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Limnology of Michigan's Nearshore Waters of Lake Michigan

LIMNOLOGY OF MICHIGAN'S

NEARSHORE WATERS OF LAKE MICHIGAN

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FOREWORD

The Great Lakes National Program Office (GLNPO) of the United States Environmental Protection Agency was established in Region V, Chicago to focus attention on the significant and complex natural resource represented by the Great Lakes.

GLNPO implements a multi-media environmental management program drawing on a wide range of expertise represented by Universities, private firms, State, Federal and Canadian Governmental Agencies and the International Joint Commission. The goal of the GLNPO program is to develop programs, practices and technology necessary for a better understanding of the Great Lakes system and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes system. The Office also coordinates U.S. actions in fulfillment of the Agreement between Canada and the United States of American on Great Lakes Water Quality of 1978.

ABSTRACT

Limnological assessments, including water and sediment che... and benthic macroinvertebrate community structure, were performed based on samples collected at 16 locations in Michigan's nearshore waters of Lake Michigan in 1976. Tributary influence on Lake Michigan's water chemistry were detectable only out to 0.5 km from shore. Tributary impacts on sediment chemistry and macroinvertebrate communities were inconsistent. Based on the water sampling and benthic macroinvertebrate communities results, the nearshore waters were classified as oligotrophic in the central and northern sections, and mesotrophic in southern Lake Michigan and Green Bay. Sediment concentrations of heavy metals and nutrients were greatest in Green Bay and southern Lake Michigan and were related to the percentage of fine sediment (<0.05 mm diameter) present. Ninety benthic macroinvertebrate taxa were identified with the amphipod Pontoporeia hoyi the most abundant macroinvertebrate, followed by the oligochaete Stylodrilus heringianus. Substrate and water depth exerted major influences on benthic macroinvertebrate communities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES APPENDED

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SECTION I

CONCLUSIONS

1. The detectable influence of rivers and lake outlets on water chemistry was found up to 0.5 km from shore. This influence was generally exhibited near the water surface and resulted in elevated concentrations of conductivity, chloride, total phosphorus, chlorophyll a, alkalinity, chemical oxygen demand, total organic carbon, total dissolved solids, organic nitrogen, sodium, magnesium and calcium.

2. The influences of rivers on sediment chemistry was not detectable at the stations nearest shore. Since sediments were not contaminated at stations nearest shore, the contaminants entering via rivers were apparently either dissolved in the water or attached to finer particles carried further offshore and deposited.

3. No conclusions could be drawn concerning the impacts of rivers on the benthic macroinvertebrate community at stations nearest to shore due to the extreme variability found in these communities.

4. Based on water sampling and benthic macroinvertebrate communities, loccations in the northern section of the lake, from the Pere Marquette River mouth to the Manistique River were classified as oligotrophic; locations in the southern section of the lake from the Galien River north to the White Lake outlet were classified as mesotrophic; and locations in Green Bay were mesotrophic approaching eutrophic conditions.

5. Medium to fine sand (0.10-0.50 mm diameter) was the major sediment component at all depths at locations on the eastern shore of Lake Michigan. In contrast, locations on the northern shore were generally more diverse with locations in Green Bay containing more silty clay substrates and locations on the northern portion of the lake dominated by medium to fine sand.

6. Concentrations of heavy metals, total Kjeldahl nitrogen, total phosphorus, chemical oxygen demand, total organic carbon and volatile solids in sediments generally increased with increasing percentages of fine sediments (<0.05 mm diameter). The highest concentrations were generally found within Green Bay (locations 14-16) while the lowest concentrations were found at the Pere Marquette River, Manistee River and Betsie Lake locations (9-11).

7. Ninety benthic macroinvertebrate taxa were found with community densities ranging from 0 to 21,482/m^2. *Pontoporeia hoyi* was the most abundant form, averaging 2846/m^2. Oligochaetes, primarily *Limnodrilus hoffmeisteri* and *Stylodrilus heringianus*, were the next most abundant group averaging 672/m^2. Substrate and depth exerted the major influences on benthic macroinvertebrate communities. Of the other factors examined, sediment chemistry, distance from shore and rivers exerted relatively minor influences on benthic macroinvertebrate communities.

SECTION II

RECOMMENDATIONS

1. The benthic macroinvertebrate communities at the Galien, St. Joseph and Black River locations in southern Lake Michigan and Manistique and the Green Bay locations in northern Lake Michigan should be monitored every five to seven years to determine if the conditions improve.

2. Monitoring should occur in the tributaries at these locations to determine and eliminate sources of contaminants.

SECTION III

INTRODUCTION

The Great Lakes collectively constitute the world's largest reservoir of fresh water and are a critical resource for both the United States and Canada. Increasing population densities in the watershed will require increased volumes of high quality water for municipal, industrial, commercial and agricultural expansion. At the same time, there will be increasing demands for high quality water for drinking, swimming, boating, fishing and other recreational pursuits. The necessity for high quality water to maintain existing natural aquatic ecosystems overlays these interwoven and often conflicting uses.

Future management strategies designed to utilize, protect and, where needed, improve the Great Lakes water resources must be based on up-to-date and comprehensive information. To provide such information the Michigan Department of Natural Resources (MDNR) surveyed the water and sediment quality and benthic macroinvertebrate communities at 16 locations in Michigan's nearshore waters of Lake Michigan during the summer of 1976. The objectives of this survey were (1) to assess the impacts of river and lake outlets and (2) to identify existing or background lake quality. In this report, lake quality is defined as the quality of the aquatic ecosystem, with emphasis on water chemistry, sediment chemistry, and benthic macroinvertebrate communities.

Lake Michigan has a volume of 4920 km^3, a maximum depth of 281 m, and a surface area of 57,580 km^2. The Michigan portion of its shoreline is approximately 2250 km. The nearshore waters, the focal point of this survey, were defined as those waters from the shore to the 45 m depth contour. These waters comprise roughly 35 percent of the lake's total volume. In the southern portion of Lake Michigan, the 45 m contour occurs from 10 to 12 km offshore, while in the northern portion the distance decreases to 4 to 5 km offshore. Nearshore waters often exhibit chemical and physical characteristics quite different from the open lake waters. Since the nearshore waters are a very productive habitat for benthic macroinvertebrates (Alley and Mozley, 1975), fish spawning, rearing and feeding (O'Gorman, 1978), they are the most sensitive to subtal changes in water quality. Consequently, the nearshore waters are the first to be adversely impacted by man's activities and can thereby serve as an early warning of impacts on whole lake quality.

SECTION IV

METHODS

Sampling Design

Sixteen locations in the nearshore waters of Lake Michigan were sampled during the summer of 1976 (Figure 1). All locations but one (Naubinway) were at or near major river mouths or lake outlets which are tributaries to Lake Michigan. Sampling started at the southernmost location (Galien River) on July 6,1976 and progressed northward, ending at the Cedar River location on August 19, 1976. Due to difficulties at the St. Joseph River on July 14, this location was sampled on September 16, 1976 at the 30 m contour. Precise locations for each station sampled are presented in Table A-1.

The sampling design at each location was based on information gathered by Mozley and Garcia (1972) and Mozley (1975) near the Donald C. Cook nuclear power plant which is located in southern Lake Michigan near Stevensville, Michigan. Mozley (1975) described sediment composition and benthic macroinvertebrate populations in the nearshore waters near this plant. His description of low benthic macroinvertebrate populations in water less than eight meters and more stable and abundant populations in deeper waters prompted a three tier sampling design (Figure 2). Tier one consisted of one station (station 1) located at the interface of the river mouth and the lake in approximately 6 m of water. Stations in this tier were not located in the dredged channel at harbor mouths. Tier two consisted of three stations (stations 2, 3 and 4) located along the 15 m contour and tier three consisted of three stations (stations 5, 6 and 7) located along the 30 m contour. Locations 3 (Black River) and 11 (Betsie Lake) each contained three additional stations (stations 8, 9 and 10) at the 45 m contour. Location 13 (Manistique River) contained three additional stations (stations 8, 9 and 10) located within the harbor (Figure 2).

Water Samples

Water samples were collected one meter below the water surface and one meter off the bottom with a PVC Van Dorn water bottle at stations 1, 3, 6 and 9. The samples were preserved, iced and shipped via air to the MDNR Environmental Laboratory in Lansing, Michigan for analysis. The parameters analyzed for, analytical techniques used, and laboratory sensitivities are described in Table A-2. Selected constituents (temperature, pH, dissolved oxygen, conductivity) were measured on-site at 2 m intervals from surface to the bottom with a Martek Mark II water quality analyzer.

Sediment and Benthic Macroinvertebrate Samples

Bottom sediments and benthic macroinvertebrate samples were collected with a Ponar grab samples (522 cm^2) at all stations. Sediments for chemical analysis were packaged in glass jars, placed on ice and shipped via air to the

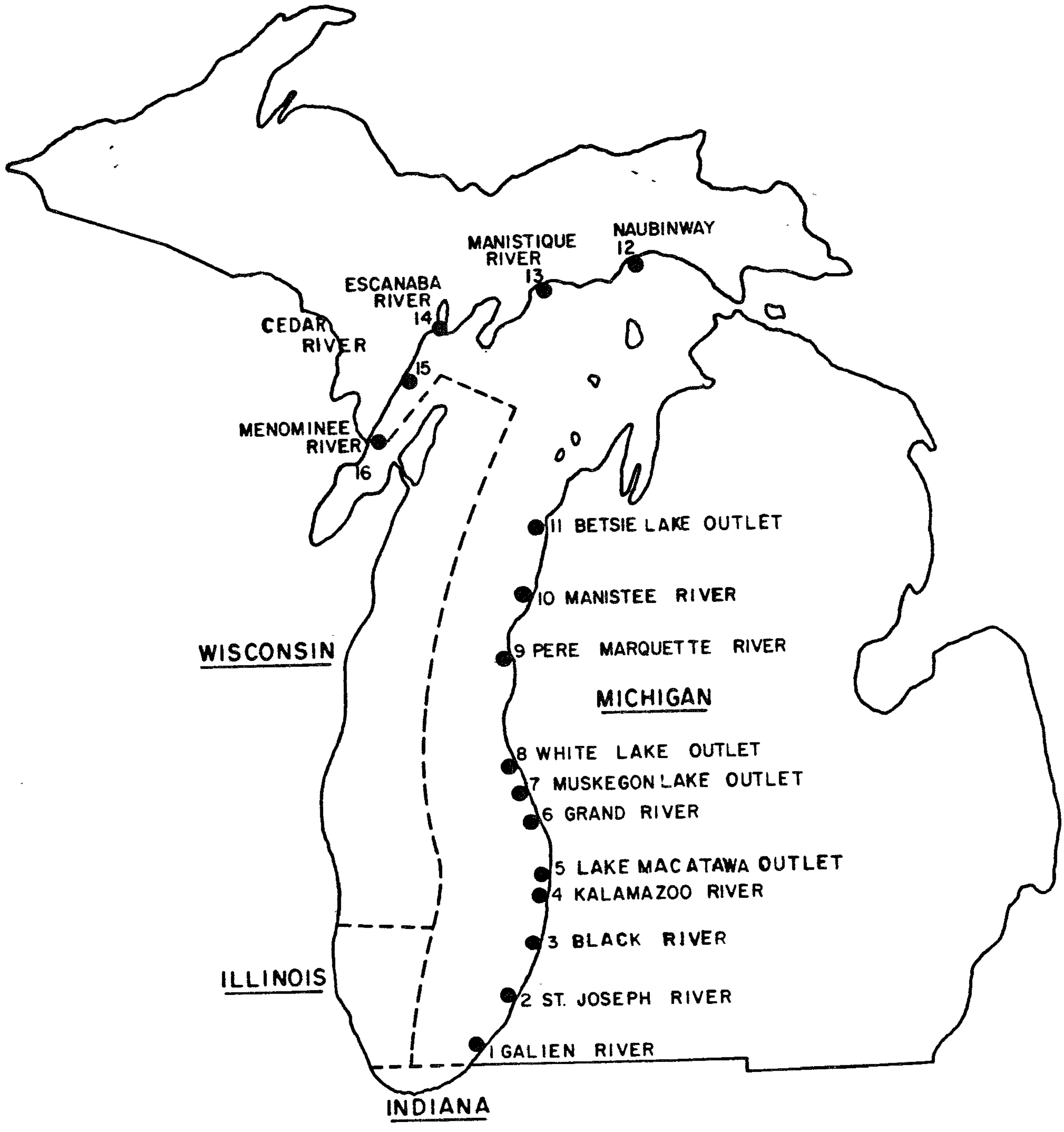
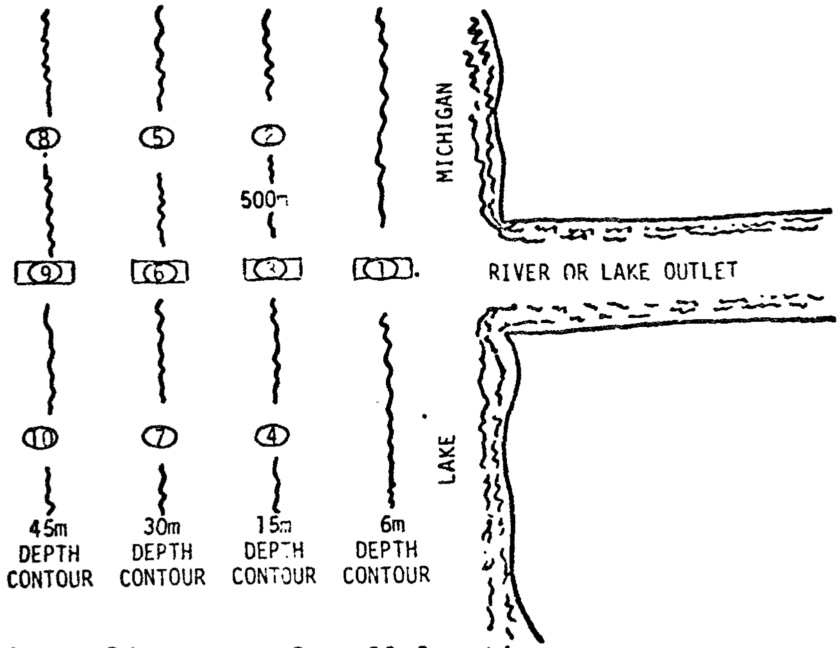


Figure 1. Sampling locations in the nearshore waters, Lake Michigan, 1976.

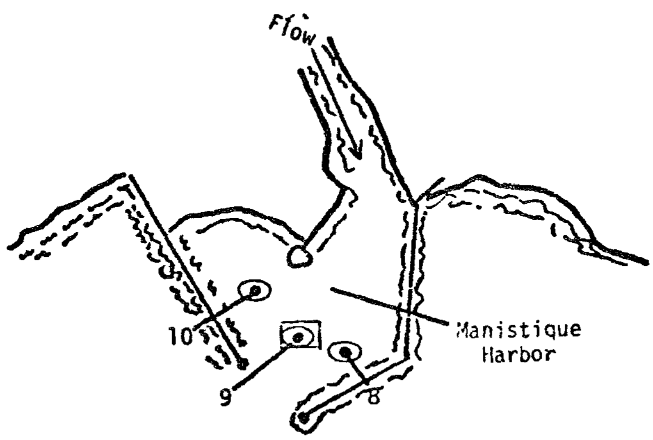


General sampling array for all locations.

LEGEND

○ Benthic macroinvertebrate and sediment sampling stations

□ Water sampling stations



Specialized sampling array within Manistique Harbor.

Figure 2. Sampling array for locations sampled in the nearshore waters of Lake Michigan, 1976.

MDNR Environmental Laboratory in Lansing. Sediment samples for analysis of particle size composition were collected as above and delivered to the Soil Science Laboratory at Michigan State University, East Lansing, Michigan. The sediment constituents measured, analytical techniques used and laboratory sensitivities are described in Table A-3.

Benthic macroinvertebrate samples were sieved through a U.S. standard #30 mesh sieve. The residue was placed in a quart jar in 5% buffered formalin and returned to the MDNR Aquatic Biology Laboratory for enumeration and identification to the lowest possible taxon.

Oligochaetes were keyed primarily according to Brinkhurst and Jamison (1971) and Hiltunen (1967). Chironomids were identified primarily according to a preliminary key prepared by Hamilton et al. (unpublished). Pelecypoda were classified according to Walter and Burch (unpublished), and Gastropoda according to Heard and Burch (1966). Trichoptera were identified following Wiggins (1977) with other macroinvertebrates identified following Pennak (1953).

SECTION V

RESULTS AND DISCUSSION

WATER

General

All data are summarized in Tables A-4, A-5 and A-7. The following two sections highlight these results and compare them to other studies. Station 1 data was excluded from the analyses due to the close proximity of this station to rivermouths and lake outlets. Data from station 1 are discussed and compared in a subsequent section relating to the effects of rivers on Lake Michigan.

Physical and General Chemical Data

Temperatures ranged from 6.0 to 25.2°C. Mean lakewide surface temperature was 20.1°C, with a mean of 20.6°C at locations 1-11 on the eastern shore and 19.1°C at locations 12-16 on the north shore. A thermocline was generally found at the 20-25 m depth.

Dissolved oxygen values ranged from 7.7 to 12.2 mg/l. All values were greater than the minimum level required by Michigan's Water Quality Standards (6.0 mg/l). Values were normally near the 100% saturation level with slight reductions in some bottom samples.

Turbidity values ranged from less than 1 to 13 formazin turbidity units (FTU). Average location values ranged from 0.5 to 3.5 FTU with a lakewide average of 1.8 FTU. Measurements of water transparency were also made with a secchi disc. Secchi disc transparency ranged from 0.4 m at location 6 to 9.8 m at location 13. There was a general trend of increasing secchi disc reading from south to north, excluding Green Bay, with northern locations averaging 2 to 4 times greater transparency than locations in the southern lake. Secchi disc readings usually increased with distance from shore with these changes more obvious in the southern basin. Secchi disc readings were comparable to results reported by Schelske and Callender (1970) and Schelske and Roth (1973).

Average suspended solids values ranged from 1 mg/l at locations 13 and 14 to 9 mg/l at locations 7 and 15. Suspended solids values are partially reflected in turbidity and secchi disc readings. Suspended solids also showed a decrease from south to north, excluding Green Bay, indicating increased transparency in the northern section of the lake.

Total dissolved solids ranged from a mean of 147 mg/l at location 12 to 164 mg/l at location 3 with a lakewide average of 157 mg/l. These values were very close to the average summer values (154-156 mg/l) found by Powers and Ayers (1967).

Mean specific conductance ranged from 256 µmhos/cm at the Galein River (location 1) to 278 µmhos/cm at White Lake (location 8) with a lakewide average of 270 µmhos/cm. These values were similar to values reported by other authors (Torrey, 1976; Auer et al., 1976).

Mean chloride concentrations ranged from 7.6 mg/l at locations 13 and 14 to 9.1 mg/l at location 1 with a lakewide mean of 8.3 mg/l. These concentrations were higher than those found by Beeton and Moffett (1964) and correspond well with predicted increases of others (U.S. EPA, 1980). The concentration of chlorides has been reported as increasing in Lake Michigan over the past century with an acceleration in the rate of increase in the recent years (Beeton, 1965). Chloride sources include municipal and industrial effluents, atmospheric and tributary inputs. Several major Michigan industries discharging high salt concentrations recently reduced their salt inputs to Lake Michigan. However, road salt, which may account for 40 to 45% of the total chloride loadings to Lake Michigan has not decreased (U.S. EPA, 1980).

Average sulfate concentrations ranged between 19 to 24 mg/l with a lakewide mean of 22 mg/l. Results for both chlorides and sulfates were similar to concentrations reported by other authors (USDOI, 1968; Powers and Ayers, 1967; Torrey, 1976).

Mean sodium concentrations ranged from 4.2 to 5.0 mg/l with a lakewide mean of 4.5 mg/l. Potassium location means varied little, ranging from 0.9 to 1.4 mg/l with a lakewide mean of 1.0 mg/l. These values fell within the range of concentrations reported for Lake Michigan by Torrey (1976). Beeton (1965) concluded that sodium and potassium concentrations remained constant from 1907 to 1962.

Calcium and magnesium are the main elements comprising hardness in Lake Michigan. Calcium location means ranged from 31 to 37 mg/l as $CaCO_3$, with a lakewide average of 34 mg/l as $CaCO_3$. Concentrations were similar to Lake Michigan results reported by Torrey (1976). Magnesium concentrations were also very consistent throughout the lake with location means ranging from 12 to 14 mg/l and a lakewide mean of 12.5 mg/l. As with calcium, results were similar to other reported values (Copeland and Ayers, 1972; Industrial Bio-Test 1972; and Limnetics, 1974).

Hydrogen ion concentrations (pH) ranged from 7.8 to 8.9 pH units. The majority of values were between 8.4 and 8.8 pH units. Generally surface waters were more alkaline than bottom waters. These pH values were similar to values reported in other studies (Torrey, 1976). Alkalinity, an indirect measurement of the buffering capacity of water, averaged 107 mg/l as $CaCO_3$ throughout the lake while location means ranged from 99 mg/l at Naubinway (location 12) to 114 mg/l at the Grand River (location 6).

Total iron location means ranged from 10 to 188 mg/l with a lakewide mean of 87 mg/l. Two values, one each at locations 1 and 14, were greater than 300 µg/l, indicating possible exceedance of the Michigan Water Quality Standard for filterable iron (300 µg/l).

Chemical oxygen demand (COD) measurements ranged from 2.1 to 12.1 mg/l. Location means ranged from 4.2 to 9.4 mg/l with a lakewide mean of 6.8 mg/l. Most of the values reported by Torrey (1976) from various intakes in the southern lake basin were similar to these concentrations.

Total organic carbon (TOC) location means ranged from 1.6 to 3.7 mg/l with a lakewide mean of 2.2 mg/l. Concentrations of TOC decreased from south to north, except for Green Bay locations.

Nutrients and Chlorophyll a

Location means for nitrate plus nitrite ranged from 0.06 to 0.24 mg/l with a lakewide mean of 0.17 mg/l. These concentrations were slightly higher than most reported open lake summer values summarized by Torrey (1976). The values from locations 14-16 in Green Bay were considerably lower than concentrations elsewhere in Lake Michigan.

Total ammonia location means ranged from 0.002 to 0.016 mg/l with a lakewide average of 0.007 mg/l. Concentrations were highest in southern Lake Michigan and lowest in Green Bay. These values were similar to concentrations from previous studies summarized by Torrey (1976).

Organic nitrogen location means ranged from 0.15 mg/l at locations 10 and 11 to 0.32 mg/l at locations 15 and 16 with a lakewide average of 0.21 mg/l. These values were similar to results reported by USDOI (1968) and Robertson and Powers (1968). Highest concentrations of organic nitrogen were found in Green Bay along with the lowest concentrations of inorganic nitrogen (nitrate, nitrite and ammonia). Excluding the Green Bay locations, there was a general decrease in organic nitrogen concentrations from the southern to northern locations.

Mean total Kjeldahl nitrogen (TKN), the sum of organic nitrogen and ammonia nitrogen, ranged from 0.15 mg/l at locations 10 and 11 to 0.33 mg/l at location 15. As indicated, organic nitrogen concentrations were an order of magnitude greater than the ammonia concentrations. Since total Kjeldahl nitrogen was comprised primarily of organic nitrogen, TKN varied similar to organic nitrogen.

Total phosphorus concentrations ranged from 0.003 to 0.035 mg/l with a lakewide mean of 0.010 mg/l. Location means ranged from 0.005 mg/l at locations 10 and 11 to 0.016 mg/l at location 15. Concentrations were highest in Green Bay (locations 14-16); somewhat lower at the southern locations; and lowest at the northern locations 9-13. These results were similar to those summarized by Torrey (1976) for Lake Michigan.

Total orthophosphorus location means ranged from 0.001 to 0.005 mg/l with a lakewide average of 0.002 mg/l. Orthophosphorus concentrations followed a pattern similar to total phosphorus, with greatest concentrations at locations in Green Bay. Orthophosphorus concentrations were similar to those summarized for Lake Michigan by Torrey (1976).

Mean dissolved silica concentrations ranged from 0.2 mg/l at location 13 to 1.1 mg/l at location 2 with a lakewide mean of 0.6 mg/l. These concentrations were less than values reported in lakewide surveys by Beeton and Moffett (1964) and were greater than those found by Schelske and Callender (1970).

Mean chlorophyll a values ranged from 1.1 μg/l at location 13 to 4.8 μg/l at location 2. The lakewide mean value was 2.2 μg/l.

In summary, locations 9-13 had the greatest water clarity as indicated by secchi disc readings, total dissolved solids, suspended solids and turbidity, the least nutrients (nitrogen, phosphorus and silica), and the lowest phytoplankton productivity (chlorophyll a). Water quality at locations 1-8 was not as good as that at locations 9-13. Water clarity at locations 1-8 was reduced, while nutrient levels and chlorophyll a values increased. Reduced water quality was even more pronounced at locations 14-16. In addition to reduced water clarity and increased nutrients and chlorophyll a at locations 14-16, there was a reduction in inorganic nitrogen relative to the other locations. The nitrogen:phosphorus ratio at locations 14-16 was less than 15:1, indicating a nitrogen limited system (U.S. EPA, 1974a). Conditions deteriorated with distance into Green Bay. The Menominee River stations, furthest into Green Bay, had the lowest nitrogen:phosphorus ratios of all stations.

Effect of Rivers and Lake Outlets

Chemical constituents in the nearshore waters of Lake Michigan varied considerably among stations 1, 3 and 6 in 1976. Conductivity, chlorides, total phosphorus, chlorophyll a, alkalinity, chemical oxygen demand, total organic carbon, total dissolved solids, organic nitrogen, sodium, magnesium and calciu were generally higher at station 1 than stations 3 and 6. Nine of sixteen locations (1, 2, 4, 6-10 and 14) generally had higher concentrations at station 1 than at stations 3 and 6. This may reflect the influence of rivers at these locations. Available MDNR water chemistry monitoring data for July, 1976 for locations 2, 4, 6-10, and 14 (Table A-14 in the appendix) showed higher concentrations of the elevated constituents in the rivers than at station 1, implicating the rivers as the source of these constituents.

To analyze the effects of rivers the ratios of the mole percentages of major cations (calcium, magnesium, sodium) and anions (chloride, sulfate, biocarbonate) were plotted for all stations sampled in Lake Michigan (Figures 3 and 4). Generally, the cation composition in Lake Michigan was about 54% calcium, 33% magnesium and 13% sodium (Figure 3) while the anion composition was about 70% bicarbonate, 15% sulfate and 15%chloride (Figure 4). Distinct outliers were evident for station 1 samples from locations 4 and 6-10. These locations, especially location 10, had elevated percentages of Cl and Na, indicating the influence of rivers at station 1 at these locations.

Of the seven locations which exhibited no elevated constitutents at station 1, one location (Naubinway) had no rivermouth nearby. MDNR water chemistry monitoring data was available for three (locations 11, 13, 16) of

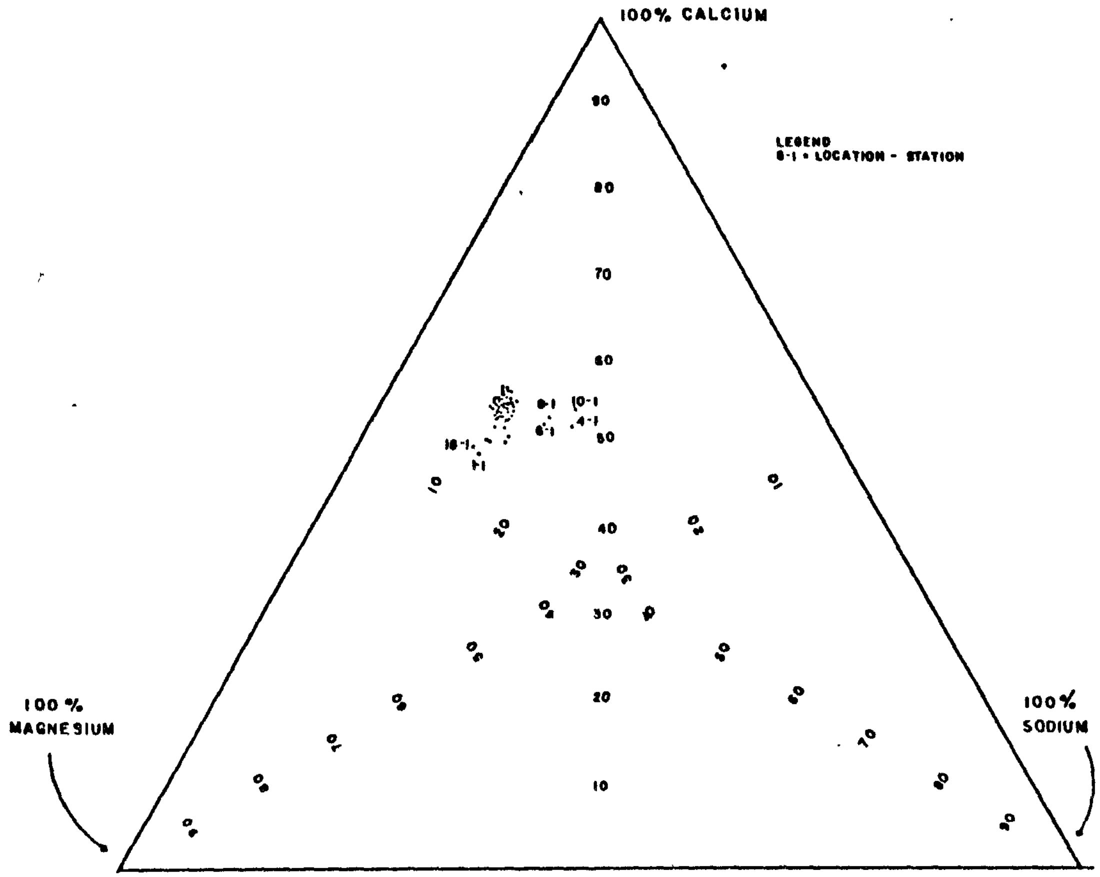


Figure 3. Mole percentages for major cations from surface water sampling, Lake Michigan, 1976.

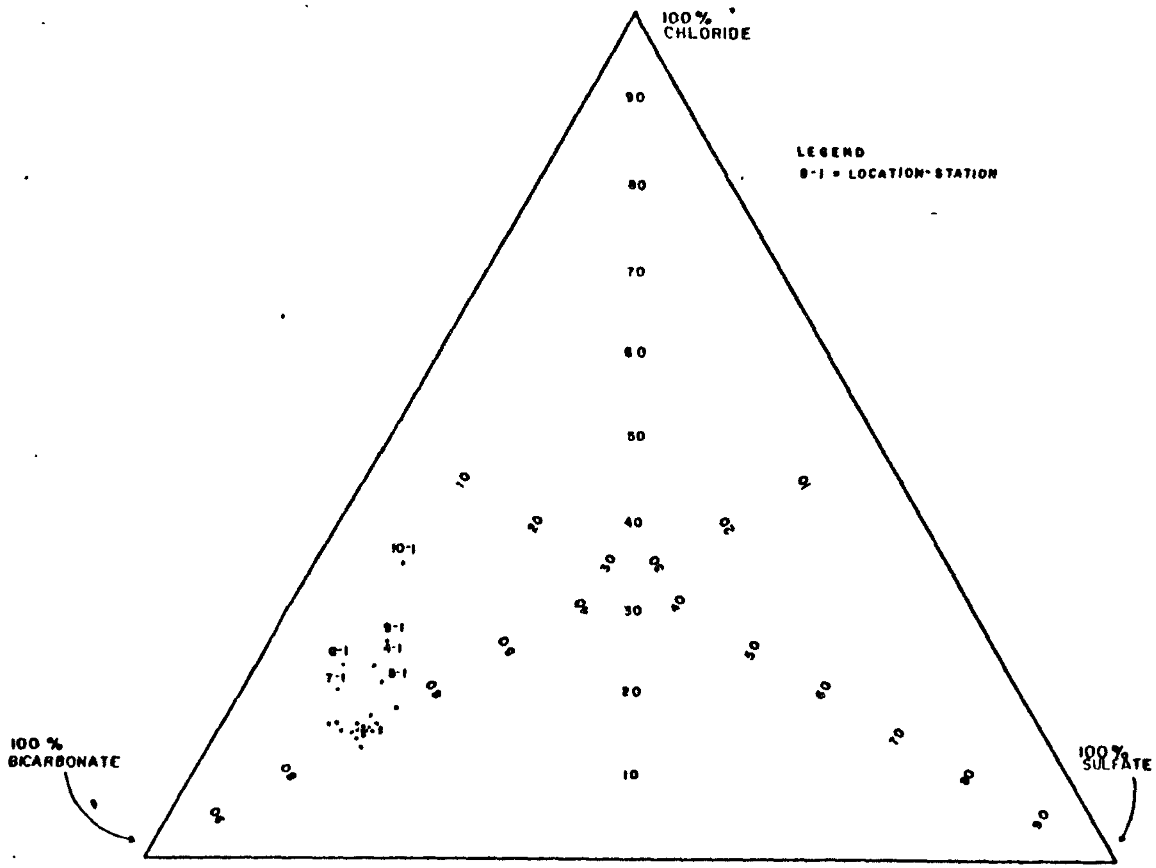


Figure 4. Mole percentages for major anions from surface water samples, Lake Michigan, 1976.

the remaining six locations. The available MDNR water chemistry monitoring data for July, 1976 indicated elevated concentrations of most constituents in the Betsie and Manistique Rivers (locations 11 and 13, respectively), relatively to nearshore Lake Michigan values, with no discernable difference in the Menominee River (location 16) (Table A-15). At Manistique, the Manistique River elevated concentrations of most constituents at station 9, situated in the harbor, but not at station 1, situated about 0.5 km southeast of the rivermouth.

The magnitude of impact upon Lake Michigan by a river largely depends on river volume and type of watershed. For example, large rivers with industrialized and urbanized watersheds have much greater impacts than smaller rivers with rural watersheds. The locations where station 1 constituents were most influenced by rivers were the St. Joseph, Kalamazoo and Grand Rivers, all of which are large rivers with industrialized and urbanized watersheds.

The influence of rivers did not extend very far into Lake Michigan. At the river-influenced locations, station 1 was less than 0.5 km from the rivermouth, while station 3, the station closest to station 1, was located between 2 and 4 km from the rivermouth. Since concentrations of most constituents were less at stations 3 and 6 than at station 1 and station 3 was not significantly different than station 6 ($P<0.01$), the influence on Lake Michigan rivers appeared to extend at least 0.5 km but less than 2 km from the rivermouth. Further, this influence appeared to be mainly confined to the surface. All river influenced locations exhibited elevated concentrations at the 1 m depth but not at the bottom, except for the Escanaba and Manistique locations. At these two locations, concentrations were elevated at the bottom depth but not at the 1 m depth, indicating subsurface river influence.

Trophic Status

Since impacts from rivers on Lake Michigan were not discernable beyond 0.5 km from the rivermouth, results from stations 3 and 6 at all locations were analyzed to assess lakewide trophic status. Dobson et al. (1974) defined trophic status in Great Lakes on the basis of nutrient levels, turbidity (secchi disc reading), and phytoplankton productivity (chlorophyll a values). Using the Dobson et al. (1974) criteria, locations 9-13 in central Lake Michigan were classified as oligotrophic, locations 1-8 in southern Lake Michigan mesotrophic and location 14-16 in Green Bay were mesotrophic, bordering on eutrophic (Table 1).

SEDIMENT

Physical Analysis

Medium to fine sand (0.10-0.50 mm diameter) was the major sediment component at all depths for locations on the eastern shore of Lake Michigan (locations 1-11) (Table A-7). At these locations medium to fine sand comprised over 80% by weight of the substrate at most stations. Since sediment particle size was very consistent at all depths, sufficient energy apparently existed

Table 1 Classification of 16 locations in Lake Michigan using Dobson et al. (1974) criteria for physical-chemical water characteristics. Criteria and mean concentrations calculated by pooling data from stations 3 and 6 for each location. The trophic classification is based on the following criteria:

Trophic classification	Secchi disc (m)	Chlorophyll *a* (μg/l)	Particulate Phosphorus (μg/l as P)
Oligotrophic (O)	>6.0	<4.4	<5.9
Mesotrophic (M)	3.0-6.0	4.4-8.8	5.9-11.8
Eutrophic (E)	<3.0	>8.8	>11.8

Location Mean	Secchi disc (m)	Chlorophyll a (μg/l)	Particulate Phosphorus (μg/l as P)	Other Notes	Approximate Trophic Classification
1	3.0(M)	1.2(O)	6(M)		M
2	3.8(M)	4.8(M)*	8(M)		M
3	0.9(E)	(no sample)	7(M)		M
4	4.0(M)	2.2(O)	5(O)		O/M
5	3.6(M)	3.2(O)	8(M)		M
6	1.6(E)	3.2(O)	8(M)		M
7	4.3(M)	2.2(O)	18(E)		M
8	4.0(M)	2.8(O)	8(M)		M
9	4.6(M)	2.6(O)	5(O)		O/M
10	7.0(O)	2.5(O)	3(O)		O
11	6.7(O)	2.4(O)	2(O)		O
12	7.0(O)	1.8(O)	6(M)		O
13	9.8(O)	1.1(O)	3(O)		O
14	4.2(M)	2.2(O)	13(E)	Reduction of inorganic Nitrogen	M
15	5.5(M)	1.8(O)	10(M)	Reduction of inorganic Nitrogen	M
16	3.2(M)	2.4(O)	10(M)	Reduction of inorganic Nitrogen	M

*September 16 value, all other values July and August, 1976 from wave-induced turbulence or alongshore currents to prevent the settling of the suspended particles at these locations. Exceptions of this trend were the predominant silty-clay substrates (<0.05 mm diameter) found at the St. Joseph River at the 30 m contour and the Black River at the 45 m contour situated 11 and 12 km offshore, respectively. The silty-clay substrates at these two locations indicated that sufficient depth was present to avoid wave-induced turbulence and distance from shore was adequate to avoid alongshore currents.

In contrast to the eastern shore, locations 12-16 on the northern shore of Lake Michigan had variable substrate types. Substrates at each of these locations were generally more diverse than at locations 1-11. Two general patterns of substrate composition were found: the locations in Green Bay (14-16) contained more silty-clay substrate while locations 12-13 outside of Green Bay were dominated by medium to fine sand.

The three locations in Green Bay, the Escanaba, Cedar and Menominee Rivers, all contained stations which were dominated by silty-clay substrates. It appears these bays generally reduce turbulence and currents thereby allowing settling of finer sediments from the water column. Silty-clay substrates were especially pronounced at the Escanaba River where four of the seven stations were dominated by silty-clay substrates. Since all stations at this location were situated within Little Bay De Noc at distances less than 2 km from shore, the Bay evidently reduced turbulence and currents at this location.

The Naubinway and Manistique River locations (locations 12 and 13) were generally dominated by medium to fine sand, similar to sediments along the eastern shore of Lake Michigan. The percentage of coarser sediments increased with some stations containing over 50% gravel. This may have been due to the many islands and submerged reefs in this area which contribute to localized turbulence and areas of gravel sediments. The Manistique harbor at stations 8-10 had a unique substrate composed primarily of wood chips. This substrate contained high percentages of organic matter (12-40%) due to the presence of wood chips in the substrate.

Chemical Analysis

The highest sediment concentrations of heavy metals, total Kjeldahl nitrogen (TKN), total phosphorus (TP), chemical oxygen demand (COD), and total organic carbon (TOC), were generally found within Green Bay (locations 14, 15, 16). The lowest concentrations of heavy metals, TKN, TP, COD and TOC were found at the Pere Marquette River, Manistee River and Betsie Lake locations (9-11). Concentrations nearly as low were found at the Galien and Manistique Rivers (outside of the harbor at stations 1-7).

Concentrations at station 1 were generally lower than the concentrations at other stations further offshore. Station 1 was the station most impacted by rivers, based on the water chemistry results. The general lack of sediment contamination at station 1 indicates that the contaminants entering via rivers were either dissolved in the water or attached to finer particles carried further offshore before deposition.

Total copper concentrations ranged from 0.1 to 71 mg/kg with most concentrations less than 10 mg/kg (Table A-9). Sediments at locations 3 (45 m) and 14 (15 m) were greater than 40 mg/kg, while the mean lakewide concentration, excluding these stations, was 3.5 mg/kg.

Total mercury concentrations ranged from <0.01 to 0.38 mg/kg. Highest concentrations were found at locations 3 (45 m) and 14 (6 and 15 m).

Total cadmium concentrations ranged from <0.1 to 3.7 mg/kg. Highest concentrations were found at locations within Green Bay (locations 14-16), where nine of twenty-one samples were greater than 1 mg/kg.

Total chromium concentrations ranged from 0.2 to 52 mg/kg. Sediments at locations 3 (45 m) and 14 (15 m) contained greater than 30 mg/kg, while the mean lakewide concentration, excluding these stations, was 4.6 mg/kg.

Total zinc concentrations ranged from 2.0 to 350 mg/kg. Sediments at locations 2 (30 m), 3 (45 m), 12 (20 m), 14 (15 m), and 16 (30 m) exceeded 90 mg/kg. Lowest concentrations were found at locations 9-11, where all values were less than 20 mg/kg.

Total nickel concentrations ranged from <0.1 to 140 mg/kg, with most concentrations less than 20 mg/kg. Concentrations were greatest within Green Bay at locations 14 (15 m), 15 (30 m), and 16 (30 m).

Total lead concentrations ranged from <0.2 to 190 mg/kg with most values less than 20 mg/kg. Concentrations were greatest at locations 3 (45 m) and 14 (15 m).

Total iron concentrations ranged from 610 to 140,000 mg/kg, with most values less than 7,000 mg/kg. Highest concentrations were found at location 15 (15 and 30 m). Concentrations were generally lower at locations 1-11 than locations 12-16.

Total manganese concentrations ranged from 3.3 to 47,000 mg/kg and were extremely variable. Lowest concentrations were found at location 1, with a location mean of 9 mg/kg. Highest concentrations were found at locations 15 and 16, with location means of 6930 and 9673 mg/kg, respectively.

Total Kjeldahl nitrogen (TKN) station concentrations ranged from 14 to 13,400 mg/kg. Mean concentrations were lowest at location 9 (41 mg/kg) and highest at location 14 (4471 mg/kg).

Total phosphorus (TP) concentrations ranged from 21 to 1900 mg/kg, with most concentrations less than 200 mg/kg. Highest concentrations were found at location 14, with a mean of 4471 mg/kg.

Chemical oxygen demand (COD) ranged from 480 to 460,000 mg/kg, with most values less than 10,000 mg/kg. Concentrations were greatest at locations 13 (within the breakwall) and 14 (6 and 15 m). Concentrations were generally lower on the eastern shore (locations 1-11) than the northern shore (locations 12-16).

Total organic carbon (TOC) concentrations ranged from 0.21 to 5 g/kg with a lakewide mean of 4.2 g/kg. Concentrations greater than 10 g/kg were found at locations 3 (45 m), 13 (6 m), 14 (6 and 15 m), and 16 (30 m). Lowest concentrations were found at locations 1, 8, 9, 10, and 11, where location means were all less than 1 g/kg.

Total volatile solids values ranged from 0.1 to 40%, with the vast majority of values less than 2%. Generally, higher values were found at locations 13 (6 m), 14 (15 m), and 16 (15 m).

Concentrations of hexane-extractable oils ranged from <10 to 3440 mg/kg, with concentrations generally less than 300 mg/kg (Table A-10). Concentrations were higher at north shore locations (12-14) than at eastern shore locations (1-11). Sediments at locations 2 (30 m) and 13 (6 m) contained the highest levels.

The pesticides dieldrin, chlordane, DDD, DDE, and DDT were not found in detectable concentrations except for DDT at locations 4 (4 stations, $\bar{x}$ = 6.1 µg/kg) and 8 (1 station at 7.4 µg/kg) (Table A-10).

Polychlorinated biphenyls (PCBs) were found only at locations 13 and 14 (Table A-10). Both areas of PCB contamination were located close to shore, indicating the rivers as the source of contamination. At location 13, sampling in 1977-78 (Kenaga, 1981) of fish and sediments showed that the source of PCBs was the Manistique Pulp and Paper Company.

Particle Size - Chemistry Relationship

Concentrations of heavy metals, TKN, TP, COD TOC and volatile solids generally increased with increasing percentages of fine sediment (<0.5 mm diameter) in the substrate. The concentrations of all parameters were highly correlated ($P<0.01$) with the percent silt/clay content of the sediment at the 15 and 30 m contour, except for lead (15 and 30 m), manganese (15 m) and iron (15 m) (Table 2). Mercury and cadmium were not included in the correlateions because most concentrations were below the level of detection. Concentrations also increased with increasing depth (Table A-9). This trend was especially pronounced where the percentage of fine sediments also increased, indicating an association between the settling of fine sediments, water depth and sediment concentration. The Escanaba River at the 15 m contour was an exception to this association since the 15 m contour sediments contained a high percentage (>44%) of fine materials. This location was well within Little Bay De Noc, which probably reduced the turbulence and allowed fine sediments to settle at this contour.

BENTHIC MACROINVERTEBRATES

General

A total of ninety taxa were identified from the sixteen locations sampled and these taxa consisted of 39 Oligochaeta, 25 Chironomidae, 6 Gastropoda,

Table 2 Correlation between selected chemical parameters and percent silt/clay composition of sediment at 16 locations, Lake Michigan, 1976.

Parameter	Number Sampled	Depth (m)	Correlation Coefficient (r)
Total Organic Carbon	15	15	*0.98
	16	30	*0.84
Total Volatile Solids	15	15	*0.91
	15	30	*0.73
Chemical Oxygen Demand	16	15	*0.98
	15	30	*0.89
Total Phosphorus	16	15	*0.79
	16	30	*0.86
Total Kjeldahl Nitrogen	16	15	*0.98
	16	30	*0.80
Total Solids	15	15	*0.99
	15	30	*0.89
Iron	16	15	0.28
	16	30	*0.70
Manganese	16	15	0.06
	16	30	*0.65
Copper	16	15	*0.98
	16	30	*0.87
Chromium	16	15	*0.96
	16	30	*0.82
Lead	16	15	0.24
	16	30	0.30
Nickel	16	15	*0.96
	16	30	*0.77
Zinc	16	15	*0.96
	16	30	*0.78

*Highly significant correlation ($P \leq 0.01$)

3 Pelecypoda and Amphipoda, 2 Hirudinea, Ephemeroptera, Coleoptera, and Trichoptera, and 1 Mysidacea, Isopoda, Turbellaria, Nematoda, Polychaeta and Corixidae. The mean number of taxa per station was 9 with a range from 0 to 26.

The lakewide mean number of organisms was $4012/m^2$ with location means ranging from 979 to $8943/m^2$. Pontoporeia hoyi was the most abundant taxon found, averaging $2846/m^2$ lakewide with location means ranging from 96 to $5565/m^2$. Oligochaetes were the next most abundant group, averaging $672/m^2$ lakewide with location means ranging from 71 to $1700/m^2$. Oligochaetes were primarily represented by Limnodrilus hoffmeisteri and Stylodrilus heringianus.

The abundance, diversity and distribution of benthic macroinvertebrates is dependent on various factors including water depth, turbulence, temperature, sediment composition, light intensity, chemical composition of water and sediment, availability of food, and interspecific and intraspecific behavior. Oftentimes these factors are interrelated such that it is impossible to identify the effect of each factor on abundance, diversity and distribution. To delineate the relative importance of factors influencing the benthic macroinvertebrate community, the influence of substrate composition, water depth, sediment chemistry, distance from shore and river influence upon the benthic macroinvertebrate communities were examined in this report.

Although it has been difficult to determine specific physical-chemical influences, benthic species composition, abundance and distribution have been used as indicators of lake quality in Lake Michigan (Brinkhurst, 1974; Mozley and Howmiller, 1977). These authors found changes in the oligochaete community which they related to lake quality. They found communities dominated by Stylodrilus heringianus in high quality which changed to communities dominated by Aulodrilus spp. and Peloscolex ferox in moderately degraded lake quality and Limnodrilus hoffmeisteri dominated communities in severely polluted waters. In this report, relative abundance of oligochaetes and other taxonomic groups, particularly Pontoporeia hoyi and oligochaete community species composition, were used as primary indicators of lake quality.

Effect of Substrate

Substrate composition definitely affected benthic macroinvertebrate species diversity, density and distribution. When substrates were similar, benthic macroinvertebrate communities were also similar. As discussed in the sediment section, substrate composition was primarily medium and fine sand (0.1-0.5 mm diameter) at all locations on the eastern shore of Lake Michigan (locations 1-11). At these locations there were no differences in the composition and abundance of benthic macroinvertebrate communities at the 30 m contour. Differences in community composition at the 6 and 15 m contours were not related to changes in substrate composition because the substrate composition did not vary greatly.

The greatest influence of the medium and fine sand substrates on the benthic community was found at locations 9-11, where substrate was least variable. The highly uniform sandy substrate at these locations resulted in fewer organisms and the lowest average number of taxa per station (5). These findings were expected since sand is considered the poorest benthic macroinvertebrate habitat (Hynes, 1970). Since these locations had the best water quality (high clarity, well oxygenated, low nutrients and primary productivity) and no sediment contamination, substrate composition appeared to be the limiting factor for the benthic community.

As substrate became more diverse at the northern shore locations (12-16), benthic macroinvertebrate communities also became more diverse. The number of taxa increased to an average of 14 per station versus 7.5 per station at locations 1-11. Location 12 (Naubinway) had the highest mean number of taxa per station (22), the most total taxa (48) and one of the most diverse substrates.

Some authors have found increases in benthic macroinvertebrate numbers associated with increases in finer sediments in Lake Michigan (Mozley and Alley, 1973). In this project, abundance did not always increase with increasing silt and clay content. High numbers or organisms were generally associated with increased amounts of silt and clay in the substrate. The substrates with the greatest amounts of silt and clay (St. Joseph River location, stations 5-7; Escanaba River location, stations 2-4), however, did not have the highest numbers of organisms.

Since Pontoporeia hoyi was the most abundant benthic organism found at most stations, the relationship between P. hoyi abundance and substrate type was examined. Both P. hoyi abundance and percent silt/clay content of the substrate generally increased with depth, suggesting a relationship between these variables. At seven of the sixteen locations, increases in P. hoyi abundance correlated significantly ($P<0.05$) with increases in the percent silt/clay content of the substrate (Table 3). At six of the seven locations, significant ($P<0.05$) positive correlations were also found between P. hoyi and total organic carbon concentration in the substrate (Table 3). Fine sediments rich in organic matter may serve as food for benthic organisms. However, large proportions of the organic matter in Great Lakes sediment were found to be composed of barely digestible humic acids and kerogen (Kemp, 1969).

Oligochaete abundance was also significantly positively correlated ($P<0.05$) with the silt/clay content of the substrate at seven locations (1, 4-7, 13, 15). Oligochaete abundance was significantly ($P<0.05$) correlated with both TOC concentrations and silt/clay content of the substrate at four locations (4-7). At four locations (5-7 and 15), similar increases in Pontoporeia hoyi abundance occurred, indicating that substrates may have been a primary factor controlling abundance at these locations. At five of the seven locations (1, 4-7), the oligochaete community was dominated by Stylodrilus heringianus.

Both Pontoporeia hoyi and oligochaete abundances were significantly negatively correlated ($P<0.05$) with medium to fine sand (0.1-0.5 mm) at seven locations (Table 3). At four of the seven locations (4-6, 13) oligochaetes were negatively correlated with medium to fine sand and positively correlated with the silt/clay content. Similar results were found for P. hoyi at four locations (2, 5, 6, 8). At two locations (5, 6) similar correlations existed for both P. hoyi and oligochaetes, indicating substrate to be a primary

Table 3

Correlation coefficients of selected variables with *Pontoporeia hoyi* and oligochaete abundance at 16 locations, Lake Michigan, 1976.

Location Number:	1		2		3		4		5		6		7		8	
Location:	Galien River		St. Joseph River		Black River		Kalamazoo River		Lake Macatawa		Grand River		Muskegon Lake		White Lake	
	Pontoporeia hoyi	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes
Variable																
Depth	0.85^{+}	0.72	0.83^{+}	0.69	0.48	0.41	0.77^{+}	0.80^{+}	0.92^{++}	0.94^{++}	0.93^{++}	0.92^{++}	0.98^{++}	0.97^{++}	0.98^{++}	0.83^{+}
Percent Gravel	0.54	0.04	0.10	0.08	-0.26	-0.83^{--}	0.68	0.26	-0.63	-0.45	-0.20	-0.13	0.92^{++}	0.99^{++}	0.65	0.80^{+}
Percent Medium Sand	-0.54	-0.71	-0.82^{-}	-0.52	0.09	0.01	-0.80^{-}	-0.97^{--}	-0.94^{--}	-0.94^{--}	-0.81^{-}	-0.78^{-}	-0.48	-0.69	-0.87^{-}	-0.45
Percent Fine Sand	0.45	0.63	-0.51	-0.16	-0.19	0.26	0.74	0.97^{++}	0.90^{++}	0.82^{+}	0.71	0.67	-0.04	0.23	0.76^{+}	0.33
Percent Silt	-0.53	0.07	0.92^{++}	0.51	0.30	0.15	0.75	0.85^{+}	0.95^{++}	0.90^{++}	0.99^{++}	0.99^{++}	0.80^{++}	0.93^{++}	0.66	0.35
Percent Clay	0.51	0.81^{+}	0.88^{++}	0.48	0.27	0.16	0.51	0.74	0.92^{++}	0.89^{++}	0.99^{++}	0.99^{++}	0.89^{++}	0.97^{++}	0.99^{++}	0.74
Sediment Total Kjeldahl Nitrogen Conc.	0.88^{++}	0.88^{++}	0.77^{+}	0.53	0.24	0.13	0.18	0.57	0.84^{+}	0.91^{++}	0.99^{++}	0.97^{++}	0.86^{++}	0.96^{++}	0.94^{++}	0.71
Sediment Total Phosphorus Conc.	0.88^{++}	0.80^{+}	0.80^{+}	0.58	0.22	0.17	0.79^{+}	0.89^{++}	0.94^{++}	0.92^{++}	0.99^{++}	0.98^{++}	0.86^{+}	0.92^{++}	0.99^{++}	0.75
Sediment COD Conc.	0.89^{++}	0.85^{+}	0.93^{++}	0.51	0.18	0.12	0.47	0.73	0.95^{++}	0.90^{++}	0.99^{++}	0.97^{++}	0.92^{++}	0.98^{++}	0.96^{++}	0.68
Sediment TOC Conc.	0.84^{+}	0.70	0.91^{++}	0.54	0.30	0.19	0.73	0.82^{+}	0.95^{++}	0.89^{++}	0.99^{++}	0.97^{++}	0.92^{++}	0.99^{++}	0.85^{+}	0.55

++ = Significant positive correlation at $P \leq 0.01$
\+ = Significant positive correlation at $P \leq 0.05$
-- = Significant negative correlation at $P \leq 0.01$
\- = Significant negative correlation at $P \leq 0.05$

Table 3 (continued)

Location Number:	9		10		11		12		13		14		15		16	
Location:	Pere Marquette River		Manistee Lake		Betsie Lake		Naubinway		Manistique River		Escanaba River		Cedar River		Menominee River	
Variable	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes	*Pontoporeia hoyi*	Oligochaetes
Depth	0.74	0.65	0.94^{++}	0.76^{+}	0.79^{++}	0.68^{+}	0.80^{+}	0.61	-0.40	0.52	0.55	0.67	0.89^{++}	0.42	0.71	-0.06
Percent Gravel	-0.03	0.56	-0.69	-0.56	0.68^{+}	0.75^{+}	0.20	-0.24	-0.07	0.09	0.71	0.67	-0.66	-0.96^{--}	-0.37	-0.37
Percent Medium Sand	0.30	0.75	-0.92^{--}	0.82^{-}	0.63	0.71^{+}	-0.19	0.53	0.36	-0.80^{--}	0.49	0.56	-0.74	-0.95^{--}	-0.50	0.43
Percent Fine Sand	-0.21	-0.71	-0.39	-0.32	-0.67^{-}	-0.75^{-}	-0.20	-0.04	-0.19	0.50	-0.55	-0.63	-0.56	-0.07	-0.38	0.67
Percent Silt	0.00	0.00	0.00	0.00	0.39	0.07	0.06	0.07	-0.36	0.62	-0.29	-0.27	0.99^{++}	0.78^{+}	0.93^{++}	-0.53
Percent Clay	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.40	-0.51	0.67^{+}	-0.37	-0.24	0.88^{++}	0.75	0.91^{++}	-0.58
Sediment Total Kheldahl Nitrogen Conc.	0.95^{++}	0.32	0.91^{++}	0.71	0.47	0.26	-0.13	-0.47	-0.48	0.77^{++}	0.12	-0.54	0.95^{++}	0.66	0.41	0.11
Sediment Total Phosphorus Conc.	0.41	-0.41	0.98^{++}	0.82^{+}	-0.18	-0.38	0.34	-0.28	-0.43	0.82^{++}	-0.02	-0.23	-0.23	-0.70	0.50	0.08
Sediment COD Conc.	0.81^{+}	0.49	0.92^{++}	0.74	0.61	0.25	-0.32	-0.36	-0.50	0.55	-0.10	-0.38	0.88^{++}	0.63	0.19	0.08
Sediment TOC Conc.	0.22	0.29	0.91^{++}	0.72	0.40	0.02	-0.66	0.03	-0.55	0.47	-0.18	-0.60	0.90^{++}	0.59	0.66	-0.24

++ = Significant positive correlation at $P \leq 0.01$
\+ = Significant positive correlation at $P \leq 0.05$
-- = Significant negative correlation at $P \leq 0.01$
\- = Significant negative correlation at $P \leq 0.05$

determining factor at these locations.

Effect of Depth

Average benthic macroinvertebrate abundance increased with depth at all locations except Manistique, primarily due to increases in Pontoporeia hoyi (Figure 5). The numbers of P. hoyi were significantly positively correlated ($P<0.05$) with depth at 11 of 16 locations (Table 1), attesting to the influence of depth on this species' distribution.

The pattern of community composition and abundance found at the various depths agreed well with patterns described by Mozley and Howmiller (1977). Station 1 averaged 6 m in depth over the 16 locations in this project and was comparable to Mozley and Howmiller's (1977) first zone (0-8 m). The community at station 1 was dominated by chironomids and oligochaetes at all locations except the Grand River location which was dominated by Pontoporeia hoyi. Numbers of organisms were variable between 0 (location 2) and 2415/m^2 (location 15) and were most often less than the number found at the deeper stations (2-7). The lower numbers reflected the harsh conditions present in this shallow zone.

Stations 2-4 were located at approximately the 15 m contour, comparable to Mozley and Howmiller (1977) second zone (8-25 m). Abundance at stations 2-4 were usually greater than at station 1 and the communities were generally dominated by Pontoporeia hoyi. Abundance and composition were less variable at stations 2-4 than at station 1.

Stations 5-7, located at the 30 m contour, and stations 8-10 at 45 m (locations 3 and 11 only), were within Mozley and Howmiller's (1977) 24-54 m zone. These deeper stations had greater abundance than stations 1-4 and relatively stable species composition. Pontoporeia hoyi numerically dominated most samples while Stylodrilus herringianus was the predominant oligochaete found in this zone.

Since consistent changes in benthic community composition were found with depth, depth was a major factor in determining the types and abundances of nearshore macroinvertebrates in Lake Michigan.

Effect of Sediment Chemistry

On the eastern shore where substrates were generally similar, no impacts were detected from elevated heavy metal concentrations in the sediments. Generally, a macroinvertebrate community has fewer taxa and lower abundance when impacted by a toxicant (Hynes, 1960; Warren, 1971). Neither the number of taxa nor abundance were reduced at the stations which contained elevated heavy metal concentrations, indicating no toxicity from these sediments.

On the north shore, four of the five locations contained sediments with elevated levels of heavy metals at either the 15 m or 30 m contour. At the

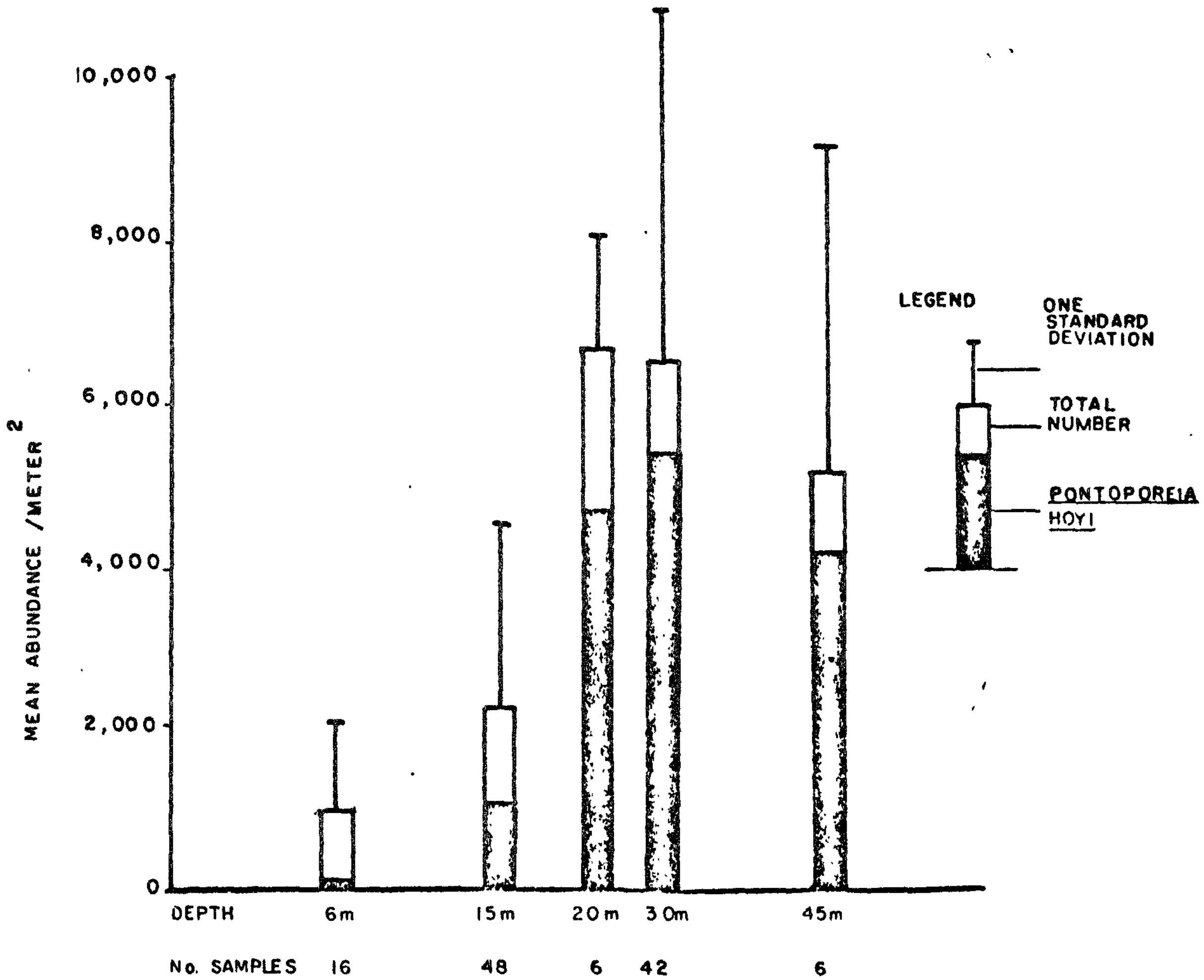


Figure 5. Average abundance of benthic macroinvertebrates and *Pontoporeia hoyi* versus depth, Lake Michigan, 1976.

30 m contour at location 12, stations 5 and 7 contained elevated levels of manganese, iron, zinc and nickel. Essentially no differences in benthic macroinvertebrate composition, abundance of diversity were found among stations 5, 6 and 7 at location 12, indicating no toxicity from these sediments. Minimal impacts from heavy metal concentrations may have occurred at locations 14 (15 m), 15 (30 m) and 16 (30 m). At these locations abundance of Limnodrilus sp. plus immature tubificids without hair setae (possible Limnodrilus) increased. Wentsel (1977) examined sediment contamination and benthic macroinvertebrate abundance in an Indiana lake and found that Limnodrilus spp. were relatively abundant in the most heavily impacted areas of the lake. However, concentrations of heavy metals were roughly twenty times higher than concentrations present at locations 14-16. Although Limnodrilus abundance increased, total abundance, composition and diversity was not dramatically different, indicating only slight effects from these heavy metal concentrations.

Concentrations of nutrients in sediments (TKN, TP or TOC) were positively correlated($P \leq 0.05$) with Pontoporeia hoyi and oligochaete numbers at ten and seven locations respectively (Table 3). However, of the four locations (3, 14-16) which contained the highest nutrient concentration, three locations (3, 14, 16) had no significant ($P \leq 0.05$) correlation between TKN, TP or TOC and P. hoyi or oligochaete numbers.

Distance from Shore

For stations located at similar depths but at different distances from shore, those stations closest to shore generally contained fewer organisms (Table 4). Benthos abundance was quite variable at these stations and may have been influenced by other factors such as depth, upwelling, or geographical location. Alley and Mozley (1975) had similar results and they concluded that the impacts of distance from shore were minor realtive to other factors. The close interrelationship between substrate composition and distance from shore was pointed out for locations 2 and 3 in the Sediment (Physical Analysis) Section. Distance from shore was an influencing factor at some locations, but was considered overall to be a minor factor influencing benthos.

Influence of Rivers

As noted in the Water Sampling Section, station 1 at locations 1, 2, 4, 6-10, and 14 were considered to be influenced by rivers. The macroinvertebrate results from station 1 were not consistently different between locations influenced by rivers and locations that were not. Variations in numbers at station 1 were extreme, with abundance ranging from $2415/m^2$ at the Cedar River location to 0 organisms/m^3 at the St. Joseph River location.

Station 1 communities were more variable in composition and abundance than communities at other stations, perhaps indicating the effects on station 1 of the turbulent zone and rivers combined. However, no conclusions could be drawn concerning the impact of rivers due to this variability and the lack of

Table 4 — Mean benthic macroinvertebrate abundance versus distance from shore at 16 locations, Lake Michigan, 1976.

Depth	Distance from shore (km)	# organisms/m² ($\bar{x}$ ± 1 std. deviation)	No. of samples
15 m	1.5-2.0	1748 ± 678	9
	2.5-3.0	2428 ± 2392	27
	3.5-4.0	2404 ± 2487	12
20 m	6	5836 ± 273	3
	20	7566 ± 1547	3
30 m	2	2409 ± 262	3
	4- 6	8299 ± 3391	15
	6.5- 8	6357 ± 2790	12
	10.5-13	5714 ± 5994	12
45 m	5	3746 ± 1276	3
	12	6724 ± 5652	3

replicate samples in this zone.

Assessment of Lake Quality

Substrate composition was decidedly different between locations 1-11 and locations 12-16. Other factors, such as geographical location and orientation to prevailing winds, were also different between these groups of locations. Therefore, comparisons of benthic macroinvertebrate communities were made within locations 1-11 and 12-16 to assess lake quality. Further, due to the variability encountered in communities at the 6 m contour and the lack of replicate samples at this depth, only the communities at the 15 and 30 m contour were considered in this assessment.

Eastern Shore (locations 1-11)

At stations greater than or equal to 30 m in depth, the amphipod *Pontoporeia hoyi* was the numerically dominant benthic macroinvertebrate at all locations with *Stylodrilus heringianus* the numerically dominant oligochaete. This assemblage has been typically associated with good lake quality in Lake Michigan (Mozley and Howmiller, 1977), thereby indicating good lake quality at the 30 m contour throughout the lake's eastern nearshore waters.

At the 15 m contour different benthic macroinvertebrate communities were found between locations. Oligochaetes, especially *Limnodrilus hoffmeisteri*, increased in importance at locations 1-3 in the southern end of Lake Michigan. At these three southern locations, oligochaetes averaged $595/m^2$ which was 34% of the total macroinvertebrate numbers. At locations 4-11 oligochaete numbers decreased to $215/m^2$ which was 15% of the total numbers. Correspondingly, *Pontoporeia hoyi* decreased from an average of 75% of the macroinvertebrate numbers at locations 4-11 ($\bar{x} = 1224/m^2$) to an average of 48% at locations 1-3 ($\bar{x} = 1080/m^2$). This pattern agreed well with the findings Alley and Mozley (1975) reported in their lakewide study.

Most of the increase in oligochaete numbers was through increases in *Limnodrilus hoffmeisteri* and immature tubificids without hair setae. The immature tubificids without hair setae include all *Limnodrilus* species, *Pontamothrix moldaviensis*, *Peloscolex freyi* and perhaps very small numbers of other taxa. Since *L. hoffmeisteri* was the numerically dominant form, *L. hoffmeisteri* and immature tubificids without hair setae were grouped together for comparative purposes and termed "probable" *L. hoffmeisteri* (Figure 6). Probable *L. hoffmeisteri* increased to 87% ($519/m^2$) of the oligochaete community at locations 1-3 versus 56% ($120/m^2$) at locations 4-11. Correspondingly, probable *L. hoffmeisteri* increased to 25% of the total macroinvertebrate community numerically at locations 1-3 from 7% at locations 4-11. Probable *L. hoffmeisteri* reached their greatest abundance at location 3 ($886/m^2$) but were numerically dominant only at location 2. At location 2, they comprised 36% ($443/m^2$) of the macroinvertebrate community, versus 31% of *Pontoporeia hoyi*, the next most abundant form.

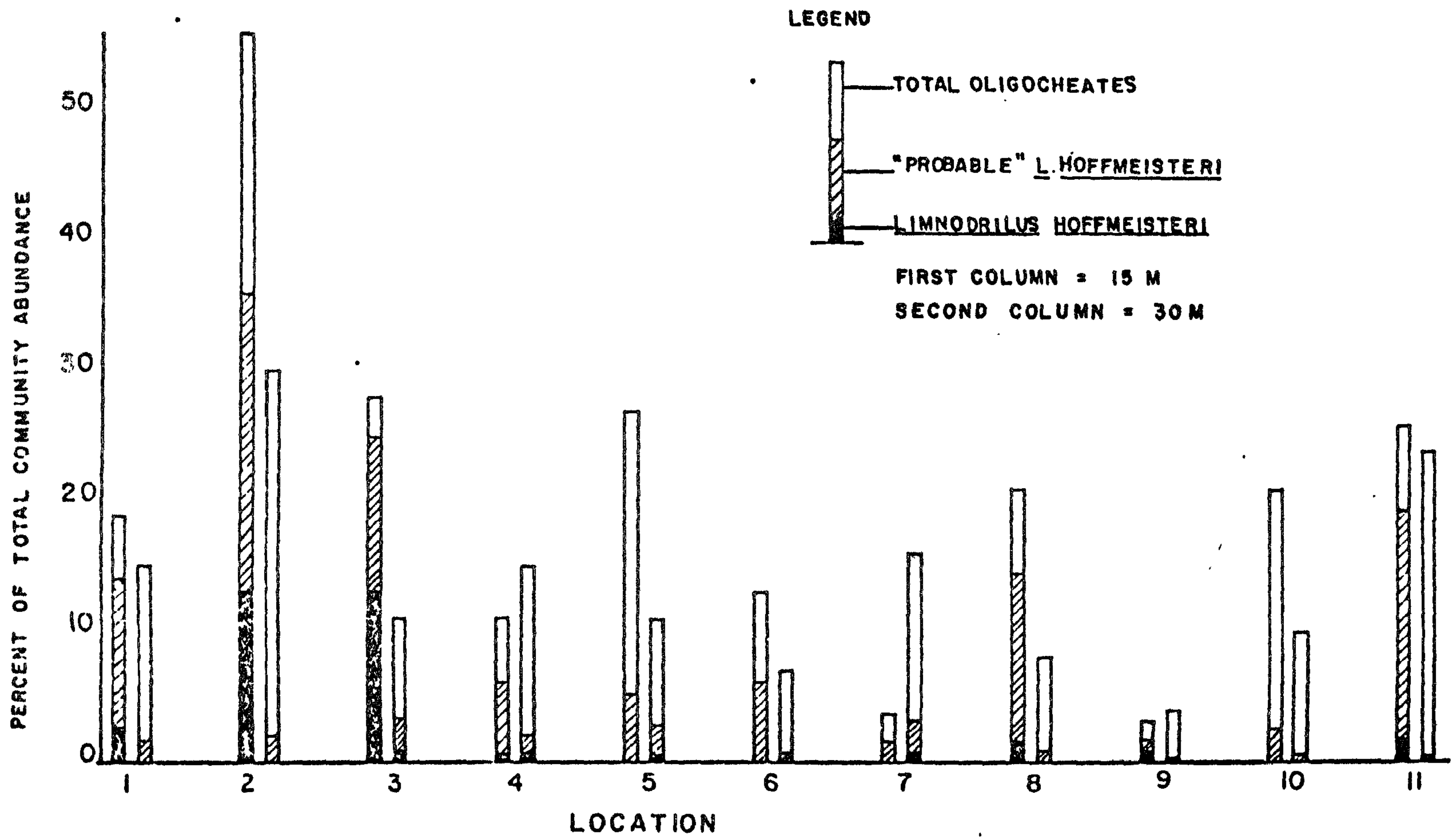


Figure 6. Percent Oligochaeta at 11 locations, Lake Michigan, 1976.

This pattern of replacement of Pontoporeia hoyi by oligochaetes, especially Limnodrilus hoffmeisteri, has been shown to indicate organic enrichment (Howmiller and Beeton, 1970; Mozley and Howmiller, 1977). Since substrate was remarkably uniform among these locations and other factors appear negligible, the benthic macroinvertebrate communities at the 15 m contour indicated degraded lake quality from organic enrichment in southern Lake Michigan. The greatest enrichment was noted at the St. Joseph River location.

Two other locations, White Lake and Betsie Lake (locations 8 and 11, respectively), on the eastern shore of Lake Michigan exhibited similar organic enrichment at the 15 m contour. At these two locations, the abundance of oligochaetes increased to an average of $424/m^2$, compared to the average of $145/m^2$ at locations 4-7 and 9-10. This increased abundance was mainly due to increased numbers of Limnodrilus spp. and immature tubificids without hair setae. Probable Limnodrilus spp. comprised 16% of the macroinvertebrate numbers at location 8 and 25% at location 11, compared to an average of 4% at locations 4-7 and 9-10. Even though oligochaete abundance increased at locations 8 and 10, their proportions of the total macroinvertebrate community did not increase relative to locations 4-7 and 9-10 (Figure 6). Although oligochaetes did not replace Pontoporeia hoyi at locations 8 and 11, the change in oligochaete community composition to dominance by Limnodrilus spp. indicated slight organic enrichment, according to previous work in Lake Michigan by Howmiller and Beeton (1970), Mozley and Howmiller (1977), Brinkhurst (1974) and Hiltunen (1967). The source of enrichment found at locations 8 and 11 was unknown. As discussed in the Water Section, impacts from rivers were found at location 8 but not at location 11. Therefore, the benthic community at these two locations indicated isolated cases of slight organic enrichment.

In conclusion, the nearshore portions of Lake Michigan's eastern shoreline were organically enriched at the southern locations from the Galein River to Black River, with improved lake quality from the Kalamazoo River to Betsie Lake except for isolated instances of slight organic enrichment at the White Lake and Betsie Lake locations. All signs of enrichment were noted only at the 15 m contour and not at the 30 m contour, indicating that the effects were localized nearshore.

Northern Shore (locations 12-16)

Although locations 1-11 and 12-16 were not compared to assess lake quality, a general comparison was made to evaluate benthic community differences. As pointed out in the Sediment (Physical Analysis) Section, more taxa on a per station basis were found at locations 12-16, perhaps in response to the increased diversity of substrate composition. Different macroinvertebrate forms were also consistently found at the north shore locations. The tubificid oligochaetes Peloscolex ferox and Aulodrilus spp., the isopod Asellus, and the chironomids Tanytarsus and Procladius were well represented at locations 12-16 but were sparse to non-existent at locations 1-11. Chrionomid numbers also increased greatly at the north shore locations to an average of $470/m^2$ from $62/m^2$ at locations 1-11.

In general, based on the benthic macroinvertebrate results, lake quality at the north shore locations declined from east to west with the worst quality within Green Bay (locations 14-16) and Manistique harbor.

The Naubinway location contained the most diverse macroinvertebrate community, averaged 21 taxa per station, and was dominated by Pontoporeia hoyi at the 15 and 30 m contours. Oligochaete communities at this location were dominated by Peloscolex ferox and Stylodrilus heringianus. As earlier noted, benthic macroinvertebrate communities dominated by P. hoyi and S. heringianus in Lake Michigan indicate good lake quality with little organic enrichment present (Mozley and Howmiller, 1977). The fairly high numbers of P. ferox found may indicate some organic enrichment. This oligochaete is generally found in mesotrophic or slightly enriched conditions (Brinkhurst, 1974; Mozley and Howmiller, 1977; Howmiller and Beeton, 1970). Howmiller and Beeton (1970) and Brinkhurst (1969) also concluded that P. ferox preferred sediments with a large sand component while avoiding more organic sediments and heavily polluted areas. Therefore, the macroinvertebrate community dominated by Pontoporeia hoyi, S. heringianus, and P. ferox at Naubinway indicated good lake quality that may be slightly enriched. As previously discussed in the Water Section, this location would be classified as oligotrophic based on criteria presented by Dobson et al. (1974).

The Manistique location was dominated by oligochaetes or chironomids at all stations. The 15 m contour was numerically dominated by chironomids (63%), mainly Heterotrissocladius. Average abundance for stations 1-4 ($981/m^2$) was similar to comparable samples taken by Willson (1969) in August, 1968 ($1262/m^2$). However, Willson (1969) found the benthic macroinvertebrate communities numerically dominated by Pontoporeia hoyi which averaged 50% of the community. P. hoyi was the second most numerically abundant form at 15 m in this survey ($89/m^2$), but comprised only 16% of the community.

The 30 m contour at Manistique had lower numbers of benthic macroinvertebrates ($\bar{x} = 716/m^2$) than other north shore locations at this contour (range of means 2409 to $12{,}393/m^2$). The community at this depth was dominated numerically by Stylodrilus heringianus (31%) and Pontoporeia hoyi (27%), organisms typically associated with good lake quality (Mozley and Howmiller, 1977). Since the sediment and water chemistry results indicated no evidence of contamination, the reason for the reduced abundance at this depth was unknown.

Conditions within Manistique harbor (stations 8, 9, 10) were distinctly different than at the other stations. The macroinvertebrate community was dominated numerically by oligochaetes (67%), mainly Limnodrilus hoffmeisteri and immature tubificids without hair setae. Chironomids were the next most abundant group, comrpising 27% of the community with Chironomus the dominant chironomid form. This assemblage of macroinvertebrates dominated by pollution-tolerant oligochaetes and chironomids indicates degraded conditions in Manistique harbor. Since a similar pollution-tolerant macroinvertebrate assemblage was not found outside the harbor breakwater, the impacts did not extend into Lake Michigan. Willson (1969) also concluded that little impact was discernable outside of Manistique harbor.

Benthic macroinvertebrate communities at location 14 (Escanaba River) were numerically dominated by oligochaetes at both the 15 and 30 m contours. Limnodrilus hoffmeisteri plus immature tubificids without hair setae (probable L. hoffmeisteri) were the dominant forms at 15 m. These organisms averaged $473/m^2$ and comprised 29% of the benthos while Pontoporeia hoyi averaged $441/m^2$ and comprised 27%. The tubificid Aulodilus pluriseta and the chironomid Procladius were also abundant at this location. The replacement of P. hoyi and Stylodrilus heringianus by probable L. hoffmeisteri forms indicated organic enrichment and degraded conditions. The impacts appear moderate since P. hoyi was still present, as was Aulodrilus pluriseta, a taxon generally not tolerant of severe pollution (Brinkhurst, 1969, 1974; Howmiller and Beeton, 1970).

At 30 m, the benthic macroinvertebrate community was dominated by oligochaetes and Peloscolex ferox replaced Limnodrilus hoffmeisteri as the numerically dominant form (25%). This community resembled the 30 m community at Naubinway in that Pontoporeia hoyi, Stylodrilus herringianus, and P. ferox were the numerically major forms. The high numbers of Aulodrilus pluriseta and Asellus here may reflect the impacts of the embayment since these forms were only found in abundance at other locations at the 15 m contour.

The benthic macroinvertebrate communities at location 14 indicated degraded and enriched lake quality, with effects lessening at the 30 m contour. Based on the water physical-chemical criteria established by Dobson et al. (1974), this location was classified as mesotrophic, approaching eutrophic which was consistent with the benthic macroinvertebrate results.

The Cedar River and Menominee River, locations 15 and 16, respectively, exhibited classical signs of eutrophication with large increases in numbers of benthic macroinvertebrates especially at the 30 m contour. There were shifts to an oligochaete community dominated by Aulodrilus pluriseta and Peloscolex ferox at 6 and 15 m contours and Limnodrilus hoffmeisteri at the 30 m contour. Stylodrilus heringianus was replaced by these forms, indicating enriched conditions. Howmiller and Beeton (1970) predicted that increased eutrophication of Green Bay would result in S. herringianus being replaced by Aulodrilus americanus, P. ferox and Potamothrix moldaviensis. The results of this survey agree well with their predictions. Based on the water physical-chemical criteria established by Dobson et al. (1974), this area was classified as mesotrophic, approaching the eutrophic category, which agrees with the benthic macroinvertebrate results.

In conclusion, locations along the north shore declined in lake quality from Naubinway to Green Bay, with the poorest quality within Green Bay and Manistique harbor. Locations within bays (14-16) were worse in quality than those not in bays. The benthic macroinvertebrate communities indicated oligotrophic conditions at location 12 (Naubinway) with perhaps slight enrichment, while communities at locations 14-16 indicated mesotrophic conditions, approaching eutrophic conditions.

SECTION VI

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A P P E N D I C E S

Table A-1 Locations sampled with associated station numbers, STORET numbers, latitudes and longitudes, Lake Michigan, 1976.

Location Number	Location	Station Number	STORET Number	Latitude N Deg	Latitude N Min	Latitude N Sec	Longitude W Deg	Longitude W Min	Longitude W Sec	Distance from shore (km)
1	Galien River	1	110429	41	48	10	86	45	4	0.1
		2	110430	41	49	39	86	47	3	4
		3	110431	41	49	44	86	46	56	4
		4	110432	41	49	48	86	46	49	4
		5	110433	41	50	27	86	48	4	6
		6	110434	41	50	30	86	47	55	6
		7	110435	41	50	34	86	47	48	6
2	St. Joseph River	1	110436	42	6	55	86	29	59	0.5
		2	110437	42	6	47	86	31	44	3
		3	110438	42	6	52	86	31	44	3
		4	110439	42	6	58	86	31	44	3
		5	110440	42	6	42	86	37	32	11
		6	110441	42	6	46	86	37	32	11
		7	110442	42	6	53	86	37	32	11
3	Black River	1	800230	42	24	1	86	17	23	0.5
		2	800231	42	23	55	86	18	51	2.5
		3	800232	42	24	1	86	18	51	2.5
		4	800233	42	24	8	86	18	51	2.5
		5	800237	42	24	3	86	23	14	8
		6	800238	42	24	9	86	23	14	8
		7	800239	42	24	16	86	23	14	8
		8	800234	42	24	8	86	26	1	12
		9	800235	42	24	16	86	26	1	12
		10	800236	42	24	23	86	26	0	12
4	Kalamazoo River	1	030216	42	40	39	86	13	4	0.5
		2	030217	42	40	31	86	14	48	2.5
		3	030218	42	40	37	86	14	48	2.5
		4	030219	42	40	40	86	14	48	2.5
		5	030220	42	40	31	86	17	40	6.5
		6	030221	42	40	37	86	17	39	6.5
		7	030222	42	40	42	86	17	39	6.5
5	Lake Macatawa Outlet	1	700356	42	46	24	86	13	5	0.5
		2	700357	42	46	13	86	14	36	2.5
		3	700358	42	46	19	86	14	36	2.5
		4	700359	42	46	24	86	14	36	2.5
		5	700360	42	46	12	86	16	48	5.5
		6	700361	42	46	17	86	16	48	5.5
		7	700362	42	46	21	86	16	48	5.5
6	Grand River	1	700363	43	3	28	86	15	27	0.5
		2	700364	43	3	24	86	17	0	2.5
		3	700365	43	3	28	86	17	0	2.5
		4	700366	43	3	34	86	17	0	2.5
		5	700367	43	3	25	86	19	17	5.5
		6	700368	43	3	31	86	19	17	5.5
		7	700369	43	3	35	86	19	17	5.5
7	Muskegon Lake Outlet	1	610298	43	13	38	86	20	55	0.5
		2	610299	43	13	34	86	22	8	2.5
		3	610300	43	13	38	86	22	8	2.5
		4	610301	43	13	45	86	22	8	2.5
		5	610302	43	13	36	86	25	22	7
		6	610303	43	13	43	86	25	22	7
		7	610304	43	13	47	86	25	22	7
8	White Lake Outlet	1	610305	43	22	40	86	25	57	0.5
		2	610306	43	22	30	86	27	2	2
		3	610307	43	22	36	86	27	2	2
		4	610308	43	22	39	86	27	2	2
		5	610309	43	22	30	86	28	25	4
		6	610310	43	22	35	86	28	25	4
		7	610311	43	22	42	86	28	25	4
9	Pere Marquette River	1	530112	43	57	11	86	28	27	0.5
		2	530113	43	57	5	86	29	23	2
		3	530114	43	57	12	86	29	23	2
		4	530115	43	57	19	86	29	24	2
		5	530116	43	56	54	86	33	39	8
		6	530117	43	57	2	86	33	39	8
		7	530118	43	57	8	86	33	39	8
10	Manistee River	1	510143	44	15	12	86	21	13	0.5
		2	510144	44	15	12	86	24	23	4
		3	510145	44	15	22	86	24	23	4
		4	510146	44	15	29	86	24	23	4
		5	510147	44	15	15	86	25	7	5
		6	510148	44	15	24	86	25	7	5
		7	510149	44	15	32	86	25	7	5

Table A-1 (continued)

Location Number	Location	Station Number	STORET Number	Latitude N Deg	Latitude N Min	Latitude N Sec	Longitude W Deg	Longitude W Min	Longitude W Sec	Distance from shore (km)
11	Betsie Lake Outlet	1	100099	44	37	47	86	15	17	0.5
		2	100100	44	37	40	86	16	37	2.5
		3	100101	44	37	48	86	16	37	2.5
		4	100102	44	37	53	86	16	37	2.6
		5	100103	44	37	38	86	17	48	4
		6	100104	44	37	46	86	17	48	4
		7	100105	44	37	53	86	17	48	4
		8	100106	44	37	37	86	18	29	5
		9	100107	44	37	44	86	18	29	5
		10	100108	44	37	52	86	18	28	5
12	Naubinway	1	490041	46	5	26	85	28	29	0.5
		2	490042	46	3	20	85	25	5	4
		3	490043	46	3	8	85	25	31	4
		4	490014	46	2	52	85	25	57	4
		5	490045	45	55	8	85	19	48	20
		6	490046	45	55	2	85	20	19	20
		7	490047	45	54	59	85	20	48	20
13	Manistique River	1	770046	45	56	11	86	13	36	0.5
		2	770047	45	54	59	86	11	46	4
		3	770048	45	54	51	86	12	3	4
		4	770049	45	54	43	86	12	15	4
		5	770050	45	51	20	86	7	32	13
		6	770051	45	51	10	86	7	46	11
		7	770052	45	51	2	86	8	1	13
		8	770053	45	56	53	86	14	36	-
		9	770054	45	56	49	86	14	44	-
		10	770055	45	56	47	86	14	47	-
14	Escanaba River	1	210123	45	46	31	87	3	9	0.5
		2	210124	45	45	51	87	1	50	2
		3	210125	45	45	45	87	2	1	2
		4	210126	45	45	37	87	2	12	2
		5	210127	45	45	6	87	0	33	2
		6	210128	45	44	56	87	0	50	2
		7	210129	45	44	48	87	1	1	2
15	Cedar River	1	550078	45	24	25	87	20	45	0.5
		2	550079	45	24	31	87	18	44	3
		3	550080	45	24	23	87	18	44	3
		4	550081	45	24	12	87	18	44	3
		5	550082	45	24	30	87	12	56	10.5
		6	550083	45	24	20	87	12	56	10.5
		7	550084	45	24	6	87	12	56	10.5

Location Number	Location	Station Number	STORET Number	Latitude N Deg	Latitude N Min	Latitude N Sec	Longitude W Deg	Longitude W Min	Longitude W Sec	Distance from shore (km)
16	Menominee River	1	550085	45	5	41	87	35	13	1
		2	550086	45	5	50	87	33	23	3
		3	550087	45	5	44	87	33	26	3
		4	550088	45	5	34	87	33	26	3
		5	550089	45	5	51	87	26	34	12
		6	550090	45	5	43	87	26	34	12
		7	550091	45	5	33	87	26	34	12

Table A-2 Methods used to analyze selected water constituents, Lake Michigan, 1976.

			Reference		
Parameter	Range	Method	Standard Methods APHA	EPA Methods 1974	ASTM Part 31 1975
Total Phosphorus	0.001-0.50 mg/l	Block Digester Automated Single Reagent	606 p. 624	p. 256(6)	--
Reactive Phosphorus	0.001-0.50 mg/l	Automated Single Reagent Ascorbic Acid Reduction	606 p. 624	p. 256	--
Particulate Phosphorus		Difference			
Silicon Dioxide, Dissolved	0.01-10.0 mg/l	Automated Molybdosilicate	426(b) p. 487	--	D859-68B p. 398
Chlorophyll *a*	0.1-10 mg/l	Flourometric Corrected	1002G p. 1031	--	--
Total Organic Nitrogen	0.01-20 mg/l	Kjeldahl Nitrogen plus Ammonia	421 p. 437	--	--
Total Kjeldahl Nitrogen	0.01-2.0 mg/l	Block Digester Automated Salicylate	--	--	--
Total Nitrogen	0.01-4.0 mg/l	Sum of Nitrate plus Nitrite and Kjeldahl Nitrogen	--	--	--
Nitrite	0.001-0.100 mg/l	Diazotization Colorimetric	420 p. 434	p. 215	--
Nitrate	0.01-2.0 mg/l	Automated Cadmium Reduction	605 p. 620	p. 207	--
Ammonia	0.001-0.50 mg/l	Automated Phenate	604 p. 616	p. 168	--
Chemical Oxygen Demand	0.3-80 mg/l	Dichromate Test Tube	508 p. 550	p. 20	D1252-67 p. 472
Total Organic Carbon	0.1-50 mg/l	Sealed Ampul Combustion IR	505 p. 532	p. 236	D2579-74 p. 467
Alkalinity	1-250 mg/l	Automated Methyl Orange	--	p. 5	--
Specific Conductance	100-1500 μmho/cm	Wheatstone Bridge Corrected to 25°C	205 p. 71	p. 275	D1125-64 p. 120

Table A-2 (continued)

Parameter	Range	Method	Reference Standard Methods APHA	 EPA Methods 1974	 ASTM Part 31 1975
Turbidity	0.1-100 FTU	Nephelometric	214A p. 132	p. 295	D1889-71 p. 223
Total Dissolved Solids	50-350 mg/l	65% Specific Conductance at 25°C	--	--	--
Residue, Total Filterable	1-100 mg/l	Gravimetric 550°C	208E p. 95	p. 272	--
Total Iron	5-500 µg	Atomic Absorption	301A p. 148	p. 110	D2576-70 p. 345
Chlorides	0.1-100 mg/l	Automated Ferricyanide	602 p. 613	p. 31	--
Sulfate	0.1-100 mg/l	Barium Chloride Turbimetric	427C p. 496	p. 277	D516-68B p. 425
Sodium	0.1-50 mg/l	Atomic Absorption	--	p. 147	--
Magnesium	0.1-25 mg/l	Atomic Absorption	301A p. 148	p. 114	D2576-60 p. 345
Calcium	10-100 mg/l	EDTA Titration	306C p. 189	p. 19	--

Table A-3 Methods used to analyze selected sediment constituents, Lake Michigan, 1976.

Parameter	Method	Sensitivity	Reference
Total Kjeldahl Nitrogen	Block Digester		
	Automated Salicylate	1 mg/kg	--
Total Phosphorus	Ascorbic acid reduction	1 mg/kg	--
Total Solids	Moisture determination balance	1%	Std. Methods, 14th edition p. 91
Volatile Solids	Moisture determination balance	0.1%	Std. Methods, 14th edition p. 95
Chemical Oxygen Demand	Dichromate reflex	10 mg/kg	Std. Methods, 14th edition
Total Organic Carbon	Sealed Ampul		Std. Methods, 14th edition
Cadmium	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 101
Chromium	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 105
Copper	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 108
Iron	Atomic Absorption	1 mg/kg	EPA (1974), p. 110
Lead	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 112
Manganese	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 116
Mercury	Cold vapor method	0.01 mg/kg	EPA (1974), p. 118
Nickel	Atomic Absorption	1 mg/kg	RPA (1974), p. 141
Zinc	Atomic Absorption	0.1 mg/kg	EPA (1974), p. 155
Dieldrin	Gas chromatograph	<10 μg/kg	EPA (1973), Fed. Reg. 38
DDT (total)	Gas chromatograph	<20 μg/kg	EPA (1973), Fed. Reg. 38
DDD	Gas chromatograph	<20 μg/kg	EPA (1973), Fed. Reg. 38
DDE	Gas chromatograph	<20 μg/kg	EPA (1973), Fed. Reg. 38
PCB (1242, 1254, 1260)	Gas chromatograph	<200 μg/kg	EPA (1973), Fed. Reg. 38
DBP	Gas chromatograph	100 μg/kg	EPA (1973), Fed. Reg. 38
DEHP	Gas chromatograph	100 μg/kg	EPA (1973), Fed. Reg. 38
Chlordane	Gas chromatograph	<50	EPA (1973), Fed. Reg. 38
HCB	Gas chromatograph	<100	EPA (1973), Fed. Reg. 38
HCBD	Gas chromatograph	<50	EPA (1973), Fed. Reg. 38
Oil and Grease	Hexane extraction	100 mg/kg	EPA (1973)

Table A-4 Descriptive statistics for selected water constituents, Lake Michigan, 1976.

Location Number	Organic Nitrogen mg/l: Location Mean	Standard Deviation	N	Total Kjeldahl Nitrogen mg/l: Location Mean	Standard Deviation	N	Chlorophyll a mg/l: Location Mean	Standard Deviation	N
1	0.24	0.04	4	0.25	0.05	4	1.2	0.1	2
2	0.20	0.03	4	0.21	0.04	4	4.8	4.0	2
3	0.19	0.04	4	0.20	0.04	4	SL	SL	-
4	0.22	0.02	4	0.22	0.02	4	2.2	0.2	2
5	0.19	0.01	4	0.10	0.01	4	2.8	0.4	2
6	0.19	0.01	4	0.20	0.01	4	3.2	0.2	2
7	0.26	0.09	4	0.27	0.09	4	2.3	0.1	2
8	0.18	0.01	4	0.20	0.01	4	2.8	0.2	2
9	0.16	0.02	4	0.16	0.02	4	2.7	0.1	2
10	0.15	0.00	4	0.15	0.01	4	2.5	0.1	2
11	0.15	0.02	4	0.15	0.02	4	2.4	0.2	2
12	0.16	0.03	6	0.16	0.02	6	1.8	0.0	2
13	0.16	0.01	4	0.16	0.01	4	1.1	0.1	2
14	0.25	0.02	4	0.26	0.02	4	1.2	0.2	2
15	0.32	0.07	4	0.33	0.07	4	2.2	1.1	2
16	0.32	0.05	4	0.32	0.05	4	2.5	1.4	2
	0.21 ± 0.06			0.21 ± 0.06			2.2 ± 0.9	SL = Sample Lost	

Location Number	Total Phosphorus mg/l: Location Mean	Standard Deviation	N	Total Orthophosphate mg/l: Location Mean	Standard Deviation	N	Particulate Phosphorus mg/l: Location Mean	Standard Deviation	N
1	0.007	0.003	4	0.002	0.001	4	0.006	0.001	4
2	0.011	0.003	4	0.002	0.003	4	0.008	0.001	4
3	0.010	0.003	4	0.003	0.001	4	0.007	0.005	4
4	0.008	0.003	4	0.003	0.000	4	0.005	0.005	4
5	0.009	0.001	4	0.001	0.000	4	0.008	0.001	4
6	0.009	0.002	4	0.001	0.000	4	0.006	0.004	4
7	0.019	0.011	4	0.001	0.000	4	0.018	0.011	4
8	0.009	0.002	4	0.001	0.000	4	0.008	0.002	4
9	0.006	0.001	4	0.001	0.000	4	0.005	0.001	4
10	0.005	0.001	4	0.002	0.001	4	0.003	0.002	4
11	0.005	0.002	4	0.001	0.001	4	0.004	0.002	4
12	0.007	0.001	6	0.001	0.001	6	0.006	0.002	6
13	0.006	0.001	4	0.001	0.001	4	0.003	0.002	4
14	0.014	0.008	4	0.005	0.001	4	0.010	0.008	4
15	0.016	0.008	4	0.003	0.001	4	0.013	0.008	4
16	0.013	0.002	4	0.002	0.002	4	0.011	0.003	4
	0.010 ± 0.004			0.002 ± 0.001			0.008 ± 0.004		

Table A-4 (continued)

Location Number	Total Nitrogen mg/l Location Mean	Standard Deviation	N	Nitrate + Nitrite mg/l Location Mean	Standard Deviation	N	Ammonia mg/l Location Mean	Standard Deviation	N
1	0.45	0.06	4	0.19	0.02	4	0.016	0.013	4
2	0.44	0.09	4	0.23	0.08	4	0.012	0.010	4
3	0.43	0.06	4	0.24	0.05	4	0.007	0.004	4
4	0.43	0.04	4	0.21	0.04	4	0.003	0.001	4
5	0.42	0.06	4	0.20	0.06	4	0.010	0.004	4
6	0.39	0.02	4	0.19	0.02	4	0.011	0.001	4
7	0.41	0.03	4	0.20	0.03	4	0.007	0.001	4
8	0.39	0.04	4	0.20	0.04	4	0.006	0.001	4
9	0.36	0.04	4	0.20	0.05	4	0.005	0.003	4
10	0.32	0.03	4	0.17	0.03	4	0.004	0.004	4
11	0.32	0.05	4	0.18	0.07	4	0.004	0.002	4
12	0.33	0.02	6	0.17	0.04	6	0.003	0.002	6
13	0.32	0.01	4	0.16	0.01	4	0.005	0.005	4
14	0.35	0.05	4	0.10	0.07	4	0.008	0.005	4
15	0.42	0.09	4	0.10	0.31	4	0.005	0.004	4
16	0.38	0.02	4	0.06	0.08	4	0.002	0.001	4
	0.38 ± 0.06			0.17 ± 0.05			0.007 ± 0.004		

Location Number	Suspended Solids mg/l Location Mean	Standard Deviation	N	Total Iron mg/l Location Mean	Standard Deviation	N	Potassium mg/l Location Mean	Standard Deviation	N
1	2	2	4	188	236	4	1.4	0.09	4
2	4	1	4	145	125	4	1.1	0.23	4
3	5	3	4	140	92	4	1.2	0.05	4
4	2	1	4	68	27	4	1.0	0.06	4
5	6	1	4	112	57	4	1.0	0.05	4
6	5	2	4	72	4	4	0.9	0.05	4
7	9	4	4	86	65	4	0.9	0.05	4
8	6	1	4	93	58	4	0.9	0.0	4
9	3	1	4	48	19	4	0.9	0.02	4
10	2	1	4	72	67	4	0.9	0.0	4
11	2	1	4	34	15	4	0.9	0.04	6
12	2	1	6	10	5	6	1.0	0.0	4
13	1	1	4	19	6	4	1.0	0.1	4
14	1	1	4	40	27	4	1.1	0.05	4
15	9	6	4	136	151	4	1.0	0.06	4
16	5	1	4	57	22	4	1.2	0.05	4
	4 ± 3			87 ± 58				1.0 ± 0.14	

Table A-4 (continued)

Location Number	Dissolved Silica mg/l: Location Mean	Standard Deviation	N	Specific Conductance umhos/cm[a]: Location Mean	Standard Deviation	N	Total Dissolved Solids mg/l (major ions): Location Mean	Standard Deviation	N
1	0.6	0.2	4	256	2	4	159	3	4
2	1.1	0.7	4	278	8	4	158	8	4
3	1.0	0.5	4	275	4	4	164	2	4
4	0.7	0.3	4	274	2	4	160	5	4
5	0.8	0.4	4	278	8	4	157	1	4
6	0.6	0.0	4	269	5	4	160	1	4
7	0.6	0.2	4	374	2	4	158	3	4
8	0.5	0.2	4	279	7	4	163	2	4
9	0.6	0.3	4	268	3	4	156	3	4
10	0.4	0.1	4	265	0	4	155	1	4
11	0.5	0.2	4	265	0	4	154	2	4
12	0.6	0.4	6	261	2	6	147	6	6
13	0.2	0.1	4	265	0	4	151	2	4
14	0.7	0.4	4	270	5	4	158	1	4
15	0.8	0.3	4	270	0	4	154	2	4
16	0.8	0.9	4	270	0	4	156	1	4
	0.6 ± 0.2			269 ± 6			156 ± 4		

Location Number	Chlorides mg/l: Location Mean	Standard Deviation	N	Sulfate mg/l: Location Mean	Standard Deviation	N	Sodium mg/l: Location Mean	Standard Deviation	N
1	9.1	0.2	4	23	1	4	5.0	0.3	4
2	8.7	0.4	4	22	3	4	4.7	0.2	4
3	6.6	0.2	4	25	0	4	4.3	0.2	4
4	8.7	0.1	4	21	4	4	4.C	0.1	4
5	8.5	0.1	4	25	1	4	4.5	0.1	4
6	8.7	0.1	4	19	1	4	4.4	0.1	4
7	8.6	0.2	4	20	2	4	4.6	0.1	4
8	8.7	0.2	4	24	1	4	4.6	0.2	4
9	8.3	0.2	4	22	1	4	4.4	0.1	4
10	8.5	0.1	4	21	0	4	4.3	0.1	4
11	8.2	0.1	4	22	0	4	4.2	0.1	4
12	6.8	0.5	6	21	1	6	4.3	0.2	6
13	7.6	0.0	4	22	0	4	4.5	0.2	4
14	7.6	0.1	4	22	0	4	4.7	0.5	4
15	8.2	0.3	4	22	1	4	4.8	0.6	4
16	7.9	0.1	4	23	1	4	4.2	0.1	4
	8.3 ± 0.6			22 ± 2			4.5 ± 0.2		

Table A-4 (continued)

Location Number	Magnesium mg/l Location Mean	Magnesium Standard Deviation	N	Calcium mg/l Location Mean	Calcium Standard Deviation	N	Total Organic Carbon mg/l Location Mean	TOC Standard Deviation	N
1	13.0	0.0	4	32	1	4	2.9	0.1	4
2	12.1	1.0	4	35	2	4	2.1	0.2	4
3	13.0	0.0	4	35	1	4	3.2	1.9	4
4	12.5	1.0	4	37	1	4	1.8	0.1	4
5	12.0	1.0	4	31	1	4	1.9	0.3	4
6	13.0	1.0	4	36	1	4	1.7	0.1	4
7	12.8	0.5	4	36	1	4	2.0	0.2	4
8	12.0	1.0	4	36	1	4	2.0	0.0	4
9	12.0	1.0	4	36	1	4	1.6	0.0	4
10	12.0	1.0	4	36	1	4	1.6	0.1	4
11	12.0	1.0	4	36	1	4	1.6	0.1	4
12	12.0	1.0	6	34	1	6	1.9	0.1	6
13	12.3	0.5	4	32	1	4	1.9	0.1	4
14	13.9	1.0	4	34	1	4	3.1	0.4	4
15	13.0	1.0	4	33	1	4	3.2	0.2	4
16	14.0	1.0	4	33	1	4	3.7	0.6	4
	12.5	± 0.6		34	± 2		2.3	± 0.7	

Location Number	Chemical Oxygen Demand mg/l Location Mean	COD Standard Deviation	N	Alkalinity mg/l Location Mean	Alkalinity Standard Deviation	N	Turbidity F.T.U. Location Mean	Turbidity Standard Deviation	N
1	4.3	0.5	4	111	4	4	2.1	0.7	4
2	4.2	1.1	4	107	3	4	3.0	2.4	4
3	6.7	2.1	4	110	1	4	3.5	1.9	4
4	6.4	2.5	4	110	0	4	2.4	0.8	4
5	6.4	1.2	4	109	1	4	2.7	0.8	4
6	5.1	0.2	4	114	0	4	2.3	0.3	4
7	5.9	1.0	4	110	2	4	2.8	1.3	4
8	6.0	1.1	4	112	1	4	2.5	0.7	4
9	8.2	5.1	4	105	3	4	1.4	0.3	4
10	9.1	2.9	4	105	1	4	1.1	0.2	4
11	9.1	3.4	4	105	2	4	1.1	0.1	4
12	7.6	3.6	6	99	7	6	0.5	0.2	6
13	4.2	1.9	4	99	13	4	0.6	0.2	4
14	8.7	0.4	4	110	1	4	1.6	2.3	4
15	6.8	1.0	4	105	1	4	1.5	1.1	4
16	9.4	2.7	4	107	1	4	0.7	0.1	4
	6.8	± 1.8		107	± 4		1.8	± 0.9	

Table A-5 Water sample chemical and physical results, Lake Michigan, 1976.

Location Number	Location	Station Number	Depth (m)	Chemical Oxygen Demand (mg/l)	Total Organic Carbon (mg/l)	Conductivity (μmho/cm)	Turbidity (formazin units)	Nitrate and Nitrite Nitrogen (mgN/l)	Ammonia Nitrogen (mgN/l)	Organic Nitrogen (mgN/l)	Total Kjeldahl Nitrogen (mgN/l)	Total Phosphorus (mgP/l)
1	Galien River	1	1	9.0	4.8	360	7.0	0.59	0.037	0.74	0.78	0.038
		1	4	6.4	3.3	285	4.0	0.27	0.012	0.31	0.32	0.019
		3	1	5.4	2.8	255	1.5	0.18	0.004	0.21	0.21	0.006
		3	14	4.4	2.9	255	2.9	0.19	0.010	0.27	0.30	0.008
		6	1	4.4	3.0	255	1.6	0.18	0.005	0.20	0.21	0.004
		6	19	4.1	2.7	260	2.2	0.22	0.023	0.27	0.29	0.010
2	St. Joseph River*	1	1	10.6	5.7	445	7.4	0.46	0.026	0.62	0.65	0.065
		1	4	5.8	3.7	290	9.7	0.25	0.014	0.29	0.30	0.026
		3	1	3.9	2.1	275	2.6	0.20	0.008	0.20	0.21	0.011
		3	14	4.4	2.3	285	6.4	0.25	0.026	0.24	0.27	0.014
		6	1	3.4	2.0	265	1.2	0.13	0.007	0.17	0.18	0.008
		6	29	6.1	1.9	285	1.7	0.33	0.006	0.18	0.19	0.009
3	Black River	1	1	8.7	2.3	280	7.8	0.24	0.008	0.23	0.24	0.016
		1	4	5.1	3.5	275	5.5	0.26	0.015	0.26	0.28	0.018
		3	1	8.5	2.3	280	6.0	0.22	0.010	0.20	0.21	0.012
		3	14	5.1	2.1	275	2.5	0.27	0.010	0.24	0.25	0.013
		6	1	4.6	2.0	270	1.6	0.17	0.005	0.16	0.17	0.006
		6	29	8.5	6.4	275	3.8	0.28	0.003	0.15	0.15	0.008
4	Kalamazoo River	1	1	14.0	[illegible]	410	13	0.23	0.002	0.64	0.64	0.073
		1	4	5.7	2.2	285	8.1	0.21	0.004	0.31	0.31	0.022
		3	1	9.6	1.9	275	2.5	0.19	0.004	0.25	0.25	0.012
		3	14	6.8	1.7	275	3.2	0.20	0.004	0.22	0.22	0.007
		6	1	3.9	1.7	270	1.2	0.17	0.001	0.20	0.20	0.006
		6	29	5.2	1.8	275	2.6	0.27	0.003	0.20	0.20	0.007
5	Lake Macatawa	1	1	4.3	2.0	275	4.5	0.16	0.015	0.26	0.28	0.016
		1	6	6.3	1.9	275	3.2	0.15	0.014	0.21	0.22	0.011
		3	1	8.1	1.8	290	2.2	0.16	0.009	0.19	0.20	0.007
		3	14	5.6	1.8	280	2.7	0.18	0.016	0.17	0.19	0.009
		6	1	6.1	2.4	270	2.0	0.16	0.009	0.19	0.20	0.008
		6	29	5.6	1.7	270	3.8	0.29	0.007	0.19	0.20	0.010

Table A-5 (continued)

Location Number	Location	Station Number	Total Orthophosphate-P (mgP/l)	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Silica (mg/l)	Chloride (mg/l)	Total Iron (ug/l)	Sulfate (mg/l)	Sodium (mg/l)	Magnesium (mg/l)	Calcium (mg/l)	Potassium (mg/l)	Alkalinity (mg/l $CaCO_3$)
1	Galien River	1	0.006	18	227	3.7	12.0	360	36	6.2	19	40	1.7	157
		1	0.002	9	172	0.88	9.5	135	27	5.3	14	32	1.4	119
		3	0.001	7	161	0.34	9.0	540	23	5.3	13	32	1.5	112
		3	0.001	9	161	0.46	9.2	82	22	4.9	13	32	1.4	114
		6	0.002	4	160	0.36	9.3	48	23	4.9	13	32	1.3	112
		6	0.003	9	154	1.02	8.7	80	22	4.7	13	31	1.3	106
2	St. Joseph River	1	0.005	17	274	4.3	16.5	410	43	8.8	21	60	1.6	172
		1	0.005	15	172	1.22	9.6	320	26	4.8	13	38	1.3	114
		3	0.002	3	163	0.57	9.0	70	25	4.5	13	35	1.3	108
		3	0.006	4	163	1.14	9.1	300	25	4.7	13	34	1.3	109
		6	<0.001	3	147	0.37	8.3	21	19	4.7	11	33	0.9	102
		6	0.001	5	157	2.2	8.2	190	19	5.0	11	37	0.9	108
3	Black River	1	0.002	16	164	0.87	8.4	340	25	4.4	13	36	1.2	109
		1	0.003	12	166	0.90	8.4	320	26	4.4	13	36	1.3	110
		3	0.004	8	166	0.79	8.7	260	26	4.5	13	35	1.3	112
		3	0.003	5	163	1.14	8.4	140	25	4.4	13	35	1.2	110
		6	0.002	1	162	0.32	8.7	35	25	4.2	13	34	1.2	110
		6	0.001	7	163	1.56	8.4	125	25	4.1	13	35	1.2	109
4	Kalamazoo River	1	0.009	26	249	1.32	20.9	620	28	12.4	17	54	1.4	166
		1	0.005	10	166	0.73	9.1	370	24	5.1	13	36	1.1	112
		3	0.003	2	160	0.64	8.7	61	20	4.7	13	36	1.1	110
		3	0.003	1	161	0.69	8.8	94	20	4.6	13	37	1.1	110
		6	0.003	4	164	0.36	8.6	33	26	4.6	12	36	1.0	110
		6	0.003	1	153	1.07	8.5	84	16	4.5	12	36	1.0	109
5	Lake Macatawa	1	0.002	8	157	0.41	8.6	170	24	4.8	12	32	1.0	110
		1	0.001	9	155	0.38	8.4	105	24	4.6	12	31	0.5	109
		3	0.001	7	157	0.57	8.6	145	23	4.6	12	32	1.0	110
		3	<0.001	5	159	0.72	8.5	125	25	4.4	12	32	1.0	110
		6	0.001	5	157	0.40	8.5	28	25	4.5	12	31	0.9	108
		6	<0.001	7	156	1.47	8.4	150	25	4.3	12	30	1.0	108

Table A-5 (continued)

Location Number	Location	Station Number	Depth (m)	Chemical Oxygen Demand (mg/l)	Total Organic Carbon (mg/l)	Conductivity (μmho/cm)	Turbidity (formazin units)	Nitrate and Nitrite Nitrogen (mgN/l)	Ammonia Nitrogen (mgN/l)	Organic Nitrogen (mgN/l)	Total Kjeldahl Nitrogen (mgN/l)	Total Phosphorus (mgP/l)
6	Grand River	1	1	10.6	4.1	345	4.4	0.21	0.061	0.37	0.43	0.037
		1	6	6.3	2.6	290	3.2	0.18	0.009	0.23	0.24	0.011
		3	1	5.3	1.8	270	2.5	0.18	0.009	0.20	0.21	0.008
		3	14	4.8	1.8	270	2.5	0.18	0.010	0.20	0.21	0.008
		6	1	5.1	1.6	275	2.2	0.18	0.011	0.17	0.18	0.007
		6	29	5.3	1.6	260	2.0	0.21	0.012	0.19	0.20	0.011
7	Muskegon Lake	1	1	10.6	3.2	290	3.0	0.16	0.010	0.30	0.31	0.020
		1	6	6.6	2.2	290	3.0	0.19	0.009	0.22	0.23	0.014
		3	1	5.3	2.1	275	2.5	0.19	0.007	0.18	0.19	0.008
		3	14	7.1	2.1	275	5.5	0.18	0.008	0.24	0.25	0.015
		6	1	4.8	1.8	270	2.1	0.25*	0.007*	0.38*	0.39*	0.035*
		6	29	6.3	1.8	275	2.0	0.18*	0.007*	0.23*	0.24*	0.019*
8	White Lake	1	1	9.9	3.2	300	5.0	0.17	0.007	0.36	0.37	0.023
		1	6	9.9	3.3	280	9.0	0.19	0.006	0.39	0.40	0.035
		3	1	4.3	2.0	270	2.2	0.18	0.005	0.18	0.18	0.007
		3	14	6.8	2.0	280	3.3	0.19	0.007	0.20	0.21	0.010
		6	1	6.6	1.9	275	1.6	0.17	0.005	0.18	0.19	0.008
		6	29	6.1	2.0	290	2.7	0.25	0.006	0.19	0.20	0.010
9	Pere Marquette River	1	1	9.3	2.8	310	3.6	0.17	0.003	0.22	0.22	0.021
		1	7	8.3	1.8	285	3.5	0.17	0.006	0.17	0.18	0.010
		3	1	5.3	1.6	265	1.2	0.17	0.002	0.15	0.15	0.007
		3	14	5.9	1.7	265	1.3	0.19	0.008	0.15	0.16	0.005
		6	1	5.6	1.6	270	1.2	0.17	0.003	0.19	0.19	0.006
		6	29	15.8	1.6	270	1.8	0.28	0.005	0.14	0.15	0.005
10	Manistee River	1	1	6.1	2.6	360	3.2	0.14	0.014	0.18	0.19	0.011
		1	9	5.9	1.6	285	1.9	0.16	0.004	0.18	0.18	0.007
		3	1	12.8	1.7	265	1.0	0.16	0.002	0.15	0.15	0.004
		3	14	6.7	1.6	265	1.3	0.15	0.003	0.15	0.15	0.005
		6	1	10.1	1.6	265	1.0	0.16	0.002	0.15	0.15	0.005
		6	29	6.9	1.5	265	1.2	0.21	0.010	0.15	0.16	0.007
11	Betsie Lake	1	1	9.9	1.6	265	1.1	0.15	0.004	0.15	0.15	0.003
		1	7	7.5	1.6	265	1.3	0.14	0.004	0.17	0.17	0.005
		3	1	6.1	1.7	265	1.2	0.13	0.002	0.16	0.16	0.003
		3	14	6.7	1.6	265	1.3	0.15	0.006	0.14	0.15	0.004
		6	1	13.6	1.6	265	1.0	0.14	0.001	0.13	0.13	0.003
		6	29	12.8	1.5	265	1.1	0.23	0.007	0.17	0.18	0.000
		9	1	5.9	1.5	265	1.0	0.14	0.003	0.15	0.15	0.004
		9	39	9.6	1.5	265	1.2	0.30	0.005	0.14	0.14	0.005

*Questionable results

Table A-5 (continued)

Location Number	Location	Station Number	Total Orthophosphate-P (mgP/l)	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Silica (mg/l)	Chloride (mg/l)	Total Iron (μg/l)	Sulfate (mg/l)	Sodium (mg/l)	Magnesium (mg/l)	Calcium (mg/l)	Potassium (mg/l)	Alkalinity (mg/l $CaCO_3$)
6	Grand River	1	0.004	7	190	0.57	15.3	150	16	8.7	15	44	1.3	130
		1	<0.001	5	161	0.39	9.4	110	15	5.3	13	38	1 0	117
		3	<0.001	8	162	0.55	8.6	69	20	4.7	13	37	0.9	114
		3	<0.001	4	160	0.53	8.8	73	18	5.0	13	36	0.9	115
		6	<0.001	5	159	0.59	8 8	70	17	4.8	13	36	0.9	114
		6	<0.001	3	159	0.59	8.7	77	20	4.8	13	36	1.0	114
7	Muskegon Lake	1	<0.001	9	168	1.01	11.4	160	17	5.9	13	38	1.0	119
		1	<0.001	7	163	0.49	10.0	160	17	5.2	13	37	0 9	116
		3	<0.001	13	161	0.51	8.7	76	22	4.7	13	35	1.0	112
		3	<0.001	11	160	0.50	8.8	180	22	4.6	13	35	0.9	111
		6	<0.001	7	155	0.79	8.4	48	17	4.5	12	36	0.9	110
		6	<0.001	5	156	0.40	8.5	38	20	4.4	12	36	0.9	108
8	White Lake	1	0.003	11	180	0.82	13.4	230	25	7.4	13	38	1.0	117
		1	0.003	26	172	0.50	10.5	540	25	5.7	13	37	0.9	116
		3	0.001	5	163	0.37	8.6	50	24	4.7	12	36	0.9	112
		3	0.001	7	165	0.47	9.1	105	25	4.8	12	36	0.9	118
		6	0.001	5	160	0.30	8.6	45	23	4.5	12	35	0.9	111
		6	0.001	7	164	0.90	8.6	170	25	4.5	12	36	0 9	112
9	Pere Marquette River	1	0.003	4	186	1.33	17.4	100	23	5.9	14	41	1.0	119
		1	0.003	4	164	0.54	10.1	110	24	4.6	12	36	0 9	111
		3	<0.001	3	156	0.44	8.4	60	20	4.5	12	36	0.85	108
		3	<0.001	2	159	0.49	8.4	52	24	4.4	12	36	0.9	106
		6	0.001	3	155	0.37	8.4	45	22	4.4	12	36	0.9	104
		6	0.001	3	153	1.20	8.0	35	21	4.2	12	36	0.9	102
10	Manistee River	1	0.004	3	210	3.7	29	100	19	10	13	46	1.1	127
		1	0.002	2	167	1.13	13.3	49	21	5.5	12	38	0.9	109
		3	0.003	1	159	0.35	8.4	40	21	4.1	12	35	0.9	106
		3	0.003	2	154	0.39	8.7	53	21	4.4	12	36	9.9	104
		6	0.002	1	154	0.38	8.4	170	21	4.2	12	36	0.9	104
		6	0.001	2	156	0.62	8.5	23	22	4.3	12	36	0.9	104
11	Betsie Lake	1	0.001	4	152	0.32	8.1	10	22	4.2	12	35	0.85	102
		1	0.001	1	151	0.31	8.1	88	21	4.2	12	35	0.9	102
		3	0.001	1	153	0.42	8.1	26	22	4.4	12	35	0.9	103
		3	<0.001	2	153	0.35	8.3	25	22	4.2	12	35	0.9	103
		6	<0.001	1	154	0.35	8.1	25	22	4.2	12	35	0.8	105
		6	0.001	2	156	0.88	8.1	26	21	4.0	12	36	0.9	107
		9	0.002	2	152	0.32	8.2	63	20	4.2	12	34	0.9	106
		9	<0.001	2	155	1.08	8.2	40	21	4.1	12	35	0.9	106

Table A-5 (continued)

Location Number	Location	Station Number	Depth (m)	Chemical Oxygen Demand (mg/l)	Total Organic Carbon (mg/l)	Conductivity (μmho/cm)	Turbidity (formazin units)	Nitrate and Nitrite Nitrogen (mgN/l)	Ammonia Nitrogen (mgN/l)	Organic Nitrogen (mgN/l)	Total Kjeldahl Nitrogen (mgN/l)	Total Phosphorus (mgP/l)
12	Naubinway	1	1	8.5	2.3	255	0.5	0.14	0.002	0.23	0.23	0.018
		1	7	3.4	2.0	230	0.5	0.15	0.001	0.18	0.18	0.011
		3	1	11.0	2.0	260	0.4	0.14	0.001	0.15	0.15	0.006
		3	14	2.7	1.7	265	0.4	0.23	0.006	0.12	0.13	0.006
		6	1	7.2	1.8	265	0.4	0.16	<0.001	0.17	0.17	0.008
		6	19	9.6	2.1	265	0.8	0.15	0.002	0.18	0.18	0 008
13	Manistique River	1	1	6.9	2.2	265	0.7	0.13	0.001	0.18	0.18	0.007
		1	5	5.3	2.8	265	3.0	0.14	0.004	0.29	0.29	0.016
		3	1	5.1	1.8	265	0.7	0.16	0.003	0.15	0.15	0.004
		3	14	3.2	1.9	265	0.7	0.18	0.012	0.15	0.16	0.006
		6	1	2.1	2.1	265	0.5	0.15	0.002	0.17	0.17	0.005
		6	29	6.4	1.8	265	0.4	0.15	0.004	0.17	0.17	0 007
		9	1	12.0	5.8	200	4.3	0.06	0 001	0.36	0.36	0.018
		9	6	23.0	2.6	265	25.0	0.14	0.007	0.90	0.91	0.096
14	Escanaba River	1	1	6.4	3.1	270	0.9	0.07	<0.001	0.32	0.32	0.012
		1	5	11.9	5.7	270	3.0	0.08	<0.001	0.71	0.71	0.087
		3	1	8.0	3.1	270	0.8	0.07	<0.001	0.28	0.28	0 011
		3	14	5.9	2.9	270	1.1	0.09	0.008	0.28	0.29	0.012
		6	1	6.2	3.1	270	0.9	0.08	0.001	0.30	0.30	0 012
		6	22	7.2	3.5	270	3.2	0.14	0.008	0.42	0 43	0.028
15	Cedar River	1	1	13.0	3.8	265	0.8	0.04	0.005	0.30	0.30	0.018
		1	5	9.0	3.3	275	0.7	0.12	0.017	0.24	0.26	0.011
		3	1	9.0	3.5	265	0.5	0.04	0.006	0.24	0.25	0.008
		3	14	9.0	3.1	275	0.4	0.11	0.014	0.26	0.27	0.011
		6	1	8.8	3.2	265	0.5	0.05	0.007	0.26	0 27	0.026
		6	29	8.1	2.5	275	0.5	0.18	0.003	0.23	0.23	0.011
16	Menominee River	1	1	11.9	5.6	270	1.5	<0.01	0.001	0.42	0.42	0.011
		1	5	13.4	5.9	275	4.3	<0.01	0.003	0.62	0.62	0.043
		3	1	8.8	4.2	270	0.6	<0.01	0.001	0.35	0.35	0.015
		3	14	12.1	3.7	270	0.6	0.05	0.003	0.33	0.33	0.011
		6	1	10.8	4.1	270	0.7	<0.01	0.001	0.34	0.34	0.011
		6	29	5.9	2.7	270	0.8	0.17	0.001	0.24	0.24	0.013

Table A-5 (continued)

Location Number	Location	Station Number	Total Orthophosphate-P (mgP/l)	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Dissolved Silica (mg/l)	Chloride (mg/l)	Total Iron (µg/l)	Sulfate (mg/l)	Sodium (mg/l)	Magnesium (mg/l)	Calcium (mg/l)	Potassium (mg/l)	Alkalinity (mg/l $CaCO_3$)
12	Naubinway	1	0.001	<1	147	0.51	7.1	41	20	4.3	12	34	1.0	100
		1	<0.001	2	139	0.66	6.8	9	18	3.7	11	30	0.9	99
		3	<0.001	1	147	0.28	7.0	6	20	4.5	12	34	1.0	101
		3	0.002	1	139	1.20	5.9	14	21	4.3	12	33	1.0	89
		6	0.001	3	151	0.25	7.1	6	22	4.3	12	34	1.0	103
		6	0.001	2	151	0.53	7.1	15	22	4.1	12	34	1.0	103
13	Manistique River	1	<0.001	2	151	0.61	7.1	44	22	4.3	12	33	1.0	104
		1	0.003	7	154	0.33	7.5	280	24	4.5	13	33	1.0	104
		3	0.004	1	152	0.16	7.6	25	22	4.4	13	33	1.0	104
		3	0.004	2	151	0.34	7.6	17	22	4.8	12	32	1.2	104
		6	0.001	<1	152	0.15	7.6	21	23	4.6	12	32	1.0	105
		6	<0.001	1	148	0.16	7.6	12	22	4.3	12	30	1.0	104
		9	0.003	3	124	5.8	7.9	480	26	1.9	8	30	0.7	72
		9	<0.001	84	150	0.39	7.6	1130	22	4.6	12	30	1.0	105
14	Escanaba River	1	0.004	6	153	0.65	8.2	54	22	4.3	13	32	1.1	105
		1	0.004	10	155	0.67	8.1	850	23	4.3	13	33	1.1	105
		3	0.003	7	151	0.44	8.1	45	20	4.5	13	32	1.1	105
		3	0.002	5	155	0.93	8.2	79	22	4.8	13	33	1.2	106
		6	0.003	5	154	0.55	8.5	56	22	5.5	13	32	1.1	104
		6	0.003	17	155	1.23	7.8	360	22	4.2	13	34	1.1	105
15	Cedar River	1	0.002	1	159	0.58	7.5	37	23	5.1	13	34	1.0	109
		1	0.004	2	159	1.10	7.5	66	22	5.2	13	34	1.1	110
		3	0.005	<1	159	0.36	7.7	21	23	5.3	13	34	1.1	110
		3	0.005	1	159	0.99	7.6	46	22	4.9	13	34	1.1	110
		6	0.005	1	157	0.21	7.6	76	22	4.9	13	34	1.0	109
		6	0.003	2	158	1.20	7.5	17	22	4.8	13	34	1.0	109
16	Menominee River	1	0.004	7	156	1.52	6.6	140	23	4.2	15	32	1.1	106
		1	0.004	24	157	0.46	7.9	300	22	4.3	14	33	1.2	108
		3	0.001	6	156	0.21	7.9	36	23	4.2	14	32	1.2	107
		3	0.001	4	156	0.60	7.9	88	22	4.1	14	33	1.2	108
		6	<0.001	6	155	0.12	8.0	53	22	4.3	14	32	1.2	107
		6	0.005	5	150	2.4	7.7	49	23	4.1	14	33	1.1	107

Table A-6

Selected river sampling results, Michigan Department of Natural Resources, 1976.

	Location	STORET Number	Date Sampled	Chemical Oxygen Demand mg/l	Total Organic Carbon mg/l	Conductivity micromho/cm	Turbidity FTU	Nitrate and Nitrite mg/l N	Ammonia Nitrogen mg/l N	Organic Nitrogen mg/l N	Total Phosphorus mg/l P
2	St. Joseph River at C & O railroad bridge, St. Joseph	110039	7/76	18.0	9.0	560	7.6	1.120	0.028	1.170	0.103
4	Kalamazoo River at old US-31 bridge, Saugatuck	030009	7/76	17.0	9.4	520	6.6	0.740	0.038	0.890	0.121
6	Grand River at mouth, Grand Haven	700026	7/76	27.0	13.7	500	7.2	1.530	0.058	1.770	0.156
7	Muskegon Lake at South bank of outlet, Muskegon	610030	7/76	15.9		320	1.9	0.040	0.019	0.780	0.036
8	White River at north bound US 21 bridge, Muskegon Co.	610178	7/76	11.2	5.9	350	3.5	0.220	0.029	0.640	0.055
9	Pere Marquette River, north channel at Pere Marquette Rd, Pere Marquette Twp.	530033	7/76	12.9	7.1	345	5.3	0.170	0.041	1.000	0.059
10	Manistee River at Maple St. bridge, Manistee	510014	7/76	8.1	3.6	415	5.4	0.150	0.064	0.330	0.030
11	Betsie River at Lewis Bridge, Crystal Lake Twp.	100067	7/76	10.4	4.8	310	7.2	0.160	0.007	0.360	0.029
13	Manistique River at end of Herbview Dr. at mouth, Manistique	770003	7/76	22.0	8.5	190	8.2	0.190	0.061	0.870	0.038
14	Escanaba River at US-2 bridge, Wells Twp.	210030	7/76	32.0	13.4	340	8.0	0.100	0.087	0.630	0.078
16	Menominee River at 26th Street, Menominee	550033	7/76	14.9	6.7	220	2.0	0.050	0.045	0.400	0.021

Table A-6 (continued)

Location	Total Ortho-phosphate mg/l	Total Dissolved Solids mg/l	Dissolved Silica mg/l Si	Chloride mg/l	Sulfate-diss mg/l	Sodium-diss mg/l	Magnesium-diss mg/l	Calcium Ca-diss mg/l	Alkalinity $CaCO_3$ mg/l	Potassium-diss mg/l
2	0.006	364	2.90	18.4	[a]47.0				196	
4	0.049	138	3.40	31.0		[a]25.0	[b]25.0	[b]69.0	204	[b]2.0
6	0.007	325	1.60	33.0	[a]56.0	[a]32.00	[a]24.0	[a]58.0	201	[a]2.20
7	<0.001	208	1.90	17.8	[a]19.0	[a]12.40	[a]14.5	[a]43.0		[a]1.03
8	0.004	228	2.90	22.0	[a]19.0	[a]13.20	[a]16.3	[a]46.0	147	[a]0.84
9	0.008	224	3.30	16.9	[a]20.0	[a]13.60	[a]16.6	[a]46.0	159	[a]1.12
10	0.010	270	3.30	40.0	[b]17.0	[b]18.00	[b]14.0	[b]42.0	147	[b]1.00
11	0.003	202	2.70	5.0	[b]13.0	[b]4.0	[b]14.0	[b]42.2	149	[b]0.58
13	0.006	124	2.50	3.0	[b]25.0	[b]1.80	[b]7.8	[b]31.0	79	[b]0.73
14	0.029	221	2.60	26.0					108	
16	0.003	143	2.40	2.9	[b]18.0	[b]3.00	[b]15.2	[b]28.0	97	[b]1.03

a = sampled 9/76
b = sampled 8/76

Table A-7 — Water column physical-chemical results* at 16 locations, Lake Michigan, 1976.

Station 1

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm*	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
1	Galien River	0	24.1	-	-	7.7	360	6.1(3m)	2.7	7/6	1430
		2	22.0	-	-	8.2	280				
		4	20.5	-	-	8.3	220				
2	St. Joseph River	-	-	-	-	-	-	8.9(1m)	0.6	7/14	930
3	Black River	-	-	-	-	-	-	-	0.8	7/13	930
4	Kalamazoo River	0	24.0	8.4	102	8.4	350	4.1(5m)	0.9	7/19	1210
		2	22.0	9.4	102	8.6	240				
		4	21.8	8.6	101	8.6	225				
5	Lake Macatawa outlet	0	20.5	9.1	103	8.6	225				
		2	20.5	8.9	101	8.6	225	3.3(5m)	1.9	7/22	725
		4	20.0	8.7	90	8.6	225				
		6	20.0	8.7	98	8.6	225				
6	Grand River	0	20.5	9.8	111	8.5	295				
		2	20.0	9.8	111	8.6	230				
		4	20.0	11.2	127	9.6	225	5.6(5m)	1.5	7/21	700
		6	20.0	11.3	129	8.6	225				
7	Muskegon Lake	0	20.5	8.9	101	8.6	240	5.8(5m)	2.1	7/21	1250
		2	20.0	8.3	94	8.7	230				
		4	19.5	8.2	91	8.6	230				
		6	19.3	8.1	90	8.6	225				
8	White Lake	0	20.0	9.1	103	8.7	240	6.4(5m)	1.5	7/21	1750
		2	19.0	9.8	109	8.6	235				
		4	19.0	9.4	104	8.6	230				
		6	19.0	9.5	105	8.6	230				
9	Pere Marquette	0	21.5	6.3	73	8.7	275	2.3(5m)	1.8	7/26	1430
		2	20.5	7.7	87	8.7	240				
		4	20.0	8.5	96	8.7	225				
		6	20.0	9.3	105	8.7	235				
		7	20.0	10.0	113	8.7	235				
10	Manistee River	0	22.0	8.8	103	8.5	340	3.1(5m)	--	7/27	1925
		2	20.0	9.5	107	8.6	260				
		4	19.8	9.6	109	8.7	245				
		6	19.4	9.8	110	8.7	230				
		8	19.1	9.9	110	8.7	225				
		9	18.9	10.0	111	8.7	225				

Table A-7 (continued)

Station 1 (continued)

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
11	Betsie Lake	0	22.2	8.8	103	8.7	230	2.9(5m)	6.5	7/27	1400
		2	20.0	9.0	102	8.7	220				
		4	19.8	9.2	104	8.8	220				
		6	19.8	8.9	101	8.8	220				
		7	19.8	8.9	101	8.8	220				
12	Naubinway	0	16.8	8.6	92	8.5	-	3.8(5m)	4.3	8/16	1020
		2	16.8	8.6	92	8.5	-				
		4	16.5	8.6	90	8.5	-				
		6	13.5	8.6	84	8.5	-				
		7	13.0	9.0	88	8.5	-				
13	Manistique River	0	19.1			8.9	198	2.1(5m)	--	8/17	830
		2	18.5			8.9	200				
		4	19.2			8.9	210				
		5	18.1			8.9	210				
14	Escanaba River	0	18.0	10.1	110	8.7	212	5.3(5m)	4.3	8/18	1630
		2	17.8	10.4	113	8.7	212				
		4	17.8	10.3	112	8.6	210				
15	Cedar River	0	19.0	11.5	128	8.8	215	6.8(5m)	3.0	8/19	815
		2	18.5	11.2	122	8.6	215				
		4	15.5	10.0	103	8.3	200				
		5	15.5	9.5	97	8.2	200				
16	Menominee River	0	20.0			8.8	245	6.9(5m)	2.3	8/18	830
		2	20.0			8.9	243				
		4	19.5			8.9	243				
		5	19.0			8.7	243				

Table A-7 (continued)

Station 3

Location Number	Location	Depth (m)	Temp. °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
1	Galien River	0	25.2	8.5	105	8.3	240	1.1(5m)	3.1	7/6	1530
		2	22.2	8.5	100	8.3	230				
		4	21.8	8.8	103	8.8	225				
		6	21.2	8.8	101	8.3	220				
		8	20.4	9.0	102	8.3	220				
		10	18.8	9.3	103	8.3	210				
		14	17.5	9.7	104	8.1	210				
2	St. Joseph River	-	-	-	-	-	-	7.6(4m)	1.8	7/14	930
3	Black River	-	-	-	-	-	-	-	0.9	7/11	1010
4	Kalamazoo River	0	20.0	9.2	104	8.6	225	2.0(5m)	2.7	7/19	1300
		2	20.0	10.8	122	8.6	225				
		4	20.0	10.9	123	8 6	225				
		6	20.0	12.0	136	8.6	225				
		8	20.0	11.6	131	8.6	225				
		10	20.0	11.8	133	8.6	225				
		14	20.0	12.2	139	8.4	225				
5	Lake Macatawa	0	20.0	9.2	104	8.6	225	3.1(5m)	3.4	7/22	830
		2	20.0	9.3	105	8.6	225				
		4	20.0	9.3	105	8.6	225				
		6	20.0	9.3	105	8.6	225				
		8	20.0	9.2	104	8.6	225				
		10	20.0	9.3	105	8.6	225				
		14	19.0	9.8	109	8.6	220				
6	Grand River	0	20.0	10.5	119	8.6	225	3.3(5m)	2.7	7/21	800
		2	20.0	10.0	113	8.5	225				
		4	20.0	9.2	104	8.5	225				
		6	20.0	10.2	115	8.6	220				
		8	20.0	10.6	120	8.5	225				
		10	20.0	10.4	118	8.5	225				
		14	20.0	10.4	118	8 6	220				

Table A-7 (continued)

Station 3 (continued)

Location Number	Location	Depth (m)	Temp. °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity umho/cm²	Chlor a (ug/l)	Secchi Disc (m)	Date Sampled	Time
7	Muskegon Lake	0	19.8	9.2	104	8.7	225	2.3(5m)	3.7	7/21	1400
		2	19.8	8.9	101	8.7	225				
		4	19.8	9.2	104	8.7	225				
		6	19.3	8.1	90	8.7	220				
		8	19.3	9.1	101	8.6	220				
		10	19.1	9.2	102	8.6	220				
		14	19.0	10.5	117	8.6	220				
8	White Lake	0	19.0	9.7	108	8.7	220	2.6(5m)	3.7	7/21	1800
		2	19.0	9.7	108	8.7	220				
		4	19.0	9.5	105	8.6	220				
		6	19.0	9.3	103	8.6	220				
		8	19.0	8.8	99	8.6	220				
		10	18.0	8.8	96	8.6	220				
		14	18.0	9.3	101	8.6	220				
9	Pere Marquette River	0	20.2	9.1	103	8.9	225	2.6(5m)	4.6	7/26	1530
		2	20.5	9.9	112	8.8	225				
		4	20.5	10.6	120	8.8	225				
		6	20.5	10.5	190	8.8	225				
		8	20.0	10.4	118	8.7	225				
		10	19.5	10.9	121	8.7	220				
		14	18.5	10.9	119	8.7	215				
10	Manistee River	0	19.2	9.3	103	8.8	218	2.6(5m)	6.7	7/27	830
		2	19.2	9.7	108	8.8	220				
		4	19.3	10.0	111	3.0	215				
		6	19.0	9.7	108	8.8	215				
		8	18.8	9.7	108	8.7	215				
		10	18.5	9.8	107	8.7	215				
		14	17.8	10.1	110	8.7	210				
11	Betsie Lake	0	21.7	8.9	104	8.8	230	2.6(5m)	6.1	7/27	1500
		2	20.0	9.1	103	8.8	220				
		4	19.8	9.3	105	8.8	220				
		6	19.5	9.1	101	8.8	220				
		8	19.3	8.9	99	8.8	220				
		10	19.1	9.2	102	8.8	215				
		14	18.8	9.2	102	8.8	215				
12	Naubinway	0	17.9	9.0	98	8.5	195	1.8(5m)	7.0	8/16	1130
		2	17.9	9.3	101	8.5	195				
		4	17.8	8.8	96	8.4	199				
		6	17.8	8.8	96	8.4	198				
		8	17.6	9.5	101	8.4	195				
		10	13.0	10.1	99	8.2	170				
		14	11.0	9.8	92	8.1	150				

Table A-7 (continued)

Station 3 (continued)

Location Number	Location	Depth (m)	Temp. °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
13	Manistique	0	19.0			8.9	210	1.2(5m)	9.8	9/17	930
		2	19.1			8.9	215				
		4	19.1			8.9	215				
		6	19.0			8.8	215				
		8	17.0			8.8	210				
		10	15.0			8.8	190				
		14	13.0			8.7	105				
14	Escanaba River	0	19.1	9.8	109	8.9	225	3.3(6m)	4.3	8/18	1730
		2	18.8	10.0	111	8.8	225				
		4	18.6	10.0	111	8.7	222				
		6	18.4	9.8	107	8.7	222				
		8	18.1	9.5	104	8.7	225				
		10	18.0	9.5	104	8.7	222				
		14	11.[illegible]	7.8	73	8.2	195				
15	Cedar River	0	20.0	9.6	109	8.8	230	1.7(5m)	5.2	8/19	915
		2	19.5	9.6	107	8.8	230				
		4	19.5	9.5	105	8.8	230				
		6	19.5	9.5	105	8.8	225				
		8	19.5	9.5	105	8.7	225				
		10	16.0	8.0	84	8.3	208				
		14	9.0	7.7	69	8.0	175				
16	Menominee River	0	20.9			8.9	220	1.1(6m)	3.0	8/18	930
		2	20.0			8.8	220				
		4	20.0			8.8	220				
		6	20.0			8.8	220				
		8	19.0			8.6	220				
		10	13.0			8.5	215				
		14	17.3			8.2	210				

Table A-7 (continued)

Station 6

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
1	Galien River	0	24.2	8.5	103	8.5	240	1.2(5m)	3.0	7/6	1730
		2	22.4	8.5	100	8.5	230				
		4	22.0	8.7	102	8.4	230				
		6	21.5	8.8	101	8.4	225				
		8	20.8	9.0	104	8.4	220				
		10	19.3	9.1	101	8.4	215				
		15	13.5	9.0	88	8.0	190				
		19	10.0	10.0	92	7.9	175				
2	St. Joseph River	0	20.2	-	-	8.5	220	2.0(5m)	5.8	9/16	1120
		2	20.3	-	-	8.5	225				
		4	20.2	-	-	8.5	223				
		6	20.2	-	-	8.5	223				
		8	20.2	-	-	8.3	223				
		10	20.2	-	-	8.3	223				
		15	19.0	-	-	8.2	223				
		20	18.0	-	-	8.1	210				
		25	11.0	-	-	7.8	185				
		29	6.0	-	-	7.8	160				
4	Kalamazoo River	0	20.0	9.2	104	8.8	218	2.4(4m)	5.2	7/19	1510
		2	19.5	9.7	108	8.8	220				
		4	19.5	9.9	110	8.8	225				
		6	19.0	10.5	117	8.8	220				
		8	19.0	10.3	114	8.7	220				
		10	18.5	10.0	109	8.7	220				
		15	16.0	10.5	110	8.5	210				
		20	13.0	10.7	105	8.2	190				
		25	11.0	11.3	106	8.2	180				
		29	9.0	11.7	105	8.2	175				
5	Lake Macatawa	0	21.0	9.0	104	8.6	230	3.4(5m)	3.7	7/22	725
		2	21.0	9.0	104	8.6	225				
		4	21.0	8.7	100	8.6	225				
		6	21.0	8.7	100	8.6	225				
		8	21.0	8.9	103	8.6	225				
		10	21.0	9.1	105	8.6	225				
		15	19.5	10.1	112	8.6	220				
		20	16.5	10.8	111	8.6	210				
		25	12.9	10.8	104	8.2	185				
		29	8.0	9.7	85	8.0	170				

Table A-7 (continued)

Station 6 (continued)

Location Number	Location	Depth (m)	Temp °C	Dissolved Oyxgen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
6	Grand River	0	20.0	9.2	104	8.7	240	3.0(5m)	0.4	7/21	1900
		2	20.0	9.2	104	8.6	240				
		4	19.8	8.8	100	8.5	240				
		6	19.8	8.5	96	8.6	240				
		8	19.8	9.3	105	8.6	235				
		10	19.6	10.3	117	8.7	230				
		15	19.0	10.4	115	8.7	225				
		20	19.0	10.5	117	8.5	230				
		25	17.0	10.8	115	8.4	215				
		29	14.0	11.6	116	8.4	190				
7	Muskegon Lake	0	19.5	9.8	109	8.7	220	2.2(5m)	4.9	7/21	1245
		2	19.5	9.1	101	8.7	225				
		4	19.5	8.7	97	9.7	220				
		6	19.0	9.7	108	8.7	215				
		8	19.0	10.2	113	8.7	220				
		10	19.0	10.4	115	9.7	270				
		15	18.5	10.4	113	8.7	215				
		20	14.0	13.4	134	8.6	190				
		25	9.5	13.2	118	8.4	175				
		29	9.0	12.8	114	8.4	170				
8	White Lake	0	19.0	9.3	103	8.8	220	3.0(5m)	4.3	7/21	705
		2	19.0	9.1	101	8.8	220				
		4	19.0	9.3	103	8.8	220				
		6	19.0	10.2	113	8.8	220				
		8	18.5	10.2	111	8.8	220				
		10	18.0	10.2	111	8.7	215				
		15	17.0	10.2	109	8.6	215				
		20	17.0	10.5	112	8.6	210				
		25	14.0	10.8	108	8.4	190				
		29	9.5	10.8	97	8.4	190				
9	Pere Marquette River	0	21.0	9.0	104	8.8	225	2.7(5m)	4.6	7/26	1430
		2	21.0	9.8	113	8.8	225				
		4	20.0	10.2	115	8.8	225				
		6	20.0	10.3	117	9.8	225				
		8	20.0	10.5	119	8.0	225				
		10	19.0	10.5	117	8.8	220				
		15	18.0	10.5	114	9.6	215				
		20	15.0	11.1	114	8.5	220				
		25	9.0	11.7	105	8.6	165				
		28	7.0	12.1	103	9.2	160				

Table A-7 (continued)

Station 6 (continued)

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
10	Manistee River	0	19.3	9.3	103	8.8	215	2.4(5m)	7.3	7/27	725
		2	19.3	9.3	103	8.8	215				
		4	19.3	9.3	103	8.8	215				
		6	19.0	9.4	104	8.8	215				
		8	19.0	9.9	110	8.8	215				
		10	18.8	10.6	119	8.8	215				
		15	18.1	10.4	113	8.7	210				
		20	17.5	10.5	112	8.7	210				
		25	16.0	10.7	112	8.5	205				
		29	14.5	10.9	112	8.5	195				
11	Betsie Lake	0	21.5	8.5	99	8.8	225	2.2(5m)	7.3	7/27	1500
		2	20.5	8.9	101	8.8	220				
		4	20.0	8.9	101	8.8	220				
		6	19.8	8.9	101	8.8	220				
		8	19.5	9.2	104	8.8	215				
		10	19.3	9.3	105	8.8	215				
		15	18.3	9.3	101	8.7	210				
		20	16.3	9.1	97	8.7	205				
		25	14.2	9.9	99	8.7	195				
		29	10.0	10.8	99	8.6	160				
12	Naubinway	0	17.8	9.6	105	8.5	198	1.8(5m)	7.0	9/16	1135
		2	17.9	9.5	103	8.5	199				
		4	17.8	9.4	102	8.5	190				
		6	16.5	9.8	103	8.4	198				
		8	16.5	9.8	103	8.3	190				
		10	16.5	9.6	100	8.3	190				
		15	15.0	9.8	100	8.3	132				
13	Manistique River	0	19.2			8.9	218	1.0(5m)	9.8	8/17	830
		2	19.2			8.9	218				
		4	19.2			8.9	218				
		6	19.2			8.9	218				
		8	19.2			8.8	218				
		10	19.1			8.8	218				
		15	19.1			8.8	218				
		20	19.5			8.7	190				
		25	11.8			8.6	170				
		29	7.5			8.5	160				

Table A-7 (continued)

Station 6 (continued)

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
14	Escanaba River	0	17.5	9.8	105	8 3	210	1.1(5m)	4.0	8/18	1630
		2	17.5	9.8	105	9 3	210				
		4	17.5	9.8	105	8.3	210				
		6	17.5	9.8	105	8 3	210				
		8	17.5	10.9	107	8.3	210				
		10	17.5	10.1	108	8.2	205				
		15	15.5	9 8	100	8 2	200				
		20	15 0	9.2	94	8.0	180				
		22	13 0	8.8	86	3.0	175				
15	Cedar River	0	20.0	9.8	111	8.9	225	2.0(5m)	5.8	8/19	815
		2	20 0	10.0	113	8.9	225				
		4	20.0	10.0	113	8.8	226				
		6	20.0	9 8	111	8.8	225				
		8	20 0	9.8	111	3.8	221				
		10	20.0	9.8	111	8.8	225				
		15	19.0	9.8	109	8.8	220				
		20	13.0	9.0	88	8.2	190				
		25	8 0	8.0	70	8 1	162				
		29	8 0	8.0	70	8.0	160				
16	Menominee River	0	20.5			8.4	225	3.8(6m)	3.4	8/18	830
		2	20.5			3.4	225				
		4	20 0			8.4	270				
		6	20 0			8.4	220				
		8	20.0			8.3	220				
		10	20.0			8.4	220				
		15	19.5			8.2	215				
		20	14.5			8.0	200				
		25	12.5			7.8	185				
		29	10.0			7.8	175				

Table A-7 (continued)

Station 9

Location Number	Location	Depth (m)	Temp °C	Dissolved Oxygen (mg/l)	% Oxygen Saturation	pH	Conductivity µmho/cm²	Chlor a (µg/l)	Secchi Disc (m)	Date Sampled	Time
3	Black River	-	-	-	-	-	-	-	4.0	7/13/76	1130
11	Betsie Lake	0	21.3	8.9	103	8.8	220	1.8(5m)	8.5	7/27/76	1800
		2	20.0	9.1	103	8.8	220				
		4	20.0	9.0	102	8.9	220				
		6	14.9	9.1	103	8.9	220				
		8	19.8	9.1	103	8.8	215				
		10	19.5	9.3	105	8.8	215				
		15	19.0	9.3	103	8.7	210				
		20	16.5	9.8	103	8.7	205				
		25	14.0	10.3	103	8.6	195				
		30	8.0	11.9	104	8.5	165				
		35	6.5	11.4	95	8.4	155				
		39	6.0	11.3	94	8.4	155				

Table A-8 Sediment particle size percent composition at 16 locations, Lake Michigan, 1976.

Location Number	Location	Station Number	Depth (m)	Solids Total % wet wt.	Total Volatile Solids % T.S.	Gravel >2 mm % dry wt.	Very Coarse Sand 1-2 mm % dry wt.	Coarse Sand 0.5-1 mm % dry wt.	Medium Sand 0.25-0.5 mm % dry wt.	Fine Sand 0.10-0.25 mm % dry wt.
1	Galien River									
		1	5	81.3		0.1	0.1	1.6	41.1	56.3
		2	15	81.2		0.1	0.1	3.7	22.8	70.8
		3	15	80.4		0.1	0.2	2.1	11.5	80.0
		4	15	80.8		0.1	0.2	2.5	18.0	76.2
		5	20	81.9		0.1	0.1	3.2	18.3	73.0
		6	20	81.1		0.1	0.3	3.1	11.8	79.2
		7	20	79.6		0.1	0.2	3.6	20.1	71.2
2	St. Joseph River									
		1	5	80.2		0.1	0.1	0.5	33.2	63.9
		2	15	81.1		0.1	0.1	3.8	33.8	56.4
		3	15	81.8		0.1	0.2	6.9	57.0	32.7
		4	15	81.5		0.1	0.2	2.6	37.9	53.9
		5	30	74.0		0.3	0.7	1.4	3.4	4.7
		6	30	72.8		0.2	0.5	1.3	3.5	9.7
		7	30	75.0		0.1	0.5	1.3	2.7	10.1
3	Black River									
		1	5	83.5		18.6	2.5	46.2	23.8	8.4
		2	15	79.9		0.1	0.1	1.6	5.5	85.1
		3	15	80.4		0.1	0.2	2.5	6.7	84.3
		4	15	81.6		0.1	0.3	2.1	6.8	82.2
		5	30	80.8		0.4	1.2	7.8	17.0	45.5
		6	30	82.3		0.2	1.0	14.7	24.6	37.2
		7	30	81.1		0.2	0.8	0.8	40.6	29.1
		8	45	41.1		0.1	0.3	0.7	1.6	2.9
		9	45	42.4		0.1	0.1	0.6	1.5	2.4
		10	45	40.8		0.1	0.2	0.6	1.6	2.7
4	Kalamazoo River	1	5	84.1		0.0	0.0	2.8	81.4	15.5
		2	15	84.4		0.0	0.0	1.4	38.3	56.3
		3	15	85.0		0.0	0.0	3.2	76.0	18.7
		4	15	85.1		0.0	0.0	4.8	73.3	20.3
		5	30	83.3		0.6	1.8	8.0	11.1	47.5
		6	30	82.8		0.1	0.5	2.3	20.2	46.9
		7	30	82.0		0.0	0.1	1.1	10.0	42.6

Table A-8 (continued)

Location Number	Station	Station Number	Very Fine Sand 0.05-0.10 mm % dry wt.	Silt 0.002-0.05 mm % dry wt.	Clay <0.002 mm % dry wt.
1	Galien River				
		1	0.5	0.2	0.1
		2	0.8	0.7	0.7
		3	2.2	1.7	2.1
		4	1.4	1.0	0.6
		5	2.2	1.4	1.5
		6	2.4	1.4	1.6
		7	2.1	1.3	1.3
2	St. Joseph River				
		1	0.9	0.9	0.8
		2	2.3	2.0	1.4
		3	1.3	1.1	0.9
		4	2.2	2.0	1.2
		5	33.1	32.3	24.2
		6	38.0	26.8	20.0
		7	38.9	25.0	21.4
3	Black River				
		1	0.2	0.1	0.1
		2	3.0	2.8	2.0
		3	2.5	2.2	1.7
		4	3.6	2.0	2.8
		5	10.1	11.0	6.8
		6	7.4	9.0	5.8
		7	5.4	6.0	3.8
		8	2.2	58.8	33.5
		9	1.7	56.0	37.6
		10	2.2	58.5	34.1
4	Kalamazoo River				
		1	0.3	<0.1	<0.1
		2	3.2	0.6	0.2
		3	1.1	0.2	0.1
		4	1.2	0.3	0.1
		5	26.6	9.2	3.1
		6	17.7	8.0	4.3
		7	33.6	7.7	4.8

Table A-8 (continued)

Location Number	Location	Station Number	Depth (m)	Solids Total % wet wt.	Total Volatile Solids % T.S.	Gravel >2 mm % dry wt.	Very Coarse Sand 1-2 mm % dry wt.	Coarse Sand 0.5-1 mm % dry wt.	Medium Sand 0.25-0.5 mm % dry wt.	Fine Sand 0.10-0 25 mm % dry wt.
5	Lake Macatawa									
		1	7	82.6		0.0	0.0	1.1	68.5	30.4
		2	15	85.4		0.4	2.3	31.5	58.5	7.0
		3	15	85.0		0.0	1.2	28.6	63.0	6.4
		4	15	85.3		0.3	2.8	31.8	58.3	6.5
		5	30	80.9		0.0	0.4	1.7	6 7	46 1
		6	30	79.4		0.3	0.8	3.0	9.7	41.4
		7	30	81.6		0.0	0.4	1.9	8.9	49.9
6	Grand River	1	7	84.7		0.0	0.1	0.4	22.3	77.0
		2	15	84.6		0.0	0.2	3.9	71.4	24.4
		3	15	83.6		0.0	0.1	3.0	71.1	25.7
		4	15	83.0		0.0	0.2	4.5	74.3	20 9
		5	30	80.1		0.2	1.1	1.7	12.1	56.8
		6	30	81.3		0.2	0.4	1.7	16.0	60.3
		7	30	82.5		0.1	0.7	3.7	17.1	53.1
7	Muskegon Lake									
		1	7	81.6		0.0	0.0	0.9	20.3	78.7
		2	15	83.7		0.0	0.0	0.5	43.1	55.5
		3	15	84.1		1.0	0.0	0.7	33.9	65.1
		4	15	84.1		0.0	0.0	1.0	37.3	60.3
		5	30	82.1		0.2	0.2	2.1	22.6	52.7
		6	30	82.6		0.0	0.1	2.4	10.2	60.4
		7	30	82.7		0.1	0.2	1.5	16.7	52.9
8	White Lake									
		1	7	83.4		0.2	0.1	1.2	40.5	55.9
		2	15	84.2		0.1	0.4	4.5	50.5	43.9
		3	15	84.3		0.4	0.7	4.4	45.6	47.0
		4	15	84.1		0.4	0.3	4.1	45.0	45.8
		5	30	82.0		0.1	0.3	5.2	31.3	58.3
		6	30	82.6		0.2	0.4	5.7	31.7	57.6
		7	30	82.3		0.1	0.2	5.3	31.0	57.6
9	Pere Marquette River									
		1	8	83.0		<0.1	0.1	0.7	11.9	82.3
		2	15	82.8		0.0	0.1	2.8	30.7	66.3
		3	15	82.8		0.0	0.1	2.7	31.5	65.7
		4	15	82.8		0.0	0.1	2.8	23.0	65.4
		5	30	83.0		0.1	0.3	7.9	55.1	36.6
		6	30	83.8		0.5	0.5	16.8	62.7	19.4
		7	30	82.5		0.3	0.2	1.1	32.8	64.7

Table A-8 (continued)

Location Number	Location	Station Number	Fine Very Sand 0.05-0.10 mm % dry wt.	Silt 0.002-0.05 mm % dry wt.	Clay <0.002 mm % dry wt.
5	Lake Macatawa				
		1	0.1	<0.1	<0.1
		2	0.4	0.1	<0.1
		3	0.5	0.1	0.1
		4	0.4	<0.1	<0.1
		5	32.2	9.7	3.3
		6	31.6	8.7	4.4
		7	25.4	9.9	3.6
6	Grand River				
		1	0.1	<0.1	<0.1
		2	0.2	<0.1	<0.1
		3	0.1	<0.1	<0.1
		4	0.1	<0.1	<0.1
		5	19.4	5.0	3.7
		6	12.6	5.0	3.7
		7	14.2	6.0	5.1
7	Muskegon Lake				
		1	0.1	<0.1	<0.1
		2	0.5	0.2	0.1
		3	0.1	<0.1	0.1
		4	1.0	0.3	<0.1
		5	15.3	3.2	3.6
		6	8.5	4.4	4.4
		7	16.9	6.1	5.6
8	White Lake				
		1	1.1	0.5	0.4
		2	0.3	0.2	<0.1
		3	0.4	0.2	0.2
		4	0.3	0.3	0.1
		5	2.7	1.1	0.8
		6	2.1	1.1	0.7
		7	3.4	1.7	0.6
9	Pere Marquette River				
		1	2.6	0.3	0.1
		2	0.1	<0.1	0.0
		3	0.1	<0.1	0.0
		4	0.2	<0.1	0.0
		5	0.1	<0.1	0.0
		6	0.2	<0.1	0.0
		7	0.1	<0.1	0.0

Table A-8 (continued)

Location Number	Location	Station Number	Depth (m)	Solids Total % wet wt.	Total Volatile Solids % T.S.	Gravel >2 mm % dry wt.	Very Coarse Sand 1-2 mm % dry wt.	Coarse Sand 0.5-1 mm % dry wt.	Medium Sand 0.25-0.5 mm % dry wt.	Fine Sand 0.10-0.25 mm % dry wt.
10	Manistee River									
		1	10	83.3		0.1	0.1	0.9	57.2	39.7
		2	15	84.3		0.1	0.9	15.8	73.6	9.6
		3	15	84.0		0.2	0.9	23.5	69.4	7.0
		4	15	84.8		0.5	2.6	24.6	65.0	7.4
		5	30	81.3		0.3	0.1	1.0	17.3	80.2
		6	30	81.0		0.2	0.2	1.2	28 8	68 4
		7	30	81.8		0.0	0.1	1.3	23.2	73.9
11	Betsie Lake									
		1	8	82.5		0.0	0.1	1.6	46.8	51.7
		2	15	82.8		0.1	0.1	0.7	29.0	69.3
		3	15	83.8		0.0	0.1	4.2	70.5	25.2
		4	15	81.0		0.0	0.1	0.3	13.8	83.0
		5	30	83.0		0.3	0.7	13.7	68.6	16.2
		6	30	84.3		0.4	0.9	15.9	73.8	8.7
		7	30	84.3		0.1	0.3	17.7	74.0	7.9
		8	40	84.3		0.2	1.4	14.1	72.4	7.9
		9	40	83.8		0.0	0.3	12.9	74.5	11.1
		10	40	83.5		0.5	0.2	9.2	71.9	10.1
12	Naubinway									
		1	8	85.0		4.6	14.8	22.2	13.5	25.5
		2	15	81.8		0.0	0.3	3.4	29.8	50.4
		3	15	84.5		0.5	2.1	23.1	41.1	24.6
		4	15	79.0		0.0	0.4	1.8	6.8	59.5
		5	20	83.0		6.8	3.3	4.7	21.2	41.8
		6	20	82.0		0.0	0.7	6.0	31.4	55.8
		7	20	79.0	4.2	61.7	12.2	10.6	8.7	3.8
13	Manistique River									
		1	6	86.8		53.5	20.2	20.1	0.0	1.0
		2	15	85.0		0.1	0.8	44.6	51.6	2.8
		3	15	84.8		0.1	0.2	16.1	77.5	6.0
		4	15	84.5		0.0	0.4	31.7	64.8	3.0
		5	30	82.8		0.5	0.6	1.8	49.9	46.7
		6	30	82.8		0.1	0.1	0.8	41.8	56.4
		7	30	83.5		0.2	0.2	3.5	58.5	37.3
		8	6	24.5	41.8	0.0	0.0	1.0	3.7	77.0
		9	6	68.8	14.3	0.0	0.1	0.9	2.9	72.5
		10	6	58.8	12.0	0.0	0.0	0.0	11.2	79.0

Table A-8 (continued)

Location Number	Location	Station Number	Very Fine Sand 0.05-0.10 mm % dry wt.	Silt 0.002-0.05 mm % dry wt.	Clay <0.002 mm % dry wt.
10	Manistee River				
		1	1.7	0.3	0.1
		2	0.1	<0.1	0.0
		3	0.1	<0.1	0.0
		4	0.1	<0.1	0.0
		5	0.8	0.3	0.1
		6	0.8	0.2	0.1
		7	1.1	0.3	0.1
11	Betsie Lake				
		1	0.1	0.0	0.0
		2	0.7	0.1	0.0
		3	0.3	0.1	0.0
		4	0.8	0.1	0.1
		5	0.5	0.1	0.0
		6	0.1	0.0	0.0
		7	0.1	0.0	0.0
		8	3.2	0.7	0.0
		9	1.0	0.2	0.1
		10	6.7	0.9	0.5
12	Naubinway				
		1	10.0	6.1	3.3
		2	8.4	5.4	2.4
		3	4.1	2.5	1.8
		4	16.1	11.1	4.4
		5	3.6	9.9	8.8
		6	4.3	1.2	0.7
		7	0.6	0.3	0.1
13	Manistique River				
		1	0.2	<0.1	<0.1
		2	0.2	<0.1	<0.1
		3	0.1	<0.1	<0.1
		4	0.1	<0.1	<0.1
		5	0.3	<0.1	<0.1
		6	0.8	<0.1	<0.1
		7	0.3	<0.1	<0.1
		8	16.1	2.7	0.6
		9	15.7	5.4	2.5
		10	5.8	3.1	1.0

Table A-8 (continued)

Location Number	Location	Station Number	Depth (m)	Solids Total % wet wt.	Total Volatile Solids % T.S.	Gravel >2 mm % dry wt.	Very Coarse Sand 1-2 mm % dry wt.	Coarse Sand 0.5-1 mm % dry wt.	Medium Sand 0.25-0.5 mm % dry wt.	Fine Sand 0.10-0.25 mm % dry wt.
14	Escanaba River									
		1	6	65.0		0.0	0.0	0.8	26.5	65.9
		2	15	14.3		1.6	4.4	6.0	5.4	9.7
		3	15	14.0		0.0	0.0	0.4	3.1	16.7
		4	15	15.8		0.0	0.0	5.4	7.2	23.6
		5	23	82.3		4.3	4.7	20.8	50.5	17.5
		6	23	66.3		0.0	0.0	0.6	2.3	4.3
		7	23	81.8		1.9	4.5	27.0	48.1	15.3
15	Cedar River									
		1	6	77.3		0.0	0.1	0.4	12.8	78.5
		2	15	69.3		0.9	3.3	13.5	24.5	44.3
		3	15	79.8		3.5	5.3	14.4	30.1	33.6
		4	15	72.8		3.3	6.8	13.7	29.4	33.8
		5	30	65.0		0.8	0.9	2.4	11.5	29.5
		6	30	63.8		0.4	0.9	3.2	12.8	2.2
		7	30	58.0		0.5	0.8	2.7	9.7	20.4
16	Menominee River									
		1	6	86.0		27.9	7.6	30.8	30.7	2.8
		2	15	62.5	6.3	1.0	1.4	2.4	9.7	49.5
		3	15	66.8	5.0	0.6	1.6	6.3	24.7	44.2
		4	15	77.8		2.6	3.2	11.2	54.5	26.9
		5	30	45.3		0.3	0.6	5.2	19.8	20.9
		6	30	58.3		2.0	1.5	3.5	7.2	2.5
		7	30	61.0		0.3	1.0	3.4	19.2	37.3

Table A-8 (continued)

Location Number	Station	Station Number	Very Fine Sand 0.05-0.10 mm % dry wt.	Silt 0.002-0.05 mm % dry wt.	Clay <0.002 mm % dry wt.
14	Escanaba River				
		1	4.7	1.1	0.9
		2	17.5	27.3	28.2
		3	21.5	34.9	21.5
		4	19.0	26.2	18.5
		5	1.1	0.6	0.4
		6	13.7	41.1	37.9
		7	1.8	0.9	0.5
15	Cedar River				
		1	4.7	2.1	1.3
		2	10.1	2.2	1.2
		3	9.7	2.0	1.4
		4	9.6	2.1	1.3
		5	10.1	31.3	13.7
		6	14.5	37.2	10.8
		7	8.2	23.6	24.6
16	Menominee River				
		1	0.2	0.1	0.0
		2	21.8	6.7	7.4
		3	10.7	6.2	5.7
		4	1.2	0.4	0.1
		5	23.5	17.8	12.0
		6	2.4	44.0	36.9
		7	14.0	16.4	8.6

Table A-9 Sediment chemistry results from 16 locations, Lake Michigan, 1976. Concentrations expressed as mg/kg dry weight except where otherwise indicated.

Location Number	Location	Depth (m)	Total Copper	Total Mercury	Total Cadmium	Total Chromium	Total Zinc	Total Nickel	Total Lead	Total Iron	Total Manganese	Total Solids (%)	Total Volatile Solids (% TS)	T.K.N.	T.P.	C.O.D.	TOC gm/kg
1	Galien River																
	Station 1	5	0.8	0.02	<0.1	1.7	7.1	9.4	2.7	1600	3.9	82	0.4	14	69	750	0.32
	Station 2	15	0.7	<0.01	<0.1	1.2	8.8	4.6	2.6	1300	3.3	84	0.4	50	84	1300	0.35
	Station 3	15	1.2	0.01	<0.1	2.0	15	4.5	6.3	2100	5.3	82	0.5	105	111	2200	0.47
	Station 4	15	1.1	0.03	<0.1	2.2	18	4.5	7.0	2400	6.9	83	0.4	67	94	1400	0.32
	Station 5	20	3.0	0.03	0.2	4.7	54	9.3	16	6500	15	82	0.5	154	155	3700	0.86
	Station 6	20	2.9	0.01	0.1	4.7	51	10	16	6400	15	81	0.5	173	194	4100	0.94
	Station 7	20	2.4	0.03	<0.1	4.3	43	9.9	14	6500	11	83	0.6	141	145	3300	1.4
2	St. Joseph River																
	Station 1	6	1.1	<0.01	<0.1	1.3	8.0	3.7	2.4	1700	43	82	0.4	28	55	680	0.39
	Station 2	15	2.2	0.01	<0.1	3.0	16	5.7	1.6	2900	75	75	0.4	72	101	1900	1.0
	Station 3	15	0.9	0.03	<0.1	1.8	11	3.6	3.0	1900	52	78	0.1	40	85	990	0.45
	Station 4	15	1.4	0.02	<0.1	2.2	12	5.3	3.2	2300	68	80	0.2	66	101	1400	0.97
	Station 5	30	14	0.05	0.4	16	120	14	32	15000	520	71	0.7	490	300	23000	6.3
	Station 6	30	14	0.05	0.5	17	120	15	32	15000	470	74	0.8	630	370	18000	5.3
	Station 7	30	15	0.06	0.4	18	130	14	33	17000	510	76	0.5	720	340	19000	6.0
3	Black River																
	Station 1	5	1.4	<0.01	<0.1	2.5	12	7.8	4.5	5100	140	88	0.3	47	99	1100	0.40
	Station 2	15	1.6	0.02	<0.1	2.3	13	6.7	6.7	2500	77	80	0.6	79	180	1800	0.44
	Station 3	15	1.1	0.01	<0.1	2.3	11	5.7	6.6	2300	67	77	0.5	89	200	2200	0.47
	Station 4	15	1.7	0.01	<0.1	3.1	15	6.9	6.1	3000	85	81	0.5	73	189	2200	0.37
	Station 5	30	6.9	0.03	0.7	8.5	59	8.9	7.9	7400	280	83	0.7	450	210	8100	2.6
	Station 6	30	5.3	0.03	0.6	6.2	51	6.2	25	6000	210	82	0.6	270	159	7700	3.6
	Station 7	30	4.7	0.02	0.4	5.5	52	7.9	20	5900	180	82	0.2	300	139	5800	2.4
	Station 8	45	40	0.20	1.2	32	190	32	42	24000	500	37	1.6	3300	590	83000	11
	Station 9	45	50	0.38	1.8	40	240	39	130	30000	680	36	1.9	3900	620	110000	18
	Station 10	45	40	0.21	1.2	32	190	35	68	13000	540	38	1.6	3500	590	84000	15
4	Kalamazoo River																
	Station 1	5	1.0	<0.01	<0.1	2.0	8.0	3.9	4.1	2000	43	83	0.6	180	56	2000	0.60
	Station 2	15	0.9	0.03	<0.1	1.9	12	4.4	3.7	2200	62	83	0.2	64	114	1500	0.76
	Station 3	15	0.8	0.01	<0.1	1.7	10	4.2	3.6	2200	58	84	0.3	38	65	1100	0.51
	Station 4	15	0.8	<0.01	<0.1	1.8	10	5.0	2.5	2400	55	84	0.2	54	68	1200	0.31
	Station 5	30	7.1	0.04	0.4	8.7	51	7.4	19	6800	290	81	0.5	184	330	7800	4.1
	Station 6	30	6.3	0.02	0.3	7.8	46	8.0	16	5600	240	82	0.4	260	260	8400	4.2
	Station 7	30	8.6	0.06	0.5	12	70	12	34	7300	420	79	0.8	410	300	13000	3.5
5	Lake Macatawa																
	Station 1	7	0.5	0.02	<0.1	1.8	7.3	4.6	2.4	1800	40	82	0.4	25	40	1600	0.36
	Station 2	15	1.0	0.03	<0.1	2.7	12	6.7	3.4	3400	92	83	0.6	40	58	1800	0.44
	Station 3	15	0.9	0.02	<0.1	2.0	9.9	4.8	2.1	2400	60	88	1.0	15	43	1500	0.27
	Station 4	15	1.0	0.01	<0.1	2.2	11.6	5.8	3.7	3000	78	89	0.9	31	64	1500	0.45
	Station 5	30	5.9	0.06	0.4	8.0	44	16	28	5800	230	73	0.7	440	260	9500	5.0
	Station 6	30	6.6	0.06	0.6	8.2	46	17	28	6400	280	80	0.6	350	270	9000	5.4
	Station 7	30	7.3	0.05	0.7	8.3	47	20	29	7900	320	79	0.4	260	280	10000	6.1

Table A-9 (continued)

Location Number	Location	Depth (m)	Total Copper	Total Mercury	Total Cadmium	Total Chromium	Total Zinc	Total Nickel	Total Lead	Total Iron	Total Manganese	Total Solids (%)	Total Volatile Solids (%TS)	T.K.N.	T.P.	C.O.D.	TOC gm/kg
6	Grand River																
	Station 1	7	1.2	0.01	<0.1	2.4	9.6	5.3	2.0	2000	45	81	0.4	54	71	1200	0.82
	Station 2	15	0.9	<0.01	<0.1	2.3	9.8	4.8	2.1	2400	44	82	0.2	23	49	940	0.31
	Station 3	15	0.7	<0.01	<0.1	1.5	8.1	3.5	2.5	1700	32	83	0.1	21	66	760	0.31
	Station 4	15	0.8	<0.01	<0.1	2.1	9.0	4.6	2.8	2200	43	82	0.1	20	57	630	0.26
	Station 5	30	7.8	0.04	0.7	10	56	16	37	6400	350	78	0.5	490	280	8900	3.2
	Station 6	30	9.0	0.04	0.6	14	67	18	35	6400	350	80	0.8	520	270	11000	2.6
	Station 7	30	9.0	0.06	0.8	11	65	16	37	6400	470	80	0.6	480	280	10000	3.2
7	Muskegon Lake																
	Station 1	7	0.5	0.03	<0.1	1.5	7.7	3.8	1.8	1600	42	80	0.2	22	40	670	0.26
	Station 2	15	0.8	0.01	<0.1	1.8	7.0	3.9	1.7	1500	34	84	0.1	22	50	1400	0.49
	Station 3	15	0.8	0.01	<0.1	1.6	8.8	4.3	2.9	1700	37	78	0.1	25	54	930	0.35
	Station 4	15	0.6	<0.01	<0.1	1.8	7.9	4.0	2.1	1600	37	83	0.1	26	55	980	0.37
	Station 5	30	8.0	0.01	0.8	9.6	64	22	46	6200	620	80	0.1	330	210	11000	3.5
	Station 6	30	7.1	0.03	0.6	8.8	58	20	35	5700	600	80	0.4	270	193	12000	3.8
	Station 7	30	7.5	0.03	0.7	9.3	57	20	37	6400	560	78	0.9	460	340	15000	3.1
8	White Lake																
	Station 1	7	0.7	0.04	<0.1	1.6	6.3	4.1	1.7	1300	31	83	0.2	48	37	1500	0.61
	Station 2	15	0.6	0.01	<0.1	1.5	5.5	3.8	1.8	1400	28	84	0.9	26	42	1200	0.41
	Station 3	15	0.7	0.02	<0.1	1.8	5.9	4.1	1.6	1500	29	83	0.2	26	38	1200	0.55
	Station 4	15	0.6	0.01	<0.1	1.5	6.0	3.2	1.8	1300	30	81	0.4	34	46	1300	0.45
	Station 5	30	3.8	0.01	<0.1	4.9	30	11	16	3200	270	81	0.6	240	120	8500	2.7
	Station 6	30	4.0	0.03	<0.1	5.1	30	11	16	3200	240	80	0.6	360	126	6200	2.3
	Station 7	30	4.3	<0.01	0.3	5.4	36	7.6	18	3100	280	81	1.1	350	126	6500	1.6
9	Pere Marquette River																
	Station 1	8	0.5	0 01	<0.1	0.9	4.5	2.6	1.9	960	72	79	0.4	22	43	780	0.46
	Station 2	15	3.2	0.02	<0.1	0.9	5.6	2.2	0.9	980	18	80	0.1	25	41	820	0.26
	Station 3	15	0.4	<0.01	<0.1	1.0	6.6	1.7	1.3	970	18	80	0.2	28	32	860	0.27
	Station 4	15	0.3	<0.01	<0.1	0.8	6.8	1.8	1.0	1000	18	82	0.6	27	43	830	0.25
	Station 5	30	0.7	0.01	<0.1	1.2	7.2	3.1	2.3	1400	38	78	0.4	59	34	1600	0.43
	Station 6	30	0.6	<0.01	<0.1	1.0	12	2.1	1.2	1300	48	82	0.2	37	33	770	0.25
	Station 7	30	1.4	0.01	<0.1	1.8	10	5.8	4.6	1300	53	74	0.4	91	51	11700	0.40
10	Manistee River																
	Station 1	10	0.9	0.01	<0.1	1.3	4.4	4.0	1.6	1100	25	82	0.2	75	42	2000	0.79
	Station 2	15	0.3	0.05	<0.1	0.6	2.9	2.1	0.2	730	11	83	0.2	16	28	580	0.23
	Station 3	15	0.3	<0.01	<0.1	1.0	3.6	2.5	0.4	1000	26	85	0.7	15	30	480	0.19
	Station 4	15	0.4	<0.01	0.3	0.2	3.4	3.3	1.2	1100	18	85	0.2	13	39	500	0.24
	Station 5	30	1.9	0.04	<0.1	2.1	10	5.5	6.8	1700	78	78	0.2	144	92	3500	1.3
	Station 6	30	2.0	0.03	<0.1	2.1	15	4.1	6.8	1600	100	80	0.2	146	74	2900	1.1
	Station 7	30	2.4	0.07	<0.1	2.7	17	5.9	9.7	2200	130	79	0.9	149	92	3800	1.5

Table A-9 (continued)

Location Number	Location	Depth (m)	Total Copper	Total Mercury	Total Cadmium	Total Chromium	Total Zinc	Total Nickel	Total Lead	Total Iron	Total Manganese	Total Solids (%)	Total Volatile Solids (%T.S.)	T.K.N.	T.P.	C.O.D.	T.O.C. gm/kg
11	Betsie Lake																
	Station 1	8	0.7	0.01	<0.1	1.1	2.8	3.7	2.2	620	14	85	0.5	19	39	560	0.21
	Station 2	15	0.6	0.01	<0.1	1.5	4.4	4.3	2.6	780	24	81	0.4	39	83	960	0.79
	Station 3	15	0.6	<0.01	<0.1	0.8	3.1	3.2	1.6	610	14	85	0.6	34	55	730	0.50
	Station 4	15	1.0	0.02	<0.1	1.8	4.1	5.0	3.3	920	28	78	0.3	45	81	2000	0.79
	Station 5	30	1.2	<0.01	<0.1	1.4	7.4	3.5	3.0	1300	50	78	0.4	84	56	3400	0.51
	Station 6	30	0.4	0.02	<0.1	0.8	4.2	1.9	0.9	850	30	83	1.0	62	39	1300	0.31
	Station 7	30	0.4	0.01	<0.1	0.7	3.5	2.3	0.4	830	21	81	0.4	29	28	2600	1.1
	Station 8	40	3.4	<0.01	<0.1	3.3	19	7.9	12	2300	170	81	0.5	210	73	5300	1.7
	Station 9	40	2.4	0.01	<0.1	2.1	13	7.5	6.9	1600	190	70	<0.1	140	72	3700	1.2
	Station 10	40	1.5	0.01	<0.1	1.6	8.1	3.8	3.4	1200	71	80	0.1	109	48	2200	0.83
12	Naubinway																
	Station 1	8	2.7	<0.01	<0.1	4.4	15	8.0	7.1	3000	53	85	0.2	310	133	7600	3.7
	Station 2	15	2.7	<0.01	0.3	3.5	14	5.5	11	1900	43	80	0.1	410	167	8800	4.6
	Station 3	15	2.4	<0.01	0.1	3.2	18	5.4	8.6	2600	46	82	0.5	260	121	7400	4.4
	Station 4	15	3.5	0.01	<0.1	3.8	20	7.4	12	2400	57	74	0.3	410	184	11000	3.3
	Station 5	20	4.1	<0.01	0.2	6.8	31	13	8.5	18000	1500	85	0.5	210	104	4000	2.0
	Station 6	20	1.7	0.01	<0.1	1.8	11	5.0	9.6	2000	74	80	0.2	210	58	5900	1.8
	Station 7	20	11	0.01	<0.1	12	110	23	21	53000	4500	79	1.0	360	300	7700	4.2
13	Manistique River																
	Station 1	6	4.2	0.01	1.0	7.5	11	18	15	10000	34	86	0.1	85	97	17000	2.2
	Station 2	15	0.1	<0.01	0.7	0.6	2.0	<1	<0.2	870	7.7	88	0.2	43	28	1200	0.31
	Station 3	15	0.3	0.01	<0.1	0.6	2.8	2.0	<0.2	880	8.0	86	0.1	49	24	1700	0.38
	Station 4	15	0.3	0.01	<0.1	0.4	2.4	<1	0.7	810	7.3	87	0.1	43	21	1000	0.33
	Station 5	30	0.7	0.02	<0.1	0.7	8.0	3.1	3.8	2400	150	82	0.4	80	61	2100	0.54
	Station 6	30	0.9	<0.01	<0.1	1.0	7.8	3.9	2.9	2000	79	80	0.5	88	79	1800	0.41
	Station 7	30	0.6	0.01	<0.1	1.3	10	3.0	4.1	2300	91	84	0.2	79	66	1700	0.43
	Station 8	6	1.6	0.04	<0.2	3.2	52	11	14	7000	72	32	40	1770	240	530000	28
	Station 9	7	1.8	0.06	<0.2	4.6	66	8.4	46	5700	92	32	12	2400	320	240000	22
	Station 10	6	3.5	0.04	<0.1	2.4	28	3.2	5.7	3600	53	62	11	670	167	250000	30
14	Escanaba River																
	Station 1	6	7.3	0.16	<0.1	4.2	38	7.3	9.2	6300	140	62	3.4	570	270	110000	25
	Station 2	15	48	0.15	2.0	35	260	36	110	37000	530	12	5.0	8700	1210	420000	55
	Station 3	15	71	0.12	3.0	52	350	65	190	51000	680	12	7.2	13400	1900	460000	32
	Station 4	15	52	0.10	2.0	38	260	64	120	40000	460	12	7.6	8100	1180	350000	44
	Station 5	23	2.7	0.01	<0.1	3.2	10	5.6	5.7	3200	77	86	9.4	103	145	3700	1.1
	Station 6	23	7.9	0.03	0.4	9.5	22	8.7	12	9300	310	75	0.3	135	270	4800	1.7
	Station 7	23	2.3	0.02	<0.1	2.6	11	2.6	4.1	3300	51	74	0.3	290	300	8900	1.7

Table A-9 (continued)

Location Number	Location	Depth (m)	Total Copper	Total Mercury	Total Cadmium	Total Chromium	Total Zinc	Total Nickel	Total Lead	Total Iron	Total Manganese	Total Solids (%)	Total Volatile Solids (%T.S.)	T.K.N.	T.P.	C.O.D.	T.O.C. gm/kg
15	Cedar River																
	Station 1	6	2.4	0.02	0.2	4.3	10	4.7	8.5	2400	11	72	0.4	290	210	7900	2.6
	Station 2	15	5.5	0.04	0.9	13	40	24	29	140000	1000	70	2.9	620	1370	17000	4.7
	Station 3	15	3.1	0.01	0.7	9.3	79	12	130	95000	4300	83	2.0	290	780	5700	2.5
	Station 4	15	5.2	0.01	1.1	13	12	18	18	130000	10000	75	1.6	780	1260	13000	5.5
	Station 5	20	11	0.04	2.8	12	110	110	20	43000	17000	46	1.3	1780	740	27000	9.1
	Station 6	30	14	0.03	1.6	21	88	56	13	32000	8000	48	1.3	1480	670	26000	7.6
	Station 7	30	13	0.05	1.2	19	95	54	17	27000	8200	52	0.8	1710	780	37000	8.8
16	Menominee River																
	Station 1	6	6.4	0.01	<0.1	5.0	15	9.3	3.1	6900	200	80	0.1	74	89	12000	0.61
	Station 2	15	6.9	0.09	0.5	4.6	32	12	12	6500	250	70	8.4	460	230	43000	9.9
	Station 3	15	4.2	0.06	0.2	4.6	26	11	8.2	10000	290	78	0.8	250	240	19000	4.0
	Station 4	15	1.9	0.03	<0.1	3.2	18	6.1	4.6	7700	170	78	0.4	118	127	4200	1.1
	Station 5	30	11	0.07	3.7	8.7	110	140	24	20000	47000	47	2.6	1160	720	18000	8.7
	Station 6	30	14	0.03	0.5	15	38	26	13	15000	1800	61	1.3	660	500	23000	12
	Station 7	30	8.9	0.06	1.9	7.7	71	22	14	16000	18000	55	2.0	1330	850	33000	9.6

Table A-10 Sediment concentrations of pesticides, hexane extractables, and other organics at 16 locations, Lake Michigan, 1976. Concentrations expressed as µg/kg dry weight except where otherwise indicated.

Location Number	Location	Station Number	Depth (m)	Dieldrin µg/kg	Chlordane µg/kg	DDD µg/kg	DDE µg/kg	o,p DDT µg/kg	p,p DDT µg/kg	HCB µg/kg	HCBD µg/kg	1242 PCB µg/kg	1254 PCB µg/kg	1260 PCB µg/kg	Oil-Hex. Ext. mg/kg
1	Galien River	1	5	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	40
		2	15	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	20
		3	15	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	60
		4	15	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	60
		5	20	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	40
		6	20	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	80
		7	20	<5	<20	<5	<4	<5	<10	<2	<2	<500	<500	<500	80
2	St. Joseph River	1	6	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		2	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		3	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	<10
		4	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	<20
		5	30	<10	<20	<10	<10	<10	<10	<5	<5	<500	<500	<500	440
		6	30	<10	<20	<10	<10	<10	<10	<5	<5	<500	<500	<500	3440
		7	30	<10	<20	<10	<10	<10	<10	<5	<5	<500	<500	<500	140
3	Black River	1	5	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		2	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	<10
		3	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	<10
		4	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	60
		5	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	140
		6	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	120
		7	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	120
		8	45	<5	<20	<10	<4	<10	<10	<5	<5	<500	<500	<500	340
		9	45	<5	<20	<10	<4	<10	<10	<5	<5	<500	<500	<500	360
		10	45	<5	<20	<10	<4	<10	<10	<5	<5	<500	<500	<500	300
4	Kalamazoo River	1	5	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		2	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		3	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	20
		4	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	10
		5	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	40
		6	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	260
		7	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	180
5	Lake Macatawa	1	7	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	20
		3	15	<5	<20	<5	<4	<5	5.9	<2	<2	<500	<200	<200	80
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	120
		5	30	<5	<20	<5	<4	<5	7.1	<2	<2	<500	<200	<200	160
		6	30	<5	<20	<5	<4	<5	5.9	<2	<2	<500	<200	<200	220
		7	30	<5	<20	<5	<4	<5	5.6	<2	<2	<500	<200	<200	560

Table A 10 (continued)

Location Number	Location	Station Number	Depth (m)	Dieldrin µg/kg	Chlordane µg/kg	DDD µg/kg	DDE µg/kg	o,p DDT µg/kg	p,p DDT µ	HCB µg/kg	HCBD µg/kg	1242 PCB µg/kg	1254 PCB µg/kg	1260 PCB µg/kg	Oil-Hex. Ext. mg/kg
6	Grand River	1	7	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	20
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	140
		3	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	100
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	80
		5	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	100
		6	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	40
		7	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	240
7	Muskegon Lake	1	7	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	10
		2	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	10
		3	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	20
		4	15	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	20
		5	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	80
		6	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	60
		7	30	<5	<20	<10	<4	<10	<10	<2	<2	<500	<500	<500	20
8	White Lake	1	7	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	140
		3	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	100
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	100
		5	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		6	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	20
		7	30	<5	<20	<5	<4	<5	7.4	<2	<2	<500	<200	<200	100
9	Pere Marquette River	1	8	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	160
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	140
		3	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	180
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		5	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	160
		6	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	40
		7	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	120
10	Manistee River	1	10	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	40
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	40
		3	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	50
		5	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	140
		6	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	80
		7	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	80

Table A-10 (continued)

Location Number	Location	Station Number	Depth (m)	Dieldrin µg/kg	Chlordane µg/kg	DDD µg/kg	DDE µg/kg	o,p DDT µg/kg	p,p DDT µg/kg	HCB µg/kg	HCBD µg/kg	1242 PCB µg/kg	1254 PCB µg/kg	1260 PCB µg/kg	Oil-Hex. Ext. mg/kg
11	Betsie Lake	1	8	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	40
		2	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	60
		3	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	140
		4	15	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	220
		5	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	260
		6	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	220
		7	30	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	260
		8	40	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	180
		9	40	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	200
		10	40	<5	<20	<5	<4	<5	<5	<2	<2	<500	<200	<200	160
12	Naubinway	1	8	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		2	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
		3	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		4	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	500
		5	20	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		6	20	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	400
		7	20	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
13	Manistique River	1	6	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		2	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
		3	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		4	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
		5	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		6	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
		7	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	100
		8	6	<10	<20	<10	<10	<10	<10	I	I	5070	5100	<500	2600
		9	7	<10	<20	<10	<10	<10	<10	I	I	2640	660	<500	1800
		10	6	<10	<20	<10	<10	<10	<10	I	I	17,500	7830	<500	700
14	Escanaba River	1	6	<10	<20	<10	<10	<10	<10	I	I	<500	1610	<500	400
		2	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	300
		3	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	400
		4	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	400
		5	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	40
		6	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	40
		7	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	200
15	Cedar River	1	6	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	520
		2	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	100
		3	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	620
		4	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	960
		5	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	400
		6	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	120
		7	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	--
															--

Table A-10 (continued)

Location Number	Location	Station Number	Depth (m)	Dieldrin µg/kg	Chlordane µg/kg	DDD µg/kg	DDE µg/kg	o,p DDT µg/kg	p,p DDT µg/kg	HCB g/kg	HCBD g/kg	1242 PCB g/kg	1254 PCB g/kg	1260 PCB g/kg	Oil-Hex. Ext. mg/kg
16	Menominee River	1	6	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	100
		2	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	400
		3	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	100
		4	15	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	20
		5	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	40
		6	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	100
		7	30	<10	<20	<10	<10	<10	<10	I	I	<500	<500	<500	60

I = interference encountered in testing, no result reported.

Table A-11 Number of benthic macroinvertebrates collected in Lake Michigan near the Galien River mouth, Location 1, July 6, 1976. Results are expressed as number of organisms per square meter.

Taxa / Station Number: / Depth (m):	1 / 5	2 / 15	3 / 15	4 / 15	5 / 20	6 / 20	7 / 20
Nematoda					19		
Mysidacea							
Mysis relicta						96	19
Amphipoda							
Hyalella azteca	19	19	115	77		19	
Pontoporeia hoyi		1343	710	2302	4296	4642	4565
Oligochaeta							
Aulodrilus pigueti		19					
Limnodrilus hoffmeisteri		19	173		38		19
L. profundicola		19	77		19	19	
Potamothrix moldaviensis		19	77				19
P. vejdovskyi					115		
Stylodrilus heringianus		19			441	921	767
Immature tubificids w/o hair setae		115	652	38	192	19	58
Immature tubificids w/hair setae			19				19
Diptera		216	998	·30	805	959	882
Chironomus	38		57	19			
Monodiamesa			19		19		38
Paracladopelma			19				
Polypedilum			77				
Procladius					19	19	19
Robackia demeijerei	19						
Tanytarsus		19					
pupae	57	19					
Pelecypoda							
Pisidium			38		192	38	153
Sphaerium		38	288	38	153	115	384
Gastropoda							
Amnicola							19
Valvata sincera					38		
Station Total	133	1648	2821	2474	5541	5888	6079
Total number taxa	4	11	13	5	12	9	12

Table A-11 (continued) Number of benthic macroinvertebrate collected in Lake Michigan near the St. Joseph River mouth, Location 2, July 14 (Station 1-4) and September 16 (Stations 5-7), 1976. Results are expressed as number of organisms per square meter.

Taxa	Station Number: Depth (m):	1 6	2 15	3 15	4 15	5 30	6 30	7 30
Mysidacea								
Mysis relicta			19			115		
Amphipoda								
Pontoporeia hoyi			748	249	134	3165	1381	1956
Oligochaeta								
Limnodrilus claparedeianus				38				
L. hoffmeisteri			64	211	211			
Peloscolex multisetosus					19			
Potamothrix moldaviensis			19					19
P. vejdovskyi						19	19	57
Stylaria lacustris			38					
Stylodrilus heringianus						896	959	574
Immature tubificids w/o hair setae			556	115	173	19	19	192
Immature tubificids w/hair setae			19		19	19	38	57
Hirudinea								
Helobdella stagnalis			288					
Diptera								
Chironomus			19		19			
Monodiamisa				19				
Pararladopelma				38		19		
Polypedilum			19	57				
Pelecypoda								
Sphaerium							19	
Station Total		0	2358	727	594	4162	2435	2855
Total Number Taxa		0	8	6	4	5	4	4

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Black River mouth (South Haven), Location 3 July 13, 1976. Results are expressed as number of organisms per square meter.

Taxa / Station Number: Depth (m):	1 5	2 15	3 15	4 15	5 30	6 30	7 30	8 45	9 45	10 45
Mysidacea										
Mysis relicta			19		38	19	38	38	57	38
Amphipoda										
Hyalella azteca			19				134		19	
Pontoporeia hoyi	19	1400	1381	1458	9839	8554	4469	3069	2013	11,719
Oligochaeta										
Limnodrilus claparedeianus			19							
L. hoffmeisteri		192	115	192	19	19	173	57		38
L. profundicola	19	19				19	19	19		
Ophidonais serpentina			19							
Piguetiella michiganensis		19	19							
Potamothrix vejdovskyi		38				57	30	38	19	38
Stylodrilus heringianus	173	77		19	786	595	441	518	786	652
Uncinais uncinata		19								
Immature tubificids w/o hair setae	19	633	706	441	153	153	403	96	134	211
Immature tubificids w/hair setae		19				38	57	38		
Hirudinea		115		77	19					
Helobdella stagnalis				38						
Piscicola geometra					19					
Diptera										
Chironomus		19								
Cryptochironomus	153	96		19						
Monodiamesa		19	19				38		19	39
Paracladopelma			19							
Polypedilum		96	19	115						
Procladius					19					
Robackia demeijerei	115		19							
Tanytarsus			19							
Gastropoda					19					
Amnicola			38	19						
Bulimus		38								
Valvata sincera		192	77	96						
Pelecypoda										
Musculium		19	38	38						
Pisidium		288	153	115	57					115
Sphaerium		30	192	479	268	173		19		384
Total number taxa	6	19	17	13	11	9	10	9	7	9
Station total	498	3336	2970	3106	11,236	9627	5810	3892	3047	13,233

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Kalamazoo River mouth, Location 4, July 19, 1976. Results are expressed as number of organisms per square meter.

Taxa / Station Number: / Depth (m):	1 5	2 15	3 15	4 15	5 30	6 30	7 30
Nematoda		38					
Isopoda							
Asellus			19				
Mysidacea							
Mysis relicta		19		38	19		
Amphipoda							
Gammarus							
Hyalella azteca			211	19			
Pontoporeia hoyi	19	3491	1439	2052	6886	3951	2762
Oligochaeta							
Homochaeta naidina			19				
Limnodrilus hoffmeisteri		19				19	
L. profundicola		38					
L. spiralis						19	
Piguetiella michiganensis		19	57				
Potamothrix vejdovskyi						57	
Stylaria lacustris		53		38			
Stylodrilus heringianus	134	77	19		671	575	652
Tubifex tubifex		19					
Immature tubificids w/out hair satae		460		77	173	57	96
Immature tubificids w/hair satae	19				96	19	57
Hirudinea		38		19			
Diptera							
Chironomus	19						
Crypochironomus	77						
Heterotrissocladius					19		
Procladius	19						
Pseudodiamesa pertinax		19					
Robackia demeijerei		19					
Pelecypoda							
Musculium		19					
Pisidium		115	19	38			
Sphaerium	19	173		19		57	57
Gastropoda							
Lymnaea				19			
Valvata		38	19				
Station total	.306	4754	1802	2338	7864	4754	3624
Total number taxa	7	15	8	9	6	8	5

Table A-11 (continued)

Number of benthic macroinvertebrates collected in Lake Michigan near the Lake Macatawa outlet, Location 5, July 22, 1976. Results are expressed as number of organisms per square meter.

Taxa	Station Number: / Depth (m):	1 / 7	2 / 15	3 / 15	4 / 15	5 / 30	6 / 30	7 / 30
Mysidacea								
Mysis relicta						19	19	
Amphipoda								
Hyalella azteca						38		
Pontoporeia hoyi		19	614	671	595	6157	4105	8094
Oligochaeta								
Limnodrilus hoffmeisteri						38	19	
L. profundicola						19		
L. udekemianus						19		
Piguetiella michiganensis			19	19	153			
Potamothrix vejdovskyi						19		
Stylodrilus heringianus		57	288	57	192	480	575	556
Tubifex kessleri americanus								19
Immature tubificids w/o hair setae			115		57	211	249	77
Immature tubificids w/hair setae						38		57
Hirudinea			19					
Helobdella stagnalis						19	38	
Diptera								
Chironomus			19					
Cryptochironomus		19						
Heterotrissocladius					19	38		19
Paracladopelma			19	38	19			77
Polypedilum fallax gp.				19	58			
Pseudodiamesa				19	19			
Robackia demeijerei		19		57				
Trichoptera								
Molanna			19		19			
Gastropoda								
Physa					38			
Pelecypoda								
Sphaerium						57	38	19
Station totals		114	1131	937	1226	7152	6081	8918
Total number taxa		4	8	7	10	13	7	8

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Grand River mouth, Location 6, July 21, 1976. Results are expressed in number of organisms per square meter.

Taxa — Station Number:	1	2	3	4	5	6	7
Depth (m):	7	15	15	15	30	30	30
Nematoda							633
Isopoda							
Asellus					19		
Mysidacea							
Mysis relicta					19		
Amphipoda							
Gammarus	77				19		19
Hyalella azteca	19				19		19
Pontoporeia hoyi	844	307	595	499	9839	9974	11,373
Oligochaeta							
Limnodrilus hoffmeisteri					38		
Peloscolex ferox						19	
Potamothrix vejdovskyi					38		
Stylodrilus heringianus	19	57	38	19	671	748	806
Immature tubificids w/o hair setae	38		77	38	96	77	57
Immature tubificids w/hair setae	19						
Hirudinea			19		19	19	
Diptera							
Chironomus	57						
Monodiamesa			19		38		
Paracladopelma	19				57	77	57
Polypedilum	19	19					
Rohackia demeijerei	96						
pupae	38						
Pelecypoda							
Pisidium				57	326	38	57
Sphaerium				38	997	364	77
Station Total	1245	383	748	651	12,195	11,316	13,155
Total Number Taxa	11	3	5	5	14	8	9

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Muskegon Lake outlet, Location 7, July 21, 1976. Results are expressed as number of organisms per square meter.

Taxa	Station Number: Depth (m):	1 7	2 15	3 15	4 15	5 30	6 30	7 30
Nematoda			19				173	19
Amphipoda		211	2589	3145	2033	5505	6387	6195
Pontoporeia hoyi								
Oligochaeta								
Limnodrilus hoffmeisteri						38	19	77
L. profundicola			19					19
Peloscolex ferox						19	38	77
P. variegatus			19			134		
Stylodrilus heringianus			19	38	19	844	940	901
Immature tubificids w/o hair setae			38	19	57	230	153	192
Immature tubificids w/hair setae							19	
Hirudinea								38
Diptera								
Chironomus		77						
Cryptochironomus		38						
Heterotrissocladius						19		19
Monodiamesa		19						
Parachironomus		38						
Paracladopelma						19		19
Psectrocladius						19		
Robackia demeijerei		96						
Tanytarsus							57	
Coleoptera								
Dubiraphia		19						
Ephemeroptera								
Baetis		19						
Gastropoda								
Valvata					19			
Pelecypoda								
Pisidium				19	19	57		
Sphaerium		19					364	96
Station total ($m/^2$)		536	2703	3221	2147	6984	8150	7652
Total number taxa		9	6	4	5	10	9	11

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the White Lake outlet, Location 8, July 21, 1976. Results are expressed as number of organisms per square meter

Taxa / Station Number:	1	2	3	4	5	6	7
Depth (m):	7	15	15	15	30	30	30
Hirudinea					19		
Mysidacea							
Mysis relicta							
Amphipoda					19	19	19
Pontoporeia hoyi	19	1975	1880	1756	10,434	10,453	9456
Oligochaeta							
Limnodrilus angustipenis			38				
L. hoffmeisteri		57	57		19		19
L. profundicola		38	19			19	19
Peloscolex superiorensis							19
Piguetiella michiganensis		38					
Potamothrix moldaviensis		19					
Stylodrilus heringianus		57	115	134	690	806	748
Immature tubificids w/o hair setae	19	575	268	115	96	57	96
Immature tubificids w/hair setae						19	
Diptera							
Chironomus	173	19					
Cladotanytarsus			77				
Cryptochironomus			19				
Heterotrissocladius			19				
Polypedilum fallax gp.			19				
Robackia demeijerei	537	19					
Tanytarsus							19
Pelecypoda							
Pisidium						96	
Sphaerium		77			57	134	134
Station total	748	2874	2511	2005	11,334	11,603	10,529
Total number taxa	4	10	10	3	7	8	9

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Pere Marquette River mouth, Location 9, July 26, 1976. Results are expressed as number of organisms per square meter.

Taxa / Station Number: / Depth (m):	1 8	2 15	3 15	4 15	5 30	6 30	7 30
Amphipoda							
<u>Pontoporeia hoyi</u>	19	748	1169	825	2206	1899	5696
Oligochaeta							
<u>Limnodrilus hoffmeisteri</u>		19		19			
<u>L. profundicola</u>		19					
<u>Stylodrilus heringianus</u>					249	115	38
Immature tubificids w/o hair setae	19	19					
Hirudinea							
<u>Helobdella stagnalis</u>						19	19
Diptera							
<u>Chironomus</u>	38						
<u>Cladotanytarsus</u>	19						
<u>Polypedilum fallax</u> gp.					19		
<u>Robackia demeijerei</u>	38						
<u>Stictochironomus</u>	19						
<u>Tanytarsus</u>				19			
Coleoptera							
<u>Ancyronyx variegata</u>			19				
Gastropoda							
<u>Valvata</u>	19				19		
Pelecypoda							
<u>Pisidium</u>					19	19	364
<u>Sphaerium</u>		38					
Station totals	171	862	1688	863	2512	2052	6117
Total number taxa	7	6	2	3	5	4	4

Table A-11 (continued) **Number of benthic macroinvertebrates collected in Lake Michigan near the Manistee Lake outlet, Location 10, July 27, 1976. Results are expressed as number of organisms per square meter.**

Taxa — Station Number: / Depth (m):	1 10	2 15	3 15	4 15	5 30	6 30	7 30
Nematoda				38			19
Amphipoda		307	230	173	7077	4431	6790
Pontoporeia hoyi							
Oligochaeta							
Paranais simplex		19	19				
Piguetiella michiganensis		38					
Stylodrilus heringianus		57	96		1285	326	614
Immature tubificids w/o hair setae	19	19		19	19		
Immature tubificids w/hair setae		19					
Diptera							
Chironomus	58						
Cladotanytarsus	38	58		115			
Eukiefferiella		58		38			
Phaenopsectra	96						
Polypedilum	19						
Tanytarsus	19						
pupae					96		
Ephemeroptera							
Hexagenia	57						
Gastropoda							
Valvata					38		
Pelecypoda							
Pisidium					480	230	115
Sphaerium		38			96	134	134
Total number taxa	6	9	3	5	7	4	5
Station total	306	613	345	383	9091	5121	7672

Table A-11 (continued) **Number of benthic macroinvertebrates collected in Lake Michigan near the Betsie Lake outlet, Location 11, July 27, 1976. Results are expressed as number of organisms per square meter.**

Taxa / Station Number: / Depth (m):	1 / 8	2 / 15	3 / 15	4 / 15	5 / 30	6 / 30	7 / 30	8 / 40	9 / 40	10 / 40
Nematoda				19						
Amphipoda										
Gammarus							19			
Pontoporeia hoyi	38	710	978	614	3529	1093	2858	1976	2819	3587
Oligochaeta										
Aulodrilus americanus							38			19
Limnodrilus hoffmeisteri			38	19						
L. spiralis		19	19	38						
L. udekemianus			115	57						
Piguetiella michiganensis			19							
Stylodrilus heringianus					786	1151	690	288	997	901
Immature tubificids w/o hair setae		153	307	230	19					
Immature tubificids w/hair setae										
Diptera										
Chironomus	19		19							
Cladotanytarsus		38		153						
Cryptochironomus		19								
Heterotrissocladius				19						
Paracladopelma						38	19			
Polypedilum fallax gp.						19				
Robackia demeijerei	19									
pupae				77	19					
Pelecypoda										
Pisidium		38			422	19	268		19	288
Sphaerium		57	39	19	153	38	96	77	230	38
Gastropoda										
Lymnaea					19					
Valvata			19			19				
Station total	76	1034	1552	1245	4947	2377	3988	2341	4065	4833
Total number taxa	3	7	9	10	7	7	7	3	4	5

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near Naubinway, Location 12, July 16, 1976. Results are expressed as number of organisms per square meter.

Taxa — Station Number: / Depth (m):	1 / 8	2 / 15	3 / 15	4 / 15	5 / 20	6 / 20	7 / 20
Turbellaria						19	
Nematoda		77	19		134	19	
Isopoda							
Asellus	173	19	19		211	38	77
Amphipoda							
Gammarus	38						
Pontoporeia hoyi	192	2666	2839	3702	5907	3165	5581
Hyalella azteca	1419	19				19	
Oligochaeta							
Allonais lardi		77		115			19
Arcteonais lomondi	58	77	38	192			19
Aulodrilus americanus						19	
Aulodrilus limnobius						19	
A. piqueti				19			
A. pluriseta	19						
Limnodrilus hoffmeisteri			19		38		
Nais sp.	19				19		
Peloscolex ferox		345	1112	211	1438	824	1035
P. multisetosus longidentus				19	19		
Specaria josinae		19		19			
Stylaria lacustris	211	96		268			
Stylodrilus heringianus	19	288	363	173	728	728	314
Uncinais uncinata	38	38	19	19		38	19
Immature tubificids w/o hair setae	595	441	403	537	19	38	19
Immature tubificids w/hair setae	38	19	19	19	38		
Hirudinea							
Helobdella stagnalis	499		19				
Diptera							
Chironomus							19
Constempellina	19						
Cryptochironomus		19	19		19		
Diamesa	19						
Heterotrissocladius		58	96	115			19
Monodiamesa			58	19			
Paracladopelma			58			38	19
Paralauterborniella				19	19		
Polypedilum	19						
P. fallax gp.	19		19				
Procladius	19	326	326	249	115		19
Psectrotanypus		19	19	19			
Stictochironomus				19		19	
Tanytarsus	211	19	192	58			38
Zavrellia	19						
pupae	58	58	77	58	19	19	

Table A-11 (continued)

Taxa	Station Number: Depth (m):	1 8	2 15	3 15	4 15	5 30	6 30	7 30
Gastropoda								
Bulimus			19					
Campeloma integrum			153	38	19			
Physa						19		
Valvata sincera			192	58		38	19	
Valvata tricarinata		58	19				19	
Pelecypoda								
Musculium		19	38			38	58	19
Pisidium		230	384	38	480	58	326	115
Sphaerium		19	345	58	268	153	537	307
Trichoptera								
Limnophilus						19		
Hemiptera								
Corixidae		134						
Station total		4161	5830	6425	6616	9048	5961	7688
Total number taxa		26	25	24	24	20	19	15

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Manistique River mouth, Location 13, August 17, 1976. Results are expressed as number of organisms per square meter.

Taxa — Station Number: / Depth (m):	1 / 6	2 / 15	3 / 15	4 / 15	5 / 30	6 / 30	7 / 30	8 / 6	9 / 6	10 / 6
Nematoda		19								
Amphipoda										
Gammarus	115						96	134		77
Pontoporeia hoyi	96	19	134	115	173	384	38			
Isopoda										
Asellus						19			19	
Oligochaeta										
Arcteonais lomondi				19						
Aulodrilus pluriseta	19									
Limnodrilus hoffmeisteri					19	38	96	115	153	77
L. spiralis								19		
Nais	96	19		38			19	58	19	
N. barbata								19		
N. communis									19	
Peloscolex multisetosus										19
Piguetiella michiganensis	441	19								
Rhyacodrilus coccineus				19					19	
Specaria josinae	38									
Stylaria lacustris			19	38						
Stylodrilus heringianus				19	230	422	19			
Tubifex tubifex									38	
Uncinais uncinata		19						19		
Immature tubificids w/o hair setae	211		19	38			96	499	633	77
Immature tubificids w/hair setat	58			19				153	288	
Hirudinae										
Helobdella stagnalis			58						19	
Hemiptera										
Corixidae	19									
Diptera										
Chironomus	19	38	19	19				58	269	
Cladotanytarsus	58	19						19		
Cryptochironomus	19							38	19	
Diamesa	19									
Heterotrissocladius	345	153	173	173						
Microtendipes	19									
Monodiamesa					19			19		
Paracladopelma	153	19	58	115						
Paralauterborniella	38							19		
Polypedilum fallax gp.	38	19								
Procladius	19							77	38	19
Potthastia longimanus	38									
Stictochironomus	58							19		
Tanytarsus	153	38	19		230	19		38	58	
pupae	153	38	58	58		19		77		
Adults		58							38	

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Escanaba River mouth, Location 14, August 18, 1976. Results are expressed as number of organisms per meter.

Taxa / Station Number: / Depth (m):	1 6	2 15	3 15	4 15	5 30	6 30	7 30
Turbellaria	58						
Nematoda	19		19		19		
Isopoda							
Asellus	230				96	728	249
Amphipoda							
Gammarus	882			38	19		38
Hyalella azteca			19		19		
Pontoporeia hoyi		288	326	710	728	173	690
Ephemeroptera							
Hexagenia		19					
Coleoptera							
Dubiraphia	19						
Oligochaeta							
Allonais lardi		19	38				
Arcteonais lomondi		19					
Aulodrilus americanus		38	38	38			19
A. pluriseta		192	288	38	96		345
Limnodrilus hoffmeisteri	19	153	115	58			115
L. spiralis			19				
Nais simplex		19					
Peloscolex ferox	19				978	268	556
P. multisetosus	19	19	77		38	19	19
Rhyacodrilus montanus	96						
Stylodrilus heringianus	134				172	441	19
Immature tubificids w/o hair setae	230	441	556	96	96	58	211
Immature tubificids w/hair setae	19				19	96	
Polycheata							
Manyunkia speciosa	19						
Diptera							
Ablabesmyia						19	38
Chironomus		173	96	96			
Cryptochironomus					19		
Heterotrissocladius						38	
Microtendipes	19					19	
Phaenospectra tribelos	38				96		
Polypedilum						96	
Procladius		153	307	307			173
Tanytarsus	19		58	38	96	19	77
pupae				19	19		
Station total	1858	1533	1956	1438	2529	2108	2590
Total number taxa	18	12	13	10	17	15	14

Table A-11 (continued)

Taxa — Station Number: / Depth (m):	1 / 6	2 / 15	3 / 15	4 / 15	5 / 30	6 / 30	7 / 30	8 / 6	9 / 6	10 / 6
Pelecypoda										
Pisidium					134	77				
Station total	2222	477	557	670	805	978	364	1380	1629	269
Total number taxa	25	13	9	12	8	8	6	13	10	5

Table A-11 (continued) **Number of benthic macroinvertebrates collected in Lake Michigan near the Cedar River mouth, Location 15, August 19, 1976. Results are expressed as number of organisms per meter.**

Taxa / Station Number:	1	2	3	4	5	6	7
Depth (m):	6	15	15	15	30	30	30
Nematoda		38	19	19	38	19	38
Mysidacae							
Mysis relicta							38
Amphipoda							
Gammarus					38	58	
Pontoporeia hoyi		38		19	5581	3987	4143
Oligochaeta							
Aulodrilus americanus	249						
A. pluriseta	364	38	19	38			
Limnodrilus claparedianus					38	19	
L. hoffmeisteri	38	38		96	518	288	403
Nais simplex					19		
Peloscolex ferox	77	96	230	19			
Potamothrix vejdoyskyi			77				
Stylaria lacustris		19	38				
Tubifex tubifex						58	
Immature tubificids w/o hair satae	633	77	58	269	901	786	921
Immature tubificids w/hair satae		19	19		77	96	249
Diptera							
Chironomus	173	19		58			
Cryptochironomus	38						
Dicrotendipes	19						
Eukifferiella		19	19	19			
Heterotrissocladius	19						
Monodiamesa					19		
Paracladopelma	19	19	19				
Phaenopsectra	19			19			
Procladius	192	58	115	96			19
Protanypus cfr *ramosus*						58	
Tanytarsus	480		652	58			
pupae	19		19				
Corixidae	38						
Pelecypoda							
Pisidium	19		38		19	19	19
Sphaerium							38
Station total	2396	478	1322	729	7229	6388	5868
Total number taxa	17	12	13	12	9	9	9

Table A-11 (continued) Number of benthic macroinvertebrates collected in Lake Michigan near the Menominee River mouth, Location 16, August 18, 1976. Results are expressed as number of organisms per square meter.

Taxa — Station Number: / Depth (m):	1 6	2 15	3 15	4 15	5 30	6 30	7 30
Nematoda							19
Hirudinae							
Helobdella stagnalis		38		38			
Isopoda							
Asellus		1592	2244	4124			
Amphipoda							
Gammarus	38	134	230				
Hyalella azteca				38			19
Pontoporeia hoyi		767	1937	1880	2819	21,175	10,376
Mysidacae							
Mysis relicta						77	38
Oligochaeta							
Aulodrilus pigueti				19			
A. pluriseta		172	901	767			
Haplotaxis denticulatus	19						
Limnodrilus hoffmeisteri		58	19	77	192	77	230
Nais communis			19				
N. elinguis	19						
Peloscolex ferox		652	268	403	19	19	
P. tenuis				58			
Piguetiella michiganensis	38						
Potamothrix vejdovskyi	77	19	38				
Stylodrilus heringianus	38	19			48	38	173
Tubifex tubifex							77
Immature tubificids w/o hair setae	268	134	249	211	499	96	1055
Immature tubificids w/hair setae	38	96		77	77		192
Diptera							
Chironomus	19						
Cryptochironomus	19						
Diamesinae							58
Dicrotendipes modestus	19						
Heterotrissocladius	345		58	77			
Paracladopelma				19			
Polypedilum							19
Potthastia longimanus	19						
Procladius		58	77	96			
Tanytarsus	38	1496	2321	2339	38		38
Thienemannimyia				19			
pupae	38						
Pelecypoda							
Pisidium			38	19			
Sphaerium		77	77	38			
Station total	1032	5313	8476	10,299	3702	21,482	12,294
Total number taxa	15	14	14	18	7	6	10

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16. ABSTRACT

Limnological assessments, including water and sediment chemistry and benthic macroinvertebrate community structure, were performed based on samples collected at 16 locations in Michigan's nearshore waters of Lake Michigan in 1976. Tributary influence on Lake Michigan's water chemistry were detectable only out to 0.5 km from shore. Tributary impacts on sediment chemistry and macroinvertebrate communities were inconsistent. Based on the water sampling and benthic macroinvertebrate communities result, the nearshore waters were classified as oligotrophic in the central and northern sections, and mesotrophic in southern Lake Michigan and Green Bay. Sediment concentrations of heavy metals and nutrients were greatest in Green Bay and southern Lake Michigan and were related to the percentage of fine sediment (<0.5 mm deimeter) present. Ninety benthic macroinvertebrate taxa were identified with the amphipod Pontoporela hoyi the most abundant macroinvertebrate, followed by the oligochaete Stylodrilus heringianus. Substrate and water depth exerted major influences on benthic macroinvertebrate communities.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field Group
Benthic Chemistry Heavy metals Oligotrophic Mesotrophic Nutrients Macroinvertebrate Monitoring Turbidity Sediment Contaminants		

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