ND	ND	ND	600	0.07
Longnose sucker	28	0	4	125	72	315	31	7	ND	ND	ND	ND	582	0.07
Coho salmon	14	0	4	376	38	19	68	0	ND	ND	ND	ND	519	0.06
Mottled sculpin	74	0	7	169	16	83	9	0	ND	ND	ND	ND	358	0.04
Gizzard shad	185	0	0	26	0	19	0	4	ND	ND	ND	ND	234	0.03
Lake trout	60	6	14	55	28	46	6	0	ND	ND	ND	ND	215	0.02
Brown trout	9	0	0	58	6	74	6	4	ND	ND	ND	ND	157	0.02
Ninespine stickleback	0	0	0	44	25	19	0	0	ND	ND	ND	ND	88	0.01
Channel catfish	37	3	18	18	6	0	0	4	ND	ND	ND	ND	86	0.01
Bloater	9	0	0	0	9	37	26	0	ND	ND	ND	ND	81	0.01
Central mudminnow	0	0	11	55	0	0	0	0	ND	ND	ND	ND	66	0.01
Black bullhead	5	0	7	41	0	9	0	0	ND	ND	ND	ND	62	0.01
Lake chub	0	0	0	12	0	19	0	0	ND	ND	ND	ND	31	<0.01
Sea lamprey	0	0	0	0	0	28	0	0	ND	ND	ND	ND	28	<0.01
Bluegill	5	0	0	0	0	19	0	0	ND	ND	ND	ND	24	<0.01
Chinook salmon	5	0	0	12	3	0	3	0	ND	ND	ND	ND	23	<0.01
Rainbow trout	5	0	0	3	0	0	9	0	ND	ND	ND	ND	17	<0.01
Tadpole madtom	0	0	0	3	9	0	0	0	ND	ND	ND	ND	12	<0.01
Johnny darter	0	0	0	0	3	9	0	0	ND	ND	ND	ND	12	<0.01
Common carp	0	3	0	9	0	0	0	0	ND	ND	ND	ND	12	<0.01
Golden shiner	0	0	0	3	0	0	6	0	ND	ND	ND	ND	9	<0.01
Pumpkinseed	0	0	0	9	0	0	0	0	ND	ND	ND	ND	9	<0.01
Lake whitefish	5	0	0	3	0	0	0	0	ND	ND	ND	ND	8	<0.01
Northern pike	0	0	4	3	0	0	0	0	ND	ND	ND	ND	7	<0.01
Brown bullhead	0	0	0	3	3	0	0	0	ND	ND	ND	ND	6	<0.01
Yellow bullhead	0	0	0	3	0	0	3	0	ND	ND	ND	ND	6	<0.01
Lake herring	5	0	0	0	0	0	0	0	ND	ND	ND	ND	5	<0.01
Shorthead redhorse	5	0	0	0	0	0	0	0	ND	ND	ND	ND	5	<0.01
Freshwater drum	5	0	0	0	0	0	0	0	ND	ND	ND	ND	5	<0.01
Rock bass	0	0	0	3	0	0	0	0	ND	ND	ND	ND	3	<0.01
Fourhorn sculpin	0	0	0	3	0	0	0	0	ND	ND	ND	ND	3	<0.01
Longnose gar	0	0	0	3	0	0	0	0	ND	ND	ND	ND	3	<0.01
Totals	3863	797	1569	133214	110541	543995	89565	2639	ND	ND	ND	ND	886183	

Table 68. Estimated weight of fish impinged on Cook Plant traveling screens, January-August 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.0	0.0	3.07	3808.71	2741.44	10839.70	1890.07	30.48	ND	ND	ND	ND	19313.48	81.29
Yellow perch	97.58	17.16	36.34	72.92	28.05	247.68	186.02	50.98	ND	ND	ND	ND	736.73	3.10
Longnose sucker	46.90	0.0	6.66	163.48	84.77	328.23	18.47	8.49	ND	ND	ND	ND	657.00	2.77
Lake trout	133.24	33.98	41.91	30.95	85.29	155.00	7.20	0.0	ND	ND	ND	ND	487.56	2.05
White sucker	51.92	1.63	8.64	33.44	97.63	262.25	23.14	0.02	ND	ND	ND	ND	478.67	2.01
Coho salmon	4.79	0.0	3.24	362.81	30.55	8.71	49.23	0.0	ND	ND	ND	ND	459.34	1.93
Spottail shiner	8.31	2.55	13.11	333.32	9.83	37.84	5.86	0.75	ND	ND	ND	ND	411.58	1.73
Brown trout	5.12	0.0	0.0	120.38	12.68	217.81	13.48	11.82	ND	ND	ND	ND	381.30	1.60
Burbot	36.46	20.24	25.26	22.07	84.57	111.05	33.47	20.79	ND	ND	ND	ND	353.92	1.49
Gizzard shad	142.19	0.0	0.0	14.84	0.0	0.01	0.0	4.03	ND	ND	ND	ND	161.08	0.68
Rainbow smelt	0.73	0.19	0.40	103.15	3.76	3.87	0.53	0.0	ND	ND	ND	ND	112.63	0.47
Common carp	0.0	20.73	0.0	28.60	0.0	0.0	0.0	0.0	ND	ND	ND	ND	49.33	0.21
Slimy sculpin	3.83	0.13	1.04	31.04	2.34	3.08	0.08	0.0	ND	ND	ND	ND	41.53	0.17
Trout-perch	1.96	0.74	0.56	11.18	1.47	9.88	1.16	0.59	ND	ND	ND	ND	27.53	0.12
Chinook salmon	2.79	0.0	0.0	23.08	0.03	0.0	0.03	0.0	ND	ND	ND	ND	25.93	0.11
Channel catfish	10.85	0.05	3.46	0.81	0.15	0.0	0.0	0.84	ND	ND	ND	ND	16.15	0.07
Rainbow trout	4.98	0.0	0.0	0.70	0.0	0.0	4.43	0.0	ND	ND	ND	ND	10.12	0.04
Tadpole madtom	0.0	0.0	0.0	0.01	5.52	0.0	0.0	0.0	ND	ND	ND	ND	5.52	0.02
Lake whitefish	3.32	0.0	0.0	2.04	0.0	0.0	0.0	0.0	ND	ND	ND	ND	5.36	0.02
Lake herring	4.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND	ND	ND	ND	4.91	0.02
Mottled sculpin	1.03	0.0	0.08	1.35	0.10	0.50	0.08	0.0	ND	ND	ND	ND	3.15	0.01
Sea lamprey	0.0	0.0	0.0	0.0	0.0	2.93	0.0	0.0	ND	ND	ND	ND	2.93	0.01
Northern pike	0.0	0.0	1.22	1.26	0.0	0.0	0.0	0.0	ND	ND	ND	ND	2.48	0.01
Black bullhead	0.32	0.0	0.80	0.99	0.0	0.18	0.0	0.0	ND	ND	ND	ND	2.28	0.01
Yellow bullhead	0.0	0.0	0.0	0.52	0.0	0.0	1.37	0.0	ND	ND	ND	ND	1.89	0.01
Lake chub	0.0	0.0	0.0	0.75	0.0	0.87	0.0	0.0	ND	ND	ND	ND	1.62	0.01
Bloater	0.06	0.0	0.0	0.0	0.06	0.37	0.30	0.0	ND	ND	ND	ND	0.80	<0.01
Shorthead redhorse	0.52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.52	<0.01
Longnose gar	0.0	0.0	0.0	0.52	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.52	<0.01
Pumpkinseed	0.0	0.0	0.0	0.43	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.43	<0.01
Ninespine stickleback	0.0	0.0	0.0	0.21	0.06	0.14	0.0	0.0	ND	ND	ND	ND	0.41	<0.01
Central mudminnow	0.0	0.0	0.11	0.28	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.39	<0.01
Brown bullhead	0.0	0.0	0.0	0.20	0.17	0.0	0.0	0.0	ND	ND	ND	ND	0.37	<0.01
Bluegill	0.04	0.0	0.0	0.0	0.0	0.19	0.0	0.0	ND	ND	ND	ND	0.23	<0.01
Rock bass	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.09	<0.01
Freshwater drum	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.08	<0.01
Fourhorn sculpin	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	ND	ND	ND	ND	0.02	<0.01
Golden shiner	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.0	ND	ND	ND	ND	0.02	<0.01
Johnny darter	0.0	0.0	0.0	0.0	0.01	0.00	0.0	0.0	ND	ND	ND	ND	0.01	<0.01
Totals	561.95	97.40	145.91	5170.12	3188.48	12230.26	2234.96	128.79	ND	ND	ND	ND	23757.86	

number of impinged fish. Large numbers of spottail shiner, yellow perch, trout-perch, slimy sculpin, and rainbow smelt were also impinged each year. Alewives ranged from 41 to 85%, averaging 62% of the estimated biomass of impinged fish, and yellow perch ranged from 6 to 26%, averaging 18% of the biomass. Lake trout, spottail shiner, and trout-perch averaged 9%, 3%, and 2%, respectively, of estimated annual biomass.

Among species of impinged fish which were less abundant in samples analyzed, salmonids were the most important sport fish. An average of 166 salmonids, mostly lake trout, was impinged during each year of one-unit operation.

1978-1981

During 4 yr of two-unit operation, annual volume of water pumped averaged 2.6×10^9 m^3, a 105% increase from volume pumped during one-unit operation. Annual estimated number of fish impinged ranged from 480,776 in 1979 to 2,307,194 in 1980 and averaged 1,364,082 fish for the 4 yr, an increase of 764% over the previous 3 yr. Alewife remained the most abundant species, averaging 64% of the total number of fish impinged. The next most abundant species impinged were spottail shiner, yellow perch, trout-perch, and rainbow smelt. Slimy sculpin was proportionally less abundant among impinged fish than previously, and bloater was proportionally more abundant than during 1975-1977. The increase in bloater impingement probably is a result of a lake-wide increase in their population. Alewife and yellow perch continued to dominate the weight of impinged fish, alewife averaging 62% and yellow perch averaging 14% of annual estimated weight of impinged fish.

An average of 979 salmonids were impinged annually during the 4 yr of two-unit operation. Lake trout were the most often impinged salmonid in 1978 and 1981. In 1979 and 1980, chinook salmon were numerically most abundant in impingement samples. In 1980, most chinook were small, probably newly planted.

Occasional periods when extremely large numbers of fish were impinged over a short time interval characterized the past 4 yr of two-unit operation. This phenomenon was most apparent in July 1978, September 1979, April 1980, and May 1980. On each occasion, both units were operating. High velocity at the intakes or large volumes of water pumped, together with large numbers of fish in the area of the intakes, resulted in extremely large numbers of fish entering the forebay. Fish may have been congregating in the vicinity of the intake as a result of some physical stimuli such as a storm, upwelling, or spring warming of inshore water. Each of these events may result in more fish passing near the intake structure within a given period of time, either by increasing fish movement, or by causing fish to congregate within a favorable environment. Two-unit impingement was discussed in more detail in the 1980 Environmental Operating Report.

1982, January-August

Through August 1982, 1.84×10^{9} m^{3} of water circulated through the plant and 886,183 fish were impinged (Table 67). Species composition was similar to that of previous years; however, alewives comprised 92% by number and 81% by weight of impinged fish (Tables 67, 68). Alewives comprised an exceptionally large proportion of the total impingement loss relative to past years' data, but this may be modified when data from September through December are examined. Fewer alewives are usually impinged during Septemer-December, but several species, such as yellow perch, spottail shiner, and trout-perch, continue to be impinged in high numbers through the fall.

Since many salmonids are normally impinged during fall months not included in the 1982 data, total inpingement of trout and salmon this year cannot be accurately assessed. However, the 215 lake trout and 519 coho salmon impinged January-August (Table 67) exceeded the number impinged during this period in all previous years. Additionally, these coho and lake trout were mostly adult fish, rather than the juvenile (and probably newly planted) salmonids which have sometimes been impinged in fairly high numbers during the spring.

Only 81 bloaters were impinged through August 1982 (Table 67). Number of bloaters impinged annually is extremely variable, but since 1976 has ranged from 1,063 to 22,810 fish annually. Bloaters normally reside farther offshore than the 9-m depth of the intakes and are probably impinged as they move shoreward during upwelling.

Over a period of several days in May 1980, more than half of the impinged alewives appeared to have been dead before they were impinged. The dead alewives appeared immediately following the unusually high impingement rates which occurred in April and May 1980. Because there was no corresponding increase in number of dead alewives washed up on the beach or collected in May fish samples, the impinged alewives probably died in the forebay from starvation and the stress of overcrowding.

During 1981 and 1982, both dead fish and trash from all impingement samples processed in the lab were weighed and recorded. There was no recurrence of the high proportion of dead fish that appeared in 1980. Of the total weight of fish impinged in both 1981 and 1982, weight of dead fish was about 1%. Trash weight equaled 3% of the weight of fish impinged in 1981 and 2% of the weight of fish impinged in 1982.

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APPENDIX C

CONSISTENCY REQUIREMENTS

APPENDIX C

PART-1

PLANT DESIGN AND OPERATION

Attachment #1

STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

PERMIT

Permit No. 82-12-4G
Date Issued
Extended
Revised
Expires

ISSUED TO

Indiana & Michigan Electric Company
P. O. Box 18
Bowling Green Station
New York, New York 10004

This permit is granted under provisions of:
☐ The Inland Lakes and Streams Act, 1972 P.A. 346, as amended.
☒ The Great Lakes Submerged Lands Act, 1955 P.A. 247, as amendec
☐ Flood Plain Regulatory Act, 1929 P.A. 245, as amended.
☐ The Goemaere-Anderson Wetland Protection Act, 1979 P.A. 203.

rmitted Act ity

-- See Attachment --

ter Course Affected	County	Town	Range	Sect	Sub. and Lot Number
Lake Michigan	Berrien	6S	19W	6	

Authority granted by this permit is subject to the following limitations:

A Initiation of any work on the permitted project confirms the permittee's acceptance and agreement to comply with all terms and conditions of this permit.
B The permittee in exercising the authority granted by this permit shall not cause unlawful pollution as defined by Act No. 245 of the Public Acts of 1929, as amended.
C This permit shall be kept at the site of the work and available for inspection at all times during the duration of the project or until its date of expiration.
D All work shall be completed in accordance with the plans and specifications submitted with the application and/or plans and specifications attached hereto.
E No attempt shall be made by the permittee to forbid the full and free use by the public of public waters at or adjacent to the structure or work approved herein.
F It is made a requirement of this permit that the permittee give notice to public utilities in accordance with Act 53 of the Public Acts of 1974, and comply with each of the requirements of that act.
G This permit does not convey property rights in either real estate or material, nor does it authorize any injury to private property or invasion of public or private rights, nor does it waive the necessity of seeking federal assent, all local permits or complying with other state statutes.
H This permit does not prejudice or limit the right of a riparian owner or other person to institute proceedings in any circuit court of this state when necessary to protect his rights.
I Permittee shall notify the Department of Natural Resources within one week after the completion of the activity authorized by this permit, by completing and forwarding the attached preaddressed post card to the office addressed thereon.
J This permit shall not be assigned or transferred without the written approval of the Department of Natural Resources.
K. Work to be done under authority of this permit is further subject to the following special instructions and specifications:

1. Before construction, permanent monuments will be placed 1000' north and south and 2000' north and south of the existing pipeline structures with locations surveyed, a map of these monuments will be sent to the DNR.

2. All excess dredge material will be placed in littoral zone 8' of water or less.

3. Monitoring of the shoreline will be conducted. Reports will be prepared 9-30-82, 4-1-83, 9-30-83, 4-1-84, 9-30-84, and as often thereafter as is deemed necessary and sent to the Department.

4. Monitoring of bottomland contours will be conducted in June, 82, June, 83, June, 84, and as is deemed necessary by the Department thereafter. The monitoring shall include an area from shore to a point 200 feet lakeward of the end of the pipeline and 200 feet on each side of the double pipeline.

(continued)

HOWARD A. TANNER
Director, Department of Natural Resources

By

M. C. Nielsen

Dist. 12 Law Supr.
LRPD, Plainwell & Region III
Public Health
Berrien Co. CEA

R270
Rev 4 8

MCN:kt

Attachment #1

ATTACHMENT

Indiana & Michigan Electric Company
DNR Permit No. 82-12-4G

PERMITTED ACTIVITY

Dredge an approximate area of 1,100 X 164 feet above and around two (2) existing discharge lines and remove approximately 40,000 cubic yards of sand. Upon completion of the dredging operation, 20,000 square yards of filter cloth will be laid over the discharge pipes in the trench; 3,700 cubic yards of mattress stone will be placed 1.5 feet deep over the filter cloth; 4,200 cubic yards of riprap stone will be placed over the mattress stone and the original sand will be replaced to the original contour. All sand excess that is used to restore the bottom contour to its preconstruction condition will be placed in the water in the littoral zone so that it will nourish beaches down drift from the construction site.

PERMIT CONDITIONS, continued

5. No dredging will be permitted until construction materials are available to refill dredged area.

6. Work may be done only on 100 feet of pipeline at any one time.

7. No bulkheading is allowed by this permit either temporary or permanent.

I have read and understand the conditions of this permit and I agree to these conditions.

Date: June 22, 1982

By:
Title: Vice President

G. P. Maloney
Vice President
Indiana & Michigan Electric Company

Attachment 2

Permit No. 82-56-4

Effective Date: [illegible]

Expiration Date: 31 December 1985

DEPARTMENT OF THE ARMY PERMIT

Indiana & Michigan Electric Company
P.O. BOX 18
Bowling Green Station
New York, New York 10004

Commander
U.S. Army Engineer District, Detroit
Box 1027
Detroit, Michigan 48231

Gentlemen:

Referring to written request dated 7 Jan 82 for a permit to:

(X) Perform work in or affecting navigable waters of the United States, upon the recommendation of the Chief of Engineers, pursuant to Section 10 of the Rivers and Harbors Act of March 3, 1899 (33 U.S.C. 403);

(X) Discharge dredged or fill material into waters of the United States upon the issuance of a permit from the Secretary of the Army acting through the Chief of Engineers pursuant to Section 404 of the Federal Water Pollution Control Act (86 Stat. 816, P.L. 92-500);

is hereby authorized by the Secretary of the Army: to dredge 40,000 cubic yards of sand from an area (1100' X 164') above and around two (2) existing circulating water system discharge pipes; place 20,000 square yards of filter cloth; place 3700 cubic yards of mattress stone; cover the mattress stone with 4200 cubic yards of stone riprap; back fill the area with the dredged material to restore lake bottom contours to pre-construction elevations; all excess dredged material shall be discharged into the littoral zone for beach nourishment

in Lake Michigan

Offshore property in Section 6, T6S, R19W, Lake Township, Berrien County, located approximately 1.1 mile northwesterly from the intersection of Red Arrow Highway and Livingstone Road near Bridgman, Michigan

in accordance with the plans and drawings attached hereto which are incorporated in and made a part of this permit, subject to the following conditions:

NCE Form 119
R 14 Aug 1981

(Previous edition of 22 Feb 1978 is obsolete)

(Re. ENG 1721)

Attachment #2

I. GENERAL CONDITIONS:

a. That all activities identified and authorized herein shall be consistent with the terms and conditions of this permit; and that any activities not specifically identified and authorized herein shall constitute a violation of the terms and conditions of this permit which may result in the modification, suspension or revocation of this permit, in whole or in part, as set forth more specifically in General Conditions j or k hereto, and in the institution of such legal proceedings as the United States Government may consider appropriate, whether or not this permit has been previously modified, suspended or revoked in whole or in part.

b. That all activities authorized herein shall, if they involve, during their construction or operation, any discharge of pollutants into waters of the United States or ocean waters, be at all times consistent with applicable water quality standards, effluent limitations and standards of performance, prohibitions, pretreatment standards and management practices established pursuant to the Federal Water Pollution Control Act of 1972 (Pub. L. 92-500; 86 Stat. 816), the Marine Protection, Research and Sanctuaries Act of 1972 (Pub. L. 92-532; 86 Stat. 1052), or pursuant to applicable State and local law.

c. That when the activity authorized herein involves a discharge during its construction or operation, of any pollutant (including dredged or fill material), into waters of the United States, the authorized activity shall, if applicable water quality standards are revised or modified during the term of this permit, be modified, if necessary, to conform with such revised or modified water quality standards within 6 months of the effective date of any revision or modification of water quality standards, or as directed by an implementation plan contained in such revised or modified standards, or within such longer period of time as the District Engineer, in consultation with the Regional Administrator of the Environmental Protection Agency, may determine to be reasonable under the circumstances.

d. That the discharge will not destroy a threatened or endangered species as identified under the Endangered Species Act, or endanger the critical habitat of such species.

e. That the permittee agrees to make every reasonable effort to prosecute the construction or operation of the work authorized herein in a manner so as to minimize any adverse impact on fish, wildlife, and natural environmental values.

f. That the permittee agrees that it will prosecute the construction or work authorized herein in a manner so as to minimize any degradation of water quality.

g. That the permittee shall permit the District Engineer or his authorized representative(s) or designee(s) to make periodic inspections at any time deemed necessary in order to assure that the activity being performed under authority of this permit is in accordance with the terms and conditions prescribed herein.

h. That the permittee shall maintain the structure or work authorized herein in good condition and in accordance with the plans and drawings attached hereto.

i. That this permit does not convey any property rights, either in real estate or material, or any exclusive privileges; and that it does not authorize any injury to property or invasion of rights or any infringement of Federal, State, or local laws or regulations nor does it obviate the requirement to obtain State or local assent required by law for the activity authorized herein.

j. That this permit may be summarily suspended, in whole or in part, upon a finding by the District Engineer that immediate suspension of the activity authorized herein would be in the general public interest. Such suspension shall be effective upon receipt by the permittee of a written notice thereof which shall indicate (1) the extent of the suspension, (2) the reasons for this action, and (3) any corrective or preventative measures to be taken by the permittee which are deemed necessary by the District Engineer to abate imminent hazards to the general public interest. The permittee shall take immediate action to comply with the provisions of this notice. Within ten days following receipt of this notice of suspension, the permittee may request a hearing in order to present information relevant to a decision as to whether his permit should be reinstated, modified or revoked. If a hearing is requested, it shall be conducted pursuant to procedures prescribed by the Chief of Engineers. After completion of the hearing, or within a reasonable time after issuance of the suspension notice to the permittee if no hearing is requested, the permit will either be reinstated, modified or revoked.

k. That this permit may be either modified, suspended or revoked in whole or in part if the Secretary of the Army or his authorized representative determines that there has been a violation of any of the terms or

Attachment #2

conditions of this permit or that such action would otherwise be in the public interest. Any such modification, suspension, or revocation shall become effective 30 days after receipt by the permittee of written notice of such action which shall specify the facts or conduct warranting same unless (1) within the 30-day period the permittee is able to satisfactorily demonstrate that (a) the alleged violation of the terms and the conditions of this permit did not, in fact, occur or (b) the alleged violation was accidental, and the permittee has been operating in compliance with the terms and conditions of the permit and is able to provide satisfactory assurances that future operations shall be in full compliance with the terms and conditions of this permit; or (2) within the aforesaid 30-day period, the permittee requests that a public hearing be held to present oral and written evidence concerning the proposed modification, suspension or revocation. The conduct of this hearing and the procedures for making a final decision either to modify, suspend or revoke this permit in whole or in part shall be pursuant to procedures prescribed by the Chief of Engineers.

l. That in issuing this permit, the Government has relied on the information and data which the permittee has provided in connection with his permit application. If, subsequent to the issuance of this permit, such information and data prove to be false, incomplete or inaccurate, this permit may be modified, suspended or revoked, in whole or in part and/or the Government may, in addition, institute appropriate legal proceedings.

m. That any modification, suspension, or revocation of this permit shall not be the basis for any claim for damages against the United States.

n. That the permittee shall notify the District Engineer at what time the activity authorized herein will be commenced, as far in advance of the time of commencement as the District Engineer may specify, and of any suspension of work, if for a period of more than one week, resumption of work and its completion.

o. That if the activity authorized herein is not started on or before 15th day of June 19 83 and is not completed on or before 31st day of Dec 19 85 this permit, if not previously revoked or specifically extended, shall automatically expire.

p. That this permit does not authorize or approve the construction of particular structures, the authorization or approval of which may require authorization by the Congress or other agencies of the Federal Government.

q. That if and when the permittee desires to abandon the activity authorized herein, unless such abandonment is part of a transfer procedure by which the permittee is transferring his interests herein to a third party pursuant to General Condition t hereof, he must restore the area to a condition satisfactory to the District Engineer.

r. That if the recording of this permit is possible under applicable State or local law, the permittee shall take such action as may be necessary to record this permit with the Register of Deeds or other appropriate official charged with the responsibility for maintaining records of title to and interests in real property.

s. That there shall be no unreasonable interference with navigation by the existence or use of the activity authorized herein.

t. That this permit may not be transferred to a third party without prior written notice to the District Engineer, either by the transferee's written agreement to comply with all terms and conditions of this permit or by the transferee subscribing to this permit in the space provided below and thereby agreeing to comply with all terms and conditions of this permit. In addition, if the permittee transfers the interests authorized herein by conveyance of realty, the deed shall reference this permit and the terms and conditions specified herein and this permit shall be recorded along with the deed with the Register of Deeds or other appropriate official.

II. SPECIAL CONDITIONS:

a. *Structures in or Affecting Navigable Waters of the United States:*

(1) That this permit does not authorize the interference with any existing or proposed Federal project and that the permittee shall not be entitled to compensation for damage or injury to the structures or work authorized herein which may be caused by or result from existing or future operations undertaken by the United States in the public interest.

(2) That no attempt shall be made by the permittee to prevent the full and free use by the public of all navigable waters at or adjacent to the activity authorized by this permit.

(3) That if the display of lights and signals on any structure or work authorized herein is not otherwise provided for by law, such lights and signals as may be prescribed by the United States Coast Guard shall be installed and maintained by and at the expense of the permittee.

(4) That the permittee, upon receipt of a notice of revocation of this permit or upon its expiration before completion of the authorized structure or work, shall, without expense to the United States and in such time and manner as the Secretary of the Army or his authorized representative may direct, restore the waterway to its former conditions. If the permittee fails to comply with the direction of the Secretary of the Army or his authorized representative, the Secretary or his designee may restore the waterway to its former condition, by contract or otherwise, and recover the cost thereof from the permittee.

(5) Structures for Small Boats: That permittee hereby recognizes the possibility that the structure permitted herein may be subject to damage by wave wash from passing vessels. The issuance of this permit does not relieve the permittee from taking all proper steps to insure the integrity of the structure permitted herein and the safety of boats moored thereto from damage by wave wash and the permittee shall not hold the United States liable for any such damage.

b. *Maintenance Dredging:*

(1) That when the work authorized herein includes periodic maintenance dredging, it may be performed under this permit for ______ years from the date of issuance of this permit;

(2) That the permittee will advise the District Engineer in writing at least two weeks before he intends to undertake any maintenance dredging.

c. *Discharges of Dredged or Fill Material Into Waters of the United States:*

(1) That the discharge will be carried out in conformity with the goals and objectives of the EPA Guidelines established pursuant to Section 404(b) of the FWPCA and published in 40 CFR 230;

(2) That the discharge will consist of suitable material free from toxic pollutants in other than trace quantities;

(3) That the fill created by the discharge will be properly maintained to prevent erosion and other non-point sources of pollution; and

(4) That the discharge will not occur in a component of the National Wild and Scenic River System or in a component of a State wild and scenic river system.

d. *Other:*

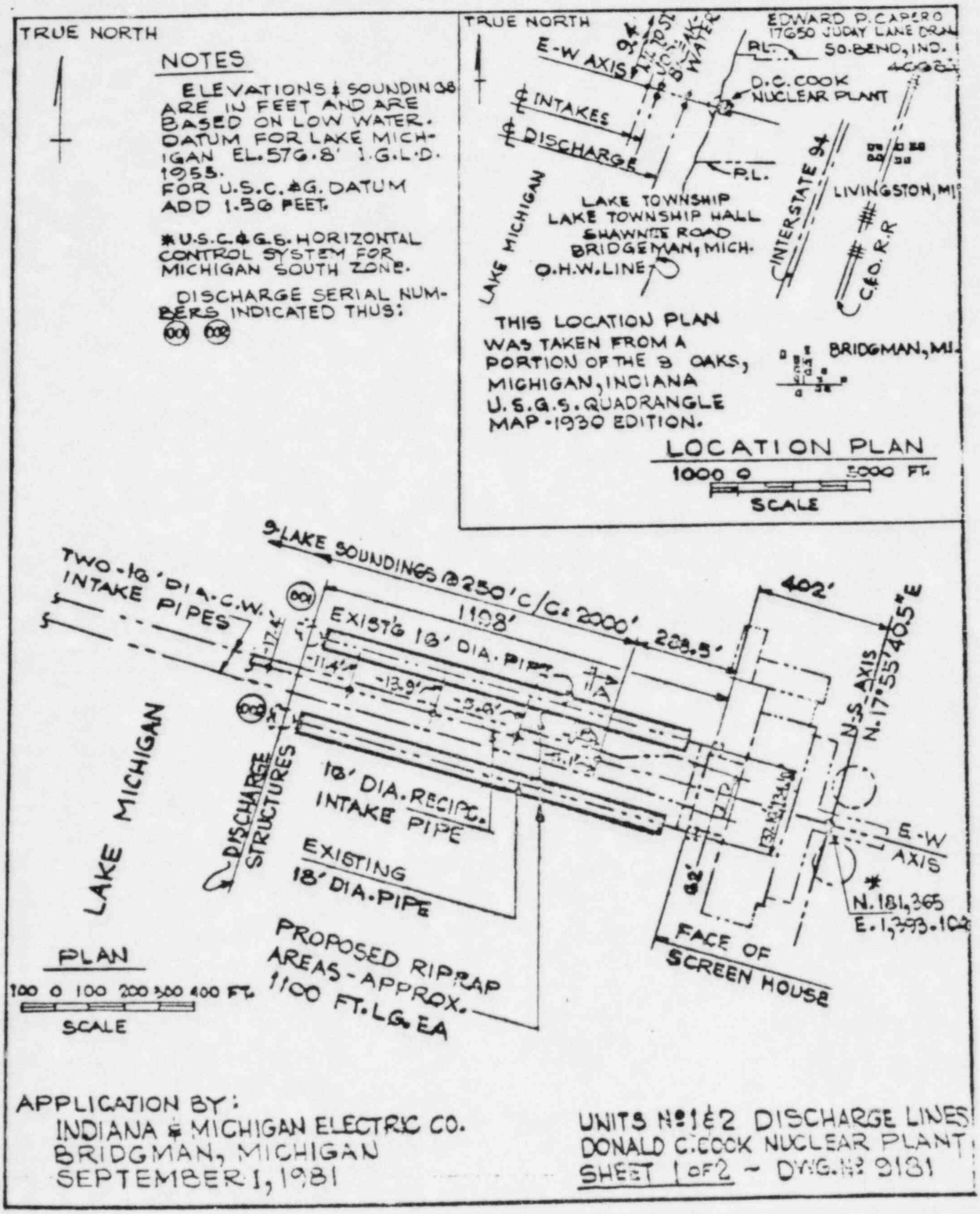
(1) That the permittee hereby recognizes the possibility that the structure/activity permitted herein may be subject to damage by ice pressure(s). The issuance of this permit does not relieve the permittee from taking all proper steps to insure the integrity of the structure/activity permitted herein and the safety of boats moored thereto from damage by ice pressure(s) and the permittee shall not hold the United States liable for such damage.

(2) Work shall be accomplished on no more than 100 feet of pipeline at any one time.

(3) Information compiled from monitoring of shoreline as required by Michigan Department of Natural Resources Permit No. 82-12-4G shall be furnished to the District Engineer upon written request.

Attachment #2

PERMIT No. 82 56



NOTES

ELEVATIONS & SOUNDINGS ARE IN FEET AND ARE BASED ON LOW WATER DATUM FOR LAKE MICHIGAN EL. 576.8' I.G.L.D. 1955. FOR U.S.C.&G. DATUM ADD 1.56 FEET.

*U.S.C.&G.S. HORIZONTAL CONTROL SYSTEM FOR MICHIGAN SOUTH ZONE.

DISCHARGE SERIAL NUMBERS INDICATED THUS: 001 002

THIS LOCATION PLAN WAS TAKEN FROM A PORTION OF THE 3 OAKS, MICHIGAN, INDIANA U.S.G.S. QUADRANGLE MAP - 1930 EDITION.

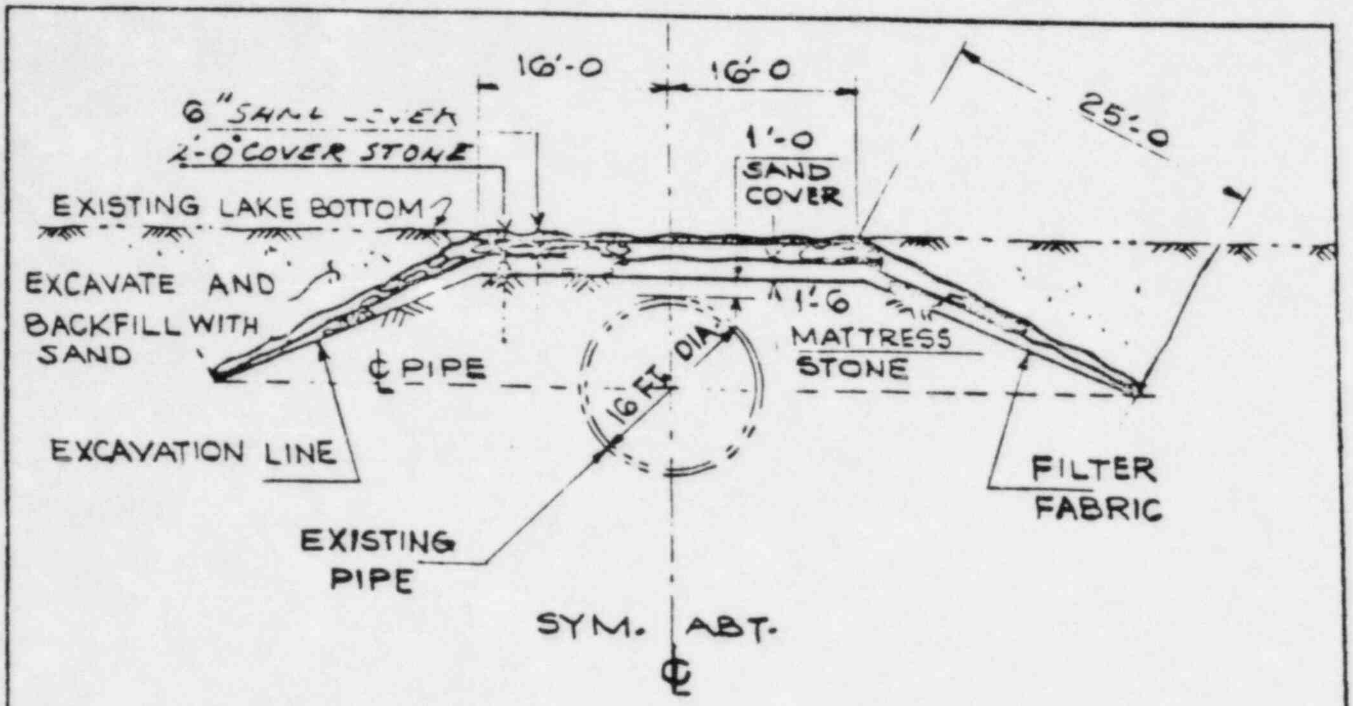
APPLICATION BY:
INDIANA & MICHIGAN ELECTRIC CO.
BRIDGMAN, MICHIGAN
SEPTEMBER 1, 1981

UNITS No 1&2 DISCHARGE LINES
DONALD C. COOK NUCLEAR PLANT
SHEET 1 OF 2 - DWG. No 9131

820055C

Attachment #2

PERMIT No. 82 56 4



SECTION A-A (TYP)

PROPOSED RIPRAP COVER FOR UNIT Nº 1 DISCHARGE
(UNIT Nº 2 SIMILAR EXCEPT PIPE DIA. = 18 FT.)

15 0 15 30 FT.
SCALE

APPLICATION BY:
INDIANA & MICHIGAN ELECTRIC CO.
BRIDGMAN, MICHIGAN
SEPTEMBER 1, 1981

UNITS Nº 1 & 2 DISCHARGE LINES
DONALD C. COOK NUCLEAR PLANT
SHEET 2 OF 2 - DWG. Nº 9131

8200.55C.

Attachment #2

This permit shall become effective on the date of the District Engineer's signature.

Permittee hereby accepts and agrees to comply with the terms and conditions of this permit.

Beverly I. Stears 6/25/82

Permitte Beverly I. Stears Date
Vice President
Indiana & Michigan Electric Company

By Authority of the Secretary of the Army:

ROBERT V. VERMILLION
Colonel, Corps of Engineers
District Engineer
25 JUN 1982

FOR THE DISTRICT ENGINEER Date

Transferee hereby agrees to comply with the terms and conditions of this permit.

Transferee Date

W Smith
Attachment #3

US Army Corps
of Engineers
Detroit District

Joint Public Notice

Applicant: Indiana and Michigan Electric Co.
Date: 25 February 1982
Exp. Date: 16 March 1982
In Reply Refer to: Process No. 820055C/82-12-4G
Section: 10 & 404

PROPOSED DREDGING AND RIPRAP FILL IN LAKE MICHIGAN NEAR BRIDGMAN, MICHIGAN

1. Indiana and Michigan Electric Company, P.O. Box 18, Bowling Green Station, New York, has made application for permits to do work described in paragraph #2 to:

a. The Detroit District U.S. Army Corps of Engineers for a Department of the Army permit under authority of Section 10 of the River and Harbor Act of 1899 and Section 404 of the Clean Water Act of 1977, to dredge and place riprap fill over existing submerged discharge pipes in Lake Michigan offshore property in Section 6, T6S, R19W, Lake Township, Berrien County, located approximately 1.1 mile northwesterly from the intersection of Red Arrow Hwy and Livingstone Road near Bridgman, Michigan.

b. The State of Michigan, Department of Natural Resources for certification of this proposed work under Section 401 of the Clean Water Act of 1977 for compliance with the applicable provisions of Section 301, 306, and 307 of the Act. This statement has the approval of the Michigan Department of Natural Resources, Land Resource Programs Division and constitutes its public notice as required by Section 401 of the Act.

c. The State of Michigan, Department of Natural Resources, for a permit under authority of 1955 P.A. 247. To comply with Federal consistency under Section 307 of the 1972 Coastal Zone Management Act (P.L. 92-583), and when applicable, Coastal Zone Management Certification (or waiver thereof) shall be required prior to issuance of a Department of the Army permit.

2. As shown on the attached plan(s), the applicant proposes to dredge an approximate area of 1100 x 164 feet above and around two (2) existing discharge lines and remove approximately 40,000 cubic yards of sand. Upon completion of the dredging operation about 20,000 square yards of filter cloth will be laid above which 3,700 cubic yards of mattress stone will be placed 1.5 feet deep. The mattress bedding will then be covered by approximately 4,200 cubic yards of riprap stone and will be backfilled to restore lake bottom to its original contours. Any excess dredged material will be carried to shore and placed upland. The purpose of the work is to stabilize two circulating water discharge lines (at the Donald C. Cook Nuclear Plant) which have shown a tendency to flex during storm conditions.

3. The applicant has not indicated that he has received or requested any other governmental authorization.

4. This notice is being published in compliance with Title 33 Code of Federal Regulations 320-340 and Michigan 1955 P.A. 247. Any interested parties and agencies desiring to express their views concerning the proposed work may do so by filing their comments in writing no later than 4:30 P.M., 20 days from the date of issuance of this notice. All responses must refer to public notice process number 820055C/82-12-4G. A lack of response will be interpreted as meaning that there is no objection to the permit application.

5. Any person may request, in writing, within the comment period specified in this notice, that a public hearing be held to consider this application. Requests for public hearings shall state, with particularity, the reasons for holding a public hearing.

6. Objections or views related to:

a. State water quality certification should be filed with the State of Michigan, Land Resource Programs Division, P.O. Box 30028, Stevens T. Mason Building, Lansing, Michigan 48926.

b. Items other than certification should be filed with the District Engineer, Detroit District, Corps of Engineers, P.O. Box 1027, Detroit, Michigan 48231.

7. The Corps and the DNR will exchange comments received after closing of the 20 day response period to the public notice.

8. The decision whether to issue the Department of the Army and/or State permits will be based on independent conclusions and decisions by the Corps of Engineers and the Michigan Department of Natural Resources, respectively, after evaluation of the probable impact of the proposed activity on the public interest. These decisions will reflect the national/state concerns for both protection and utilization of important resources. The benefit which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. All factors which may be relevant to the proposal will be considered; among those are conservation, economics, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land use classification, navigation, recreation, water supply, water quality and, in general, the needs and welfare of the people. The permits will not be granted unless issuance is found to be in the public interest.

9. A preliminary determination indicates that the proposed activity will not affect any known listed endangered species or their critical habitat; therefore, no formal consultation between the Corps, U.S. Fish and Wildlife Service, and National Marine Fisheries Service is planned. If future determinations by any of these agencies indicate that the proposed permit action will affect listed endangered species or their critical habitat, formal consultation will be completed prior to final action.

10. This activity involves the discharge of dredged or fill material in to navigable waters. Therefore, the U.S. Army Corps of Engineers evaluation of

the impact of the activity on the public interest will include application of the guidelines promulgated by the Administrator of the Federal Environmental Protection Agency, under the authority of Section 404 (b) of the Clean Water Act of 1977.

11. After review of the application, the U.S. Army Corps of Engineers has made a preliminary determination that an Environmental Impact Statement is not required for the proposed work described in this notice.

HOWARD A. TANNER
Director
Michigan Dept. of Natural Resources

ROBERT V. VERMILLION
Colonel, Corps of Engineers
District Engineer

NOTICE TO POSTMASTERS:

It is requested that the above notice be conspicuously and continuously posted for 20 days from the date of issuance of this notice.

Proposed Permit No. 82-56-4

Attachment #3

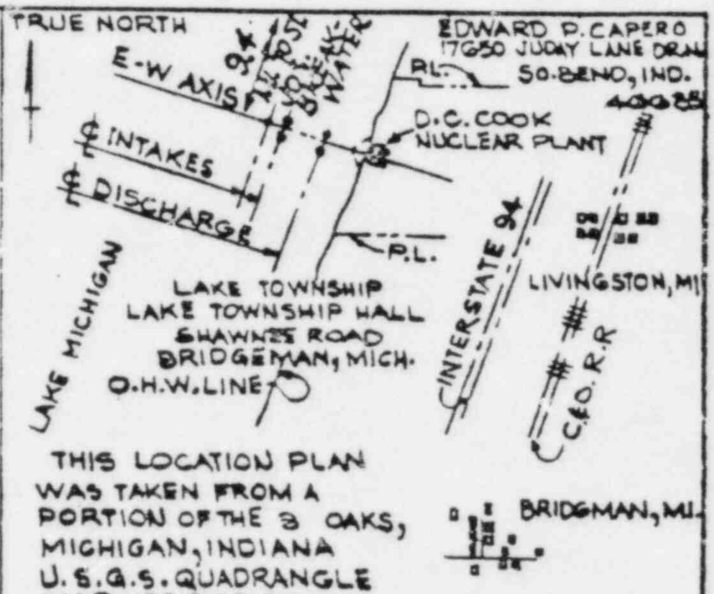
TRUE NORTH

NOTES

ELEVATIONS & SOUNDINGS ARE IN FEET AND ARE BASED ON LOW WATER. DATUM FOR LAKE MICHIGAN EL. 576.8' I.G.L.D. 1955.
FOR U.S.C.&G. DATUM ADD 1.56 FEET.

*U.S.C.&G.S. HORIZONTAL CONTROL SYSTEM FOR MICHIGAN SOUTH ZONE.

DISCHARGE SERIAL NUMBERS INDICATED THUS: ⓪⓪① ⓪⓪②

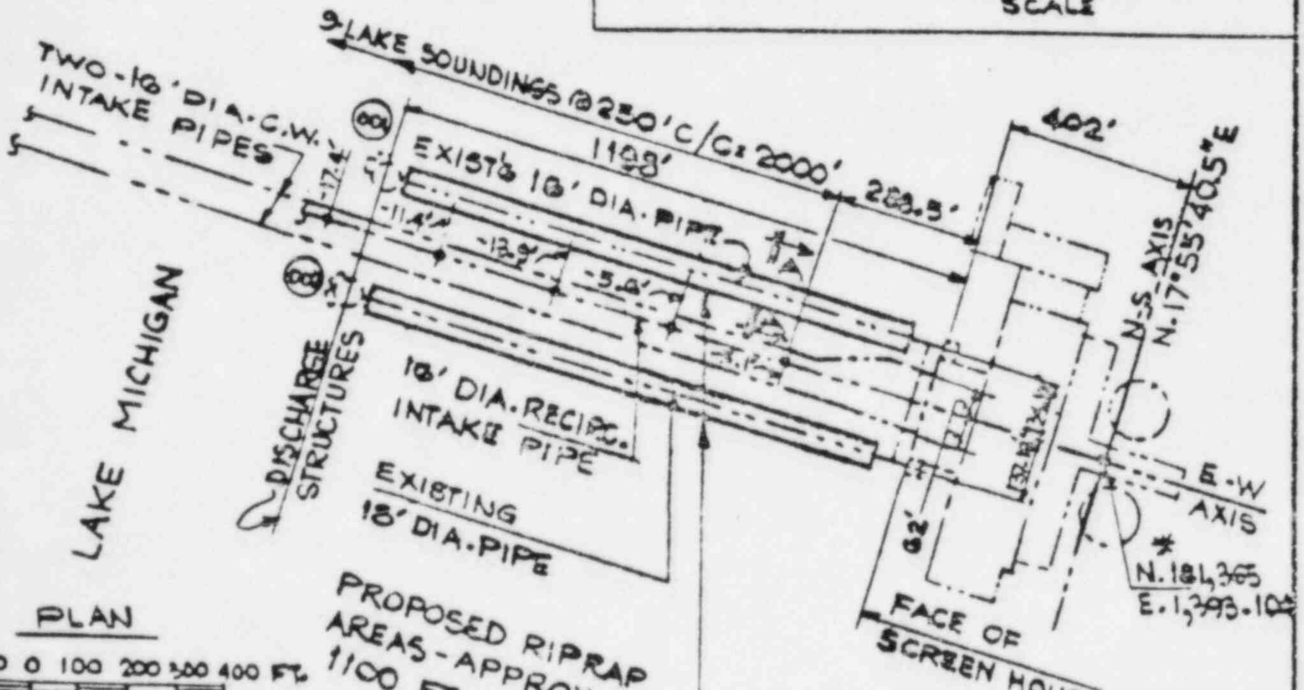


THIS LOCATION PLAN WAS TAKEN FROM A PORTION OF THE 3 OAKS, MICHIGAN, INDIANA U.S.G.S. QUADRANGLE MAP - 1930 EDITION.

LOCATION PLAN

1000 0 3000 FT.

SCALE



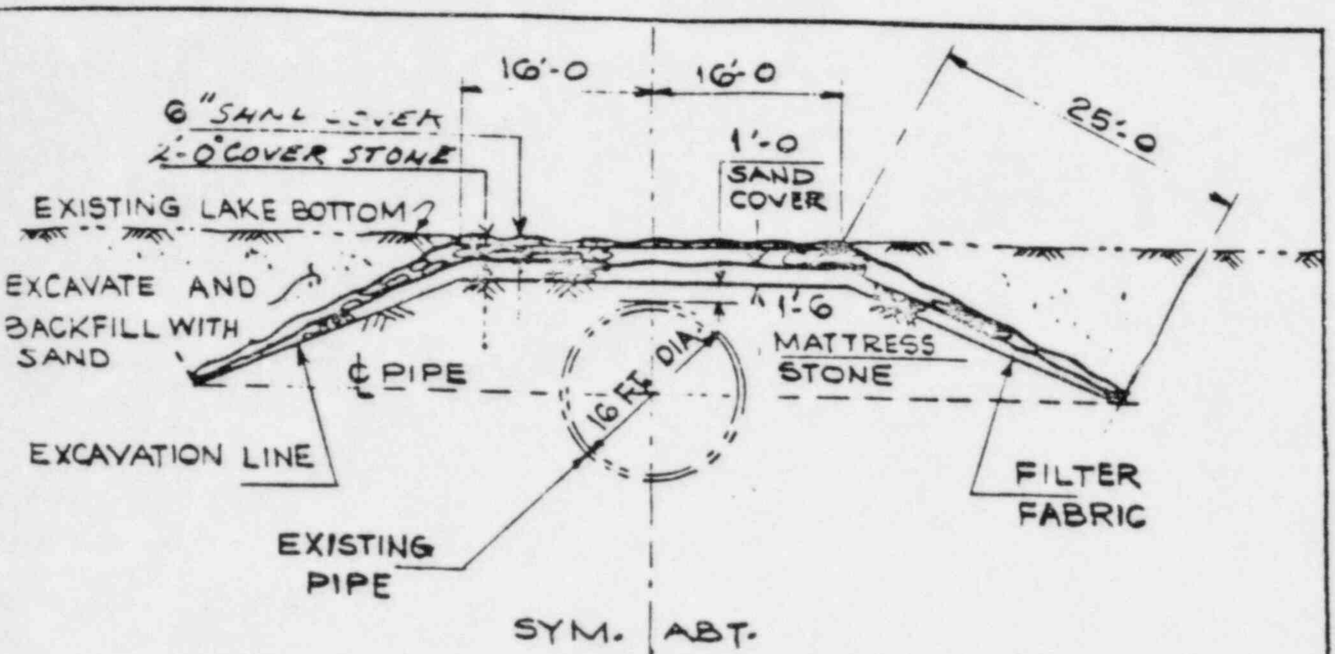
PLAN

APPLICATION BY:
INDIANA & MICHIGAN ELECTRIC CO.
BRIDGMAN, MICHIGAN
SEPTEMBER 1, 1981

UNITS No. 1 & 2 DISCHARGE LINES
DONALD C. COOK NUCLEAR PLANT
SHEET 1 OF 2 ~ DWG. No. 9181

8200550.

Attachment #3



SECTION A-A (TYP)

PROPOSED RIPRAP COVER FOR UNIT Nº 1 DISCHARGE
(UNIT Nº 2 SIMILAR EXCEPT PIPE DIA. = 18 FT.)

15 0 15 30 FT.
SCALE

APPLICATION BY:
INDIANA & MICHIGAN ELECTRIC CO.
BRIDGMAN, MICHIGAN
SEPTEMBER 1, 1981

UNITS Nº 1 & 2 DISCHARGE LINES
DONALD C. COOK NUCLEAR PLANT
SHEET 2 OF 2 - DWG. Nº 9181

8200550.

Attachment #4

American Electric Power System
INDIANA & MICHIGAN ELECTRIC COMPANY
DONALD C. COOK NUCLEAR PLANT
P.O. Box 458, Bridgman, Michigan 49106
(616) 465-5901

July 26, 1982

Howard A. Tanner-Director, Dept. of Natural Resources
STATE OF MICHIGAN
Department of Natural Resources
Stevens T. Mason Building
Box 30028
Lansing, MI 48909

Subject: Cook Plant Michigan DNR Permit No. 82-12-4G
Units 1 and 2 Discharge Lines

Gentlemen:

Enclosed you will find a map showing the location of the monuments installed near the shore at the D. C. Cook Plant. The monuments described were installed on June 28, 1982 to meet the requirements under Item #1 of Permit No. 82-12-4G.

Sincerely,

E. Mallen

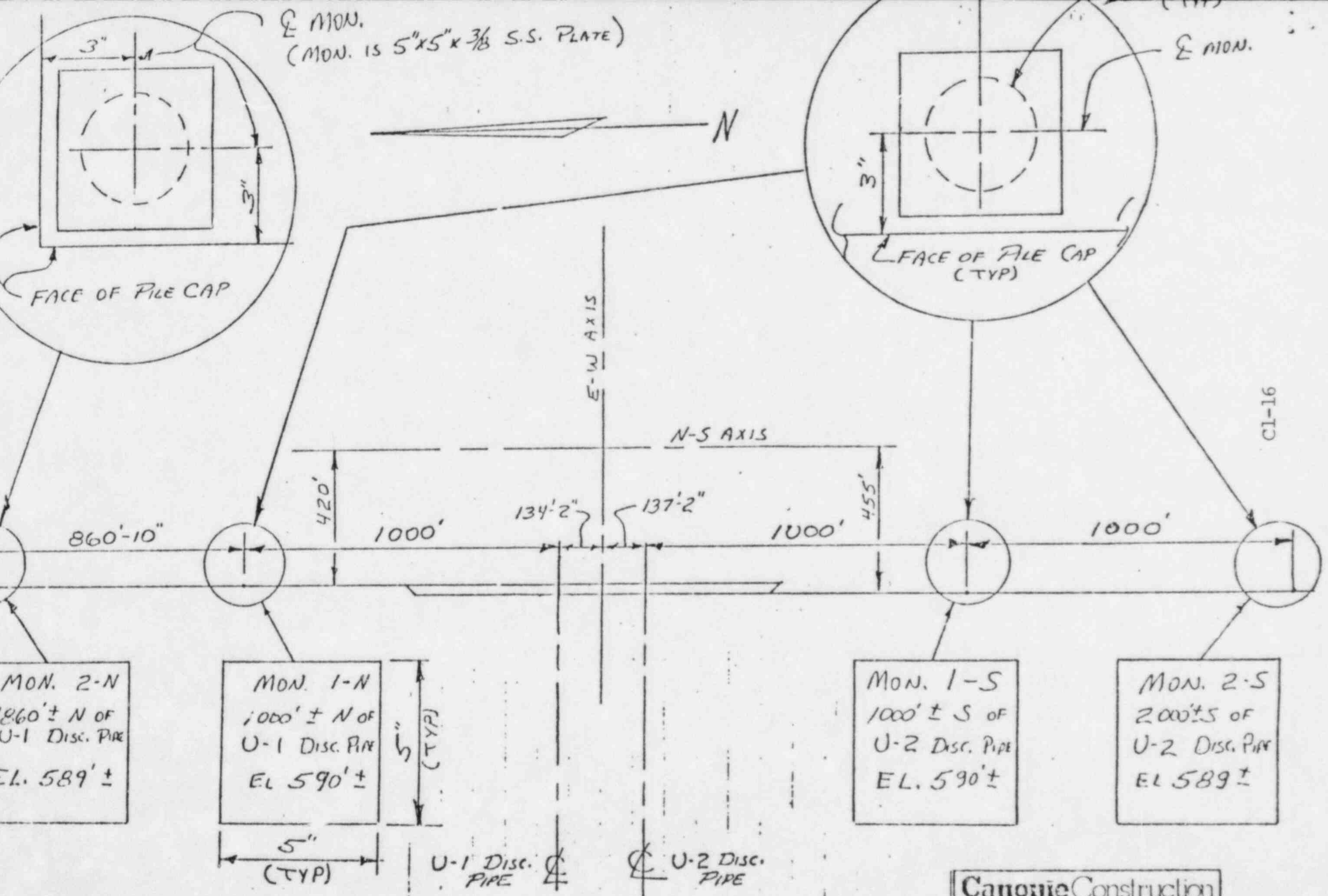
Eric Mallen
Engineer Technologist

tsc

Enclosure

cc W. G. Smith/B. A. Svensson/E. L. Townley
E. A. Smarrella
T. A. Kriesel 7/30/82

Attachment #4



Canonie Construction

DATE 6-28-82
REF. 12-3019; 12-3020
RFC N/A
NO. FS82021

Attachment #4

SHORELINE LOCATION RECORD

DISTANCES FROM MONUMENTS TO WATER'S EDGE

DATE	MON. 2-N 1860'± N. OF U-1 DISC. PIPE	MON. 1-N 1000'± N. OF U-1 DISC. PIPE	FACE OF SHEET PILING @ PLANT CENTERLINE (E-W AXIS)	MON. 1-S 1000'± S. OF U-2 DISC. PIPE	MON 2-S 2000'± S. OF U-2 DISC. PIPE
6-29-82	77'	163'	95'	123'	100'

6-28-82 FS 82021A

Attachment #5

American Electric Power System
INDIANA & MICHIGAN ELECTRIC COMPANY
DONALD C. COOK NUCLEAR PLANT
P.O. Box 458, Bridgman, Michigan 49106
(616) 465-5901

September 30, 1982

State of Michigan
Department of Natural Resources
Attn Howard A. Tanner
Stevens T. Mason Building
Box 30028
Lansing, MI 48909

Subject: Cook Plant Michigan DNR Permit No. 82-12-4G
Units 1 and 2 Discharge Lines

Gentlemen:

Enclosed you will find a shoreline monitoring report performed on September 28, 1982 and required under Item #3 of Permit No. 82-12-4G. The report includes a table showing the measurements taken from the permanent monuments installed on June 28, 1982 to the shoreline. Additional measurements were also taken between the monuments and are shown on the enclosed map. Photographs have also been submitted for comparison.

Sincerely,

E Mallen

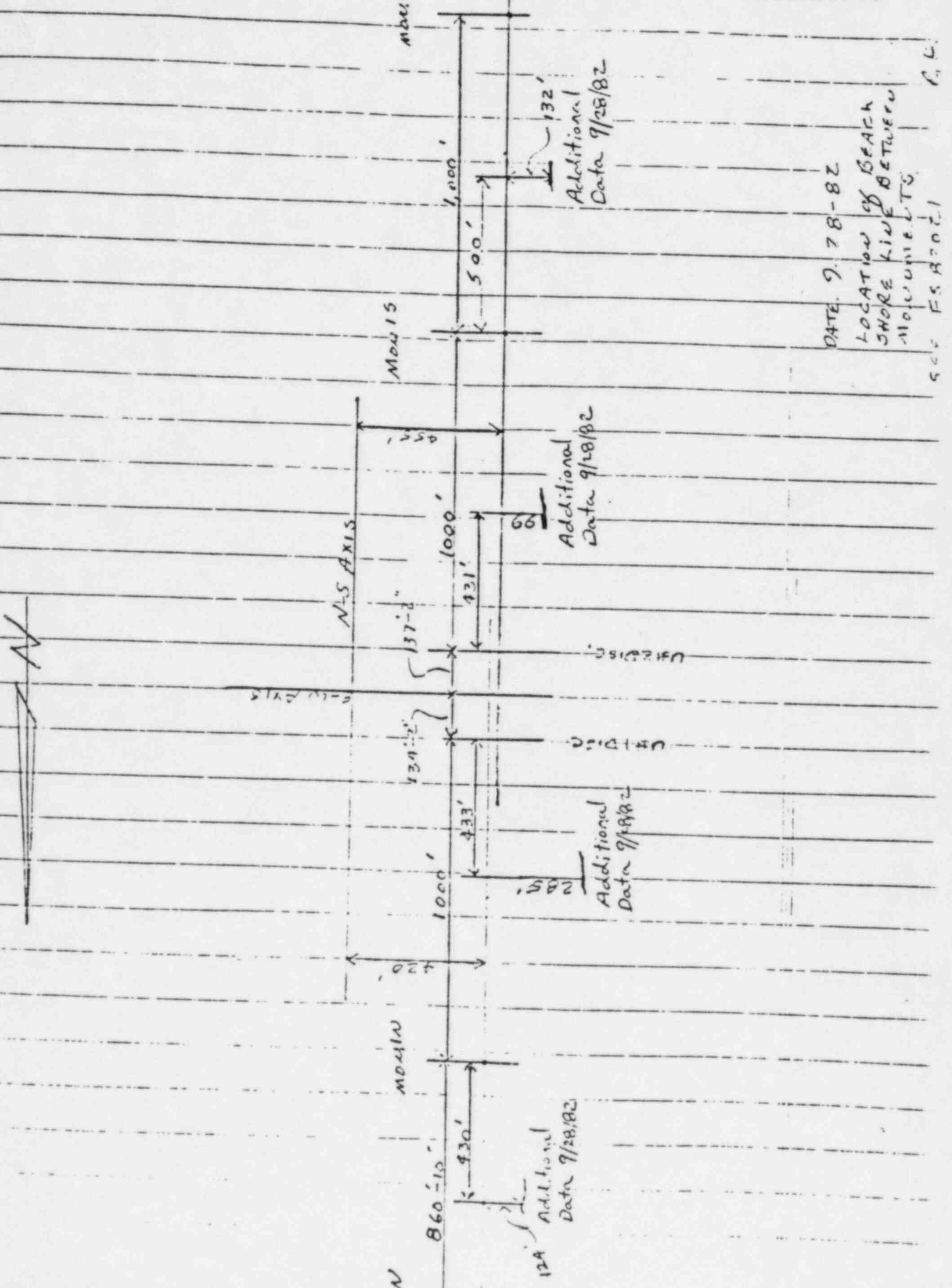
Eric Mallen
Engineer Technologist/Environmental

tsc

Enclosures

cc W. G. Smith Jr./B. A. Svensson/E. L. Townley
E. A. Smarrella
T. A. Kriesel
W. F. Scott, II

Attachment #5 -



C1-19

SHORELINE LOCATION RECORD

DISTANCES FROM MONUMENTS TO WATER'S EDGE

DATE	MON. 2-N 1860'± N. OF U-1 DISC. PIPE	MON. 1-N 1000'± N. OF U-1 DISC. PIPE	FACE OF SHEET PILING @ PLANT CENTERLINE (E-W AXIS)	MON. 1-S 1000'± S. OF U-2 DISC. PIPE	MON 2-S 2000'± S. OF U-2 DISC. PIPE
6-29-82	77'	163'	95'	123'	100'
9-28-82	80'	231'	99'	198'	102'

Attachment #5

Attachment #6

American Electric Power System
INDIANA & MICHIGAN ELECTRIC COMPANY
DONALD C. COOK NUCLEAR PLANT
P.O. Box 458, Bridgman, Michigan 49106
(616) 465-5901

October 28, 1982

Mr. John C. Arnsman
Submerged Lands Management Unit
Land Resource Programs Division
State of Michigan
Department of Natural Resources
Stevens T. Mason Building
Box 30028
Lansing, Michigan 48909

RE: Cook Plant Michigan DNR Permit No. 82-12-4G
Units 1 and 2 Discharge Lines

Dear Mr. Arnsman:

Enclosed you will find a bottomland contour monitoring report performed on June 28, 1982, and required under Item #4 of Permit No. 82-12-4G. It is to be noted that the report reflects the pre-construction bottomland contours.

We have also acknowledged your request in your letter of October 12, 1982, to inspect the project site in the spring of 1983. Please contact me at (616) 465-5901, Ext. 1096 when you know the date that you wish to perform the inspection, and I will make the necessary arrangements.

Sincerely,

Eric Mallen
Engineer Technologist/Environmental

/sb

cc: W. G. Smith, Jr./B. A. Svensson/E. L. Townley
T. A. Kriesel
W. F. Scott

Attachment #6

eta engineering, inc.

415 E. PLAZA DRIVE • WESTMONT, ILLINOIS 60559 • (312) 323-4663

D. C. Cook Bottom Profile Measurements
for June 28, 1982

Measurements of the Lake Michigan bottom contours in the vicinity of the Donald C. Cook Nuclear Plant cooling water intake and discharge structures were made on June 28, 1982 to comply with the requirements of the State of Michigan's Department of Natural Resources Permit No. 82-12-4G. The measurements were made throughout an area that extended approximately 3,200 feet offshore (about 700 feet lakeward from the end of the pipeline) and approximately 1,000 feet on each side of the cooling water intake pipes (about 850 feet on each side of the cooling water discharge pipes and structure).

The lake bottom contour data was reduced and plotted by computer into a topographical representation (Figure 1A). Three sections were taken from Figure 1 to show on Figure 2 the lake bottom profile for these sections. Profile 1S is approximately 190 feet south of the south discharge structure. Profile 1C is on the plant east-west axis that passes through the center intake structure. Profile 1N is approximately 195 feet north of the north discharge structure.

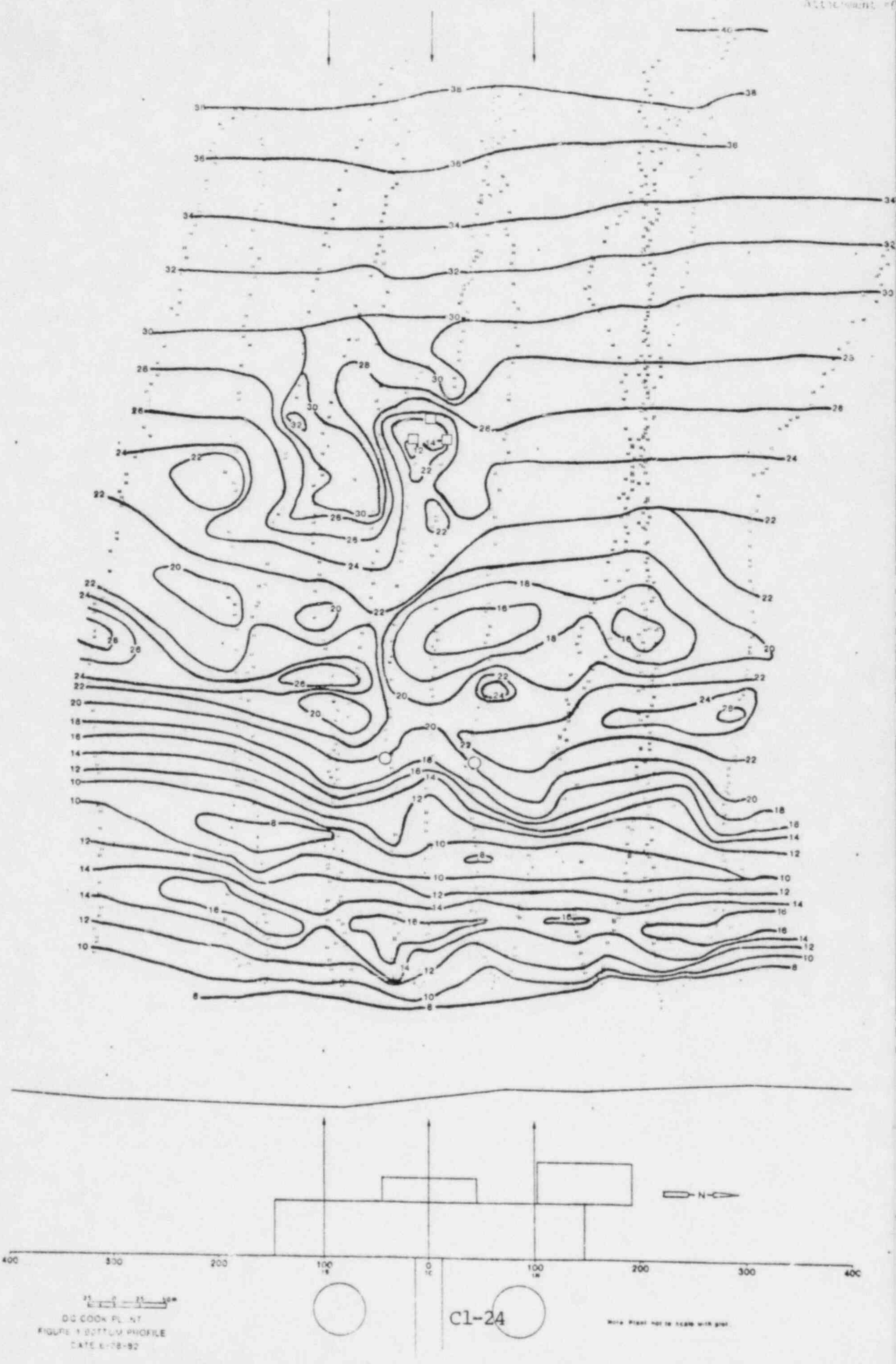
Data Acquisition

The system used to acquire the lake bottom contour data consisted of the Vidar Autodata Eight data acquisition device, the Signet Mk71 D3D digital depth sounder and the Motorola Mini-Ranger III system with two fixed transponders on shore to provide a triangulated location of the boat. The Vidar would poll the Signet for a depth reading and the Mini-Ranger for location coordinates. This combined information was recorded on the Facit punched paper tape unit and printed on the Vidar tape for monitoring and verification of meaningful data.

Attachment #6

A computer program converted the Mini-Ranger readings to x-y coordinates and the corresponding depth measurements were corrected for the depth sounder transducer depth. The computer plotted the depth on a diagram of the plant discharge and intake structures and the lines of constant depth were drawn by hand on these plots. Cross sections of the lake bottom profile were then prepared for the three transects near the discharge and intake structures.

Attachment



DC COOK PLANT
FIGURE 1 BOTTOM PROFILE
DATE 6-28-92

Note: Plant not to scale with plot.

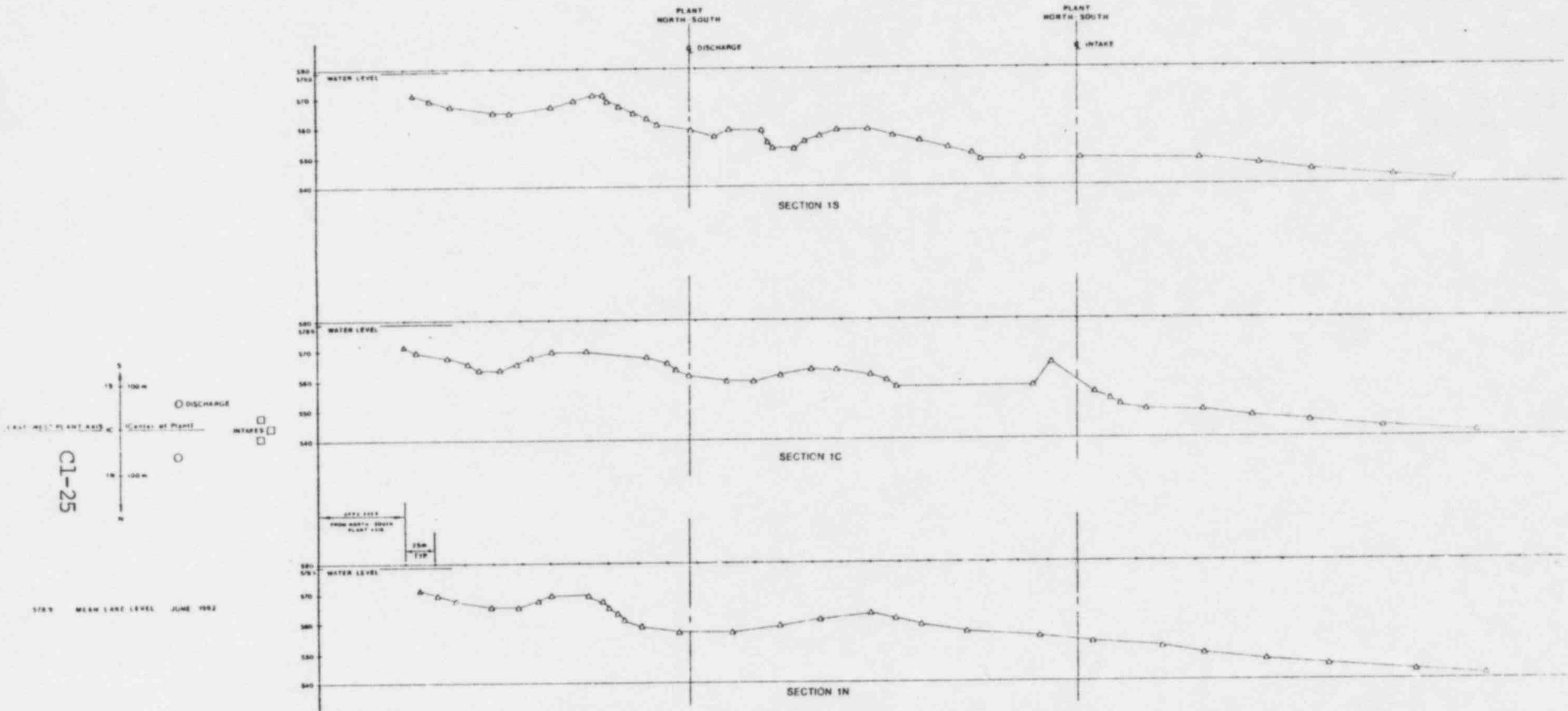


FIGURE 2 D.C. COOK BOTTOM PROFILE

APPENDIX C

PART-II

NPDES PERMITS AND STATE CERTIFICATIONS

Date: ______________

PUBLIC NOTICE

Michigan Water Resources Commission
Stevens T. Mason Building
Lansing, Michigan 48909
517/373-6088

Permit Number:
MI 0005827

NOTICE: Indiana & Michigan Electric Company, Cook Nuclear Plant, Bridgman, Michigan, has applied for reissuance of its National Pollutant Discharge Elimination System (NPDES) Permit to discharge condenser cooling water, steam generator blowdown, and sanitary wastewater into the waters of the State of Michigan. The permit will be issued by the Michigan Water Resources Commission in conformance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 1251 et seq; the "Act"), and the Michigan Water Resources Commission Act, as amended, (Act 245, Public Acts of 1929, as amended, the "Michigan Act").

The applicant manufactures electrical energy. The applicant discharges its effluent to Lake Michigan and [illegible].

On the basis of preliminary staff review and application of applicable standards and regulations, the Michigan Water Resources Commission proposes to issue a permit for the discharge subject to certain effluent limitations and special conditions. The permit expiration date will not exceed five (5) years from the date of issuance.

The proposed determination to issue an NPDES Permit is tentative. Persons wishing to comment upon, or object to, the proposed determination are invited to submit the same in writing to:

Permits Section
Water Quality Division
Department of Natural Resources
P.O. Box 30028
Lansing, Michigan 48909

The name of the permittee and permit application number should appear next to the above address on the envelope and the first page of any submitted comments. All comments received within thirty (30) days of the date of issuance of this Public Notice will be considered in the formulation of the final determinations. If no written comments are received, the Michigan Water Resources Commission will issue its final determinations no later than sixty (60) days following the date of this notice.

The application, proposed permit including proposed effluent limitations and special conditions, comments received, and other information, are on file and may be inspected at the Water Quality Division Offices, 8th Floor, Stevens T. Mason Building, Lansing, Michigan and at the District Office located at 350 Ottawa Street, Grand Rapids, Michigan, Phone 616/456-6231, at any time between 9:00 a.m. and 3:30 p.m., Monday through Friday. Copies of the Public Notice and corresponding Fact Sheet summarizing application information and proposed permit conditions and other information are available at a cost of 5¢ per page.

Please bring the foregoing to the attention of persons whom you know would be interested in this matter.

Attachment #7

Permit Number:
MI 0005827

FACT SHEET

Lake Michigan is classified for Recreation - total body contact; Fish, Wildlife, and Aquatic life - intolerant fish, cold-water species; Agriculture; Commercial; Water Supply - industrial; and other uses. A more complete description of the discharges and a sketch of their location follows below:

Description of Existing Discharge - A summary of the permittee's monthly operating reports for the period of October 1980 through September 1981.

PARAMETER	Yearly Avg.	Monthly Avg Max	Monthly Avg Min	Sample Freq.	Sample Type
Outfall 001 - Noncontact condenser cooling water from Unit 1 (110393)					
Flow (MGD)	960	1189	0	Daily	Calculation
pH	---	7.7	6.8	Weekly	Grab
Total Residual Chlorine (mg/l)	0.0	0.0	0.0	5x Weekly	Grab
Oil and Grease (0-4)	0	0	0	Daily	Visual Observation
Heat Addition (MBTU/hr)	6919	7418	0	Daily	Calculation
Temperature (°F)	68.3	89.5	57.0	Daily	Continuous
Intake Temperature (°F)	51.8	71.6	36.3	Daily	Continuous
MBTU = Million BTU					
OUTFALL 002 - Noncontact condenser cooling water from Unit 2 (110394)					
Flow (MGD)	1117	1743	0	Daily	Calculation
pH	----	7.7	6.8	Weekly	Grab
Total Residual Chlorine (mg/l)	0.0	0.0	0.0	5x Weekly	Grab
Oil and Grease (0-4)	0	0	0	Daily	Visual Observation
Heat Addition (MBTU/hr)	6637	7832	0	Daily	Calculation
Temperature (°F)	66.7	86.3	51.4	Daily	Continuous
Intake Temperature (°F)	51.8	71.6	38.8	Daily	Continuous
OUTFALL 003 - Facility discharge water used for deicing of intake structures (110395)					
Flow (MGD)	18	18	0	Daily	Calculation
pH	----	7.5	7.5	Weekly	Grab
Total Residual Chlorine (mg/l)	0.0	0.0	0.0	5x Weekly	Grab
Oil and Grease (0-4)	0	0	0	Daily	Visual Observation
Heat Addition (MBTU/hr)	109	109	0	Daily	Continuous
Temperature (°F)	51.0	51.0	51.0	Daily	Continuous

Note Outfall 003 was used for four days during the period of record (Oct. 1980-Sept. 1981).

FACT SHEET

Permit Number:
MI 0005827

Parameter	Yearly Avg.	Monthly Avg Max	Monthly Avg Min	Sample Freq.	Sample Type
OUTFALL 00A - Steam generator blowdown from Unit 1 ([illegible])					
Flow (MGD)	0.074	0.093	0.000	Per Occurrence	Grab
Total Suspended Solids (mg/l)	0.3	10.7	0.1	Per Occurrence	Grab
Total Copper (ug/l)	0.0	0.0	0.0	Monthly	Grab
Total Iron (ug/l)	10.0	100.0	0.0	Monthly	Grab
pH	----	9.3	8.0	Per Occurrence	Grab
OUTFALL 00B - Steam generator blowdown from Unit 2 ([illegible])					
Flow (MGD)	0.068	0.097	0.000	Per Occurrence	Grab
Total Suspended Solids (mg/l)	1.8	120.9	0.1	Per Occurrence	Grab
Total Copper (ug/l)	0.0	0.0	0.0	Monthly	Grab
Total Iron (ug/l)	0.0	0.0	0.0	Monthly	Grab
pH	----	9.7	8.4	Per Occurrence	Grab
OUTFALL 00C - Boiler blowdown from auxillary boiler ([illegible])					
Flow (MGD)	0.014	0.014	0	Per Occurrence	Grab
Total Suspended Solids (mg/l)	25.5	35.6	2.5	Per Occurrence	Grab
Total Copper (mg/l)	0.791	1.300	0.230	Monthly	Grab
Total Iron (mg/l)	3.900	6.400	0.800	Monthly	Grab
pH	-----	10.2	9.5	Per Occurrence	Grab

The outfall 00C was used for twelve (12) days during period of record

Parameter	Yearly Avg.	Monthly Avg Max	Monthly Avg Min	Sample Freq.	Sample Type
OUTFALL 00D - Softener backwash, demineralizer backwash, clarifier cleanings and boiler cleanings to groundwaters ([illegible])					
Flow (MGD)	0.475	0.614	0.266	Daily	Continuous
Dissolved Solids (mg/l)	401.7	551.0	269.0	During Regeneration	24 hour Composite
Total Phosphorus (mg/l)	0.4	0.9	0.0	Weekly	24 Hour Composite
	-----	8.9	5.6	Daily	Continuous
Total Cadmium (ug/l)	0.0	0.0	0.0	No Boiler Cleaning	Grab
Chlorides (mg/l)	10.1	11.7	7.6	Weekly	24 Hour Composite
COD (mg/l)	14.1	43.5	5.3	Weekly	24 Hour Composite
Oil and Grease (mg/l)	2.1	7.8	0.7	Weekly	Grab
Sulfate (mg/l)	110.2	210.0	70.0	During Regeneration	24 Hour Composite

---

Attachment #7

FACT SHEET

Permit Number:
MI 0005827

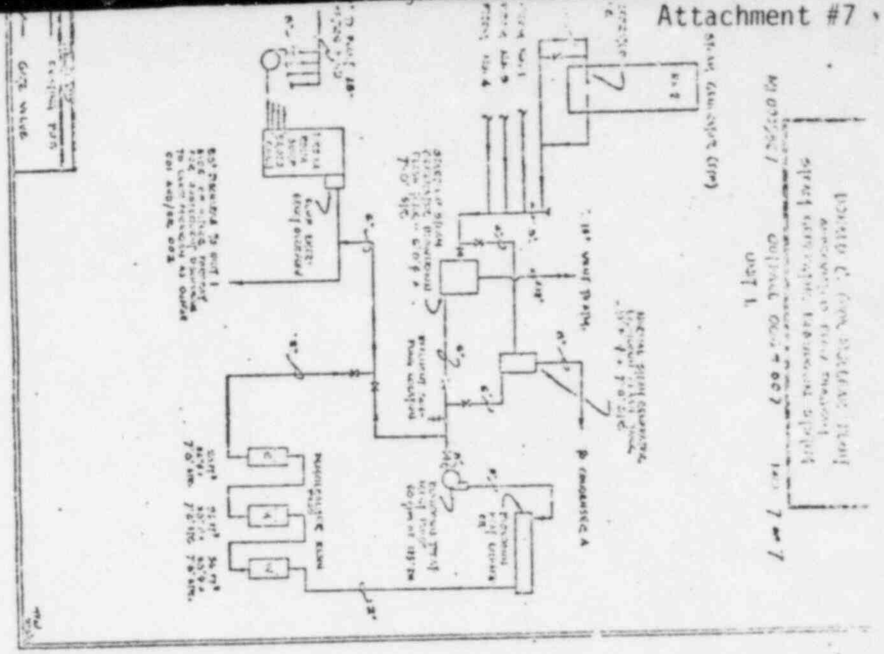
Parameter	Yearly Avg.	Monthly Avg Max	Monthly Avg Min	Sample Freq.	Sample Type
OUTFALL 00E - Treated sanitary sewage to the groundwater (110341)					
Flow (MGD)	0.031	0.041	0.023	Daily	Continuous
Monitoring Well #8, 100 ft. east of the 765 KV switch yard (110400)					
Total Dissolved Solids (mg/l)	430.5	602.0	358.0	Quarterly	Grab
Total Boron (ug/l)	0.05	0.20	0.00	Quarterly	Grab
Total Cadmium (ug/l)	0.01	0.05	0.00	Quarterly	Grab
Total Chloride (mg/l)	53.5	80.2	12.4	Quarterly	Grab
Total Chromium (ug/l)	0.00	0.00	0.00	Quarterly	Grab
Chemical Oxygen Demand (mg/l)	11.0	18.6	2.2	Quarterly	Grab
Total Copper (ug/l)	125.0	500.0	0.0	Quarterly	Grab
Hardness (mg/l)	222.0	230.0	208.0	Quarterly	Grab
Nitrate - N (mg/l)	0.3	0.5	0.0	Quarterly	Grab
Oil and Grease (mg/l)	0	0	0	Quarterly	Grab
PCB (ug/l)	< 0.31	< 0.31	< 0.31	Quarterly	Grab
pH	---	7.5	6.4	Quarterly	Grab
Total Phosphorus (mg/l)	0.3	0.5	0.0	Quarterly	Grab
Sodium (mg/l)	58.8	115.0	34.8	Quarterly	Grab
Sulfate (mg/l)	4.8	11.0	0.0	Quarterly	Grab
Static Water Elev. (USGS Elv.)	606.27	609.47	598.37	Quarterly	Reading
Monitoring Well #11, 200 ft. northwest of the absorption pond (110401)					
Total Dissolved Solids (mg/l)	594.0	700.0	410.0	Quarterly	Grab
Total Boron (ug/l)	0.08	0.30	0.00	Quarterly	Grab
Total Cadmium (ug/l)	0.01	0.05	0.00	Quarterly	Grab
Total Chloride (mg/l)	11.8	13.4	10.5	Quarterly	Grab
Total Chromium (ug/l)	0.00	0.00	0.00	Quarterly	Grab
Chemical Oxygen Demand (mg/l)	2.6	5.5	0.0	Quarterly	Grab
Total Copper (ug/l)	0.00	0.00	0.00	Quarterly	Grab
Hardness (mg/l)	204.3	220.0	180.0	Quarterly	Grab
Nitrate - N (mg/l)	0.3	1.1	0.0	Quarterly	Grab
Oil and Grease (mg/l)	0	0	0	Quarterly	Grab
PCB (ug/l)	< 0.31	< 0.31	< 0.31	Quarterly	Grab
pH	---	8.0	6.6	Quarterly	Grab
Total Phosphorus (mg/l)	0.1	0.2	0.0	Quarterly	Grab
Sodium (mg/l)	93.2	142.0	54.5	Quarterly	Grab
Sulfate (mg/l)	249.8	333.0	176.0	Quarterly	Grab
Static Water Elev. (USGS Elv.)	597.72	603.73	593.14	Quarterly	Reading

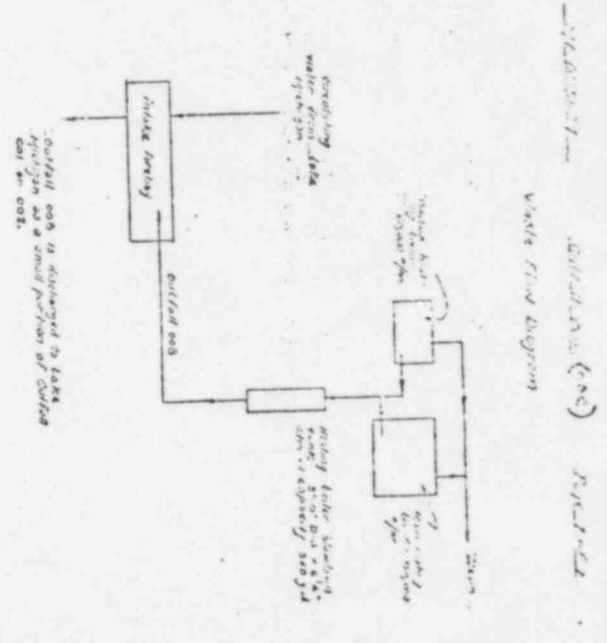
FACT SHEET

Permit Number:
MI 0005827

Attachment #7

Parameter	Yearly Avg.	Monthly Avg-Max	Monthly Avg-Max	Sample Freq.	Sample Type
Monitoring Well #12, 700 ft. west of the absorption pond					
Total Dissolved Solids (mg/l)	518.5	688.0	296.0	Quarterly	Grab
Boron (mg/l)	0.03	0.30	0.00	Quarterly	Grab
Cadmium (mg/l)	0.01	0.05	0.00	Quarterly	Grab
Chlorides (mg/l)	21.6	52.0	10.7	Quarterly	Grab
Chromium (mg/l)	0.03	0.00	0.00	Quarterly	Grab
Chemical Oxygen Demand (mg/l)	5.2	19.2	0.00	Quarterly	Grab
Copper (mg/l)	0.00	0.00	0.00	Quarterly	Grab
[illegible]	191.8	228.0	165.0	Quarterly	Grab
Nitrate - N (mg/l)	0.6	2.1	0.0	Quarterly	Grab
Oil and Grease (mg/l)	0.0	0.0	0.0	Quarterly	Grab
[illegible]	< 0.31	< 0.31	< 0.31	Quarterly	Grab
	-----	3.0	6.7	Quarterly	Grab
Total Phosphorus (mg/l)	0.3	0.9	0.0	Quarterly	Grab
[illegible] (mg/l)	107.7	213.0	35.3	Quarterly	Grab
[illegible] (mg/l)	131.4	295.0	82.5	Quarterly	Grab
Ground Water Elev. (USGS Elv.)	596.57	599.23	594.14	Quarterly	Grab
Monitoring Well #1A, 750 ft. south, southeast of the absorption pond					
Total Dissolved Solids (mg/l)	285.5	570.0	94.0	Quarterly	Grab
Boron (mg/l)	0.03	0.10	0.00	Quarterly	Grab
Cadmium (mg/l)	0.01	0.05	0.00	Quarterly	Grab
Chlorides (mg/l)	40.1	84.0	10.8	Quarterly	Grab
Chromium (mg/l)	0.00	0.00	0.00	Quarterly	Grab
Chemical Oxygen Demand (mg/l)	15.5	28.8	2.2	Quarterly	Grab
Copper (mg/l)	0.00	0.00	0.00	Quarterly	Grab
[illegible]	137.0	180.0	94.0	Quarterly	Grab
Nitrate - N (mg/l)	0.5	1.4	0.0	Quarterly	Grab
Oil and Grease (mg/l)	0.0	0.0	0.0	Quarterly	Grab
[illegible]	< 0.31	< 0.31	< 0.31	Quarterly	Grab
	-----	7.5	5.8	Quarterly	Grab
Total Phosphorus (mg/l)	0.1	0.2	0.0	Quarterly	Grab
[illegible] (mg/l)	20.0	42.6	3.1	Quarterly	Grab
[illegible] (mg/l)	33.6	98.2	0.0	Quarterly	Grab
Ground Water Elev. (USGS Elv.)	598.75	612.60	568.74	Quarterly	Grab



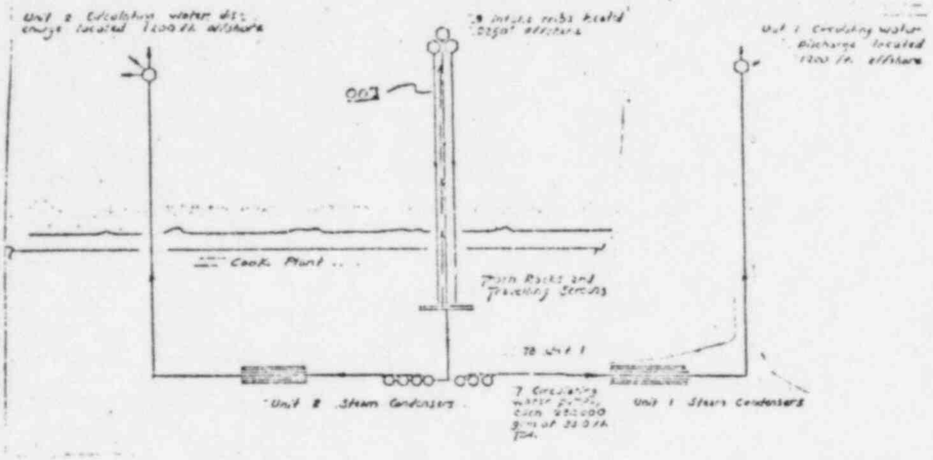


MI 0005827 Outfall 002 Page 7 of 7

Waste Flow Diagram

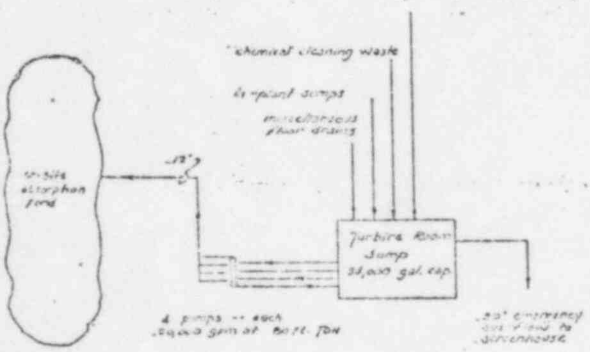
Outfall 001 Page 7 of 8

Waste Flow Diagram



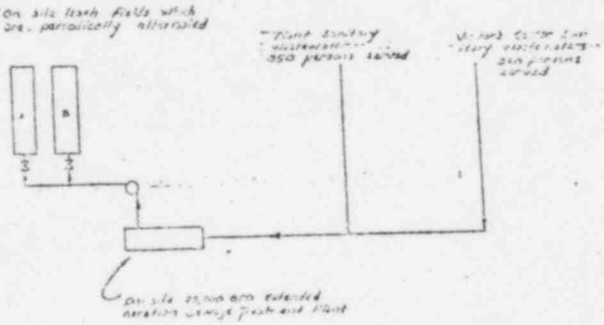
MI 0005827 Outfall 004 Page 7 of 7

Waste Flow Diagram



MI 0005827 Outfall 005 Page 7 of 7.

Waste Flow Diagram.



FACT SHEET

Proposed Determinations

The Water Quality Division has examined the above application. The effluent limitations contained in the proposed permit are based upon application of guidance criteria or engineering judgment reflecting "best practicable control technology currently available", "best available technology economically achievable" or "best conventional pollutant control technology", and the State Water Resources Commission Act, as amended, and the Water Quality Standards promulgated thereunder, whichever are more restrictive. The Michigan Water Resources Commission proposes to issue the applicant a permit to discharge subject to effluent limitations and certain other conditions. The following is a brief description of the proposed effluent limitations and special conditions:

1. Proposed Limitations

[illegible]	MINIMUM	AVERAGE	MAXIMUM
OUTFALLS [illegible] and [illegible]: Steam generator blowdown (Units 1 and 2)			
Total Suspended Solids		30 mg/l	100 mg/l
OUTFALL [illegible]: Heating boiler blowdown (Main and backup heating boiler)			
Total Suspended Solids		30 mg/l	100 mg/l
Outfall Observation			
OUTFALLS 001, 002, 003: Condenser cooling water, steam generator blowdown, and heating boiler blowdown to Lake Michigan			
Total Residual Chlorine		0.04 mg/l	0.1 mg/l
Chlorine Application Time Per condenser			30 min.
pH	6.0		9.0

The discharges of Outfalls 001, 002, and 003 shall not increase the temperature of the Lake Michigan at the edge of the mixing zone, described as an area equivalent to the [illegible] (an area equivalent to a circle with a 2,811 foot radius) by more the 3°F and greater than the following monthly temperatures:

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
45	45	45	55	60	70	80	80	80	65	60	50

	MINIMUM	AVERAGE	MAXIMUM
OUTFALL [illegible]: Utility wastewater to the groundwater			
Outfall Observation - Weekly; Visual			
pH	6.0		9.0

FACT SHEET

2. Proposed Special Conditions

The Company shall meet the terms of this permit upon issuance. Monitoring of essential parameters with monthly reporting are specified in the permit. The permit expiration date will not exceed five (5) years from the date of issuance.

The Company shall not cause a net discharge of Polychlorinated Biphenyl Compounds (PCB's) as a result of their operation.

The Company shall collect and remove debris that accumulates on the intake trash bars and screens and dispose of such material in an appropriate manner.

The Company shall submit and receive approval from the Chief of the Water Quality Division for a Residual Management Plan.

The company shall submit and receive approval from the Chief of the Water Quality Division for a Hydrogeological Investigation.

The Company shall adhere to and implement the Water Resource Commission's decision in its final disposition form concerning Clean Water Act 316(b) Intake Design Requirements.

Register of Interested Persons

Any person interested in a particular application or group of applications, may leave his name, address, and phone number as part of the file for an application. The list of names will be maintained as a means for persons with an interest in an application to contact others with similar interests.

Public Hearing

If submitted comments indicate a significant public interest in the application, or if useful information may be produced thereby, the Michigan Water Resources Commission, at its discretion, may hold a public hearing on the application. Any person may submit a written request to the Michigan Water Resources Commission to hold a public hearing. A request for a hearing shall indicate the reasons why a hearing is requested, and specifically indicate which portions of the application or other NPDES forms or information constitues necessity for a public hearing.

Public notice of a hearing will be circulated at least thirty (30) days in advance of hearings. The hearing will be held in the vicinity of the discharge. Thereafter, the Michigan Water Resources Commission will formulate its final determination within sixty (60) days. Further information regarding the conduct and nature of public hearings concerning discharge permits may be obtained by writing or visiting the address shown on the Public Notice.

Permit No. MI 0005827

MICHIGAN WATER RESOURCES COMMISSION

AUTHORIZATION TO DISCHARGE UNDER THE

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 1251 et seq; the "Act"), and the Michigan Water Resources Commission Act, as amended, (Act 245, Public Acts of 1929, as amended, the "Michigan Act"),

Indiana & Michigan Electric Company
2101 Spy Run Avenue
Fort Wayne, Indiana 46801

is authorized to discharge from a facility located at

Donald C. Cook Nuclear Plant
Bridgman, Michigan

to receiving waters named Lake Michigan

in accordance with effluent limitations, monitoring requirements and other conditions set forth in Parts I and II hereof.

This permit shall become effective on the date of issuance.

This permit and the authorization to discharge shall expire at midnight, ________. In order to receive authorization to discharge beyond the date of expiration, the permittee shall submit such information and forms as are required by the Michigan Water Resources Commission no later than [illegible] days prior to the date of expiration.

This permit is based on the company's application dated May, 1979, and shall supersede any and all permits, Orders of Determination, Stipulation, or Final Orders of Determination previously adopted by the Michigan Water Resources Commission.

Issued this _____ day of ____________, for the Michigan Water Resources Commission, superseding NPDES Permit No. MI 0005827 expiring October 31, 1979, and State Permit No. M00264.

Robert J. Courchaine
Executive Secretary

PART I

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. Final Effluent Limitations

During the period beginning upon issuance of this permit and lasting until expiration of this permit, the permittee is authorized to discharge up to five hundred thousand (500,000) gallons per day of steam generator blowdown from units 1 and 2 (outfalls 00A and 00B) to the intake forebays via the turbine room sump emergency overflow line and then through outfalls 001 & 002 to Lake Michigan. Such discharge shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations				Monitoring Requirements	
	kg/day (lbs/day)		Other Limitations			
	Monthly Average	Daily Maximum	Monthly Average	Daily Maximum	Measurement Frequency	Sample Type
Flow, M^3/Day (MGD)					Daily	Calculated
Total Suspended Solids			30 mg/l	100 mg/l	Daily	Grab

a. The discharge shall not cause excessive foam in the receiving waters. The discharge shall be essentially free of floating and settleable solids.

b. The discharge shall not contain oil or other substances in amounts sufficient to create a visible film or sheen on the receiving waters.

c. Samples taken in compliance with the monitoring requirements shall be taken prior to mixing with other wastewater streams.

Final Effluent Limitations

During the period beginning upon issuance of this permit and lasting until expiration of this permit, the permittee is authorized to discharge up to nineteen thousand (19,000) gallons per day of heating boiler blowdown from outfall 00C to the intake screenhouse then through outfalls 001 & 002 to Lake Michigan. Such discharge shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations kg/day (lbs/day) Monthly Average	Daily Maximum	Other Limitations Monthly Average	Daily Maximum	Monitoring Requirements Measurement Frequency	Sample Type
Flow, M³/Day (MGD)					Daily	Calculated
Total Suspended Solids			30 mg/l	100 mg/l	Weekly	Grab

The discharge shall not cause excessive foam in the receiving waters. The discharge shall be essentially free of floating and settleable solids.

The discharge shall not contain oil or other substances in amounts sufficient to create a visible film or sheen on the receiving waters.

Samples taken in compliance with the monitoring requirements above shall be taken prior to mixing with other wastewater streams.

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3. Final Effluent Limitations

During the period beginning upon issuance of this permit and lasting until expiration of this permit, the permittee is authorized to discharge up to three billion four hundred million (3.40×10^9) gallons per day of condenser noncontact cooling water, steam generator and heating boiler blowdown from outfalls 001 & 002 to Lake Michigan. Such discharge shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations kg/day (lbs/day) Monthly Average	Daily Maximum	Other Limitations Monthly Average	Daily Maximum	Monitoring Requirements Measurement Frequency	Sample Type
Flow, M³/Day (MGD)					Daily	Calculated
Temperature (°F)						
Intake					Daily	Continuous
Discharge					Daily	Continuous
Total Residual Chlorine*			0.04 mg/l**	0.1 mg/l**	5x Weekly	Three grab samples equally spaced during each treatment
Chlorine Application Time per condenser				30 min.	Daily	Direct Measurement
Heat Addition (BTU/hr.)					Daily	Calculation

The discharges of 001 & 002 shall not increase the temperature of Lake Michigan at the edge of the mixing zone, described as an area equivalent to 285 acres (an area equivalent to a circle with a 1,405 foot radius) by more than 3°F nor greater than the following monthly temperatures:

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
45	45	45	55	60	70	80	80	80	65	60	50

*Measured by amperometric titration techniques or other method of equal or better accuracy. Total time of application shall be minimized to the lowest time needed to prevent condenser biofouling and in no instance shall the time of chlorination exceed 30 minutes per unit in any 24-hour period nor shall both units be chlorinated simultaneously.

**The amount of chlorine applied shall be limited to the minimum amount needed to prevent condenser biofouling and in no instance shall the concentration at the condenser outlet exceed the stated limit. Samples to be taken at condenser outlet.

[illegible] noncontact cooling water shall mean water used for cooling which does not [illegible] into direct contact with any raw material, intermediate product, by-product, [illegible] product, or finished product.

[illegible] The pH shall not be less than 6.0 nor greater than 9.0. The pH shall be [illegible] as follows: weekly; grab.

[illegible] The discharge shall not cause excessive foam in the receiving waters. The discharge shall be essentially free of floating and settleable solids.

[illegible] The discharge shall not contain oil or other substances in amounts sufficient to create a visible film or sheen on the receiving waters.

[illegible] Samples taken in compliance with the monitoring requirements above shall be [illegible] prior to discharge to Lake Michigan.

[illegible] In the event the permittee shall require the use of water treatment additives, the permittee shall notify the Chief of the Water Quality Division. The permittee [illegible] obtain written approval from the Chief of the Water Quality Division to use [illegible] at a specified level. The permit may be modified in accordance with [illegible] of Part II, Section A-1 if a constituent of the additive or additives [illegible] limiting.

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4. Final Effluent Limitations

During the period beginning upon issuance of this permit and lasting until the expiration of this permit, the permittee is authorized to discharge up to two million, five hundred thousand (2,500,000) gallons per day of utility wastewater from outfall 00D to the groundwater via an on-site absorption pond. Such discharge shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations kg/day (lbs/day) Monthly Average	 Daily Maximum	 Other Limitations Monthly Average	 Daily Maximum	Monitoring Requirements Measurement Frequency	 Sample Type
Flow, M^3/Day (MGD)					Daily	Continuous
COD, mg/l					Weekly	24 Hr. Composite
Total Dissolved Solids, mg/l					Daily*	24 Hr. Composite
Sulfate (SO_4), mg/l					Daily*	24 Hr. Composite
Chloride (Cl), mg/l					Weekly	24 Hr. Composite
Total Phosphorus (as P), mg/l					Weekly	24 Hr. Composite
Total Cadmium, ug/l					During boiler cleaning water discharge	Grab
Oil and Grease					Weekly	Grab
Lagoon Observation**					Weekly	Visual

*During regeneration of ion exchange resins

**Any structural or operational malfunction of the lagoon and pond (i.e., dike erosion, dike leakage, rodent burrows, broken or plugged pipes or valves, or unusual erosion) or any unusual characteristics of the lagoon and pond contents which would not be expected from utility wastewater (i.e., discoloration, oil film, etc.) shall be reported immediately to the District Office of the Water Quality Division. A written report by the permittee must follow within five days, detailing the findings of the investigation and the steps taken to correct the condition.

The disposal of utility wastewater by an on-site absorption pond shall be at such location and at such rate that the disposal shall not adversely affect public health, safety, or welfare or which may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses made or to be made of the surface or groundwaters of the state.

The disposal to the groundwater of this discharge to any other location is not authorized by this permit.

a. The pH shall not be less than 6.5 nor greater than 9.0. The pH shall be monitored as follows: continuously; report minimum and maximum daily.

b. The discharge shall not contain any other substances in amounts which are or become injurious to any uses of the waters of the state.

c. Samples taken in compliance with the monitoring requirements above shall be taken prior to discharge to the absorption pond.

d. Observations or measurements made in compliance with the monitoring requirements shall be made as follows: Lagoon Freeboard and Observation: at the absorption pond.

e. In the event the permittee shall require the use of water treatment additives, the permittee shall notify the Chief of the Water Quality Division. The permittee shall obtain written approval from the Chief of the Water Quality Division to use such additives at a specified level. The permit may be modified in accordance with the requirements of Part II, Section A-1 if a constituent of the additive or additives requires limiting.

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5. Final Effluent Limitations

During the period beginning upon issuance of this permit and lasting until expiration of this permit, the permittee is authorized to discharge up to three hundred ten thousand (310,000) gallons per day of treated sanitary sewage from outfall 00E to the groundwaters via two on-site seepage fields. Such discharge shall be limited and monitored by the permittee as specified below:

Effluent Characteristic	Discharge Limitations kg/day (lbs/day) Monthly Average	Discharge Limitations kg/day (lbs/day) Daily Maximum	Discharge Limitations Other Limitations Monthly Average	Discharge Limitations Other Limitations Daily Maximum	Monitoring Requirements Measurement Frequency	Monitoring Requirements Sample Type
Flow, M^3/Day (MGD)					Daily	Continuous
Seepage area used					List when areas are alternated	List the beginning & ending date and time each area is used.

The disposal of treated sanitary sewage by activated sludge treatment techniques shall be at such location and at such rate that the disposal shall not adversely affect public health, safety, or welfare or which may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses made or to be made of the surface or groundwaters of the state nor cause nuisance conditions such as, but not limited to, obnoxious odors. There shall be no runoff from the disposal site.

a. The discharge shall not contain any other substances in amounts which are or may become injurious to any uses of the waters of the state.

b. Observations or measurements made in compliance with the monitoring requirements shall be made as follows: Prior to discharge to the seepage areas.

c. In the event the permittee shall require the use of water treatment additives, the permittee shall notify the Chief of the Water Quality Division. The permittee shall obtain written approval from the Chief of the Water Quality Division to use such additives at a specified level. The permit may be modified in accordance with the requirements of Part II, Section A-1 if a constituent of the additives or additives requires limiting.

Groundwater Monitoring

To demonstrate continued compliance with Part I-A of this permit, the permittee [illegible] monitor the approved system of groundwater monitoring wells, (well #8, (110400) [illegible]; well #12, (110402); well #1A, (110403). The monitoring wells [illegible] be sampled for the parameters, at the frequency specified below, and in accordance with the procedures specified below and in Plant Procedure Number 12 THP [illegible] LAB 040.

a. The static water level measurement shall be made from the top of the casing with the elevation of all casings in the monitoring well system related to a permanent reference point, using United States Geological Survey datum.

b. All wells shall be securely capped when not in use.

c. A volume of water equal to or greater than three times the amount of water in the well and/or gravel pack shall be exhausted before obtaining a sample for analysis. In the case of very low permeability soils, the wells may have to be pumped and allowed to refill before a sample is collected, or, alternatively follow procedures 5.1.3 through 6.1.7 of the plant procedure cited above.

d. All sampling equipment shall be thoroughly rinsed before use in each monitoring well.

e. A pressure tank shall not be used with a sampling system since the pressure tank cannot be practically cleaned between samplings.

f. Water pumped from each monitoring well shall be discharged to the ground away from the well to avoid recycling of the flow.

g. Samples must be collected, stored, and transported to the laboratory in a manner consistent with the references specified in Part I, C-4.

h. Procedures 6.1. 2-6 of Plant Procedure Number 12 THP 6020 LAB 040 cannot be accepted as a standard procedure.

PARAMETER	MONITORING FREQUENCY	SAMPLE TYPE
Static Water Level Measurements	Quarterly	Reduced to USGS datum
[illegible]	Quarterly	Grab
[illegible]	Quarterly	Grab
[illegible]	Quarterly	Grab
[illegible]	Quarterly	Grab
[illegible]	Quarterly	Grab
[illegible] (as N)	Quarterly	Grab
[illegible]	Quarterly	Grab
Polychlorinated Biphenyls	Quarterly	Grab
[illegible] Oxygen Demand	Quarterly	Grab
[illegible]	Quarterly	Grab
Total Phosphorus	Quarterly	Grab
Total Dissolved Solids	Quarterly	Grab
[illegible]	Quarterly	Grab
[illegible]	Quarterly	Grab

Results of groundwater monitoring samples shall be submitted on or before the tenth of January, April, July and October.

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7. Final Limitation

Beginning upon the date of issuance and lasting until the expiration of this permit, the permittee shall collect and remove debris accumulated on intake trash bars and screens and dispose of such material on land in an appropriate manner.

8. Final Limitation

The permittee shall not cause a net discharge of Polychlorinated biphenyl compounds (PCB's) as a result of their operation.

9. Special Condition

This permit may be modified, or, alternatively revoked and reissued to comply with any applicable standard(s) or limitation(s) promulgated under Sections 301(b)(2)(C)(D), 304(b)(2) and 307(a)(2), if the effluent standard(s) or limitation(s) so promulgated:

(a) is (are) either different in conditions or more stringent than any effluent limitations in the permit; or

(b) control(s) any pollutant not limited in the permit.

10. Special Condition - Residual or Sludge Disposal

Solids, sludges, or residuals resulting from wastewater treatment shall be disposed of in accordance with a "Residuals Management Plan", which shall be submitted to and receive the approval of the Chief of the Water Quality Division.

Such plan shall document the characteristics of the residuals or sludges including laboratory analyses and provide a method for disposal which will not result in unlawful pollution of the air, surface waters or groundwaters of the state nor create unlawful nuisance conditions.

If the permittee desires to make any substantial changes in the plan, such proposed changes shall be submitted to and approved by the Chief of the Water Quality Division prior to implementation.

Solids residual shall be disposed of in accordance with Act 641, P.A. of 1978, "Solid Waste Management Act".

11. Special Condition 316(b) Intake Design

The NPDES permit issued December 27, 1974 required the permittee to conduct a study to assure that the intake design represented the best available technology, considering location and design to minimize any adverse environmental impact upon the [illegible] population of aquatic organisms in the vicinity of the intake in accordance with Section 316(b) of Public Act 92-500 as amended. The permittee has submitted the results of the study and are awaiting the decision of the Water Resources Commission.

If the Commission finds that the location and design of the cooling water intake structure does not represent the Best Available Technology, the permittee will be so notified, and this permit will be modified in accordance with Part II, B-4 to provide a time schedule for the installation of the defined technology.

Condition - Hydrogeological Evaluation

mittee shall submit a Hydrogeological Investigation of sufficient detail the vertical and horizontal extent of any groundwater contamination past operations and disposal practices. The investigation shall the criteria set forth in the part 22 rules, as amended, by the Water Commission, and in conformance to the Schedule of Compliance, Part I, C-4. ation of the investigation, if it is determined that degradation of the red or can occur, then this permit will be modified in accordance with [illegible]

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PART I

B. MONITORING AND REPORTING

1. Representative Sampling

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

2. Reporting

All reports shall be postmarked no later than the 10th day of the month following each completed report period.

a. Existing Discharge - First Permit Issuance

The permittee shall submit monitoring reports containing results obtained during the previous month. The first report shall be submitted within 90 days of the date of issuance of this permit.

b. Proposed Discharge

The permittee shall submit monitoring reports containing results obtained during the previous month. Monitoring shall commence at the time discharge first occurs.

c. Existing Discharge - Permit Modified or Reissued With No New Parameters

The permittee shall continue to submit monitoring reports containing results obtained during the previous month.

d. Existing Discharge - Permit Modified or Reissued With New Parameters Previously Not Monitored

The permittee shall continue to submit monitoring reports containing results obtained during the previous month for parameters currently monitored. The first report for parameters specifically excluded in Part I-A shall be submitted within 90 days of the date of issuance of this permit.

3. Definitions

a. The monthly average discharge is defined as the total discharge by weight, or concentration if specified, during the reporting month divided by the number of days in the reporting month that the discharge from the production or commercial facility occurred. When less than daily sampling occurs, the monthly average discharge shall be determined by the summation of the measured daily discharges by weight, or concentration if specified, divided by the number of days during the reporting month when the samples were collected, analyzed and reported.

b. The daily maximum discharge means the total discharge by weight, or concentration if specified, during any calendar day.

c. The Regional Administrator is defined as the Region V Administrator, U.S. EPA, located at 230 South Dearborn, 13th Floor, Chicago, Illinois 60606.

d. The Michigan Water Resources Commission is located in the Stevens T. Mason Building. The mailing address is Box 30028, Lansing, Michigan 48909.

4. Test Procedures

Test procedures for the analysis of pollutants shall conform to regulations published pursuant to Section 304(h) of the Act, under which such procedures may be required.

5. Recording Results

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

a. The exact place, date, and time of sampling;

b. The dates the analyses were performed;

c. The person(s) who performed the analyses;

d. The analytical techniques or methods used; and

e. The results of all required analyses.

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6. Additional Monitoring by Permittee

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Monthly Operating Report. Such increased frequency shall also be indicated.

7. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years, or longer if requested by the Regional Administrator or the Michigan Water Resources Commission.

C. SCHEDULE OF COMPLIANCE

1. The permittee shall continue to operate the installed facilities to achieve the effluent limitations specified for outfalls 001 and 002.

2. The permittee shall continue to comply with the requirements of Section 10, Part II-A.

3. The permittee shall achieve compliance with the Residual or Sludge Disposal Requirements of Part I-A on page 10 of in accordance with the following schedule. All submittals shall be to the Chief of the Water Quality Division.

a. On or before May 31, 1983, submit and receive approval of a "Residuals Management Plan".

b. On or before August 31, 1983, certify in writing that the approved "Residuals Management Plan" has been implemented.

4. The permittee shall comply with the Hydrogeological Evaluation requirements of Part I, A-12 in accordance with the following schedule. All submittals shall be to the Chief of the Water Quality Division of the Department of Natural Resources.

a. On or before June 31, 1983, submit and receive approval of a study plan and time schedule.

b. On or before September 30, 1983, submit the final hydrogeological evaluation report.

5. No later than June 30, 1933, the permittee shall submit the report concerning the scaling and plugging problems associated with the utility wastewater discharge absorption pond, and shall make recommendations as to the corrective actions necessary to eliminate such problems.

The permittee shall take such steps as necessary to correct the problems associated with the above study report no later than June 30, 1934.

6. No later than 14 calendar days following a date identified in the above schedule of compliance, the permittee shall submit either a report of progress or, in the case of specific actions being required by identified dates, a written statement of compliance or noncompliance. In the latter case, the statement shall include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirements. Failure to submit the written statement is just cause to pursue enforcement action pursuant to the commission act and the Part 21 rules.

PART II

A. MANAGEMENT REQUIREMENTS

1. Duty to Comply

All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit more frequently than or at a level in excess of that authorized shall constitute a violation of the permit.

It is the duty of the permittee to comply with all the terms and conditions of this permit. Any noncompliance with the Effluent Limitations, Special Conditions, or terms of this permit constitutes a violation of Public Acts 245 of 1929, as amended, and/or PL 92-500, as amended, and constitutes grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or denial of an application for permit renewal.

2. Change of Conditions

Any anticipated facility expansion, production increases, or process modification which will result in new, different, or increased discharges of pollutants must be reported by submission of a new application or, if such changes will not violate the effluent limitations specified in this permit, by notice to the permit issuing authority of such changes. Following such notice, the permit may be modified to specify and limit any pollutant not previously limited.

3. Containment Facilities

The permittee shall provide facilities for containment of any accidental losses of concentrated solutions, acids, alkalies, salts, oils, or other polluting materials in accordance with the requirements of the Michigan Water Resources Commission Rules, Part 5. This requirement is included pursuant to Section 5 of the Michigan Water Resources Commission Act, 1929 PA 245, as amended, and the Part 5 rules of the General Rules of the Commission.

4. Operator Certification

The permittee shall have the waste treatment facilities under direct supervision of an operator certified by the Michigan Water Resources Commission, as required by Section 6a of the Michigan Act.

5. Noncompliance Notification

If, for any reason, the permittee does not comply with or will be unable to comply with any daily maximum effluent limitation specified in this permit, the permittee shall provide the Chief of the Surface Water Quality Division with the following information, in writing, within five (5) days of becoming aware of such condition:

a. A description of the discharge and cause of noncompliance; and [illegible] noncompliance, including exact dates and times; or, [illegible] the anticipated time the noncompliance is expected [illegible] the steps taken to reduce, eliminate and prevent [illegible] noncomplying discharge.

[illegible] any spill or loss of any product, [illegible] any other pollut- [illegible] of groundwaters of the state by [illegible] Emergency Response telephone [illegible] ten (10) days of the spill [illegible] as to the cause and discovery [illegible] taken, preventative measures [illegible]. This requirement is included pursuant [illegible] Commission Act, 1929 PA 245, as amended.

[illegible] properly operate and maintain all treatment [illegible] used by the permittee to achieve compliance [illegible]

[illegible] to minimize any adverse [illegible] resulting from noncompliance [illegible] permit including, but not limited [illegible] necessary to determine the nature [illegible] noncompliance.

[illegible] bypass of facilities necessary to maintain compliance [illegible] this permit is prohibited, except (i) where unavoid- [illegible], personal injury, or severe property damage, or (ii) where [illegible] any facilities necessary for compliance [illegible] of this permit. The permittee shall [illegible] Commission and the Regional Administrator, [illegible]

[illegible] with the effluent limitations and prohibi- [illegible] shall either:

[illegible] sufficient to operate facilities [illegible] compliance with the effluent limita- [illegible] this permit which provision shall be indicated [illegible] of a specific compliance date in each [illegible] of Compliance for Effluent Limitations".

Attachment #7

b. Upon the reduction, loss, or failure of one or more of the primary sources of power to facilities utilized by the permittee to maintain compliance with the effluent limitations and conditions of this permit, the permittee shall halt, reduce or otherwise control production and/or all discharge in order to maintain compliance with the effluent limitations and conditions of this permit.

11. Removed Substances

Solids, sludges, filter backwash, or other pollutants removed from [illegible] resulting from treatment or control of wastewaters shall be disposed of in a [illegible] such as to prevent any pollutant from such materials from entering [illegible] or the entry of toxic or harmful contaminants thereof onto the [illegible] trations or amounts detrimental to the groundwater resource.

12. Upset Noncompliance Notification

If a process "upset" (defined as an exceptional incident in which there is unintentional and temporary noncompliance with technology based [illegible] limitations because of factors beyond the reasonable control of [illegible] occurred, the permittee who wishes to establish the affirmative defense of upset shall notify the Chief of the Surface Water Quality Division by [illegible] 24 hours of becoming aware of such conditions and within five (5) days [illegible] in writing, the following information:

a. That an upset occurred and that the permittee can identify the cause(s) of the upset;

b. That the permitted wastewater treatment facility was, at the time, being properly operated;

c. That the permittee has specified and taken action on all [illegible] steps to minimize or correct any adverse impact in the [illegible] resulting from noncompliance with his permit.

If any enforcement proceedings, the permittee seeking to establish the occurrence of an upset, has the burden of proof.

13. Any requirement of this permit which is included under the [illegible] of Michigan, the Water Resources Commission, Act 245, P.A. 1929, as [illegible] rules promulgated thereunder, is not enforceable under the Federal [illegible] regulations.

B. RESPONSIBILITIES

1. Right of Entry

The permittee shall allow the Executive Secretary of the Michigan Water Resources Commission, the Regional Administrator and/or their authorized representatives, upon the presentation of the credentials:

a. To enter upon the permittee's premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit; and

b. At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; and to sample any discharge of pollutants.

2. Transfer of Ownership or Control

In the event of any change in control or ownership of facilities from which the authorized discharge emanate, the permittee shall notify the succeeding owner or controller of the existence of this permit by letter, a copy of which shall be forwarded to the Michigan Water Resources Commission and the Regional Administrator.

3. Availability of Reports

Except for data determined to be confidential under Section 308 of the Act and Rule 2128 of the Water Resources Commission Rules, Part 21, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the State Water Pollution Control Agency and the Regional Administrator. As required by the Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for in Section 309 of the Act and Section 7 of the Michigan Act.

4. Permit Modification

After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following:

a. Violation of any terms or conditions of this permit;

b. Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts; or

c. A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge.

Attachment #7

5. Toxic Pollutants

Notwithstanding Part II, B-4 above, if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, this permit shall be revised or modified in accordance with the toxic effluent standard or prohibition and the permittee so notified.

6. Civil and Criminal Liability

Except as provided in permit conditions on "By-Passing" (Part II, A-7) and "Power Failures" (Part II, A-10), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance, whether or not such noncompliance is due to factors beyond his control, such as accidents, equipment breakdowns, or labor disputes.

7. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee may be subject under Section 311 of the Act except as are exempted by federal regulations.

8. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Act.

9. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize violation of any Federal, State or local laws or regulations, nor does it obviate the necessity of obtaining such permits or approvals from other units of government as may be required by law.

10. Severability

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

11. Notice to Public Utilities (Miss Dig)

The issuance of this permit does not exempt the permittee from giving notice to public utilities and complying with each of the requirements of Act 53 of the Public Acts of 1974, being sections 460.701 to 460.718 of the Michigan Compiled Laws, when constructing facilities to meet the terms of this permit.

Attachment #7

Indiana and Michigan Electric Company
Donald C. Cook Nuclear Plant
Bridgman, Michigan

MI 0005827

The mixing zone for the purpose of evaluating compliance with the state water quality standards is defined as an area equivalent to 285 acres; a circle with a radius of 1,405 feet from the point of each discharge.

APPENDIX D

ICE CONDITIONS AT THE DONALD C. COOK NUCLEAR PLANT

ICE CONDITIONS AT COOK PLANT, WINTER 1981-82

The winter of 1981-82 was colder than usual until mid-February when there was a warm spell and the well-developed shore ice complex underwent melting. The influx of warmer air over the snow-covered ground produced a period of foggy days during which our charter-flight pilots refused to fly our ice-survey overflight. When flight conditions became acceptable, melting of the shore ice was well along.

On 25 February 1982 the shore ice of Lake Michigan from Michigan City, Indiana, to Grand Haven, Michigan, was overflown during melting conditions and easterly winds. Broken ice extended an estimated 3-10 miles from shore while along shore the ice complex showed the remains of a normal well-developed 3-ridge and 3-lagoon structure.

As usual, the ice deterioration was more rapid south of the St. Joseph River than north of it. Figure 1, north of the St. Joseph piers, shows successively lakeward: a partially bare sand beach, a thin dark icefoot at water's edge, a narrow first lagoon, a continuous white first ice ridge, a wider second lagoon, a wider sand-darkened second ridge, a still wider third lagoon, and a wider higher somewhat sandy third ridge next to the open water. This is the complex which was present in a more deteriorated condition at Cook Plant.

Figure 2, at Cook Plant, shows successively lakeward: the nearly bare sand beach with a thin icefoot, the first lagoon (of open water except directly in front of the plant), the first ridge, ice-filled second lagoon, second ridge, third lagoon (ice-filled in foreground and background but open in front of the plant and for some distance north and south of the plant), and the third ridge

Figure 1. Well-developed 3-ridge and 3-lagoon shore ice complex north of the St. Joseph piers. Roll 3, slide #2, 25 February 1982.

Figure 2. Deteriorated 3-ridge and 3-lagoon ice complex at Cook Plant. Roll 2, slide #17, 25 February 1982.

(continuous north and south of the plant but breached and reduced to isolated blocks in front of the plant).

In Figure 2 the first ridge, second lagoon, and second ridge are breached at about the level of the south end of the turbine building. Figure 3 shows this breaching somewhat more clearly. The cause of the breaching is not known to us, but its location suggests that it might be related to leakage from the south discharge pipe.

Despite melting in front of the plant, there always remained sufficient shore ice to protect the plant site from wave damage.

WEST-LOOKING CAMERA, DAILY ICE CONDITIONS

30 December 1981.	Icefoot formed at water's edge, apparently spray ice.
31 Dec.	Gradual melting of icefoot.
1 January 1982.	Icefoot gone. No ice in lake.
2 Jan.	As on 1st.
3 Jan.	No ice or snow visible.
4 Jan.	Heavy surf, otherwise as on 3rd.
5 Jan.	As on 3rd.
6 Jan.	As on 3rd.
7 Jan.	Moderate surf. Icefoot re-formed of iceballs.
8 Jan.	Moderate surf. Rapid accumulation of iceballs and spray ice overnight. Complex consists of icefoot, ice-filled first lagoon, first ridge, ice-filled second lagoon, and second ridge with iceballs in water beyond it. Heavy snow in late afternoon.

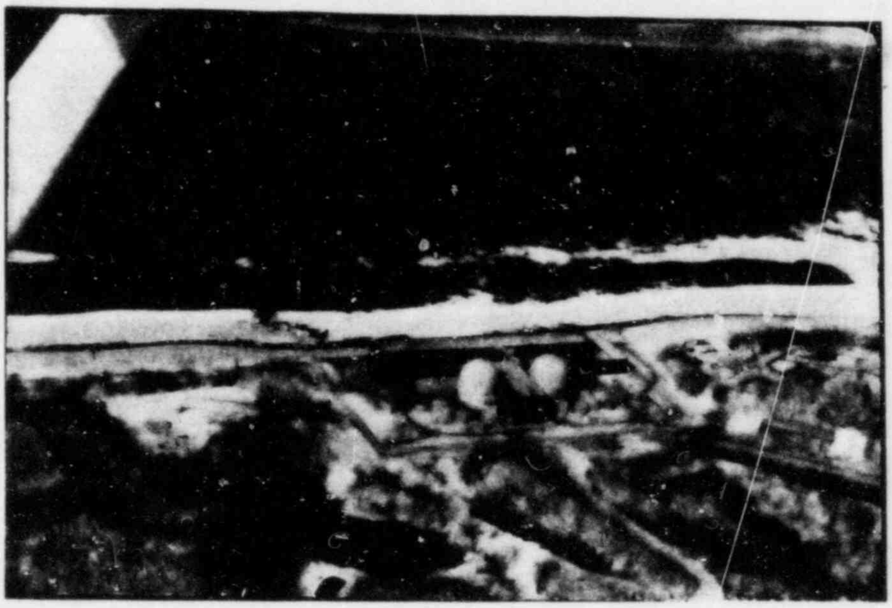

Figure 3. Breached first ridge, second lagoon, and second ridge near the south end of the Cook turbine building. First lagoon is open water. Roll 2, slide #14, 25 February 1982.

9 Jan.	New snow covering the ice. Slush ice and iceballs accumulated in third lagoon; similar ice visible in open water.
10 Jan.	Heavy snow. Second ridge augmenting.
11 Jan.	Snow, poor visibility. Third lagoon ice-filled. Camera broke down in afternoon.
12, 13 Jan.	Missing.
14 Jan.	Blowing snow. First lagoon shows a narrow strip of open water. First ridge, second lagoon, and second ridge present and snow-covered. Open water beyond second ridge with an ice field in the distance.
15 Jan.	Second ridge augmenting. In the afternoon an ice field moved in against face of second ridge.
16 Jan.	Melt-hole outside the second ridge. A few floes of pancake ice in the melt-hole. Ice field beyond the melt-hole.
17 Jan.	Missing.
18 Jan.	Outer ice field moved lakeward during the day, barely visible by late afternoon.
19 Jan.	Scattered ice floes in open water outside second ridge. Open water in first lagoon has widened.
20 Jan.	As on 19th, except the second ridge is breached in one place.
21 Jan.	As on 20th, but open first lagoon wider and with ice cakes on it.
22, 23, 24 Jan.	Missing.

25 Jan.	Influx of ice floes. Second ridge augmented, third lagoon filled with loose ice, third ridge established but discontinuous. Open water and distant ice field outside third ridge.
26 Jan.	As on 25th.
27 Jan.	Loose ice moved out, leaving open third lagoon and low discontinuous third ridge.
28 Jan.	Loose ice refilled third lagoon between second and third ridges.
29 Jan.	Third ridge gone. Scattered loose ice in open water beyond second ice ridge. Distant ice field visible.
30, 31 Jan.	Missing.
1 February	Loose ice containing the melt-hole lies outside the second ridge. Extensive ice field outside the melt-hole.
2 Feb. - 11 Feb.	West-looking camera film jammed and no shots were obtained. Ice conditions have been reconstructed from shots of the northwest-looking camera. This was a period of cold with frequent snowfalls. The northwest-looking camera recorded no change in the heavy shore ice complex during the period. The pictures from the west-looking camera on both 1 February and 12 February show an ice-surrounded melt-hole, a narrow band of open water in the first lagoon, and three modest blowhole cones on the second ice ridge. The blowhole cones on the 12th are recognizable as those seen on 1 February.

12 Feb.	Heavy shore ice complex. Melt-hole outside the third ridge. Narrow strip of open water in the first lagoon.
13 Feb.	As on the 12th.
14 Feb.	As on the 12th.
15 Feb.	As on the 12th.
16 Feb.	As on the 12th, but open water in the first lagoon is wider.
17 Feb.	Wind from the north. Outer ice field, during the day, moved south out of sight leaving melt-hole continuous with open lake.
18 Feb.	As on the 17th. First ridge is lower and calving into the open first lagoon.
19 Feb.	As on the 18th. New snow covering on ice and beach.
20 Feb.	Essentially as on the 19th but open first lagoon is wider and has breached the first ridge. Third lagoon filled with loose ice.
21 Feb.	Large outer ice field has moved shoreward and re-defined the melt-hole. Further melting in the first lagoon.
22 Feb.	As on the 21st.
23 Feb.	Further melting. Only pieces of the first ridge remain. The second ridge has been breached by the third lagoon. Ice in the third lagoon is more scattered than previously. Ice foot has melted.

24 Feb.	Further melting. Pieces of discontinuous third ridge visible beyond open water of the third lagoon. Only a piece of the first ridge remains; open water of the first lagoon reaches through the first ridge into the second lagoon. Melt-hole filled with loose ice from the third lagoon.
25 Feb.	Only a few ice cakes in third lagoon, otherwise as on 24th. Some distant scattered ice. OVERFLIGHT THIS DAY.
26 Feb.	As on 25th.
27 Feb.	As on 25th.
28 Feb.	No distant ice. Third ridge has been augmented somewhat. First lagoon, first ridge, second lagoon, and second ridge are as on 24th.
1 March	No third ridge remnants. Iceballs against face of second ridge. Second lagoon broken but pieces are in place.
2 Mar.	Remnant of first ridge is gone. Ice in second lagoon is broken and loose. Breach through second ridge has widened.
3 Mar.	First ridge augmented with iceballs during the night.
4 Mar.	New snow cover on ice and beach.
5 Mar.	Heavy influx of the lake ice field; ice to the horizon.
6 Mar.	Ice field moved lakeward during the night but re-approached during the day.
7 Mar.	Ice field back in contact with the first ridge.
8 Mar.	Ice field moved lakeward during the day and was out of sight by late afternoon. No change in the shore ice.
9 Mar.	Ice field returned during the night. Ice to the horizon.

10 Mar.	Ice field moved lakeward during the night and was barely visible on the horizon. No change in the shore ice.
11 Mar.	Ice field remained distant but iceballs and small cakes blew in from it and contacted the first ridge. Melting resumed in the first lagoon. Snow on beach melted.
12 Mar.	Heavy arrivals of iceballs and cakes temporarily re-created the second ridge but it melted or dispersed during the afternoon and night.
13 Mar.	Substantial melting of the first ridge during the day. No change in the first lagoon.
14 Mar.	Substantial influx of iceballs from the lake, with some getting through the breached first ridge into the first lagoon.
15 Mar.	Only some scattered ice cakes outside the first ridge.
16 Mar.	Substantial melting of first ridge and first lagoon.
17 Mar.	First ridge reduced to wreckage ice and pushed ashore.
18 Mar.	Progressive melting of the wreckage ice.
19 Mar.	Further melting of the wreckage ice.
20 Mar.	As on the 19th.
21 Mar.	Only remaining ice are a few small cakes on the beach edge.
22 Mar.	Progressive melting of the small cakes on the beach edge.
23 Mar.	Final melting of the ice on the beach.
24 Mar.	No ice. The sand content of the icefoot forms a small sand ridge on the beach.
25 Mar.	Sand ridge wiped out by wave action.

26 Mar.	Influx of iceballs (evidently from breakup farther north) re-creating the first ridge and first lagoon.
27 Mar.	Further influx of iceballs augmenting the first ridge and forming the second lagoon and second ridge.
28 Mar.	Second ridge breached and second lagoon partly open water.
29 Mar.	As on the 28th.
30 Mar.	Second ridge and second lagoon gone. Melting of first ridge.
31 Mar.	First ridge reduced to small amount of wreckage ice at beach edge.
1 April	Wreckage ice melted.
2 Apr.	No ice.

APPENDIX E

ENVIRONMENTAL RADIATION DATA

ENVIRONMENTAL SAMPLING AND ANALYSIS PROGRAM
FOR
DONALD C. COOK NUCLEAR PLANT
AMERICAN ELECTRIC POWER SERVICE CORPORATION

ANNUAL REPORT

JANUARY - DECEMBER 1982

Reported by

EBERLINE LABORATORIES
ALBUQUERQUE, NM

Reviewed and Approved by: Chandrasekaran K

Chandrasekaran, E.S., Manager

Date: 03/28/83

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PAGE NO.

SECTION 1

PREFACE

ABSTRACT

This report presents the data obtained from the analyses of environmental samples collected for the American Electric Power Service Corporation Donald C. Cook Nuclear Station Environmental Radiological Surveillance Program for the period 01 January 1982 through 31 December 1982.

The activity present above the detection limits in the routinely collected sample media was observed to be of natural and atomospheric origin. In no case did radioactivity from the Cook Nuclear Plant exceed the design objectives of the Cook Radiological Environmental Technical specifications.

INTRODUCTION

The Donald C. Cook Nuclear Station of American Electric Power Service Corporation consists of two Westinghouse PWR units (Unit 1 and Unit 2). Each unit consists of a pressurized water reactor (PWR) which generates about 3250 megawatts (MW) of heat to generate about 1100 MW of electricity. The station is located in Benton Harbor, Michigan.

The D.C. Cook Plant utilizes a pressurized water reactor with a radwaste hold-up and treatment system that has been designed to keep radioactive releases to as low as is practible levels. However, small quantities of noble gases and radioiodine may be released to Lake Michigan. The quantities of radionuclides released to the environment are expected to be miniscule and insignificant as a source of potential exposure to flora and fauna in the area. However, direct radiation exposure to man and radionuclide accumulations in various components of food chains to man will be carefully monitored.

The environmental radiological monitoring program is intended to serve the following purposes:

a) To yield average values of radiation levels and concentrations of radioactive material in various media of the environment.

b) To identify sample locations and/or types of samples that deviate from the averages.

c) To document seasonal variations that could be erroneously interpreted when the power station is operating.

d) To indicate the range of values that should be considered "background" for various types of samples.

The basic approach for the Donald C. Cook Nuclear Plant is to control the release of radioactive material at levels far below that which would be expected to cause detrimental impact on the environment. The environmental radioactivity surveillance program will be closely coordinated with conditions of plant operation and subject to periodic review.

Levels of environmental radioactivity are subject to change for reasons in no way related to the operation of the D.C. Cook Nuclear Plant. Therefore, the radioactivity surveillance program has been designed to include reference or "background" stations as well as "indicator" stations. The program is summarized in Table I.

This report contains a compilation of the results of analyses of various types of samples collected during the period January 1982 through December 1982.

SECTION 2

SAMPLING PROGRAM

All samples are collected by Eberline personnel and shipped to the Eberline Laboratory in West Chicago, Illinois during the first half of the year. The samples collected during the second half of the year were shipped to Eberline, Albuquerque Laboratory in New Mexico. The sample collection procedures remained the same as those detailed in the semi-annual report for the period 01 January through 30 June 1973.

Upon receipt of the samples, the Laboratory staff enters the samples in a log book identifying them as to sample type, collection date, and sample code number of location, then verifies the specific analyses to be performed on each sample. The samples are then stored, awaiting analysis, on shelves expressly for this purpose to assure accountability through the Laboratory processes.

Table 1 lists the sample analysis program - sample type, frequency, and the type of analysis required.

Table 2 lists the LLD's (Lower Limits of Detection) for the analytical program. These LLD's are based on the Regulatory Guide 4.8. For analyses not listed in Regulatory Guide 4.8, Federal EPA, former requirements for similar programs or other appropriate guides are used. The LLD's are calculated at the 3σ (99% confidence) level.

The Guide specifically states that the LLD's are priori, not a posteriori (after the fact) limit for a particular measurement. When however, RG 4.8 or other LLD's have not been achieved, a footnote giving a brief explanation has been inserted.

Maps of sampling locations are shown on pages 11-13. Figure I gives the air sampling locations, Figure II shows other sampling locations and TLD monitoring locations.

TABLE 1

ENVIRONMENTAL MONITORING PROGRAM

DONALD C. COOK NUCLEAR PLANT

Sample Type	No. Station		Collection Frequency	Analysis Frequency	Type Analysis	Remarks
	Ind. -	Bkg.				
Air Particulate	6	4	Weekly	Weekly	Gross Beta	
				Monthly	Gamma Isotopic Composite, 2 Samples	By indicator and background samples.
				Quarterly	Sr-89, Sr-90	
Airborne I-131	6	4	Weekly	Weekly	Gamma Isotopic	
Precipitation	6	4	Monthly	Monthly	Gamma Isotopic Composite, 2 Samples	By indicator and background samples.
				Semi-annual	Sr-89, Sr-90 Composite, 2 Samples	By indicator and background samples.
Lake Water	3	4	Monthly	Monthly	Gamma Isotopic Composite, 2 Samples	By indicator and background samples.
				Quarterly	Tritium Composite, 2 Samples	By indicator and background samples.
Well Water	4	3	Every 18 wks.	Every 18 wks.	Gamma Isotopic Tritium	
Fish	2	2	2 per year	2 per year	Gamma Isotopic Sr-89, Sr-90	Edible portion only.

TABLE 1 (Cont'd)

ENVIRONMENTAL MONITORING PROGRAM

DONALD C. COOK NUCLEAR PLANT

Sample Type	No. Stations		Collection Frequency	Analysis Frequency	Type Analysis	Remarks
	Ind. -	Bkg.				
Aquatic Organisms	2	2	2 per year	2 per year	Gamma Isotopic Sr-89, Sr-90	When available
Milk	3	2	Monthly	Monthly	Gamma Isotopic Sr-89, Sr-90 I-131	
Sediment	2	2	2x per year	2x per year	Gamma Isotopic Sr-89, Sr-90	
TLD	9	14	Quarterly	Quarterly	Total Dose	
Food Crops	1	1	Annually	Annually	Gamma Isotopic	

Table 2

LOWER LIMITS OF DETECTION
(LLD's)

Sample Class	Analysis	LLD	Units
Air Particulates	Gross Beta	0.01	pCi/m^3
	Gamma Isotopic	0.01	pCi/m^3
	Sr-89	0.002	pCi/m^3
	Sr-90	0.001	pCi/m^3
Airborne Iodine	I-131	0.01	pCi/m^3
Milk	I-131	0.05	pCi/l
	Gamma Isotopic	10	pCi/l
	Sr-89	5	pCi/l
	Sr-90	1	pCi/l
Well Water	LS Tritium	1000	pCi/l
	Gamma Isotopic	10	pCi/l
Precipitation	Gamma Isotopic	10	pCi/l
	Sr-89	2	pCi/l
	Sr-90	1	pCi/l
Lake Water	Gamma Isotopic	10	pCi/l
	Enriched Tritium	0.2	pCi/ml
Aquatic Organisms	Gamma Isotopic	1	pCi/g wet
	Sr-89	0.05	pCi/g wet
	Sr-90	0.005	pCi/g wet
Sediment	Gamma Isotopic	1	pCi/g dry
	Sr-89	0.05	pCi/g dry
	Sr-90	0.005	pCi/g dry
Fish	Gamma Isotopic	1	pCi/g wet
	Sr-89	0.05	pCi/g wet
	Sr-90	0.005	pCi/g wet
Food Crops	Gamma Isotopic	1	pCi/g wet
Background Radiation (TLD)	Gamma Dose	-	mR/week

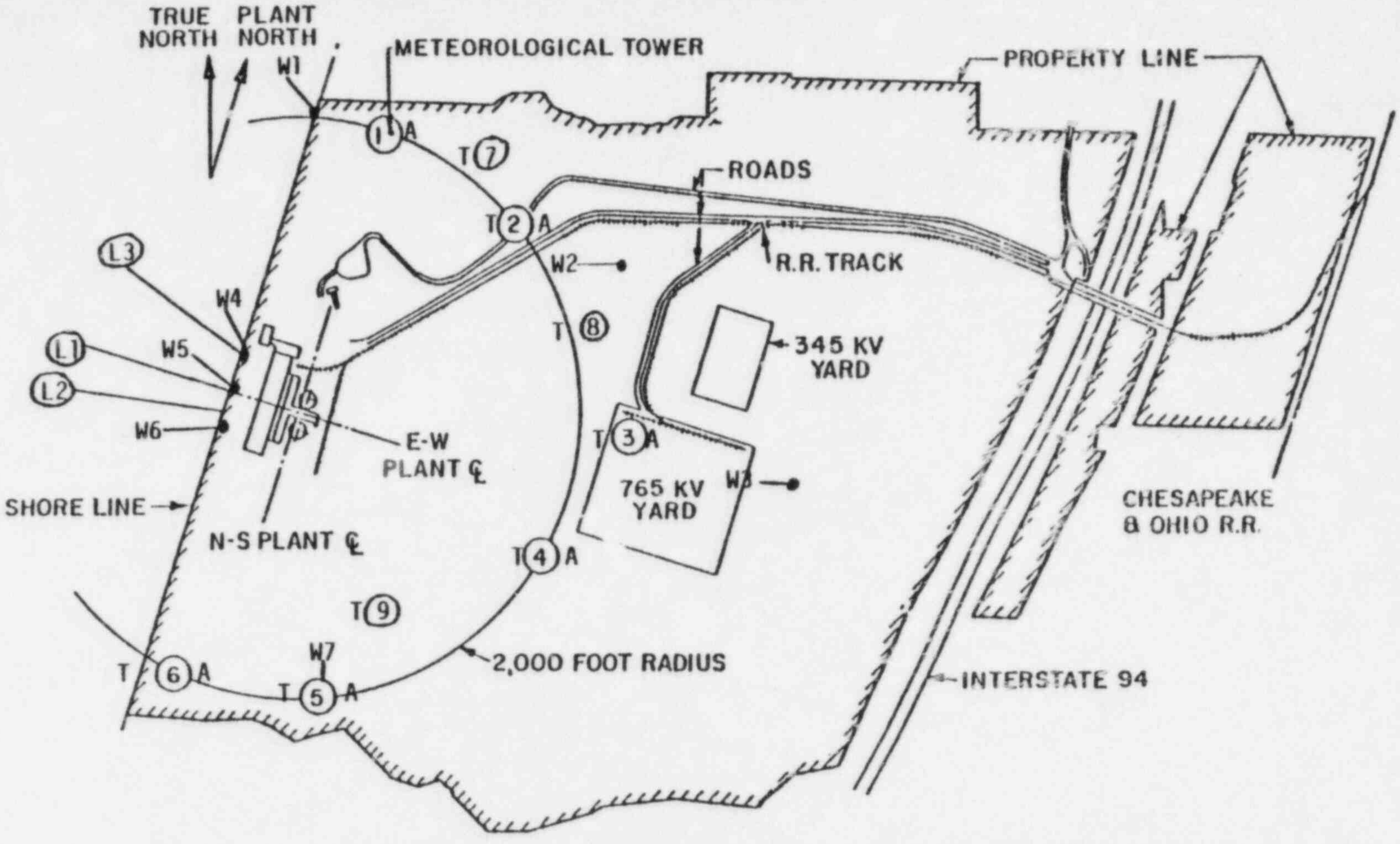

FIGURE I

LOCATIONS
OF INDICATOR AIR SAMPLING STATIONS

A	Air, Precipitation
T	TLD Station
W	Well Water
L	Lake Water (taken at shoreline)

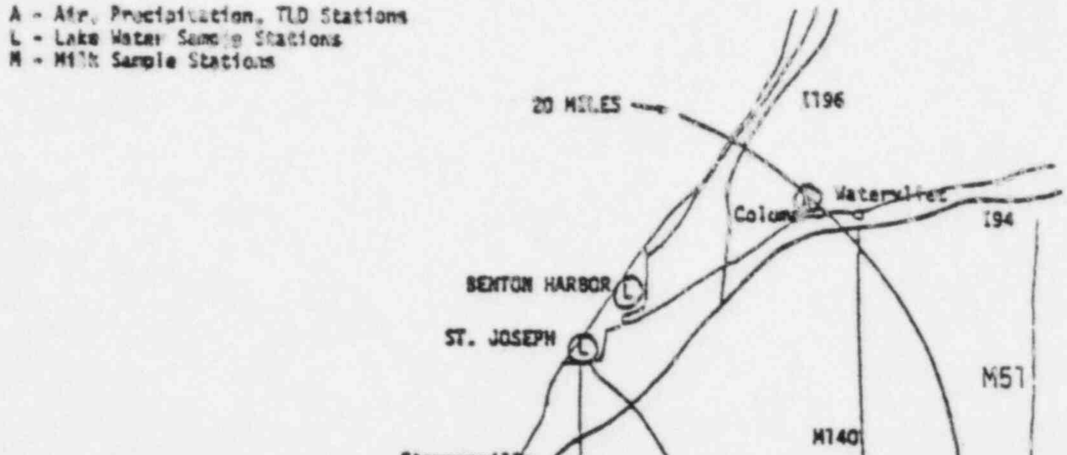

FIGURE II
OFF-SITE
LOCATIONS OF SAMPLING STATIONS

1. Red Arrow Highway and vicinity of I-94 overpass.
2. Stevensville Sub Station.
3. Washington Avenue midway between Brentwood Drive and Kingman Drive.
4. Washington Avenue and Linco Road.
5. Cleveland Avenue and Shawnee Road.
6. Holden Road and Snow Road.
7. Bridgman Sub Station.
8. California Road between Browntown and Snow Roads.
9. Ruggles Road between Hinchman and Lemon Creek Roads.
10. At intersection of Hildebrant Road and Red Arrow Highway.

FIGURE III

TLD MONITOR LOCATIONS
LOCATED ON THE FIVE MILE
RADIUS FROM THE PLANT

SECTION 3

ANALYSIS PROGRAM

ANALYTICAL PROCEDURES

Samples received at the laboratory are analyzed for the various radioactive components by standard radiochemical methods. These methods are equal to, and in most cases, identical with, those of the U.S.D.O.E.[1] or those of the Federal E.P.A.[2]

Brief descriptions of analytical procedures are available in the Laboratory Procedures Manual available at the Cook Nuclear Plant and the radioanalytical contractor's laboratory.

AIR PARTICULATE FILTERS

Gross Beta - Exposed air particulate filters are counted in low background Geiger or proportional flow beta counters using anti-coincidence background suppression after the short-lived naturally occurring radon and thoron daughters have decayed. Filters are counted long enough to ensure that the required sensitivity (LLD) is met.

Gamma Isotopic - Monthly composites of air particulate filters grouped by indicator and background stations into two samples are counted in high resolution (GeLi) gamma spectrometers for periods of time long enough to ensure that the required program sensitivity (LLD) is met.

Strontium-89 and Strontium-90 - After carrier strontium is added to semiannual composite samples of air particulate filters, the strontium is then separated and purified by either ion exchange chromatography (EPA method) or straight wet chemistry (HASL method). The chemical

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[1] HASL Procedures Manual, edited by John H. Harley, Health and Safety Laboratory, US Atomic Energy Commission, 1972 edition, revised annually.

[2] National Environmental Research Center, Environmental Protection Agency; Handbook of Radiochemical Analytical Methods. Program Element 1HA 325. Office of Research and Development, Las Vegas, Nevada 89114.

yield for strontium is determined by atomic absorbtion spectrometry or gravimetric methods. After a suitable period (usually 14 days) to allow for ingrowth of Y-90, the sample is counted in a low background beta counter (equilibrium or total Sr count). The strontium is next put into solution, carrier yttrium added, and the strontium and yttrium fractions separated. The yttrium is counted and from the Y-90 (Sr-90 daughter) count, the Sr-90 concentration can be determined. The difference between the total strontium concentration as determined by the equilibrium count and the Sr-90 concentration as determined from the Y-90 count is the Sr-89 concentration. Equations are available to permit calculation of Sr-89 and Sr-90 by counting the purified strontium fraction at two points during ingrowth of the Sr-90 daughter Y-90. While either method is acceptable, we find the former method provides more consistent results.

WATER SAMPLES (Includes Lake, Well, Precipitation)

Gamma Isotopic - A measured aliquot of the sample is evaporated to a small controlled volume and counted in a standard geometry in a high resolution (GeLi) gamma spectrometer long enough to ensure meeting the sensitivity requirements of the program. See also the Introduction to Data Tables.

Strontium-89 and Strontium-90 - Stable strontium carrier is added to a measured aliquot of sample. The strontium is then treated from this point on in the same manner as are air particulate samples.

Tritium - Tritium as tritiated water is analyzed by liquid scintillation counting after distillation. If high sensitivity is not required (ie. LLD ~500 pCi/l) the sample is distilled, mixed with the appropriate counting phosphors and counted with no further treatment. If higher sensitivity is required (ie. <~300 pCi/l) the sample is isotopically enriched in tritium concentration prior to liquid scintillation counting. Isotopic enrichment is done by the classical method of Ostlund which involves alkaline electrolysis of a purified aliquot of sample under controlled conditions of temperature and electrode current density.

MILK SAMPLES

I-131 - Measured amounts of carrier iodide are added to a known volume of milk and the iodine extracted on anion exchange resin. The iodine is recovered and purified by classical iodine chemistry methods which are similar to those given in former Regulatory Guide 4.3. The yield or recovery of iodine is measured gravimetrically and the precipitated sample is mounted and counted in a low level beta detector for a long enough period to ensure that the required LLD is met.

Gamma Isotopic - A measured aliquot of sample is evaporated and oven-dried to a standard volume and counted in a fixed geometry in a high resolution (GeLi) gamma spectrometer for a long enough period to ensure that the required LLDs are reached (see also Introduction to Data Tables).

Strontium-89 and Strontium-90 - Stable strontium carrier is added to an aliquot of the sample which is then dried and ashed at high temperature (>700°c). The ash is dissolved and the solution treated from this point on in the same manner as are air particulate samples.

ORGANIC SAMPLES (Aquatic Organisms, Food Crops, Fish)

Gamma Isotopic - A measured aliquot of sample is oven-dried or ashed as appropriate, placed in a controlled geometry and counted in a high resolution (GeLi) gamma spectrometer for a period long enough to ensure that the LLDs of the program will be set (see also Introduction to Data Tables).

Strontium-89 and Strontium-90 - Stable strontium carrier is added to a weighed aliquot of the sample and the sample is ashed at high temperature (>700°c). The ashed sample is then dissolved and processed in the same manner as are air particulate samples.

SEDIMENT SAMPLES

Gamma Isotopic - The sample is oven-dried to facilitate handling and then sieved to remove pieces of stone and/or other large pieces of material. An appropriate sized, weighed aliquot of the sample is then transferred into a standard geometry container and counted for a period long enough to ensure that the LLDs of the program will be met. (See also Introduction to Data Tables.)

Strontium-89 and Strontium-90 - A sample is ashed until free of carbon. The ash, with carriers added, is dissolved in hydrochloric acid, then processed in the same manner as are air particulate samples.

THERMOLUMINISCENT DOSIMETERS

Environmental radiation doses are measured using badges comprizing five chips sealed in plastic protective holders having a density of 50 mg/cm². The TLD chips are 1/8" x 1/8" x 1/32 LiF (thallium activated) known commercially as Harshaw-100. The chips are all selected to provide uniform response to within five percent of the mean for the batch.

Prior to installation, the chips are annealed by a standard cycle of 60 minutes at 400°c and immediate cooling to ambient temperature by placing the tray containing the annealed chips on an aluminum block

12" x 12" x 1".

After exposure the chips are read on an Eberline Instrument Corporation Model TLR-6 reader. The system employs a preheat cycle which removes low temperature peaks and integrates and digitizes only the light output in a selected temperature range.

The dose is calculated from the average light output for the five chips and the statistical uncertainty is the standard deviation of the five readings. Control badges are used to detect any unusual exposure to the badge which might occur during shipment.

QUALITY ASSURANCE PROGRAM

A. Design of Plan

Quality of product or service has always been a primary key to increase is sales, customer satisfaction, and profit. The management of Eberline Instrument Corporation recognizes the ever increasing demand for higher quality and reliability for services related to protection of workers and the environment. It is our firm belief that in order to judge the worth of a support service, one must know the philosophy behind it. Eberline will provide only those services for which it is qualified and these will be provided in a manner that is reliable, with a quality assurance program that maintains a high degree of client confidence. This quality assurance program has been prepared cosistent with the following specifications, per the Technical and Quality Assurance Requirements for Special Purposes.

ANSI-N45.2, American National Standard Institute
NRC Branch Technical Position of November 1979
NRC Regulatory Guide 4.15, Revision 1 of February 1979.

B. Intercomparison Program

Results of Eberline's Midwestern Facility (1st half of 1982) and Albuquerque Laboratory (2nd half of 1982) participation in the USEPA's Crosscheck Program are included in the monthly and annual reports provided to the client. Other intercomparisons in which we routinely participate include:

Environmental Protection Agency
Environmental Measurement Lab DOE Quality Assessment Program
Battelle Northwest Laboratories
IAEA Analytical Quality Control Service
US National Bureau of Standards

Each of the laboratory managers is responsible for preparing spikes and blanks to be run routinely. Every tenth sample is a spike, a blank, or a split sample.

Regular QC reports are prepared by a laboratory manager on a monthly schedule and forwarded to each client. Each report routinely includes:

results from EIC interlaboratory comparison,
results from EPA Crosscheck program, and
results from other intercomparison programs.

Results are reviewed by the laboratory manager. If a problem is indicated by the data, the nature of the problem is investigated and corrective steps taken immediately. A copy of each report is also provided to the Quality Assurance Manager of the Nuclear Services Division.

C. Quality Assurance Plan

The Quality Assurance Program follows the requirments of Company and Division Manuals. The discussion below outlines Quality Assurance Programs as conducted in the laboratory and as required in our QA Manual.

Procedure Approval

Each procedure goes through a vigorous evaluation and review process before it is incorporated into the EIC Procedures Manual. Established procedures of the Environmental Protection Agency (EPA) or the Environmental Measurements Laboratory of the US Department of Energy (EML) are used unless thorough testing has demonstrated that an alternate procedure is equal to or better than the EPA or EML procedure. Uniform procedures are used at both laboratories to the fullest extent possible, except when deviations are necessary to meet the specific requirements of the client. The manager of each laboratory and the quality assurance manager review and approve significant procedural changes before they are implemented.

Equipment Calibration and Maintenance

Equipment used for qualitative or quantitative measurements is carefully calibrated and maintained with records of each calibration or maintenance action kept in appropriate logbooks. To the extent possible, certified standards are used for all primary calibrations. The following standards are used for the application indicated:

Measurement	Calibration Standard
Gross Beta	Solution of Standard ^{137}Cs certified by NBS or Amersham Searle
Tritium	Solution standard of ^{3}H certified by NBS
Gamma Spectrometry	Solution standards of various gamma emitters certified by NBS or Amersham Searle. Standards are used to calibrate each counting geometry used.
Strontium-89 and 90	Solution standards of ^{90}Sr certified by Amersham Searle or NBS
Gross Alpha	Solution standards of ^{239}Pu certified by NBS or Amersham Searle.
Radiation Dose	^{137}Cs gamma source cross-referenced with NBS using R-meters. ^{226}Ra is used for some special application.

When suitable standards are not available for a specific gamma emitter, quantitative gamma isotopic analysis is based on an energy calibration of the gamma spectrometer and the gamma energy and abundance information provided in Table of Isotopes, Sixth Edition by Ledrer, Hollander, and Perlman.

The results of the Quality Control Programs are summarized in Section 6.

SECTION 4

RESULTS AND DISCUSSION

Table 3

Environmental Radiological Monitoring Program

Name of Facility: Donald C. Cook Nuclear Station Docket Number: 50-315 and 50-316

Location of Facility: Berrien (County) Michigan (State) Reporting Period: January - December 1982

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean[1] (Range)	Location with Highest Mean		Control Locations Mean[1] (Range)	Number of Non-routine Reported Measurements
				Name	Mean (Range)		
Air Particulates (pCi/m^3)	Gross β 515	0.01	0.03 (270/311) 0.01-0.08	On Sites 3, 5, and 6	0.04 0.01-0.08	0.03 (186/204) 0.01-0.10	0
	Ce-144 24	0.01	ALL LLD	Not Applicable		ALL LLD	0
	Zr-95 24	0.01	ALL LLD	Not Applicable		ALL LLD	0
	Nb-95 24	0.01	ALL LLD	Not Applicable		ALL LLD	0
	Ce-141 24	0.01	ALL LLD	Not Applicable		ALL LLD	0
	Ru-103 24	0.01	ALL LLD	Not Applicable		ALL LLD	0
	Other γ 24	0.01	ALL LLD	Not Applicable		All LLD	0
	Sr-89 8	0.002	ALL LLD	Not Applicable		All LLD	0
	Sr-90 8	0.001	ALL LLD	Not Applicable		All LLD	0
Airborne Iodine (pCi/m^3)	I-131 515	0.01	ALL LLD	Not Applicable		All LLD	0
Well Water (pCi/l)	Tritium 21	1000	1767 (3/12) 1100-2100	On Sites 4 and 5	2100 (a)	All LLD	0
	γ Spec. 21	10	ALL LLD	Not Applicable		All LLD	0

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[1] Mean and range based on detectable measurements only. Fractions indicated in parentheses.

Table 3 (continued)

Facility: Donald C. Cook Nuclear Station

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean[1] (Range)	Location with Highest Mean		Control Locations Mean[1] (Range)	Number of Non-routine Reported Measurements
				Name	Mean (Range)		
Milk (pCi/l)	I-131 58	0.05	All LLD	Not Applicable		All LLD	0
	Sr-89 58	5	All LLD	Not Applicable		All LLD	0
	Sr-90 58	1	4.2 (35/35) 1-12	Bridgman	4.2 (12/12) 1-12	4.6 (23/23) 1-11	0
	γ Spec. 58	10	All LLD	Not Applicable		All LLD	0
Precipitation (pCi/l)	γ Spec. 24	10	All LLD	Not Applicable		All LLD	0
	Sr-89 4	2	All LLD	Not Applicable		All LLD	0
	Sr-90 4	1	All LLD	Not Applicable		4 (1/2) 4	0
Lake Water (pCi/l)	γ Spec. 20	10	All LLD	Not Applicable		All LLD	0
	Tritium 8	200	300 1/4 (a)	Not Applicable		200 (1/4) (a)	0
Aquatic Organisms (pCi/g wet)	Ce-144 8	1	All LLD	Not Applicable		ALL LLD	0
	Nb-95 8	1	All LLD	Not Applicable		ALL LLD	0
	Zr-95 8	1	All LLD	Not Applicable		ALL LLD	0
	Cr-51 8	1	All LLD	Not applicable		All LLD	0
	Ce-141 8	1	All LLD	Not Applicable		ALL LLD	0
	Other γ 8	1	All LLD	Not Applicable		All LLD	0

[1] Mean and range based on detectable measurements only. Fractions indicated in parentheses.

(a) Range is not reported as only one detectable measurement was available

Facility: Donald C. Cook Nuclear Station

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean[1] (Range)	Location with Highest Mean Name	Location with Highest Mean Mean (Range)	Control Locations Mean[1] (Range)	Number of Non-routine Reported Measurements
Aquatic Organisms (pCi/g wet)	Sr-89 8	0.05	All LLD	Not Applicable		All LLD	0
	Sr-90 8	0.005	ALL LLD	Not Applicable		ALL LLD	0
Sediment (pCi/g dry)	γ Spec. 12	1	All LLD	Not Applicable		All LLD	0
	Sr-89 12	0.05	All LLD	Not Applicable		All LLD	0
	Sr-90 12	0.005	ALL LLD	Not Applicable		ALL LLD	0
Food Crops (pCi/g wet)	γ Spec. 4	1	All LLD	Not Applicable		All LLD	0
Fish (pCi/g wet)	γ Spec 8	1	All LLD	Not Applicable		All LLD	0
	Sr-89 8	0.05	All LLD	Not Applicable		All LLD	0
	Sr-90 8	0.005	0.019 (2/4) 0.017-0.020	On Site, South	0.020 (1/2) (a)	0.022 (2/4) 0.016-0.027	0
Background Radiation (TLD) (mR/week)	γ Dose 91	0.1	1.1 (35/35) 0.6-1.7	On-Site	1.3 (4/4) 1.1-1.7	1.2 (56/56) 0.8-1.8	0

(a) Range is not reported as only are detectable measurement was available.

[1] Mean and range based on detectable measurements only. Fractions indicated in parentheses.

Results of all the analyses for January through December 1982 are presented in full in section 5, Data Tables pages 32 through 46.

Table 3 summarizes the range and average concentrations for measurements at the indicator and control locations with the highest annual mean.

Specific finding for the various environmental media are discussed below.

AIR PARTICULATE SAMPLES

Atmospheric particulate matter at a field location is accumulated for a one-week on a glass fiber filter using a low-volume air sampler at a collection rate of one cubic foot per minute. This particulate matter contained on the filter is counted for beta activity in a low background counting system after the short-lived naturally-occurring radon and thoron daughters have decayed.

The average gross beta concentration for the year for all indicator stations was 0.03 pCi/m^3, and was 0.03 pCi/m^3 for the background stations. Data for anayses of individual filters are given on page 35 through 38 in Section 5.

The following table summarizes the average gross beta concentrations for both indicator and background stations for each year from 1973 through 1982. The preoperational data were collected in 1973 and 1974; operational data were collected from 1975 through the present.

TABLE 3

	Indicator pCi/m^3	Background pCi/m^3
Preoperational		
1973	0.04	0.04
1974	0.16	0.16
Operational		
1975	0.08	0.09
1976	0.09	0.08
1977	0.22	0.22

	Indicator	Background
	pCi/m^3	
Operational		
1978	0.12	0.11
1979	0.04	0.04
1980	0.04	0.04
1981	0.12	0.11
1982	0.03	0.03

The elevated levels of gross beta activity at both indicator and background locations during preoperational and operational phases from 1974 through 1982 were mainly the result of nuclear test explosions in the atmosphere by the people's republic of China. Such tests took place on 27 June 1973, 17 June 1974, 23 January 1976, 26 September 1976, 17 November 1976, 17 September 1977, 13 March 1978, 14 December 1978 and October 1980.

The data indicate that there is significantly no difference between the levels of gross beta activity measured at the indicator and background locations for the operational and preoperational phases of the program.[1] The activity detected are not attributable to the operation of the Cook Plant.

Airborne I-131 concentration was less than 0.1 pCi/m^3 for all samples received.

The gamma spectrometry data for monthly composites of air particulate files begins on page 39. Be-7, a naturally occurring nuclide formed by the cosmic ray interaction with nuclei in the upper atmosphere, was detected in the composites. These were generally in the range to be expected from measurement of this nuclide in this medium. No other gamma emitters were detected.

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[1] See Annual Environmental Monitoring Reports for D.C.Cook Plant from previous years for details.

Quarterly composites of air particulate filters were analyzed for Sr-89 and Sr-90. Sr-89 concentrations were below the detection limit of 0.002 pCi/m^3, and Sr-90 were also below the detection limit of 0.001 pCi/m^3 for both indicator and background locations. Data are presented on page 39.

MILK SAMPLES

Milk samples were collected monthly and were analyzed for I-131, Sr-89, Sr-90, and gamma emitters.

Sr-89 concentrations measured below the detection limit of 5 pCi/l in all samples collected during the year. Sr-90 concentrations continued to display considerable variation, which is typical for this type of sample. This nuclide is attributable to worldwide fallout from both recent and older nuclear test programs. Data are given on page 40.

I-131 concentrations were below the detection limits of the program. Data are presented on page 40.

Gamma emitters other than those which occur in nature were not detected in all samples at a measurement sensitivity of 10 pCi/l. Data are given on page 41.

PRECIPITATION SAMPLES

Gamma isotopic analyses of monthly precipitation samples from indicator and background locations indicate the presence of no gamma emitters in concentrations exceeding 10 pCi/l (<3000 pCi/m^2). Sr-89 and Sr-90 concentrations were below the detection limits of the program. Data are presented on page 42.

WELL WATER SAMPLES

Well water is collected from seven locations at 18 week intervals during the year and analyzed for tritium and gamma emitters. Low concentrations of tritium were detected in samples from three indicator stations during January-February 1982. It is possible that the tritium found in these samples is a result of plant operations. Gamma emitters were below the detection limit in all samples analyzed. Data are presented on page 43.

LAKE WATER SAMPLES

Samples of water from Lake Michigan are composited by indicator and background locations and analyzed for gamma emitters on a monthly basis. Quarterly composites of the monthly composites are analyzed for tritium.

The gamma emitters in the monthly composites were measured to be less than the detection limit of 10 pCi/l per nuclide for all samples.

The tritium concentrations in the quarterly composites were in the range of <200 to 300 pCi/l for in indicator locations and <200 to 200 pCi/l for the background locations. These concentrations are in the range to be expected from measurements of this nuclide in this medium. Data is presented on page 44.

AQUATIC ORGANISM SAMPLES

Aquatic organisms were collected twice during the year from areas north and south of the plant, at on-site and off-site locations. The samples were analyzed for gamma emitters, Sr-89, and Sr-90. Data is presented on page 44.

No gamma emitters were detected in all samples collected during the year below the detection limit 1 pCi/g.

Sr-89 and Sr-90 were not detected in any of the samples above the detection limit of 0.05 pCi/g (wet) for Sr-89 and 0.005 pCi/g (wet) for Sr-90.

SEDIMENT SAMPLES

Sediment samples were collected twice during the year from areas north and south of the plant, at the on-site and off-site locations. The samples were analyzed for gamma emitters, Sr-89, and Sr-90.

The gamma emitters were below the detection limit of 1 pCi/g (dry) in all samples. Sr-89 and Sr-90 were also below the detection limit, 0.05 pCi/g (dry) for Sr-89 and 0.005 pCi/g (dry) for Sr-90. Data are given on page 45.

FISH SAMPLES

Fish samples collected from areas north and south of the plant, both on-site and off-site locations, were analyzed for gamma emitters, Sr-89 and Sr-90.

For all samples, gamma emitters were below the detection limit of 1 pCi/g (wet), and Sr-89 was below the detection limit of 0.05 pCi/g (wet). Sr-90 ranged in concentration from 0.016 to 0.027 pCi/g (wet). The concentrations observed were attributable to worldwide fallout and were generally in the range to be expected from measurements of this nuclide in this medium. Data are given on page 45.

FOOD CROP SAMPLES

Grapes and grape leaves were collected during the fall harvest period from on-site and off-site locations and were analyzed for gamma emitters. They were found to be below the detection limit of 1 pCi/g (wet) at both on-site and off-site locations. Data are given on page 45.

GAMMA DOSE

Gamma radiation dose was measured with Thermoluminiscent Dosimeters (TLDS) on a quarterly schedule. A total of 23 field locations(9 indicator and 14 background) were monitored during the year.

Throughout the year, there was no statistically significant difference in dose rates between indicator and background locations, nor do they differ significantly from dose rates measured in previous years. Data are presented on page 46.

SECTION 5

DATA TABLES

INTRODUCTION TO THE DATA TABLES

The following information will be helpful in understanding the presentation of the data in the tables in this section.

Wet Weight	a reporting unit used with organic tissue samples such as vegetation and animal samples in which the amount of sample is taken to be the weight as received from the field with no moisture removed.
Dry Weight	a reporting unit used for soil and sediment in which the amount of sample is taken to be the weight of the sample after removal of moisture by drying in an oven at about 110° for about 15 hours.
pCi/m³	a reporting unit used with air particulate and radioiodine data which refers to the radioactivity content expressed in picocuries of the volume of air expressed in cubic meters passed through the filter and/or the charcoal trap. Note that the volumes are not corrected to standard conditions.
Gamma Emitters or Gamma Isotopic	samples were analyzed by high resolution (GeLi) gamma spectrometry. The resulting spectrum is analyzed by a computer program which scans from about 50 to 2000 kev and lists the energy peak of any nuclides present in concentrations exceeding the sensitivity limits set for that particular experiment.
NA, NS, NR	used in place of a concentration when a sample was not available (NS), or when a sample was not analyzed for some specific measurement (NA), or when an analysis is not required (NR).
Error Terms	figures following "±" are error terms based on counting uncertainties at the 2σ (95% confidence) level. Values preceded by the "<" symbol were below the stated concentration at the 3σ (99% confidence) level.
Exponents	Exponents necessary to prevent data tables from being cumbersome are handled in the conventional manner of including them in the column headings.
Sensitivity	In general, all analyses meet the sensitivity requirements of the program as given in Table 3. For the few samples that do not (because of inadequate sample quantities, analytical interferences, etc.) the sensitivity actually obtained in the analysis is given.
<u>Comment</u>	when all analyses of a particular type during the period resulted in concentrations below the sensitivity limits, a <u>statement</u> is made on the appropriate table rather than presenting a whole page of "<" data. If all but one or two data points are below the sensitivity limits, the previously mentioned convention is followed and the finite data are given as footnotes.

COOK

LISTING OF MISSED SAMPLES

1982

Sample Type	Location	Expected Collection Date	Reason
AP/CC	DOW, COL	01/09/82	Weather conditions
AP/CC	SBN, COL	01/23/82	Weather conditions- frozen locks
Lake Water	All points	02/06/82	Lake frozen
AP/CC	ONS-1	08/31/82	No power to unit
Milk	SBN	09/04/82	Not available
Milk	GAL	11/06/82	Not available

DONALD C. COOK

AIRBORNE IODINE-131* and GROSS BETA in AIR PARTICULATE FILTERS
(Weekly Collections)

	Gross Beta 10^{-2} pCi/m^3									
	ON-SITE 1		ON-SITE 2		ON-SITE 3		ON-SITE 4		ON-SITE 5	
Collection Date	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β
01/04/82	340	<1	380	1±1	370	5±1	395	5±1	335	6±1
01/11-12/82	400	2±1	470	1±1	385	4±1	505	1±1	410	8±1
01/18/82	350	1±1	290	1±1	395	1±1	375	1±1	390	1±1
01/26/82	390	<1	370	1±1	410	6±1	485	6±1	495	6±1
02/02/82	360	1±1	325	1±1	360	6±1	465	2±1	475	6±1
02/09/82	360	1±1	305	1±1	360	6±1	430	5±1	485	7±1
02/16/82	340	<1	445	1±1	355	7±1	435	6±1	485	4±1
02/23/82	390	<1	305	1±1	310	4±1	435	3±1	385	4±1
03/02/82	380	1±1	275	1±1	315	3±1	450	2±1	395	5±1
03/09/82	380	<1	250	<1	310	5±1	420	5±1	415	5±1
03/16/82	205	<1	360	<1	305	4±1	410	4±1	415	5±1
03/23/82	345	<1	505	<1	315	2±1	325	<1	335	1±1
03/30/82	370	<1	500	1±1	395	3±1	350	2±1	350	4±1
04/06/82	345	<1	495	1±1	390	3±1	330	3±1	360	3±1
04/13/82	340	<1	500	2±1	400	5±1	340	5±1	360	5±1
04/20/82	415	<1	375	1±1	410	3±1	335	2±1	390	4±1
04/27/82	495	<1	345	1±1	415	6±1	385	5±1	370	7±1
05/04/82	485	<1	350	<1	390	4±1	380	4±1	375	6±1
05/11/82	365	<1	380	<1	415	5±1	425	4±1	460	5±1
05/18/82	275	<1	375	1±1	415	4±1	435	4±1	370	5±1
05/25/82	335	<1	215	1±1	340	2±1	485	<1	365	3±1
06/01/82	325	<1	335	1±1	340	3±1	280	3±1	335	3±1
06/08/82	280	1±1	320	2±1	330	3±1	280	3±1	320	2±1
06/15/82	275	1±1	315	3±1	340	4±1	460	3±1	320	5±1
06/22/82	330	1±1	310	2±1	340	3±1	455	2±1	340	3±1
06/29/82	355	1±1	285	2±1	350	4±1	440	3±4	330	5±1

* Iodine cartidges are sampled weekly. Concentrations are <0.10 pCi/m^3 unless otherwise noted.

DONALD C. COOK

AIRBORNE IODINE-131* and GROSS BETA in AIR PARTICULATE FILTERS
(Weekly Collections)

Gross Beta 10^{-2} pCi/m^3

Collection Date	ON-SITE 1		ON-SITE 2		ON-SITE 3		ON-SITE 4		ON-SITE 5	
	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β	Volume (m^3)	Gross β
07/06/82	360	1±1	290	2±1	340	4±1	435	4±1	340	2±1
07/13/82	330	2±1	275	5±1	360	4±1	535	2±1	340	7±1
07/20/82	305	3±1	270	2±1	380	5±1	685	5±1	350	7±1
07/27/82	435	<1	290	1±1	385	5±1	565	<1	345	<1
08/03/82	430	1±1	320	3±1	385	5±1	630	3±1	380	5±1
08/10/82	375	1±1	360	2±1	390	4±1	600	3±1	365	5±1
08/17/82	365	1±1	345	2±1	385	3±1	485	2±1	375	3±1
08/24/82	400	1±1	340	1±1	410	2±1	310	2±1	350	2±1
08/31/82	(a)	-	335	1±1	420	4±1	310	5±1	335	4±1
09/07/82	385(b)	4±1	335	3±1	405	3±1	275	4±1	345	4±1
09/14/82	295	1±1	380	3±1	415	3±1	310	4±1	395	5±1
09/21/82	330	<1	280	2±1	315	2±1	310	2±1	375	2±1
09/28/82	370	1±1	295	4±1	345	3±1	335	3±1	375	4±1
10/05/82	385	1±1	315	2±1	345	5±1	315	3±1	405	5±1
10/12/82	380	<1	350	<1	350	3±1	315	2±1	390	4±1
10/19/82	360	<1	290	2±1	335	2±1	300	1±1	380	2±1
10/26/82	345	1±1	270	3±1	320	4±1	295	<1	440	4±1
11/02/82	355	1±1	355	3±1	315	4±1	260	4±1	360	4±1
11/09/82	340	<1	370	<1	315	3±1	235	3±1	325	3±1
11/16/82	385	1±1	365	1±1	280	4±1	315	<1	380	3±1
11/23/82	280	4±1	360	2±1	290	6±1	270	5±1	385	<1
11/30/82	295	<1	335	4±1	295	5±1	235	2±1	395	4±1
12/07/82	320	<1	365	3±1	350	3±1	265	3±1	375	2±1
12/14/82	305	<1	395	<1	345	4±1	375	3±1	355	5±1
12/21/82	300	2±1	280	2±1	340	5±1	305	4±1	300	6±1
12/28/82	295	1±1	315	1±1	345	3±1	325	3±1	245	2±1

* Iodine cartidges are sampled weekly. Concentrations are <0.10 pCi/m^3 unless otherwise noted.

(a) See Listing of Missed Samples page.

[illegible] based on an estimated average volume for the week.

DONALD C. COOK

AIRBORNE IODINE-131* and GROSS BETA in AIR PARTICULATE FILTERS
(Weekly Collections)

	Gross Beta 10^{-2} pCi/m^3										
	ON-SITE 6			NEW BUFFALO		SOUTH BEND		DOWAGIAC		COLOMA	
Collection Date	Volume (m^3)	Gross Beta	Collection Date	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta
01/04/82	345	5±1	01/02/82	380	7±1	335	5±1	370	6±1	335	7±1
01/12/82	395	8±1	01/09/82	365	6±1	310	5±1	(a)		(a)	
01/18/82	350	3±1	01/17/82	450	5±1	335	10±1	720	3±1	670	2±1
01/26/82	400	5±1	01/23/82	330	6±1	(a)		370	4±1	(a)	
02/02/82	375	6±1	01/30/82	390	4±1	600	2±1	385	1±1	660	5±1
02/09/82	390	7±1	02/06/82	380	4±1	365	4±1	385	1±1	350	3±1
02/16/82	385	2±1	02/13/82	410	5±1	375	7±1	395	<1	345	1±1
02/23/82	380	5±1	02/20/82	360	3±1	365	3±1	405	5±1	295	2±1
03/02/82	380	5±1	02/27/82	385	3±1	385	4±1	470	3±1	345	3±1
03/09/82	385	4±1	03/06/82	370	3±1	345	2±1	440	1±1	345	2±1
03/16/82	375	4±1	03/13/82	345	5±1	380	5±1	335	4±1	315	3±1
03/23/82	360	1±1	03/20/82	330	1±1	325	1±1	300	1±1	385	1±1
03/30/82	365	4±1	03/27/82	375	2±1	365	3±1	315	2±1	425	<1
04/06/82	360	3±1	04/03/82	360	1±1	340	2±1	325	3±1	370	1±1
04/13/82	375	5±1	04/10/82	445	5±1	375	5±1	325	6±1	440	4±1
04/20/82	340	3±1	04/17/82	355	2±1	360	3±1	340	2±1	405	3±1
04/27/82	330	6±1	04/24/82	390	6±1	320	6±1	320	5±1	495	4±1
05/04/82	335	5±1	05/01/82	355	4±1	330	<1	345	3±1	470	2±1
05/11/82	335	4±1	05/08/82	345	3±1	330	3±1	330	5±1	515	1±1
05/18/82	345	5±1	05/15/82	350	5±1	335	1±1	365	4±1	580	2±1
05/25/82	370	2±1	05/21/82	340	2±1	335	1±1	325	2±1	360	2±1
06/01/82	345	3±1	05/29/82	365	2±1	330	1±1	325	2±1	415	1±1
06/08/82	315	3±1	06/05/82	310	3±1	360	3±1	320	3±1	420	3±1
06/15/82	300	4±1	06/12/82	325	3±1	355	3±1	365	3±1	405	3±1
06/22/82	310	2±1	06/19/82	340	3±1	340	4±1	360	3±1	340	3±1
06/29/82	310	4±1	06/26/82	340	3±1	315	3±1	395	1±1	390	2±1

* Iodine cartridges are sampled weekly. Concentrations are <0.10 pCi/m^3 unless otherwise noted.

(a) See Listing of Missed samples page.

DONALD C. COOK

AIRBORNE IODINE-131* and GROSS BETA in AIR PARTICULATE FILTERS
(Weekly Collections)

Gross Beta 10^{-2} pCi/m^3

	ON-SITE 6			NEW BUFFALO		SOUTH BEND		DOWAGIAC		COLOMA	
Collection Date	Volume (m^3)	Gross Beta	Collection Date	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta	Volume (m^3)	Gross Beta
07/06/82	320	4±1	07/03/82	335	4±1	405	5±1	410	4±1	420	5±1
07/13/82	325	5±1	07/10/82	340	4±1	375	5±1	415	4±1	445	6±1
07/20/82	330	4±1	07/17/82	355	4±1	385	4±1	405	4±1	625	3±1
07/27/82	335	5±1	07/24/82	400	2±1	380	3±1	405	2±1	625	2±1
08/03/82	360	4±1	07/31/82	375	4±1	310	4±1	430	3±1	640	3±1
08/10/82	365	4±1	08/07/82	385	4±1	400	5±1	435	4±1	690	3±1
08/17/82	555	1±1	08/14/82	385	1±1	465	<1	415	2±1	640	2±1
08/24/82	605	2±1	08/21/82	395	3±1	570	2±1	505	2±1	455	3±1
08/31/82	620	3±1	08/28/82	370	2±1	590	3±1	475	4±1	265	3±1
09/07/82	565	2±1	09/07/82	420	1±1	510	1±1	415	3±1	320	4±1
09/14/82	610	1±1	09/11/82	440	4±1	600	3±1	455	5±1	360	4±1
09/21/82	235	1±1	09/18/82	305	2±1	300	1±1	295	2±1	350	1±1
09/28/82	230	5±1	90/25/82	300	2±1	285	<1	255	<1	280	<1
10/05/82	240	3±1	10/02/82	295(a)	<1	315	3±1	310	5±1	265	2±1
10/12/82	240	2±1	10/09/82	400	2±1	335	2±1	340	4±1	310	<1
10/19/82	280	2±1	10/16/82	630	<1	335	<1	360	<1	300	1±1
10/26/82	265	2±1	10/23/82	475	2±1	325	2±1	375	1±1	340	<1
11/09/82	345 (a)	<1	11/06/82	480	2±1	330	1±1	345	2±1	340	3±1
11/12/82	275	4±1	10/30/82	510	2±1	330	3±1	390	<1	310	3±1
11/16/82	360	4±1	11/13/82	415	5±1	290	3±1	320	5±1	380	4±1
11/23/82	405	5±1	11/20/82	400	<1	250	1±1	345	3±1	320	5±1
11/30/82	445	1±1	11/27/82	355	5±1	350(a)	2±1	360	2±1	450	<1
12/07/82	410	2±1	12/04/82	325	3±1	310	5±1	340	1±1	360	3±1
12/14/82	375	4±1	12/11/82	340	3±1	375	3±1	345	<1	355	2±1
12/21/82	390	4±1	12/18/82	350	2±1	485	1±1	360	1±1	210	3±1
12/28/82	425	2±1	12/25/82	335	4±1	410	3±1	350	<1	320	5±1

* Iodine cartridges are sampled weekly. Concentrations are <0.10 pCi/m^3 unless otherwise noted.

(a) Power failure. Date based on an estimated average weekly volume.

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GAMMA ISOTOPIC ANALYSIS OF MONTHLY AIR PARTICULATE COMPOSITES

Month	Indicator Stations pCi/m³ Be-7	Indicator Stations pCi/m³ Other γ	Background Stations pCi/m³ Be-7	Background Stations pCi/m³ Other γ
January	0.06±0.01	<0.01	0.09±0.01	<0.01
February	0.07±0.01	<0.01	0.12±0.01	<0.01
March	0.09±0.01	<0.01	0.07±0.01	<0.01
April	0.09±0.01	<0.01	0.18±0.02	<0.01
May	0.10±0.01	<0.01	0.13±0.02	<0.01
June	0.19±0.10	<0.01	0.20±0.12	<0.01
July	0.21±0.11	<0.01	0.14±0.09	<0.01
August	0.09±0.05	<0.01	0.14±0.09	<0.01
September	<0.07	<0.01	0.11±0.04	<0.01
October	<0.1	<0.01	<0.2	<0.01
November	<0.1	<0.01	<0.2	<0.01
December	0.03±0.01	<0.01	0.07±0.02	<0.01

STRONTIUM 89 AND STRONTIUM 90 ANALYSIS OF QUARTERLY AIR PARTICULATE COMPOSITES

Collection Period	Indicator Stations pCi/m³ Sr-89	Indicator Stations pCi/m³ Sr-90	Background Stations pCi/m³ Sr-89	Background Stations pCi/m³ Sr-90
1st Quarter	<0.002	<0.001	<0.002	<0.001
2nd Quarter	<0.002	<0.001	<0.002	<0.001
3rd Quarter	<0.002	<0.001	<0.002	<0.001
4th Quarter	<0.002	<0.001	<0.002	<0.001

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Sr-89*/90 and I-131 CONCENTRATIONS in MILK SAMPLES
(Monthly Collection)

Collection Site:	Indicator Stations			Background Stations	
	Bridgman K2	Stevensville K1	Galien	Dowagiac K1	South Bend K1
Collection Date	**I-131 pCi/l**				
01/09/82	<0.5	<0.5	<0.5	<0.5	<0.5
02/06/82	<0.5	<0.5	<0.5	<0.5	<0.5
03/06/82	<0.5	<0.5	<0.5	<0.5	<0.5
04/17/82	<0.6(a)	<0.7(a)	<0.7(a)	<0.7(a)	<0.7(a)
05/08/82	<0.5	<0.5	<0.5	<0.5	<0.5
06/12/82	<0.9(a)	<0.9(a)	<0.9(a)	<0.9(a)	<0.9(a)
07/10/82	<0.5	<0.5	<0.5	<0.5	<0.5
08/07/82	<0.5	<0.5	<0.5	<0.5	<0.5
09/04/82	<0.5	<0.5	<0.5	<0.5	(b)
10/09/82	<0.5	<0.5	<0.5	<0.5	<0.5
11/06/82	<0.5	<0.5	(b)	<0.5	<0.5
12/04/82	<0.5	<0.5	<0.5	<0.5	<0.5
	Sr-90 pCi/l				
01/09/82	2±1	1±1	1±1	2±1	3±1
02/06/82	2±1	2±1	2±1	5±1	2±1
03/06/82	3±2	4±1	3±2	6±1	2±1
04/17/82	2±1	2±1	4±1	5±1	2±1
05/08/82	2±1	2±1	3±1	7±1	3±1
06/12/82	3±1	2±1	2±1	2±1	3±1
07/10/82	12±1	7±1	8±1	1±1	1±1
08/07/82	1±1	3±1	2±1	2±1	1±1
09/04/82	3±1	4±1	4±1	4±1	(b)
10/09/82	9±1	9±1	6±1	11±1	10±1
11/06/82	5±1	12±1	(b)	11±1	7±1
12/04/82	6±1	8±1	7±1	7±1	8±1

* Sr-89 was determined on each sample and was <5 pCi/l unless otherwise noted.

(a) Too much decay for lower sensitivity requirement between collection date and receipt of samples at lab.

(b) Sample not available see listing of missed.

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RADIONUCLIDES in MILK SAMPLES
(Monthly Collections)

	Indicator Stations			Background Stations	
Collection Site:	Bridgman K2	Stevensville K1	Galien	Dowagiac K1	South Bend K1
Collection Date	Cs-137 pCi/l				
01/09/82	<10	<10	<10	16±3	<10
02/06/82	<10	<10	<10	<10	<10
03/06/82	<10	<10	<10	<10	<10
04/17/82	<10	<10	<10	<10	<10
05/08/82	<10	<10	<10	<10	<10
06/12/82	<10	<10	<10	<10	<10
07/10/82	<10	<10	<10	<10	<10
08/07/82	<10	<10	<10	<10	<10
09/04/82	<10	<10	<10	<10	(a)
10/09/82	<10	<10	<10	<10	<10
11/06/82	<10	<10	(a)	<10	<10
12/04/82	<10	<10	<10	<10	<10
	Other Gamma Emitters pCi/l				
01/09/82	<10	<10	<10	<10	<10
02/06/82	<10	<10	<10	<10	<10
03/06/82	<10	<10	<10	<10	<10
04/07/82	<10	<10	<10	<10	<10
05/08/82	<10	<10	<10	<10	<10
06/12/82	<10	<10	<10	<10	<10
07/10/82	<10	<10	<10	<10	<10
08/07/82	<10	<10	<10	<10	<10
09/04/82	<10	<10	<10	<10	(a)
10/09/82	<10	<10	<10	<10	<10
11/06/82	<10	<10	<10	<10	<10
12/04/82	<10	<10	<10	<10	<10

(a)Sample was not available. See listing of missed samples.

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GAMMA ISOTOPIC ANALYSIS OF PRECIPITATION SAMPLES
(Monthly Collections)

Collection Sites:	Indicator		Background	
Collection Period	pCi/l	nCi/m²	pCi/l	nCi/m²
January	<10	<0.3	<10	<0.4
February	<10	<0.3	<10	<0.5
March	<10	<0.3	<10	<0.3
April	<10	<0.3	<10	<0.2
May	<10	<0.3	<10	<0.2
June	<10	<0.3	<10	<0.2
July	<10	<0.2	<10	<0.2
August	<10	<0.3	<10	<0.3
September	<10	<0.2	<10	<0.2
October	<10	<0.2	<10	<0.2
November	<10	<0.2	<10	<0.2
December	<10	<0.2	<10	<0.2

RADIOSTRONTIUM CONCENTRATIONS IN PRECIPITATION SAMPLES
(Semiannual Analysis on Composites of Monthlys)

	Indicator		Background	
	pCi/l		pCi/l	
Collection Period	Sr-89	Sr-90	Sr-89	Sr-90
1st semi annual 82	<2	<1	<2	<1
2nd semi annual 82	<2	<3*	<2	<2*

*lower sensitivity due to low chemical recovery

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RADIONUCLIDES IN WELL WATER SAMPLES
(18-week Interval Collections)

	Background Stations			Indicator Stations			
Collection Site:	ONS 1	ONS 2	ONS 3	ONS 4	ONS 5	ONS 6	ONS 7
Collection Date	Gamma Emitters pCi/l						
01/28,02/04/82	<10	<10	<10	<10	<10	<10	<10
06/03/82	<10	<10	<10	<10	<10	<10	<10
10/14/82	<10	<10	<10	<10	<10	<10	<10
	Tritium pCi/l						
01/28, 02/04/82	<1000	<1000	<1000	2100±400	2100±400	1100±400	<1000
06/03/82	<1000	<1000	<1000	<1000	<1000	<1000	<1000
10/14/82	<1000	<1000	<1000	<1000	<1000	<1000	<1000

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GAMMA EMITTERS IN LAKE WATER SAMPLES
(Monthly Composites of Indicator and Background Stations)

Month	Gamma Emitters pCi/l/nuclide Indicator Composite	Background Composite
January	<10	<10
March	<10	<10
April	<10	<10
May	<10	<10
June	<10	<10
July	<10	<10
August	<10	<10
September	<10	<10
October	<10	<10
November	<10	<10
December	<10	<10

TRITIUM IN LAKE WATER SAMPLES
(Quarterly Composites of Monthly Samples)

Quarter	Tritium pCi/l Indicator Stations	Background Stations
1st	300±100	200±100
2nd	<200	<200
3rd	<200	<200
4th	<200	<200

RADIONUCLIDES IN AQUATIC ORGANISMS
(Semiannual Collections when Available)

Location	Collection Date	pCi/g (wet) Sr-89	Sr-90	Ce-144	Other γ
North - on-site	05/25/82	<0.05	<0.005	<1	<1
North - off-site	05/25/82	<0.05	<0.005	<1	<1
South - on-site	05/25/82	<0.05	<0.005	<1	<1
South - off-site	05/25/82	<0.05	<0.005	<1	<1
North - on site	10/22/82	<0.05	<0.005	<1	<1
North - off site	10/22/82	<0.05	<0.005	<1	<1
South - on site	10/26/82	<0.05	<0.005	<1	<1
South - off site	10/26/82	<0.05	<0.005	<1	<1

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RADIONUCLIDES IN SEDIMENT SAMPLES
(Semiannual Collections)

Collection Site	Collection Date	pCi/g (dry) Gamma Emitters	Sr-89	Sr-90
N ONS	04/27/82	<1	<0.05	<0.005
S ONS	04/27/82	<1	<0.05	<0.005
N OFS	04/27/82	<1	<0.05	<0.005
S OFS	04/27/82	<1	<0.05	<0.005
S OFS	05/25/82	<1	<0.05	<0.005
S ONS	05/25/82	<1	<0.05	<0.005
N OFS	05/25/82	<1	<0.05	<0.005
N ONS	05/25/82	<1	<0.05	<0.005
N ONS	10/12/82	<1	<0.05	<0.005
S ONS	10/12/82	<1	<0.05	<0.005
N OFS	10/12/82	<1	<0.05	<0.005
S OFS	10/12/82	<1	<0.05	<0.005

RADIONUCLIDES IN FISH SAMPLES
(Semiannual Collections)

Collection Site	Collection Date	pCi/g (wet) Gamma Emitters	Sr-89	Sr-90
N ONS	04/14/82	<1	<0.05	0.017±0.012
S ONS	04/14/82	<1	<0.05	0.020±0.007
N OFS	04/14/82	<1	<0.05	0.016±0.013
S OFS	04/14/82	<1	<0.05	0.027±0.016
N ONS	10/25/82	<1	<0.05	<0.005
S ONS	10/25/82	<1	<0.05	<0.005
N OFS	10/25/82	<1	<0.05	<0.005
S OFS	10/25/82	<1	<0.05	<0.005

RADIONUCLIDES IN FOOD CROPS
(Annual Fall Harvest Collection)

Collection Date	Collection Site: Sample Type	ON Site pCi/g (wet) Gamma Emitters	OFF Site
09/82	Grapes		<1
09/82	Leaves		<1
09/82	Grapes	<1	
09/82	Leaves	<1	

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GAMMA RADIATION
(Quarterly)

(Measured using Thermoluminiscent Dosimeters)

Date Annealed:	12/16/81	03/17/82	06/16/82	09/15/82
Date Read:	04/06-08/82	07/01-02/82	10/07/82	01/07/83

Location	1st Qtr.		2nd Qtr.		3rd Qtr.		4th Qtr.	
	Main TLD	Backup TLD	Main TLD	Backup TLD	Main TLD	Backup TLD	Main TLD	Backup TLD
	Measured mR/week							
Indicator Stations								
On-Site 1	1.2±0.1	1.5±0.2	1.1±0.2	1.2±0.2	1.0±0.3	0.8±0.2	1.1±0.2	1.0±0.3
On-Site 2	1.5±0.4	1.3±0.2	1.3±0.1	1.1±0.2	0.9±0.1	0.8±0.2	1.1±0.3	1.1±0.2
On-Site 3	1.4±0.4	1.5±0.3	1.3±0.3	1.1±0.2	0.9±0.1	0.8±0.1	1.0±0.1	1.0±0.2
On-Site 4	1.3±0.4	1.2±0.3	1.0±0.1	1.0±0.2	0.8±0.1	0.6±0.2	0.9±0.2	0.9±0.1
On-Site 5	1.3±0.4	1.3±0.1	1.2±0.1	1.2±0.3	0.9±0.1	0.9±0.1	1.0±0.1	1.0±0.1
On-Site 6	1.2±0.3	1.4±0.5	1.3±0.2	missing	0.9±0.1	0.8±0.1	1.1±0.2	1.0±0.1
On-Site 7	1.6±0.9	1.4±0.4	missing	missing	0.9±0.2	0.9±0.2	1.0±0.2	1.1±0.1
On-Site 8	1.3±0.3	1.2±0.2	1.0±0.1	1.1±0.2	0.9±0.1	0.8±0.1	1.1±0.1	1.0±0.1
On-Site 9	1.7±0.5	1.4±0.5	1.2±0.3	1.0±0.2	1.2±0.1	1.1±0.1	1.1±0.1	1.0±0.2
Background Stations								
Coloma	1.6±0.9	1.4±0.1	1.0±0.1	1.0±0.4	0.9±0.2	0.8±0.1	1.0±0.1	0.9±0.1
Dowagiac	1.5±0.5	1.7±0.7	1.3±0.4	1.1±0.2	0.9±0.1	0.8±0.1	1.0±0.2	0.9±0.1
New Buffalo	1.7±1.0	1.3±0.2	1.0±0.2	1.0±0.2	0.9±0.1	0.8±0.1	1.1±0.1	1.0±0.1
South Bend	1.8±0.9	1.2±0.2	1.0±0.1	1.0±0.2	0.9±0.1	1.0±0.2	1.0±0.1	1.1±0.1
Off-Site- 1	1.5±0.5	1.6±1.5	1.1±0.3	1.1±0.2	0.8±0.2	0.8±0.2	1.1±0.1	1.0±0.2
Off-Site- 2	1.1±0.4	1.3±0.2	1.0±0.2	1.1±0.3	0.9±0.1	0.8±0.1	1.0±0.1	1.1±0.1
Off-Site- 3	1.5±0.2	1.5±0.4	1.2±0.5	1.0±0.3	0.9±0.1	0.8±0.1	1.1±0.1	1.0±0.2
Off-Site- 4	1.6±0.5	1.5±0.4	1.1±0.1	1.2±0.1	1.1±0.1	0.9±0.2	1.0±0.1	1.1±0.3
Off-Site- 5	1.4±0.4	1.4±0.5	1.0±0.3	1.2±0.2	0.9±0.1	0.9±0.2	1.1±0.1	1.1±0.2
Off-Site- 6	1.6±0.8	1.4±0.2	1.2±0.2	1.1±0.2	1.0±0.1	0.9±0.2	1.1±0.2	1.0±0.2
Off-Site- 7	1.7±0.5	1.4±0.4	1.1±0.2	1.1±0.2	1.0±0.1	0.9±0.1	1.3±0.1	1.1±0.2
Off-Site- 8	1.3±0.3	1.4±0.1	1.2±0.2	1.1±0.2	1.0±0.2	1.0±0.2	1.3±0.1	1.2±0.1
Off-Site- 9	1.3±0.3	1.4±0.3	1.1±0.2	1.2±0.1	1.0±0.2	1.0±0.2	1.2±0.3	1.2±0.2
Off-Site-10	1.4±0.4	1.4±0.5	1.0±0.1	1.0±0.2	0.8±0.2	0.9±0.2	1.0±0.1	1.1±0.2

SECTION 6

QUALITY ASSURANCE DATA

TLD Intercomparison Badges
Irradiated by Battelle Northwest Labs

1982

	Total mR less transportation control					
	1st Qtr		2nd Qtr		3rd and 4th Qtr	
Badge	**Known**	**Measured**	**Known**	**Measured**	**Known**	**Measured**
A	22	19.9±7.5	11	9.0±3.3	30	29±4
B	30	26.5±4.2	11	11.5±3.8	30	28±4
C	43	39.2±9.4	27	24.7±3.2	51	49±12
D	62	59.5±9.3	27	25.3±3.8	51	46±7
E	75	72.6±4.4	42	40.7±4.8	73	68±16
F	75	70.0±9.5	42	42.6±5.0	73	64±14
G	80	81.1±18.2	73	69±8	91	90±9
H	80	77.0±13.1	73	72±8	91	88±13
J	100	94.5±13.1	89	80±9	100	95±22
K	100	115.8±10.4	89	80±9	100	96±14

TABLE 3.2

1982 USEPA - EBERLINE INTERCOMPARISON PROGRAM

Sample Type	Analysis	Value (EPA)	Value (EIC)	Units
Air Filter	Alpha	25±11	27±2	pCi/Filter
Air Filter	Beta	52±8.7	58±2	pCi/Filter
Air Filter	Sr-90	16±2.6	24±3	pCi/Filter
Air Filter	Cs-137	19±8.7	32±7	pCi/Filter
Air Filter	Alpha	32±8	24±19	pCi/Sample
Air Filter	Beta	67±5	77±10	pCi/Sample
Air Filter	Sr-90	20±1.5	17±4	pCi/Sample
Air Filter	Cs-137	27±5	27±9	pCi/Sample
Food	Sr-89	38±5	15±4	pCi/kg
Food	Sr-90	23±1.5	21±2	pCi/kg
Food	Co-60	30±5	46±16	pCi/kg
Food	Cs-137	33±5	54±14	pCi/kg
Food	K	2730±137	2870±290	pCi/kg
Food	Ba-140	0	<114	pCi/kg
Water	Alpha	21±9.1	20±3	pCi/l
Water	Beta	23±8.7	15±2	pCi/l
Water	Alpha	24±10	22±2	pCi/l
Water	Beta	32±8.7	30±2	pCi/l
Water	Cr-51	34±8.7	44±25	pCi/l
Water	Co-60	22±8.7	24±3	pCi/l
Water	Zn-65	24±8.7	23±4	pCi/l
Water	Ru-106	0	<26	pCi/l
Water	Cs-134	21±8.7	20±2	pCi/l
Water	Cs-137	32±8.7	36±3	pCi/l
Water	Alpha	80±35	73±7	pCi/l
Water	Beta	111±8.7	107±6	pCi/l
Water	Co-60	0	<1	pCi/l
Water	Sr-89	21±8.7	25±4	pCi/l
Water	Sr-90	14.4±2.6	16±2	pCi/l
Water	Cs-134	12±8.7	10±2	pCi/l
Water	Cs-137	15±8.7	15±2	pCi/l
Water	Ra-226	12.7±3.3	11.7±3.5	pCi/l
Water	Ra-228	9.2±2.4	12.9±1.6	pCi/l
Water	Gross U	15±10	15±1	pCi/l
Water	Cr-51	0	<58	pCi/l
Water	Co-60	20±9	20±3	pCi/l
Water	Zn-65	15±9	16±4	pCi/l
Water	Ru-106	20±9	<25	pCi/l
Water	Cs-134	22±9	22±2	pCi/l
Water	Cs-137	23±9	27±2	pCi/l
Water	I-131	8.4±1.5	<75	pCi/l
Water	Uranium	35±6	26±6	pCi/l
Water	H-3	1820±590	1990±690	pCi/l
Water	Ra-226	10±2	11±3	pCi/l
Water	Ra-228	9±1	13±2	pCi/l

Sample Type	Analysis	Value (EPA)	Value (EIC)	Units
Water	Pu-239	6.7±1.2	5.8±0.2	pCi/1
Water	Sr-89	21±8.7	17±4	pCi/1
Water	Sr-90	12±2.6	10±2	pCi/1
Water	H-3	2860±620	1890±600	pCi/1
Water	ALpha	16±5	16±3	pCi/1
Water	Beta	23±5	16±7	pCi/1
Water	H-3	1830±340	1760±510	pCi/1
Water	H-3	2890±380	2830±820	pCi/1
Water	Ra-226	13.4±2.0	13.6±4.0	pCi/1
Water	Ra-228	8.7±1.3	9.4±3.6	pCi/1
Water	I-131	4.4±0.7	5.5±1.8	pCi/1
Water	I-131	87±8.7	67±14	pCi/1
Water	Cr-51	23±5	<59	pCi/1
Water	Co-60	29±5	31±3	pCi/1
Water	Zn-65	26±5	29±10	pCi/1
Water	Ru-106	0	<25	pCi/1
Water	Cs-134	35±5	36±3	pCi/1
Water	Cs-137	25±5	28±3	pCi/1
Water	Ra-226	10.5±1.6	8.4±2.5	pCi/1
Water	Ra-228	11.0±1.7	17.7±14.7	pCi/1
Water	Uranium	30±6	24±4	pCi/1
Water	Pu-239	6.9±0.7	7.2±0.4	pCi/1
Water	Alpha	19±8.7	8±4	pCi/1
Water	Beta	24±8.7	24±5	pCi/1
Water	Alpha	55±24	27±13	pCi/1
Water	Beta	81±8.7	64±6	pCi/1
Water	Cs-134	1.8±8.7	<10	pCi/1
Water	Cs-137	20±8.7	16±7	pCi/1
Water	Ra-226	12.5±3.2	11.8±3.5	pCi/1
Water	Ra-228	3.6±0.9	3.4±1.9	pCi/1
Water	Gross Uranium	16±10	9±1	pCi/1
Milk	Sr-89	25±5	12±7	pCi/1
Milk	Sr-90	16±1.5	13±3	pCi/1
Milk	Co-60	30±5	51±9	pCi/1
Milk	Cs-137	28±5	39±19	pCi/1
Milk	Ba-140	0	<489	pCi/1
Milk	K	1500±75	1310±120	mg/1
Milk	I-131	5.4±0.8	6.7±3.1	pCi/1

TABLE 3.4

1982 Quality Control Analyses Summary

The tables below summarize results of samples run for process quality control purposes during the subject year. These listings are in addition to such measurements as detector backgrounds, check source values, radiometric-gravimetric comparisons, system calibrations etc. Detailed listings of each measurement are maintained at the laboratory and are available for inspection if required.

Blank Samples

Nuclide Analyzed	Number of Determinations	Number of Analyses Exceeding the LLD for that Analysis
Gross Alpha	47	0
Gross Beta	37	0
Tritium	75	0
Sr-89-90	26	0
I-131	*	
Am-241	12	0
Pb-210	27	0
Po-210	2	0
Pu-239	37	0
Ra-226	44	0
Fe-55	3	0
Isotopic Uranium	38	0
Isotopic Thorium	17	0

* Blank I-131 analyses are performed with each batch of samples processed. All blank data were below the detection limit.

Spiked Samples

Nuclide Analyzed	Number of Det'ns	Within 2σ of known	Within 3σ of known	Differing from known by > 3σ
Gross Alpha	47	47	-	-
Gross Beta	37	37	-	-
Tritium	75	75	-	-
Sr-89-90	26	26	-	-
Am-261	12	12	-	-
Pb-210	27	27	-	-
Po-210	2	2	-	-
Pu-239	37	37	-	-
Ra-226	44	44	-	-
Fe-55	3	3	-	-
Isotopic Uranium	38	38	-	-
Isotopic Thorium	17	17	-	-

Split Samples

Nuclide Analyzed	Number of Det'ns	No. Agreeing Within 2σ	No. Agreeing Within 3σ	No. Differing by > 3σ
Gross Alpha	17	17	-	-
Gross Beta	20	20	-	-
Tritium	20	20	-	-
Sr-89-90	7	7	-	-
I-131	2	2	-	-
Gamma Emitters	14	14	-	-
Pb-210	4	4	-	-
Po-210	2	2	-	-
Pu-239	3	3	-	-
Am-241	2	2	-	-
Isotopic Thorium	3	3	-	-
Isotopic Uranium	16	16	-	-
Ra-226	13	13	-	-

SECTION 7

LAKE WATER SAMPLES

Radiological Environmental Monitoring

Water Samples

Samples of water from Lake Michigan are composited by indicator and background stations and analyzed for gamma emitters on a monthly basis. All samples throughout the year 1982 for the five indicator stations and two background stations were analyzed for gamma emitters on a monthly basis. All samples throughout the year 1982 for the five indicator and two background stations showed analysis results less than the concentration levels for each isotope listed in Table I.

Quarterly composites of the lake water composites are analyzed for Sr-89, Sr-90, and H-3. Results of these analyses are listed in Table II. The first quarter H-3 samples for 1982 were collected, however, the analysis was not performed.

TABLE I

DONALD C. COOK NUCLEAR PLANT

1982 LAKE WATER MONTHLY COMPOSITE GAMMA ISOTOPIC ANALYSIS

Isotope	Concentration (μCi/cc)
I-131	<5.761 E-8
Cs-137	<2.147 E-8
Cs-134	<1.619 E-8
Co-60	<4.144 E-8
Co-58	<3.550 E-8
Mn-54	<1.288 E-8
Zn-65	<3.204 E-8
Nb-95	<2.099 E-8
Zr-95	<3.302 E-8
Cr-51	<1.506 E-7

TABLE II

DONALD C. COOK NUCLEAR PLANT

QUARTERLY LAKE WATER COMPOSITE SR-89, Sr-90

H-3 ANALYSIS 1982

Location	Quarter	Concentration(μci/cc) Sr-89	Sr-90	H-3
North Lake	1	<2.0 E-9	<1.0 E-9	-
South Lake	1	<2.0 E-9	<1.0 E-9	-
Benton Harbor	1	<2.0 E-9	<1.0 E-9	-
Bridgman	1	<2.0 E-9	<1.0 E-9	-
Lake Township	1	<2.0 E-9	<1.0 E-9	-
New Buffalo	1	<2.0 E-9	<1.0 E-9	-
St. Joseph	1	<2.0 E-9	(1.0±1.0)E-9	-
North Lake	2	<1.0 E-8	<1.0 E-8	<5.87 E-7
South Lake	2	<1.0 E-7	<6.0 E-8	<5.87 E-7
Benton Harbor	2	<3.0 E-8	<2.0 E-8	<5.87 E-7
Bridgman	2	<1.0 E-7	<6.0 E-8	<5.87 E-7
Lake Township	2	<2.0 E-8	<2.0 E-8	<5.87 E-7
New Buffalo	2	<3.0 E-8	<2.0 E-8	<5.87 E-7
St. Joseph	2	<1.0 E-8	<1.0 E-8	<5.87 E-7
North Lake	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
South Lake	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
Benton Harbor	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
Bridgman	3	<6.0 E-9	<2.0 E-9	<5.22 E-7
Lake Township	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
New Buffalo	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
St. Joseph	3	<2.0 E-9	<2.0 E-9	<5.22 E-7
North Lake	4	<3.0 E-8	<4.0 E-8	<5.47 E-7
South Lake	4	<3.0 E-8	<3.0 E-8	<5.47 E-7
Benton Harbor	4	(1.4±0.6)E-8	(3.3±1.3)E-8	<5.47 E-7
Bridgman	4	<6.0 E-9	<7.0 E-9	<5.47 E-7
Lake Township	4	<3.0 E-8	<3.0 E-8	<5.47 E-7
New Buffalo	4	(1.8±0.9)E-8	(1.6±0.5)E-8	<5.47 E-7
St. Joseph	4	<6.0 E-9	<7.0 E-9	<5.47 E-7