WATER QUALITY INVESTIGATIONS

LAKE MICHIGAN BASIN

BIOLOGY

A technical report containing background data
for a water pollution control program.

January 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Great Lakes Region Chicago, Illinois

ENVIRONMENTAL PROTECTION AGENCY

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FOREWORD

The study of the biology of the Lake Michigan Basin was conducted under the administrative guidance of H. W. Poston, Regional Director, Great Lakes Region, FWPCA. Sample collections and analyses and data compilation and organization were made by regional personnel. Final draft of the report was prepared by biologists of the Technical Advisory and Investigations Branch, FWPCA, Cincinnati, Ohio.

SUMMARY AND CONCLUSIONS

1. The biota of the mid-water area of Lake Michigan reflects an unpolluted environment. Free floating algal populations were less than 500 per milliliter. Pollution-sensitive scuds predominated in the bottom associated organism population. Sludgeworm populations were less than 1,000 per square meter and midges were principally of the clean water variety.
2. Extensive inshore areas of pollution totaling 3,475 square miles were found along the entire southern perimeter of Lake Michigan specifically Milwaukee, Racine and Chicago-Calumet and in Green Bay. The loss of the Green Bay fly, a fish food organism, and other detrimental pollution associated conditions have impaired commercial fishing in Green Bay. Swimming beaches have been closed in Milwaukee, Chicago and other areas when large mats of foul smelling algae have been deposited on the beaches. Aesthetic values associated with water have been impaired by algae on many occasions. Short filter runs and taste and odors resulting from high

phytoplankton populations have increased the cost of water treatment at Green Bay, Milwaukee, Kenosha, Chicago, and other cities.

3. Other more localized inshore areas of pollution totaling 350 square miles resulted in increased sludgeworms and free floating algal populations offshore from: Manitowoc, Sheboygan, Port Washington, Benton Harbor, South Haven, Saugatuck, Grand Haven, Muskegon, Ludington, Manistee, and Manistique.

4. Pollution of inshore areas: supported pollution-tolerant sludgeworm populations exceeding 1,000 per square meter; suppressed gamefish food organisms; supported nuisance algal populations exceeding 500 per milliliter and as high as 20,000 per ml. in Green Bay; produced dense growths of attached algae in shallow water areas that break loose and become deposited on swimming beaches. Soluble phosphate (PO_4) concentrations averaged 0.04 mg/l with values as high as 5.0 in these areas. These concentrations exceed the adopted standard of an annual average total phosphate (PO_4) of 0.03 mg/l and a single daily average or value of 0.04 mg/l.

BIOLOGICAL EFFECTS ON WATER USES

The biological examination of waters and bottom materials incorporates both a qualitative determination of the kinds of organisms present and a quantitative estimate of their numbers or bulk. This information aids in the interpretation of physical and chemical analyses, indicates pollution by wastewaters, determines the progress of self-purification within the waterways, assists in the limnological study of the environment, measures damages inflicted on aquatic life and water use potentials, and indicates impact of nuisance organisms on water uses.

Suspended microscopic plants (algae) are the primary convertors of light energy to organic matter; they are the original source of most of the food that nourish fish and other aquatic animals. Changes in the physical and chemical properties of the water affect both algal quantities and species composition. When the quantity of fertilizing nutrients increases, the number of algae will increase and the species composition will change. Dense green algal populations reduce the aesthetic

values of a water and interfere with water uses such as boating and swimming. Windrows of dead and odoriferous decaying algae are nuisances and obstruct uses at beaches and surrounding lands. Changes in both the concentration and relative composition of the fertilizing material produce detectable changes in the species composition of the algal populations. High concentrations of phosphorus favor the blue-green algae which are capable of using nitrogen from the atmosphere as a source of nitrogenous nutrition; these algae are particularly obnoxious because they are more buoyant than other forms thus tending to form windrows more readily and produce especially obnoxious "pigpen" odors because of chemical compounds peculiar to them.

Bathing beaches have been closed for extensive periods near Milwaukee, Chicago and other localities because of rotting foul-smelling algae and dead fish, and threats to public health from water contaminated by sewage. A seemingly inexhaustible supply of algae that has washed ashore in recent years has defied maintenance attempts to keep some beaches usable during the recreational period. Bathers and sun-bathers must travel farther to enjoy their sport. The aesthetic beauty of Lake Michigan has been severely impaired.

Excessive quantities of algae in Lake Michigan have caused short filter runs in water treatment plants. When the runs are shorter than 20 hours, the result is a loss in revenue because of loss of plant capacity and the use of larger amounts of wash water. Kenosha, Wisconsin obtains its water supply from an intake pipe extending 4,200 feet into Lake Michigan to a depth of 30 feet and has experienced three-hour filter runs in recent years along with taste and odor problems. Because algae and other microorganisms are implicated in both of these water supply problems, Kenosha in 1961 installed four microstrainers at a cost of $330,000 to reduce the number of microorganisms. At this time Kenosha was receiving as much as 450 pounds per day of wet algae through the water intake pipe. Following microstrainer installation, that resulted in 90 percent algal removal, taste and odor problems disappeared and filter runs increased to an average of 48 hours. Problem algae were: Stephanodiscus, Tabellaria, Asterionella, Synedra, and others.

At Green Bay, Sheboygan, Milwaukee, Waukegan, Evanston, Chicago, Gary-Hobart, Michigan City, Benton Harbor, Holland, Grand Rapids, and Musekgon, 37 percent of filter runs were less than 20 hours in 1961.

Bottom animals serve as a vital link in the aquatic food web by converting plant food into animal food for predatory fishes. Changes in numbers of bottom animals and in composition of the bottom-animal community produce changes in the fish population. For example, a community consisting predominantly of burrowing worms favors a community of fishes such as carp and suckers that root for their food. An increase in worms is a product of an increased food supply from sedimentation of organic waste materials or dead algae. Changes in the kinds and numbers of bottom animals are effects that are frequently a product of pollutants; these changes result in damages to desirable aquatic organisms, and may produce increased numbers of undesirable aquatic organisms that interfere with and reduce the uses that can be made of the waters.

Environmental changes resulting from pollution eliminated the burrowing mayfly (Green Bay fly) from major sectors of Green Bay in recent years. Concurrently commercial fishing was severely impaired, thus affecting another water use by disrupting the aquatic food web.

MID-LAKE AREA RESULTS

The deep-water areas of Lake Michigan are presently unaffected by the pollution observed in many areas closer to shore. Soluble phosphate (PO_4) averaged 0.02 milligrams per liter (mg/l) in deep water areas with some values as high as 0.14 mg/l. Inshore areas averaged 0.04 mg/l PO_4 with values as high as 5.00 mg/l. Adopted water quality standards for Lake Michigan open water and shore water limit annual average total phosphate (PO_4) to 0.03 mg/l and a single daily average or value to 0.04 mg/l. Obviously these standards are now exceeded in some areas and high nutrient concentrations are reflected in increased biological growths. Inorganic nitrogen averaged 0.19 milligrams per liter in deep-water (ranging as high as 1.15) compared to 0.27 milligrams per liter inshore (ranging as high as 2.2 near Milwaukee). The distribution of populations of benthic animals and phytoplankton generally reflects the pattern of distribution of soluble nutrients.

With one exception, the population of bottom organisms decreased with increasing depth (Table 1). In the deepest

area (260-269 meters) there was an increase in the population of all organisms to 5,000 per m^2; this is characteristic of organism population distribution in many deep lakes. Scuds of the genus Pontoporeia, are pollution-sensitive organisms; they were the predominant bottom-associated organisms in areas not greatly influenced by organic sediments.

The population of scuds in much of the deep central basin numbered less than 1,500 per square meter (Figure 1). There is a combination of depth dependent factors such as sediment types and nutrient content that limits scud populations in depths greater than 50 meters. In the deep central areas of the lake sludgeworm populations numbered less than 1,000 per square meter. This relatively low population of sludgeworms as shown in Figure 2 indicates an unpolluted environment. The midge larval population in the central section of Lake Michigan averaged 37 per square meter and was composed of 84 percent clean-water species and no pollution-tolerant species with the remaining being of variable tolerance. This further indicates the unpolluted condition of the sediments of the central basin.

The deep-water areas of Lake Michigan supported planktonic algal communities of low population density that generally ranged from 100 to 300 organisms per milliliter (Figure 3). Conversely, nutrient-enriched inshore areas supported larger

populations of phytoplankton, generally numbering more than 500 organisms per milliliter.

For many years, the planktonic algae of Lake Michigan have been dominated by the genera Tabellaria, Asterionella, and Synedra. These forms are found in nonfertile lakes. However, pollution of Lake Michigan has caused Cyclotella and Stephanodiscus to become the predominant forms in most samples; even in samples in which Asterionella, Tabellaria and Synedra predominated, Cyclotella and Stephanodiscus usually were abundant. Table 2 lists the genera of phytoplankton most commonly encountered in Lake Michigan waters.

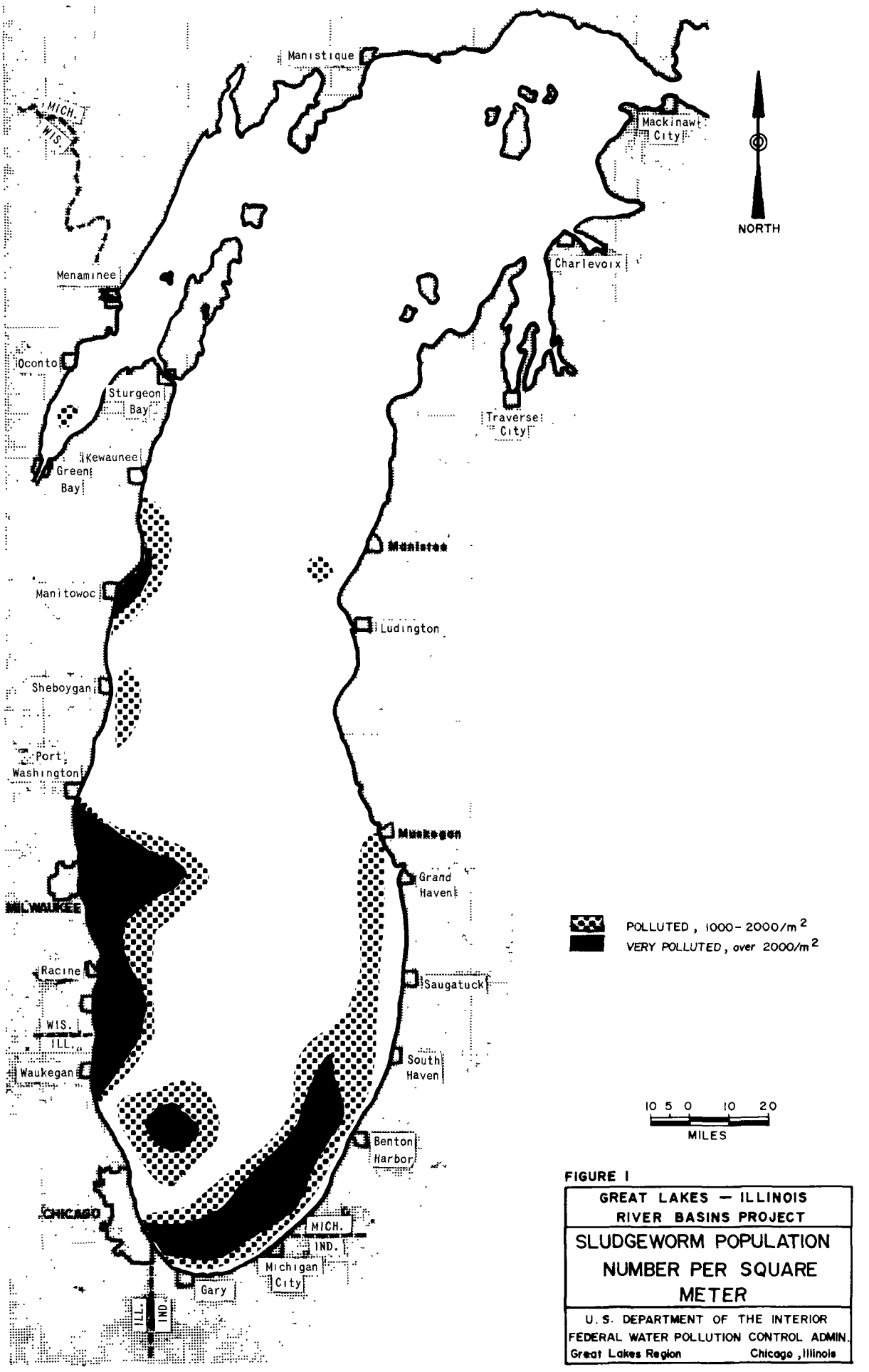

FIGURE 1

GREAT LAKES — ILLINOIS RIVER BASINS PROJECT

SLUDGEWORM POPULATION NUMBER PER SQUARE METER

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMIN.
Great Lakes Region Chicago, Illinois

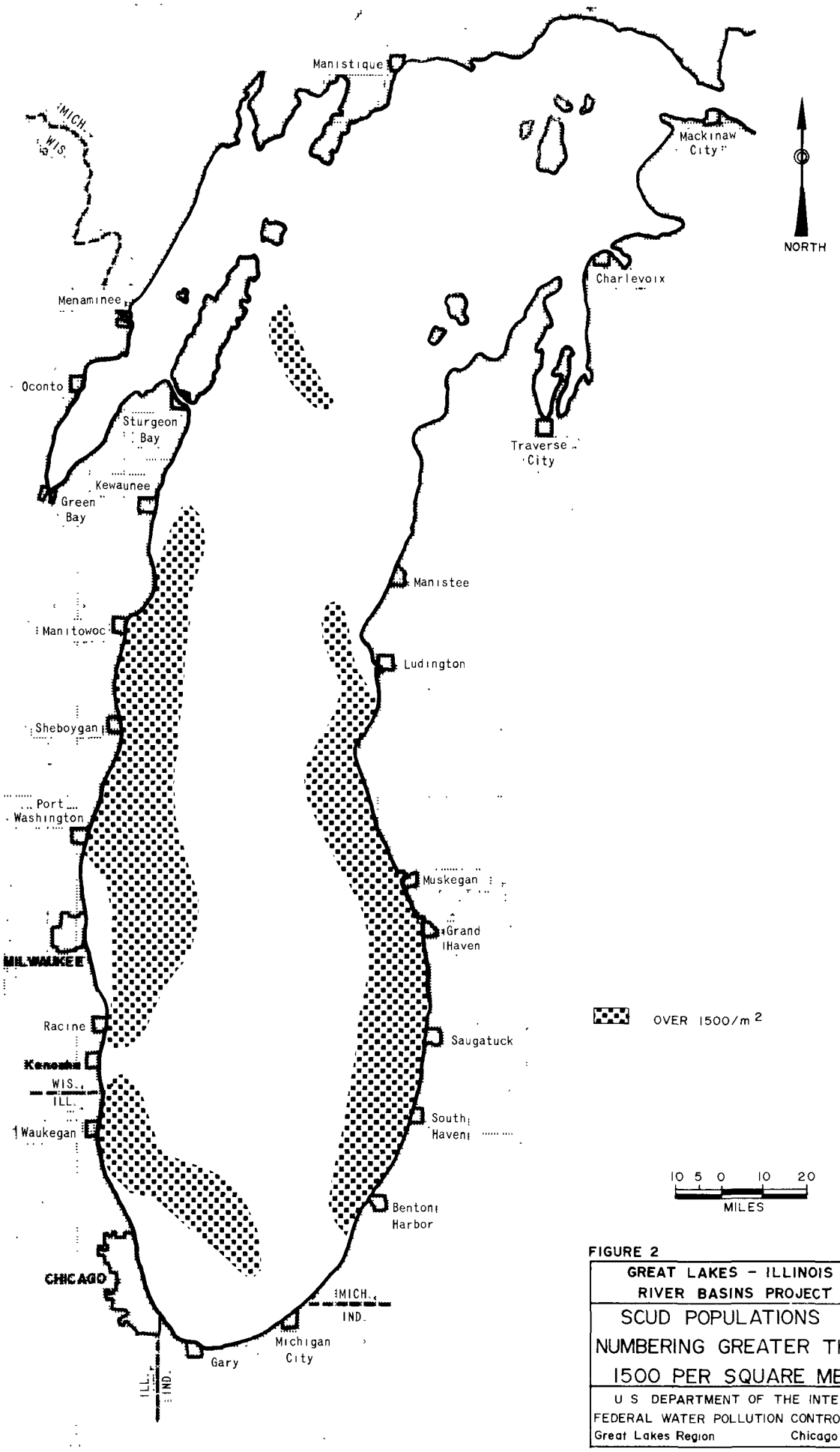

FIGURE 2

GREAT LAKES - ILLINOIS RIVER BASINS PROJECT
SCUD POPULATIONS NUMBERING GREATER THAN 1500 PER SQUARE METER
U S DEPARTMENT OF THE INTERIOR FEDERAL WATER POLLUTION CONTROL ADMIN Great Lakes Region Chicago, Illinois

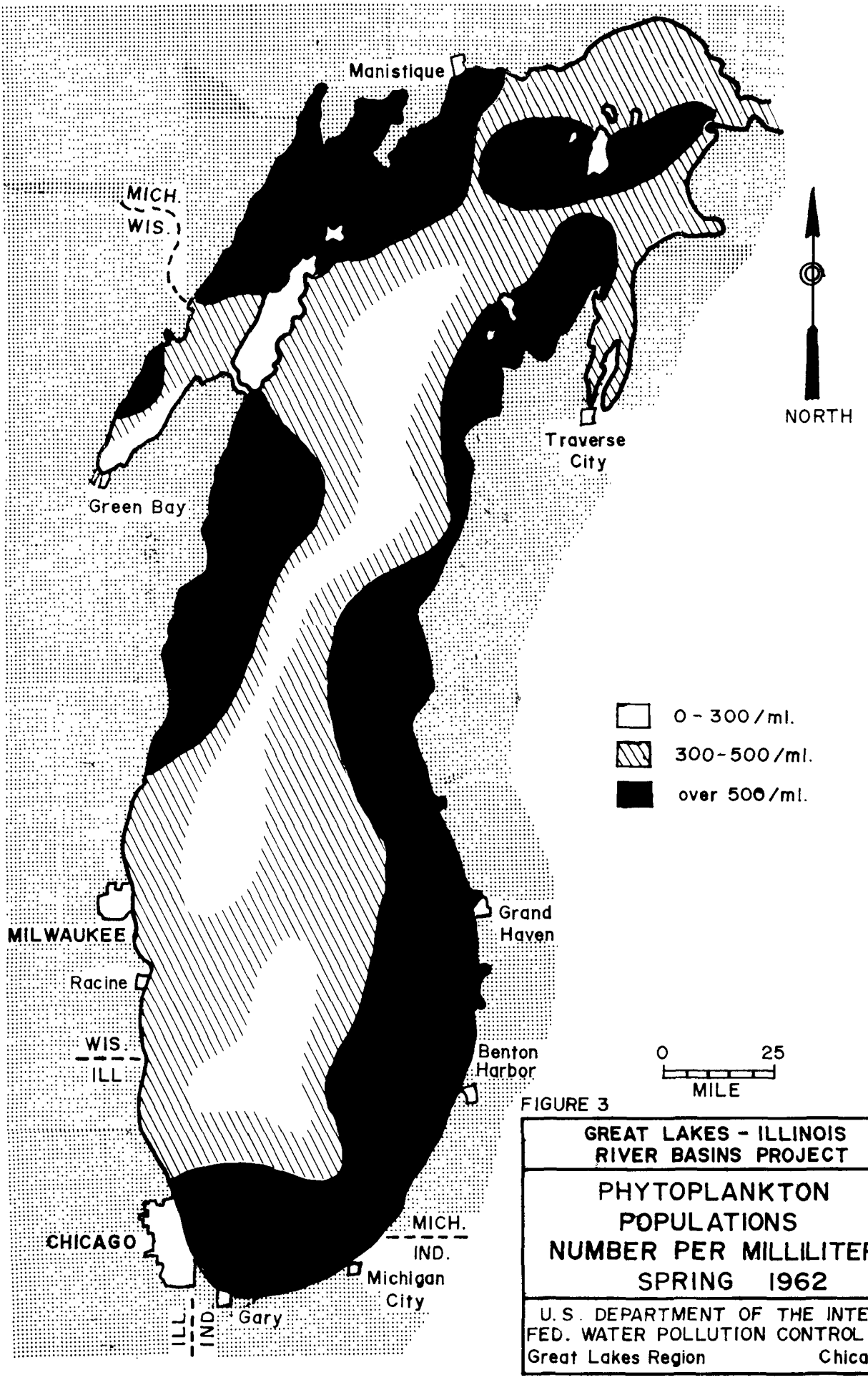

FIGURE 3

GREAT LAKES - ILLINOIS RIVER BASINS PROJECT
PHYTOPLANKTON POPULATIONS NUMBER PER MILLILITER SPRING 1962
U.S. DEPARTMENT OF THE INTERIOR FED. WATER POLLUTION CONTROL ADMIN. Great Lakes Region Chicago, Ill.

INSHORE AREA RESULTS

Massive areas along the perimeter of the southern half of Lake Michigan are polluted to such an extent that large populations of pollution-tolerant sludgeworms occur. The 2,100 square mile area classified as polluted in Figure 2, extending from Chicago northeastward around the southern tip of Lake Michigan, results from organic nutrients discharged by the large metropolitan areas bordering the lake. Lake sediments supporting populations of sludgeworms greater than 100 per square foot (approximately 1,000 per square meter) are considered polluted. Other areas that have polluted lake bed sediments occur in Green Bay, adjacent to the shorelines of Manitowoc, Sheboygan, Port Washington to Waukegan, and between Ludington and Manistee. Despite generally higher sludgeworm densities in inshore areas, the average number of organisms was depressed in a narrow band along the Chicago and Indiana shoreline. This was probably a result of wave action in the inshore areas which did not allow the settling of fine organic particles.

SPECIFIC AREAS - BOTTOM ANIMALS

Inshore areas receiving municipal wastes supported increased populations of pollution-tolerant bottom animals such as sludgeworms. The principal bottom material found at the southern tip of Green Bay was organic sediment, a favorable habitat for sludgeworms and bloodworms which were the predominant organisms. Total populations of bottom-dwelling organisms in 1962 and 1963 averaged 1,980 organisms per square meter near the mouth of the Fox River and gradually decreased to 500 or less ten miles out into the bay (Table 3). Burrowing mayflies were not found. Some pollution-sensitive snails occurred about five miles from the mouth of Fox River.

Twenty-eight square miles of lower Green Bay are classed as polluted; large number of sludgeworms inhabit this area. The number of sludgeworms was greater than the number of scuds in this area; this indicates a pollution by organic wastes. The population of bottom organisms inhabiting the area influenced by the Fox River is affected adversely, altered in composition, and does not supply the fish food potential necessary for maximum water use.

The area of Green Bay affected by the Oconto River discharge was degraded, as indicated by the types of benthic animals; only a few pollution-sensitive organisms were found within two miles of the river mouth. Benthic populations in 1962 and 1963 were highest near the mouth of the Oconto River with populations of 1,020 organisms

per square meter. Five miles from the mouth, populations had decreased to about 500 benthic animals per square meter; bloodworms predominated. A few pollution-sensitive scuds existed less than two miles from the mouth. The discharge of rich organic wastes from the Oconto area contributes to the enrichment and degradation of Green Bay.

Polluted conditions were also indicated in the vicinity of the Menominee and Peshtigo Rivers. In 1962 and 1963 there were fewer benthic organisms in the vicinity of the Menominee and the Peshtigo River outlets than there were in southern Green Bay. A benthic population of 800 per square meter, which consisted mainly of pollution-tolerant bloodworms and sludgeworms, was found at the mouth of the Peshtigo. Twenty-five hundred organisms per square meter, mostly sludgeworms and bloodworms were found near the mouth of the Menominee. Rapid improvement in conditions, in a predominantly sandy bottom, was shown by 1,300 scuds per square meter occurring about three miles from the mouth of this river.

The sand and clay bottom deposits in the near vicinity of Manitowoc and Twin Rivers supported a population of bottom organisms predominated by scuds because organic materials do not settle in this wave-swept area. Populations of 5,000 to 10,000 benthic animals per square meter, mostly sludgeworms, were collected four miles east of the Manitowoc River, indicating severe pollution caused by the deposition

of organic matter. A 228 square mile area off shore from the town of Manitowoc is classified as polluted because the sediments supported more than 1,000 sludgeworms per square meter indicating an organic enrichment of the lake bed.

The Sheboygan River outlet area was found to be degraded one mile from shore. Samples showed more than fifty percent sludgeworms out of a total of 7,000 organisms per square meter. In an 88 square mile area, sludgeworms numbered more than 1,000 per square meter thus indicating polluted conditions. Improved conditions were indicated by a predominance of pollution-sensitive scuds five miles from shore.

Degraded biological conditions in the Milwaukee River outlet area in 1962 and 1963 were indicated by the population of bottom organisms. The harbor was almost devoid of pollution-sensitive organisms. Populations of sludgeworms as high as 150,000 per square meter were found within Milwaukee harbor and further pollution was indicated seven miles from the river outlet by a predominance of pollution-tolerant organisms.

Fifty-six percent of the midges collected in the area from Port Washington to Kenosha were of the pollution-tolerant group. The entire 1,350 square mile shore area from Port Washington to Waukegan is classified as polluted with 1,100 square miles of it being extremely polluted. The pollution-sensitive scud population is depres-

sed in the area off Milwaukee. The existing bottom-animal population indicates organic pollution and a decreased fish food supply.

The deposition of organic materials in shore areas from Port Washington past Chicago to Benton Harbor is influenced by currents that flow parallel to the shore and reverse with the wind direction. These currents deposit organic materials in a band around the southern end of Lake Michigan.

The Root River (Racine) area of Lake Michigan was biologically degraded. Pollution-tolerant forms were very abundant near the mouth of the river and predominated five miles out into the lake. A benthic population averaging 18,560 per square meter (up to 97,000 per square meter) was found near the mouth of Racine Harbor. Ninety-six percent of these organisms were pollution-tolerant sludgeworms.

An examination of bottom samples in the harbor areas along the southern shore indicated that waste discharges were and are such that they contribute to a bottom deposit inhibitory to the establishment of large populations of bottom animals. Some of these deposits appeared to contain significant quantities of oil, grease and allied petroleum waste. The degradation of bottom organisms in the southern end of Lake Michigan extended out as far as twenty miles. The total area degraded by organic wastes discharged from the Chicago-Calumet area is 2,100 square miles as indicated by the increased population

of sludgeworms. Offshore from the Calumet area streams, pollution-tolerant organisms averaged 2,700 to 4,300 per square meter and there were only a few pollution-sensitive organisms. The depression of the population of clean water associated scuds results from toxic wastes being discharged from the Calumet area (Figure 1). To the north, along the Chicago shoreline, pollution-tolerant organisms averaged about 10,000 per square meter and pollution-sensitive forms averaged 500 per square meter indicating severe pollution.

The inshore areas of Lake Michigan from Calumet Harbor to Burns Ditch were and are extensively degraded biologically in degrees ranging from severe near Indiana and Calumet Harbors to less severe near Burns Ditch. Evidence that wastes from the Calumet area are deposited in the lake was found in the bottom materials and the odors of dredgings from this area of Lake Michigan. Petroleum odors were often detected in bottom muds. Pollution-tolerant organisms, mostly sludgeworms and sphaeriid clams, predominated in the areas along the southern shore.

Continuing along the south shore of Lake Michigan in a counter-clockwise direction, the southern tip of Lake Michigan reflected the effects of pollution in the vicinity of Trail Creek and the Galien River (Michigan City-New Buffalo area). Many of the bottom samples collected in the vicinity of the Galien River and Trail Creek were predominantly sludgeworms with populations of 5,000 to 10,000 benthic

animals existing a few miles from shore. One sample collected two miles northeast of Trail Creek consisted of fine black sand and supported a population of over 26,000 organisms per square meter--90 percent of which were sludgeworms. Many of the samples collected about four miles from shore were devoid of pollution-sensitive organisms. These conditions represent sustained degradation of the waters in this area through the discharge of wastes via Trail Creek and the Galien River.

Sludgeworms predominated within the South Haven Harbor. The bottom habitat emitted a sewage odor. The discharge of organic materials from the communities of South Haven, Saugatuck, Grand Haven and Muskegon results in a band of organically enriched sediments five miles off shore. This organically degraded lake bed supports a sludgeworm population exceeding 1,000 per square meter and a midge population that numbered 61 per square meter and was made up of 74 percent pollution-tolerant forms.

Organic enrichment in the area immediately adjacent to the outlet of White Lake at Whitehall was evident during 1962 to 1963. Almost 1,000 midges per square meter, mostly pollution-tolerant Tendipes plumosus and riparius, were found at that station.

Water quality conditions appeared good near the Pentwater and Little Sable Point areas. The bottom community in the sandy area off the Pentwater River, consists of mostly midges, scuds and sphaeriid clams, from 1,000 to 7,000 per square meter.

Water quality also appeared good near Little Sable Point. The benthic community consisted of about 5,000 organisms per square meter with substantial numbers of clean water scud.

The benthic population around the mouth of the Pere Marquette River was composed of less than 500 pollution-tolerant sludgeworms and midges per square meter. Amphipods, from 3,000 to 6,000 per square meter, predominated in samples collected within a two mile radius. The Ludington Spoil Bank supported a small community that was mostly scuds, less than 500 per square meter. The degradation of the lake bottom was less severe out from the communities of Ludington and Manistee in that midge populations increased to 124 per m^2 and pollution-tolerant forms comprised 46 percent of the total number (Table 4). However, a 36 square mile area between the towns supported a population of pollution-tolerant sludgeworms exceeding 1,000 per m^2.

The bottom fauna of Manistee Lake consisted mostly of pollution-tolerant midges and sludgeworms in populations of 500 to 1,000 per square meter. Near the outlet of the lake, no organisms were found. Lake Manistee deposits emitted sewage and petroleum odors. In adjacent Lake Michigan, bottom animal populations were less than 100 per square meter, although midges still predominated. The bottom fauna (approximately 1,000 organisms per square meter) consisted of over 50 percent amphipods about two miles out from the mouth of Manistee Lake.

No appreciable effects were noted from the Betsie River or the City of Frankfort on the benthic fauna of adjacent areas of Lake Michigan. Populations consisting mostly of 100 to 3,000 amphipods per square meter inhabited the sandy bottom.

At the northern tip of Lake Michigan, degraded localized conditions appeared near Manistique. Samples collected near the Manistique River mouth indicated that benthic populations were less than 1,000 per square meter. Only 67 midges per square meter were dredged up near the harbor. The bottom was found to consist mainly of organic matter and had a foul odor as the result of paper mill wastes. One mile south of this area, 100 to 250 pollution-sensitive scuds per square meter were found.

SPECIFIC AREAS - ALGAE

For several years the Chicago Park District has reported that beaches became fouled with algae washed in from the lake. In 1961, the offending organism at Oak Street and Montrose beaches was found to be Dichotomosiphon, a green filamentous alga similar in appearance to Cladophora. In 1962 Cladophora was the principal alga but Oedogonium was also present. All of these organisms require a hard substratum, or attachment surface. The windrows of algae that completely lined the beaches became four-smelling after a few days exposure to the summer heat. Flies and other insects covered the decaying masses.

In July, 1963 large floating masses of Cladophora and Mougeotia were found in southern Green Bay near the western shore. The pollution-tolerant blue-green alga, Lyngbya, was found attached to rocks on the bottom of Calumet Harbor in May 1963.

Phytoplankton concentrations of more than 500 organisms per milliliter are considered excessive; they may give the water an objectionable appearance, induce tastes and odors in domestic water supplies, and increase the cost of water treatment. The City of Kenosha has found it necessary to install a very expensive microstraining system for adequate water treatment because of excessive algae in the raw water. Other cities that have experienced taste and odor problems in their water supplies include Michigan City, Gary-Hobart and Chicago.

Green Bay is an example of accelerated eutrophication induced by man-made wastes. Severe oxygen depletion often occurs. Soluble phosphate levels averaged 0.07 mg/l as PO_4 and ranged as high as 0.60 mg/l; the critical level for algal blooms is considered to be 0.03 mg/l as PO_4. Ammonia nitrogen averaged 0.17 mg/l while NO_3-N averaged only 0.08. The highest phytoplankton populations occurred near the mouth of the Fox River. In July 1963, total populations of 20,000 per milliliter were found. These numbers decreased to 5,000 to 10,000 about ten miles out into the bay. The kinds of phytoplankton in this area were mostly green flagellates, centric diatoms and green coccoids. Blue-green forms were also found in

large numbers, from 700 to 1,500 per milliliter. Light penetration in Green Bay was greatly reduced (Secchi disc readings were only 0.2 meters compared to 16 meters in the northern basin). Near the mouth of the Fox River, average inorganic nitrogen values were close to 0.5 milligrams per liter and average total soluble phosphates were 0.20 milligrams per liter, or nearly seven times greater than the critical level necessary for algal blooms.

The algal population near the Oconto River mouth in July 1963 averaged over 80,000 phytoplankters per milliliter and consisted mostly of green flagellates and green coccoids. These same types predominated in the adjacent lake area in nuisance numbers, from 1,000 to 20,000 per milliliter. The proportion of diatoms was higher in Green Bay than in the Oconto River. Numbers of algae were considerably less on the eastern shore of Green Bay, from 500 to 5,000 per milliliter.

In spring, 1962, phytoplankton populations in excess of 1,200 organisms per milliliter were collected from the Manitowoc-Sheboygan area (Figure 3). This condition resulted from high soluble phosphate levels, ranging from 0.04 to 0.07 mg/l.

Milwaukee Harbor was found to be severely polluted by organic enrichment. It is estimated that 9,300 pounds per day of total phosphate was discharged into Lake Michigan at the mouth of the Milwaukee River. Soluble phosphate concentrations averaged 0.44 mg/l (nearly 15 times the level of phosphates considered critical for the

stimulation of algal blooms) and ranged as high as 1.4 mg/l. Adjacent water offshore averaged 0.07 mg/l. Total inorganic nitrogen in Milwaukee Harbor averaged 1.25 mg/l and ranged as high as 2.94 mg/l. Adjacent areas offshore averaged 0.32 mg inorganic N/l and ranged as high as 2.2 mg/l total inorganic nitrogen. A Secchi disc was visible to less than one meter in the harbor.

High phytoplankton counts in the Milwaukee area indicated enrichment. In the fall of 1962 over 1,500 organisms per milliliter were collected from the harbor. Generally, populations decreased with distance from shore, from over 1,000 per milliliter to less than 100 per milliliter at mid-lake (Figure 4). Predominant genera were Cyclotella, Stephanodiscus, Tabellaria, and Asterionella.

In June of 1963, populations of almost the same size and kind existed both in the river mouth and harbor area, from 1,000 to 20,000 per milliliter. Centric diatoms were the predominant kinds of algae. In spring, 1963, phytoplankton numbered nearly 6,000 per milliliter at the mouth of the Milwaukee River.

These biological findings reflect the deteriorated water quality in the Milwaukee vicinity of Lake Michigan and represent the gross pollution resulting from the domestic and industrial wastes discharged in this area.

The Root River (Racine) area of Lake Michigan was severely polluted with organic enrichment. In 1962 and 1963 soluble phosphate (PO_4) averaged 0.07 mg/l and ranged as high as 0.10 mg/l. Phytoplankton

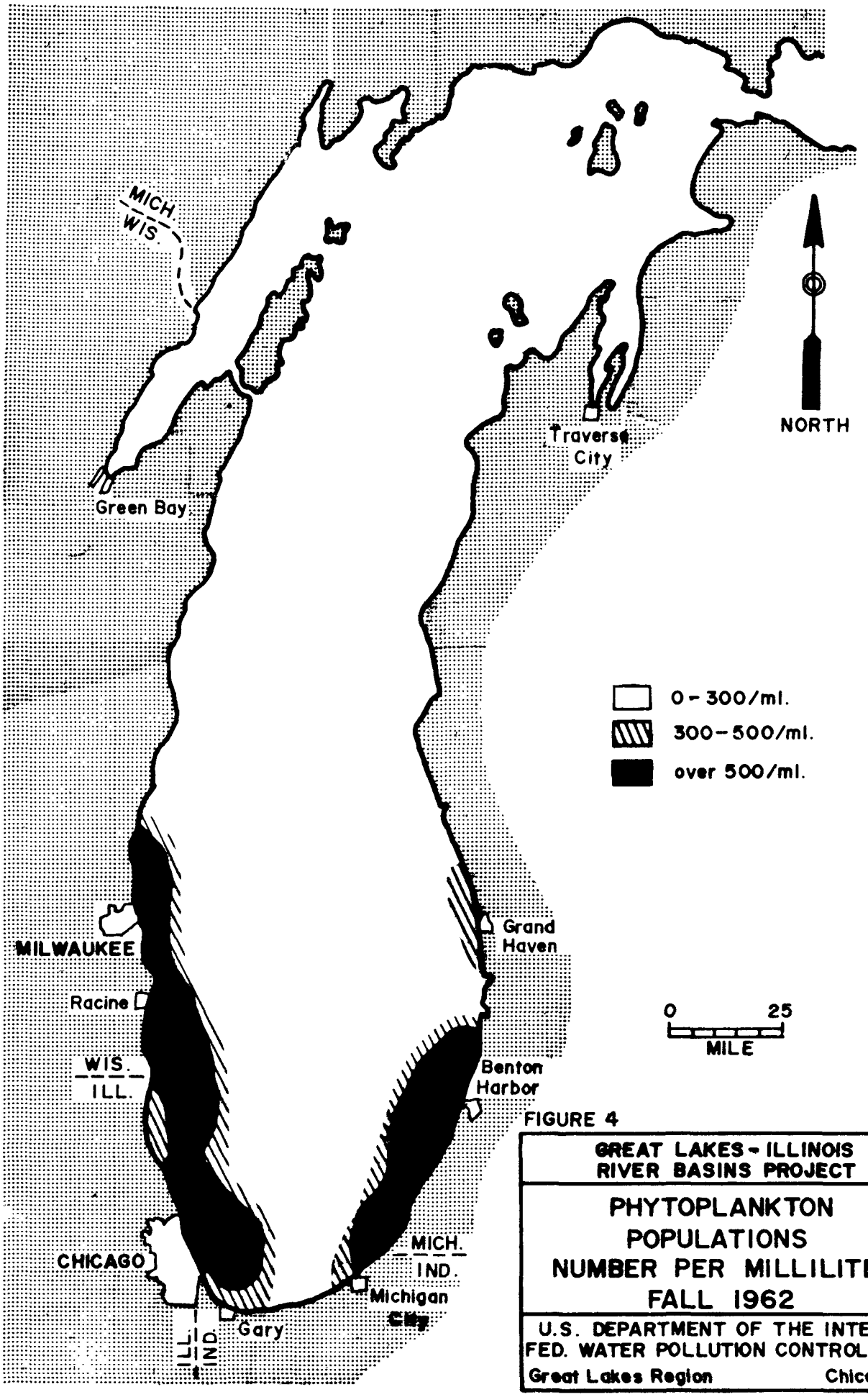

FIGURE 4

GREAT LAKES - ILLINOIS RIVER BASINS PROJECT
PHYTOPLANKTON POPULATIONS NUMBER PER MILLILITER FALL 1962
U.S. DEPARTMENT OF THE INTERIOR FED. WATER POLLUTION CONTROL ADMIN. Great Lakes Region Chicago, Ill.

samples in the fall of 1962 contained 2,229 organisms per milliliter (Figure 4); this was one of the most dense phytoplankton populations encountered during the fall survey and may be compared with concentrations of less than 200 phytoplankton organisms per milliliter in the mid-lake deepwater areas. Cyclotella, Stephanodiscus, Tabellaria and Asterionella were the predominant algal forms. Melosira became the predominant form in the summer.

The waters of Chicago Harbor, Calumet Harbor and Indiana Harbor each contained excessive amounts of algal-stimulating nutrients. In Chicago Harbor, soluble phosphates averaged 0.04 mg/l and ranged as high as 0.15 mg/l. In Calumet Harbor, soluble phosphates averaged 0.05 mg/l and ranged as high as 0.14 mg/l; total inorganic nitrogen averaged 0.35 mg N per liter and ranged as high as 1.02 mg/l. Indiana Harbor water contained an average of 0.05 mg/l soluble phosphorus and ranged as high as 0.12 mg/l. Total inorganic nitrogen averaged 1.56 mg/l and ranged as high as 3.14 mg/l. A concentration of 0.30 mg/l inorganic nitrogen is considered critical for stimulation of algal growth in the presence of adequate phosphorus.

Phytoplankton populations in the Chicago-Calumet area remained very dense during the period of study. In 1962, up to 1,298 organisms per milliliter of sample were found (Figure 3). In 1963, phytoplankton populations increased to 2,143 phytoplankton organisms per milliliter. Light penetration in the Indiana Harbor Canal was severely restricted; a Secchi disc was not visible at one meter.

The distribution of phytoplankton in Lake Michigan was generally influenced by wind-produced currents. In spring, 1962, over 500 phytoplankton per milliliter were collected from inshore waters, beginning at the Chicago-Calumet area and continuing north up the entire eastern lake shore (Figure 3). By the summer of 1962, the current pattern had changed; phytoplankton distribution became more random, except for high numbers of organisms (over 300 per ml) near Chicago and South Haven (Figure 5). Fall, 1962, phytoplankton counts again revealed high concentrations of over 500 organisms per milliliter along both the southeastern and southwestern shores (Figure 4).

The effects of heavy pollutional loads were evident in the vicinity of the St. Joseph River and Benton Harbor. Soluble phosphate concentrations in the St. Joseph River averaged 0.24 mg/l and ranged as high as 0.94 mg/l. Total inorganic nitrogen concentrations averaged 1.12 mg/l and ranged as high as 3.04 mg/l. In spring, 1962, phytoplankton populations of 3,100 organisms per milliliter were concentrated in the waters just offshore from Benton Harbor (Figure 3). Mid-lake waters contained less than 200 phytoplankton organisms per milliliter in spring, 1962.

Lake Michigan waters in the vicinity of Grand Haven, Mighican consistently exhibited the effects of pollutional nutrient loadings. The Grand River, which enters the lake at this point, carries total soluble phosphate concentrations averaging 0.52 mg/l and ranging as high as 1.1 mg/l. Total inorganic nitrogen in Grand River water

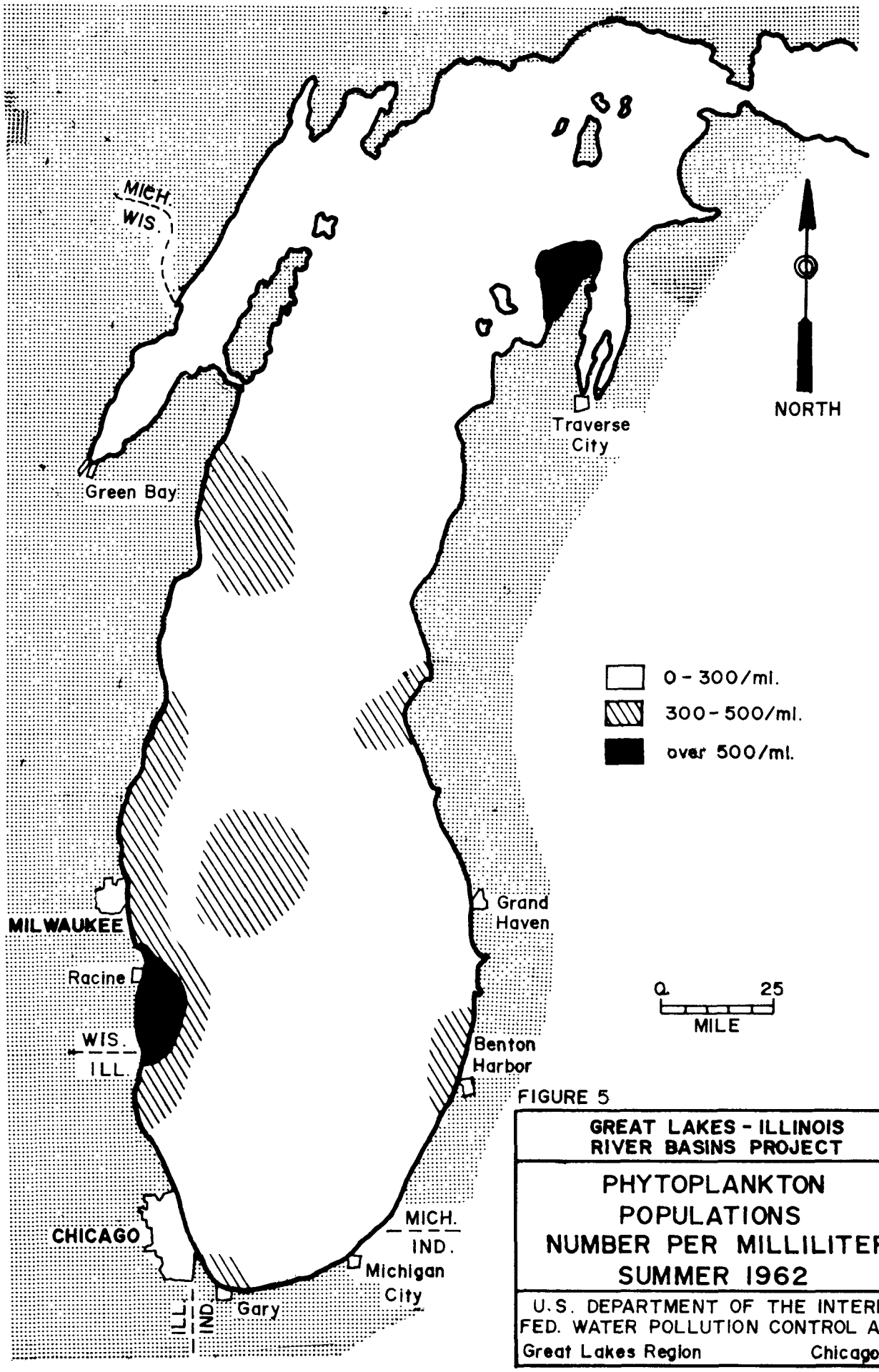

FIGURE 5

GREAT LAKES - ILLINOIS RIVER BASINS PROJECT

PHYTOPLANKTON POPULATIONS NUMBER PER MILLILITER SUMMER 1962

U.S. DEPARTMENT OF THE INTERIOR
FED. WATER POLLUTION CONTROL ADMIN.
Great Lakes Region Chicago, Ill.

GPO 806-408-4

averaged 1.4 mg (N)/l and ranged as high as 3.9 mg/l. Phytoplankton populations in adjacent Lake Michigan waters were correspondingly high. Phytoplankton counts averaged 2,230 organisms per milliliter in summer, 1962 (Figure 3). A high concentration of 630 phytoplankton organisms was again found in the Grand Haven area in fall, 1962 (Figure 4).

The Manistique River at the northern tip of Lake Michigan, carried heavy concentrations of algal-stimulating nutrients. Soluble phosphate concentrations in this river averaged 0.04 mg/l and ranged as high as 0.09 mg/l. Total inorganic nitrogen concentrations averaged 0.47 mg/l and ranged as high as 2.46 mg/l. Phytoplankton populations in Lake Michigan offshore from Manistique consisted of 528 organisms per milliliter in spring, 1962. Mid-lake waters in northern Lake Michigan contained less than 300 organisms per milliliter (Figure 3).

APPENDIX

METHODS

BOTTOM ANIMALS

Sampling of bottom organisms was accomplished with three Petersen dredge hauls at each lake station. These were washed through U. S. Standard No. 30 mesh bronze seine cloth and the remaining organisms and debris preserved with formalin for further analysis in the laboratory.

PHYTOPLANKTON

Samples for phytoplankton identification were collected with polyvinylchloride (PVC) sampling bottles attached to a cable at intervals of zero, 5, 15, 30, 50, 75 and 100 meters from the surface, and at surface, mid-depth and near bottom where depths were less than ten meters. Sufficient formalin was added to each phytoplankton sample to effect a 3 percent solution. One milliliter of the water sample was placed in a Sedgwick-Rafter counting cell and examined microscopically at 200 X.

LIGHT PENETRATION

Light penetration was determined with a standard, 20 centimeter diameter Secchi disc. The limit of visibility was defined as the mid-point between the depths of disappearance upon lowering and reappearance with the disc was again raised. Measurements were reported in meters.

TABLE 1

DISTRIBUTION OF BOTTOM ORGANISMS BY DEPTHS
LAKE MICHIGAN, 1962-64

Depth in Meters	Number per Square Meter
0-9	7494
10-19	3357
20-29	4694
30-39	5752
49-49	3020
50-59	2713
60-69	2146
70-79	1505
80-89	889
90-99	642
100-109	647
110-119	721
120-129	264
130-139	425
140-149	506
150-159	186
160-169	201
170-179	70
220-229	140
230-239	88
260-269	5019

TABLE 2

LAKE MICHIGAN PHYTOPLANKTON
MOST COMMONLY ENCOUNTERED GENERA

Anabaena
Anacystis
Ankistrodesmus
Asterionella
Chlorella
Chodatella
Closteriopsis
Cocconeis
Cyclotella
Dinobryon
Euglena
Fragilaria
Golenkenia
Gomphosphaeria
Gonium
Melosira
Navicula
Nitzschia
Oocystis
Phormidium
Rhizosolenia
Scenedesmus
Schroederia
Selenastrum
Stephanodiscus
Synedra
Tabellaria
Unidentified Green Coccoids
Unidentified Green Flagellates

NOTE: Only those genera whose average total per milliliter exceeds 10 percent of the average grand total are considered predominant.

TABLE 3

BIOLOGICAL DATA - LAKE MICHIGAN, 1962-1964

	BOTTOM ORGANISMS Numbers per square meter				PHYTOPLANKTON Numbers per milliliter				
Quad. 1	Scuds	Sludge-worms	Midges	Total*	Spring 1962	Summer 1962	Fall 1962	Spring 1963	Summer 1963
F-19	1,450	780	100	2,650		176			
E-19	470	1,310	20	2,000		171	246	1,155	1,106
D-19	50	1,950	20	2,210		301	398	1,311	1,035
C-19	80	4,630	20	6,000		1,036		1,588	1,036
G-18	1,190	1,670	100	3,160			694		
F-18	720	4,750	130	6,200		248	175	1,870	
E-18	2,710	1,730	140	5,160	748		172		
D-18	610	240	20	920	1,298	258	350	2,143	
C-18	180	490	70	1,670		233	588	1,347	
H-17	3,180	1,660	140	5,540			1,022		
G-17	1,940	4,620	120	7,030	3,108	224	261		
F-17	310	100	0	410	322		66		
E-17	1,120	470	x	1,600		66	119		
D-17	3,840	2,180	30	6,090	420	66	239		
C-17	1,610	1,850	50	3,910		225	546	357	
B-17	1,240	400	260	1,910					
H-16	4,020	1,040	30	5,490		357	853		
G-16	1,170	1,760	10	3,400	900	98	148		
F-16	220	170	0	410			154		

*Includes miscellaneous organisms not mentioned in Table

1. See Figure 6 for locations of quadrangles.

	BOTTOM ORGANISMS Numbers per square meter				PHYTOPLANKTON Numbers per milliliter				
Quad.	Scuds	Sludge-worms	Midges	Total*	Spring 1962	Summer 1962	Fall 1962	Spring 1963	Summer 1963
E-16	130	190	x	330		165	132		
D-16	190	40	x	240	253	28	143		
C-16	2,260	1,590	80	4,810		402	1,035	572	
B-16	3,220	5,420	180	10,270		384	371	638	
I-15	1,700	380	30	2,300			154		
H-15	4,360	1,130	40	5,860	1,503	294	203		
G-15	340	180	10	540	638	70	110	416	
E-15	80	60	0	140	182				
D-15	150	70	x	220	364	198			
C-15	1,160	2,400	120	3,730		694	2,229	2,552	
B-15	1,200	15,910	210	18,560		896	1,867		
I-14	3,060	300	40	3,660			443		
H-14	2,280	1,240	0	3,580			108		
G-14	390	10	10	410				836	
C-14	5,820	1,370	50	7,340		270	145		
B-14	10	13,980	820	16,360		423	1,530		
H-13	3,970	1,140	20	5,530	2,230	134	295		
G-13	810	530	20	1,400	474	121	196	660	
E-13	1,200	520	20	1,800	378				
D-13	1,560	1,620	100	3,330	210	385			
C-13						242	121		
B-13	500	15,770	90	16,980		484	1,770	6,310	
H-12	4,550	860	290	5,860			270		

*Includes miscellaneous organisms not mentioned in Table.

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	BOTTOM ORGANISMS Numbers per square meter				PHYTOPLANKTON Numbers per milliliter				
Quad.	Scuds	Sludge-worms	Midges	Total*	Spring 1962	Summer 1962	Fall 1962	Spring 1963	Summer 1963
B-12	1,810	610	30	2,660				1,107	
H-11	4,180	80	140	4,880					924
G-11	3,770	980	80	5,180	1,664	354			1,452
F-11	300	90	10	400		252		1,474	
E-11	1,070	760	0	1,850		121			
D-11	170	60	x	230	264	154			
C-11	5,010	1,470	50	7,140	896	322		1,267	
B-11	5,150	320	40	6,590				1,232	
H-10	1,150	140	170	1,630					
G-10	1,440	70	60	1,720					
F-10	60	10	0	90					
C-10	3,770	690	20	4,580					
H-9	310	120	60	520					
G-9	1,760	1,130	110	3,090	616			1,689	
E-9	140	90	10	240	168	308			512
D-9	1,740	750	40	2,590		319		1,035	
C-9	3,020	2,890	80	6,140	3,696	220		5,940	
H-8	80	20	80	230	373			1,078	
G-8	30	90	10	130	189				
E-8	30	10	0	40	770				

*Includes miscellaneous organisms not mentioned in Table.

	BOTTOM ORGANISMS Numbers per square meter				PHYTOPLANKTON Numbers per milliliter				
Quad.	Scuds	Sludge-worms	Midges	Total	Spring 1962	Summer 1962	Fall 1962	Spring 1963	Summer 1963
D-8	2,990	650	10	3,840					
C-8	x	0	0	x					
I-7	400	100	390	920					462
H-7	630	120	30	790	463				352
G-7	1,120	540	160	1,900	165				
D-7	20	140	30	210	1,254				
C-7	0	80	210	290					2,728
B-7	10	1,620	280	1,980	209				16,209
A-7	0	300	0	300					60,088
L-6	60	10	0	70					
K-6	110	20	40	190					
I-6	950	1,240	20	2,250	858				
E-6	240	110	x	370	308				
D-6	950	920	80	1,960					2,882
C-6	0	90	110	240					2,100
B-6	10	190	780	1,020	468				5,375
L-5	440	60	10	520					
K-5	470	110	20	620	1,067	1,067			
G-5	20	30	0	60					
F-5	2,060	10	10	2,280					
D-5	20	130	10	200	484				
C-5	200	720	170	1,220	440			6,160	2,018

*Includes miscellaneous organisms not mentioned in Table.

	BOTTOM ORGANISMS Numbers per square meter				PHYTOPLANKTON Numbers per milliliter				
Quad.	Scuds	Sludge-worms	Midges	Total	Spring 1962	Summer 1962	Fall 1962	Spring 1963	Summer 1963
N-4	10	10	0	20					
M-4	140	60	30	260					
L-4	760	470	210	1,510	407			1,056	
K-4	1,420	180	20	1,660	660				
J-4	500	320	30	860	319			396	
F-4	440	100	10	610	693				
L-3	1,060	730	10	1,810	253			896	
I-3	690	480	30	1,240	231				
H-3	10	50	10	80	792			3,124	
E-3	370	380	50	1,150	968			968	
N-2	20	70	180	290	308				
M-2	20	310	40	410					
K-2	30	100	60	420	330				
I-2	600	210	70	890	528			1,008	

*Includes miscellaneous organisms not mentioned in Table.

TABLE 4

MIDGE LARVAE DATA WITHIN TEN MILE LIMIT FROM SHORE

Area	Total No. Per M^2	Percent of Total			
		Pollution Tolerant	Cosmo-politan	Clean Water	Other
Lower Green Bay	201	80	16	0	4
Kenaunee-Sheboygan	53	0	29	22	49
Fort Washington-Kenosha	118	56	19	3	22
Waukegan-Evanston	113	24	57	0	19
Chicago-Gary	39	6	79	0	14
Michigan City to Buffalo	92	37	59	0	4
Benton Harbor-South Haven	121	51	34	0	5
Saugatuck-Muskegon	61	74	7	7	12
Ludington-Manistee	124	46	16	10	28
Arcadia-Mackinaw City	61	21	56	13	10
Kewaunee-St. Ignace	12	0	23	37	40

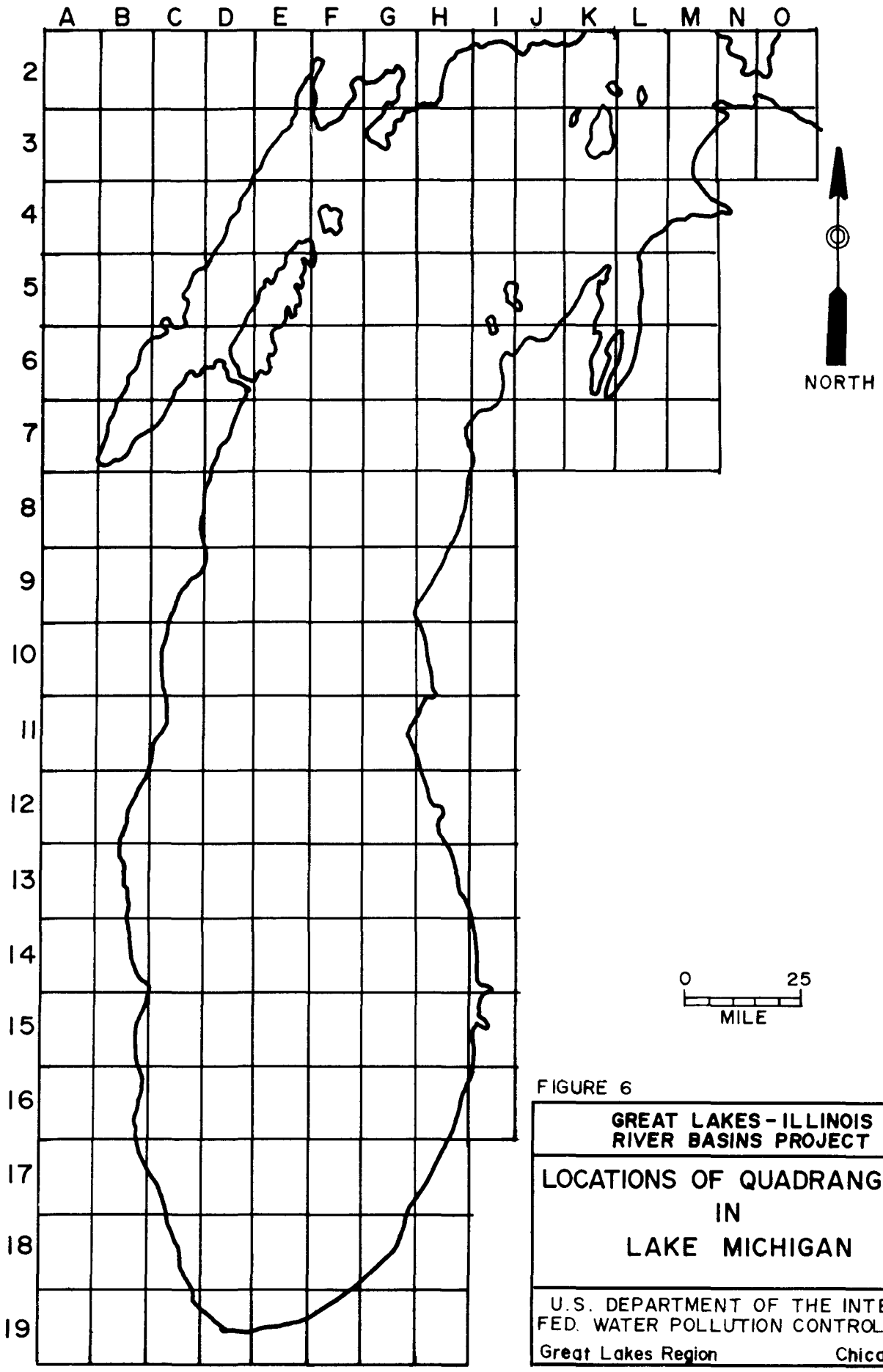

FIGURE 6

GREAT LAKES - ILLINOIS RIVER BASINS PROJECT

LOCATIONS OF QUADRANGLES IN LAKE MICHIGAN

U.S. DEPARTMENT OF THE INTERIOR
FED. WATER POLLUTION CONTROL ADMIN.
Great Lakes Region Chicago, Ill.

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