MACROBENTHIC SURVEY OF NAVIGATION POOL NO. 8 OF THE UPPER MISSISSIPPI RIVER, WITH SPECIAL REFERENCE TO ECOLOGICAL RELATIONSHIPS

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Catherine Ann Elstad

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Candidate: Catherine Ann Elstad

We recommend acceptance of this thesis to the College of Arts, Letters, and Sciences in partial fulfillment of this candidate's requirements for the degree Master of Science in Biology. The candidate has completed her oral defense of the thesis.

Thomas O. Claflin — Thesis Committee Chairperson — Sept. 20, 1977 Date

Thesis Committee Member — Sept 20, 1977 Date

Arden Ross — Thesis Committee Member — Sept. 20, 1977 Date

Thesis Committee Member — Sept 20, 1977 Date

This thesis is approved for the College of Arts, Letters, and Sciences

Dean, College of Arts, Letters and Sciences — 9/21/77 Date

ABSTRACT

The macrobenthic fauna of Navigation Pool No. 8 of the Upper Mississippi River was inventoried and correlated with the average physical-chemical conditions encountered in the pool. Forty-one sampling areas, numbered in order of increasing current velocity, were delineated on the basis of characteristic chemical and physical properties during the summer of 1975. A trend toward decreasing eutrophy occurred from area 1 to area 41.

Benthos samples were collected twice during the summer in each of the study areas. One hundred forty-four taxa were found in the 616 Ponar-dredge collections. Over half of the collected taxa were insect nymphs and larvae. A total of 90,693 representatives of the Phyla Platyhelminthes, Nematoda, Annelida, Arthropoda, and Mollusca were counted, weighed, and identified. Oligochaetes were by far the most ubiquitous and dominant macroinvertebrates. Greatest oligochaete densities were respectively recorded during Sampling Periods I and II in areas 3 ($17,306.10/m^2$) and 18 ($16,609.98/m^2$) and in areas 1 ($10,302.11/m^2$) and 18 ($10,894.18/m^2$).

The qualitative and the quantitative compositions of the benthic communities varied among the 41 study areas. Habitat preferences of particular benthic forms were reflected in the distributional relationships between the macroinvertebrates and the physical-chemical conditions. Benthic production, in terms of the total wet weight/m^2 and the mean number of macroinvertebrates/m^2 in each area, was generally greater in the more eutrophic areas. The more eutrophic areas supported fewer taxa. These taxa generally consisted of pollution-tolerant

organisms, such as oligochaetes and certain chironomids, which were capable of burrowing into the depositional-type substrates. More taxa and greater numbers of gill breathers and filter feeders, such as caddisflies, mayflies, stoneflies, and dipterans, were collected from the less eutrophic areas.

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LIST OF SYMBOLS AND ABBREVIATIONS

Key to taxonomic symbols and abbreviations

1 = Tur. = Turbellaria
2 = Nem. = Nematoda
3 = Oligo. = Oligochaeta
4 = Hir. = Hirudinea
5 = A. mil = *Asellus militaris*
6 = H. azt. = *Hyalella azteca*
7 = G. fasc. = *Gammarus fasciatus*
8 = Deca. = Decapoda
9 = Hydra. = Hydracarina
10 = P. plac. = *Perlesta placida*
11 = Siph. = *Siphlonurus*
12 = Steno. = *Stenonema*
13 = Tri. = *Tricorythodes*
14 = Brach. = *Brachycercus*
15 = Hex. = *Hexagenia*
16 = Eph. = *Ephoron*
17 = Enal. = *Enallagma*
18 = Ophio. = *Ophiogomphus*
19 = Corix. = Corixidae
20 = Neur. = *Neureclipsis*
21 = Cheum. = *Cheumatopsyche*
22 = Hydro. = *Hydropsyche*
23 = Stacto. = *Stactobiella*
24 = Oec. = *Oecetis*
25 = Nym. = *Nymphula*
26 = Sten. = *Stenelmis*
27 = Chao. = *Chaoborus*
28 = Simu. = *Simulium*
29 = Chiro. = *Chironomus*
30 = Crypto. = *Cryptochironomus*
31 = Endo. = *Endochironomus*
32 = Glypto. = *Glyptotendipes*
33 = Poly. = *Polypedilum*
34 = Xeno. = *Xenochironomus*
35 = Tany. = *Tanytarsus*
36 = Coelo. = *Coelotanypus*
37 = Pent. = *Pentaneura*
38 = Atrich. = *Atrichopogon*
39 = Palp. = *Palpomyia*
40 = Amni. = *Amnicola*
41 = Musc. = *Musculium*
42 = Sphaer. = *Sphaerium*

Key to substrate symbols

1 = gravel and debris
2 = coarse sand
3 = medium sand
4 = fine sand
5 = silt
6 = clay

INTRODUCTION

The primary objective of this investigation was to inventory the benthic invertebrates in Navigation Pool No. 8 of the Upper Mississippi River and thus provide adequate quantitative and qualitative baseline data for measuring future changes in the quality of the aquatic environment. Data were collected on the composition of the bottom fauna, distribution, density, number of taxa, number of individuals per taxon, and total wet weights of the benthic communities. A total of 144 taxa, including several species of Oligochaeta, Nematoda, Hirudinea, and Turbellaria, were examined. The large taxonomic categories in addition to those already mentioned, included the Isopoda, Amphipoda, Decapoda, Hydracarina, Plecoptera, Ephemeroptera, Odonata, Hemiptera, Megaloptera, Trichoptera, Lepidoptera, Coleoptera, Diptera, Gastropoda, and Pelecypoda. This study is an attempt to relate this data to the chemical, physical, and biological conditions in Pool 8 and to investigate the role of benthic macroinvertebrates as ecological indicator organisms and bioassay tools.

LITERATURE REVIEW

Macrobenthic research has been conducted in numerous aquatic systems. Buchanan (1963) studied the distribution of benthic communities and bottom sediments in an area of the North Sea off the coast of Northumberland. Three bottom communities were recognized and were found to be poorly correlated with the nature of the bottom sediments. Thorup (1963) studied the growth and life cycles of Danish spring invertebrate fauna taken from two large springs in the Himmerland area of Jutland, Rold Kilde and Ravnkilde, and the influence of environmental conditions, such as temperature, food supply, and sediment texture. The composition and spatial-temporal distributions of the bottom fauna of 50 streams in the Scottish Highlands were assessed in 1960 by Morgan and Egglishaw (1965). Lillehammer (1966) conducted a three-year benthic research study on the river Suldalslågen, West Norway, and measured the importance of influencing ecological factors. The relative abundance, diversity, and general distributional patterns of the macrobenthic fauna of the River Duddon, Lake District, England, was studied by Minshall and Kuehne (1969). The fauna of the Upper and Lower Duddon were strikingly different. The discontinuity of the fauna between the two portions of the Duddon was thought to be caused by differences in nutrients or other water quality factors, although temperature may have been a limiting factor. The effects of physical barriers, substratum differences, variations in discharge and current velocity, and behavioral differences were thought to be relatively insignificant. Badcock (1954a) and Ulfstrand (1967) assessed the benthic macroinvertebrates inhabiting Swedish streams. Badcock undertook a quantitative investigation of the benthic fauna of the Bråån and the Skogsmöllebäcken, two Swedish tributaries of the Kävlinge River. The study concluded that the rich, varied benthic communities could support a thriving salmonid population. The investigations of Ulfstrand, conducted on the river Vindelälven and its tributary Tjulån, located in Swedish Lapland, dealt primarily with the Ephemeroptera, Plecoptera, Trichoptera, and Simuliidae (Diptera) and their associations with depth, current velocity, and substrate conditions. Badcock (1954b) also attempted to assess the problems encountered in classifying streams for comparative purposes. The macroinvertebrates in streams were reported to be influenced by such factors as geographical distribution, temperature range of the water, rainfall and topography, chemical composition of the water, and shelter provided by vegetation.

Studying the aquatic life in many diverse habitats of nine streams and rivers located in eastern and southern portions of the United States, Patrick (1961) assessed the quantitative and qualitative variations concerning algae, protozoa, insects, and fish inhabiting the similar and dissimilar river types. Richardson (1925) examined the bottom fauna of the Illinois River and Peoria Lake during the summer of 1923 and categorized most of the macroinvertebrates as pollution-tolerant species. The distribution, abundance, valuation, and index value in the study of stream pollution of the macrobenthic populations of the Middle Illinois River were determined from a study of 1,308 benthic collections taken from 1913 to 1925 (Richardson 1928). Lee (1944) quantitatively studied the marine invertebrates inhabiting the bottom sediments of Menemsha Bight which is a flounder fishing grounds in the

Woods Hole region. A study concerning the vertical distribution of the macrobenthos in the sediments of Douglas Lake, Michigan, concluded that the top 14 cm supported 93% of the benthic macroinvertebrates, with more individuals located in the 1-2 cm stratum than in any other level (Cole 1953). Hechtel (1968) inventoried the macrobenthic invertebrates of Flax Pond, a marine tidal marsh-pond which is located near Long Island Sound, New York. The results of the five-year study of 14 Ohio River and tributary stations were used to assess the relationships between the biological water quality and the physical-chemical water quality of the system (Mason, Lewis, and Anderson 1971). Clark (1973) compiled a list of macrobenthic invertebrates which were collected during a general limnological survey of the Navasota River, Texas. Needham and Usinger (1956) and Britton and Averett (1974) conducted benthic surveys on aquatic habitats in California. The benthic investigation of Prosser Creek, California, by Needham and Usinger was an attempt to determine the number of samples necessary to give statistically significant figures on the total number and weight of organisms present, the number of samples needed to obtain representatives of all benthic forms present, the degree of variation introduced when more than one investigator is involved with the collection of samples, and the correlations between the macrofauna and physical parameters of the aquatic habitat. They concluded that while only two square foot samples are necessary to be reasonably certain of obtaining representatives of the dominant macroinvertebrates, an excessive number of samples would be required to provide signigicant data on total weights and total numbers of bottom organisms. Also, if collectors were properly trained, one investigator need not collect all samples. Britton and Averett conducted a year-long limnological study of the Sacramento River, California. A decrease in the diversity of the benthic macroinvertebrates was noted downstream and representatives of the Order Diptera, especially those belonging to the Family Chironomidae, were found to be the most commonly collected organisms. The benthic inhabitants of several aquatic systems in Ohio have been studied. Quantitative and qualitative descriptions of the bottom invertebrates of the Hocking River, Ohio, were obtained and related to various physical-chemical conditions and seasonal variations by Ludwig (1932). The species composition, population density, and seasonal variations of the bottom populations of Sandusky Bay which is located in northwestern Ohio were studied by Lindsay and Herdendorf (1975). Olive and Smith (1975) surveyed the benthic fauna of the Scioto River Basin, Ohio, and assessed the role of macroinvertebrates in the evaluation of water quality. Much benthic research has been done on the Great Lakes and was reviewed by Henson (1966). The physical, chemical, and biological changes occurring in western Lake Erie were assessed by Britt et al. (1973).

Benthic communities of the Mississippi River have also been investigated. Dorris (1958) conducted a limnological study of the Middle Mississippi River and adjacent waters during August 1949 to July 1952. The seasonal and annual variations in the plankton and bottom fauna of four lakes were studied and related to environmental factors. The Middle Mississippi River was studied by Ragland (1974) for purposes of evaluating three side channels and the main channel as fish habitat. Ninety-six percent of the benthic community was found to be composed of aquatic insects. Distinct habitat preferences of various benthic organisms were obvious. A biological survey of the Upper Mississippi River was conducted in 1926 to assess the effects of pollution from the Twin Cities on aquatic life and to determine the distance downstream the effects of this pollution were detectable (Wiebe 1927). The Mississippi River between Minneapolis and Winona, Minnesota, and tributaries including the Minnesota, St. Croix, Cannon, and Chippewa rivers were investigated. The bottom macroinvertebrates collected from the Mississippi River above Minneapolis to Red Wing were all pollution-tolerant species. Clean-water species were taken at and below Red Wing, Minnesota. The more polluted sections of the study area yielded fewer taxa than did the less polluted or unpolluted waters. Carlson (1968) surveyed the benthic fauna of the Upper Mississippi River above Dam 19, Keokuk, Iowa, during the summers of 1960 and 1961. *Sphaerium transversum* was the dominant organism in 1960 and 1961. The dominant insects in 1960 and 1961 were respectively *Hexagenia* nymphs and *Tendipes (Chironomus) plumosus*. Carlson characterized the benthic fauna as a climax community typical of mature streams and demonstrating no adverse effects from pollution.

Benthic research has often focused on particular inhabitants of the bottom community. Klemm (1971, 1972) and Kopenski (1972) surveyed the distribution of leeches in Michigan. A systematic investigation of 30 species and subspecies of amphipods, excluding subterranean species, inhabiting the fresh waters of glaciated North America was undertaken by Bousfield (1958). White (1974) compiled a list of stoneflies collected from the Salt River, Kentucky, during August 1970 to July 1971. The Ephemeroptera, especially those representatives of the Family Ephemeridae, of the Upper Mississippi River (Carlander et al. 1967, Fremling 1960, 1964, 1970, Gooch 1967) and other aquatic systems (Burks 1953, Gilpin 1969, Hamilton 1959) has been comprehensively studied. Scott (1958) assessed the Trichoptera of the River Dean, Cheshire. Parfin (1952) compiled a list of 23 genera, 41 species, and nine varieties belonging to the Orders Megaloptera and Neuroptera collected in Minnesota during the years 1947 to 1949. Wu (1931) and Obrecht (1949) respectively reported on the distribution and biology of *Simulium* and Michigan mosquitoes. The biology, distribution, and life history of the dipteran Family Chironomidae has been studied by Oliver (1971). Many investigators have been involved with mollusks. Shoup (1943) correlated the distribution of 47 dominant gastropods collected in Tennessee during the four summers of 1938 to 1941 with measured values of total stream alkalinities. Heard (1963) assembled information on the biology of the pill clam *Pisidium (Neopisidium) conventus*. Isom (1974) compiled a list of 77 species of Pelecypoda collected from the Green River, Kentucky. The burrowing abilities and survival of *Sphaerium transversum* and *S. striatinum* under added substrates of sand, silt, and a mixture of sand and silt were assessed by Rogers (1976).

The effects of pollution on macrobenthic fauna and the role of macroinvertebrates as indicators of pollution have been assessed by Anderson et al. (1965), Brown (1971), Claassen (1932), Gaufin (1958), Gaufin and Tarzwell (1952, 1956), Hawkes (1963), Patrick (1950), and Wurtz (1955). As indicator organisms which reflect environmental conditions, they can be used to characterize and monitor the water quality of an aquatic environment. Biological populations, responding to chemical and physical variations in the habitat, can be used to prevent, detect, assess, and control water pollution. Benthic macroinvertebrates differ in their ability to tolerate organic pollution. Although the assignment of particular macroinvertebrates to specific levels of pollution tolerance is arbitrary, Weber (1973) defined three categories of pollution tolerance. Tolerant organisms are often associated with excessive organic contamination and low oxygen levels. Members of the Classes Oligochaeta and Hirudinea, *Chironomus*, and *Physa* are often considered representatives of this pollution-tolerant category. Pollution-facultative macroinvertebrates are capable of surviving under a wide range of ecological conditions and are frequently associated with moderate levels of pollution. Intolerant or sensitive organisms are usually associated with clean waters having no or little organic contamination and high oxygen contents. The distribution of a taxon within an aquatic habitat is not totally dependent on the amount of organic contamination present but is modified by various environmental characteristics, such as substrate and current velocity (Weber 1973). Pollution-sensitive forms could therefore possibly survive in aquatic habitats containing moderate levels of organic contamination.

Claassen (1932) reported that biological analyses are the most reliable methods of evaluating a stream. While chemical and physical evaluations of a body of water reflect the conditions or water quality at the moment of examination, biological analyses indicate water-quality conditions not only at the time of examination but also over considerable time periods prior to sampling (Claassen 1932, Paine and Gaufin 1956, Patrick 1950). Patrick (1950) also reported that the biological composition of an environment represents the interaction of all the chemical and physical properties present. The chemical and physical monitoring of that environment cannot feasibly evaluate all such possible chemical-physical parameters.

Disadvantages and limitations concerning the biological monitoring of aquatic environments exist. Mason (1975) has reported that the lack of positive and complete identifications of immature benthic forms has caused much criticism concerning the assignment of benthic macroinvertebrates to definite biological pollution indicator categories. He also stated that the "pollutional" classification of a macroinvertebrate, which takes into account the general ecological characteristics of that organism, is very subjective and the results cannot frequently be reproduced. Several other difficulties arise when trying to compartmentalize benthic organisms according to pollution-tolerance levels. For example, many organisms which abound under polluted conditions are also present in limited numbers under cleaner situations (Gaufin 1958, Gaufin and Tarzwell 1952). Many species occur so infrequently that their use as indicators is limited and discouraged (Gaufin and Tarzwell 1952). Other factors, apart from the degree of organic contamination, may govern the occurrence and distribution of benthic organisms. Depth, oxygen level, substrate type, current velocity, pH, temperature, and food supply are a few controlling factors which may override the importance of contamination. Gaufin and Tarzwell (1952) have indicated that the entire benthic community and the relative abundance of the faunal constituents are important and must be considered for evaluating water quality.

Many organisms have been promoted as good biological indicators of water quality. Goodnight and Whitley (1960), Brinkhurst (1965), and Smith (1975) have reviewed the importance of oligochaetes as indicators of water quality. Fremling (1964) and Britt (1975) investigated the role of mayflies as ecological indicator organisms. The use of mayflies, specifically *Hexagenia bilineata*, *H. limbata*, and *Pentagenia vittigera*, as bioassay tools on the Upper Mississippi River was evaluated by Fremling. In his seven-year study which began in 1957, Fremling noted that significant mayfly populations were absent from two sections of the Upper Mississippi River which were located south of the Twin Cities and St. Louis and which received large quantities of industrial and municipal wastes. Paine and Gaufin (1956) and Mason (1975) examined the utility of aquatic Diptera as water-quality indicators.

The distribution of the macrobenthic fauna in aquatic habitats and the governing factors have been discussed by Allen (1959), Hynes (1960), and Patrick (1962). Brundin (1951) evaluated the relationships between macrobenthic invertebrates, especially chironomid larvae, and oxygen concentrations at the substrate-water interface. The importance of plant detritus as a factor in determining the distribution of the macrofauna in streams was examined by Egglishaw (1964). Egglishaw concluded that the benthic distribution of invertebrates was significantly correlated with the distribution of plant detritus. Current velocity, as a factor determining the spatial distribution of bottom inhabitants, was assessed by Dorier and Vaillant (1948), Nielsen (1950), Jaag and Ambühl (1963), and Edington (1965). Hunt (1930), Wene and Wickliff (1940), Cummins and Lauff (1969), Brusven and Prather (1974), and de March (1976) discussed the effects of substrate on macrobenthic distribution. Relationships between the nature of the substrate and the distributional patterns of mayflies (Eriksen 1968, Linduska 1942), chironomid larvae (Wene 1940), and the fingernail clam *Sphaerium transversum* (Gale 1971) have been investigated.

METHODS AND MATERIALS

Field Methods

Forty-one sampling areas in Navigation Pool No. 8 of the Upper Mississippi River were delineated on the basis of characteristic chemical and physical properties during the summer of 1975. Two areas were located in the main channel of the river. The remaining 39 areas were established in adjacent waters. The study areas were numbered in order of increasing current velocity.

A systematic sampling procedure for the collection of bottom samples (Weber 1973) was conducted in most of the 41 areas. Linear transects, along which sampling stations or sites were located, were established at uniform intervals with the aid of aerial photographs. The transects were coded from north to south and the sampling stations along each transect were coded from west to east. Depending on the size of the sampling area, at least two (usually three) transects were defined with three sampling stations per transect. Of the three sampling stations, two were located near opposite shores and one was centrally located. Sampling sites were randomly selected (simple random sampling of the entire study area) in those areas where transects could not be feasibly established (Weber 1973).

Benthos samples were collected twice during the summer. A minimum of six samples was collected in most areas during each sampling period. Bottom samples taken during the first sampling period (15 June to 15 July 1975) contained a single dredge haul representing 0.023 m^2 of bottom material. Those bottom samples collected during the second sampling period (15 July to 15 August 1975) contained two dredge hauls representing 0.046 m^2 of bottom material. Of the 616 samples analyzed, 311 were composed of two dredge grabs and 305 were composed of single dredge grabs.

Benthos samples were quantitatively collected with a 6-in Ponar dredge. The collected samples were washed into plastic tubs and labelled with regard to location, date, and size of sample (single or double dredge haul). The benthos samples were then washed in the field through a U. S. Standard No. 30 sieve into plastic containers and preserved in 10% formalin. Rose bengal stain was added to the samples to facilitate the separation of the benthic organisms from the debris (Mason and Yevich 1967).

Laboratory Methods

In the laboratory, each sample was again washed through a U. S. Standard No. 30 sieve to remove the formalin. The benthic invertebrates were hand sorted from the residual debris, placed in clear plastic vials, and preserved with 5-10% formalin. A low power lens was used when necessary to aid the hand sorting.

Total wet weights were obtained for each sample. The organisms were hand sorted from the excess debris and blotted dry (Davis 1938, Dorris 1958, Lillehammer 1966, Morgan and Egglishaw 1965, Needham and Usinger 1956). The organisms were then placed on tared weighing paper, allowed to air dry for two minutes, and weighed to the nearest 0.01 milligram.

Identifications of benthic invertebrates were carried down to the generic level in most cases and to the species level whenever possible.

Species level identifications were not always possible or feasible because of the absence of adult forms needed for positive identification, the early life history stages encountered, and the uncertainties in the taxonomy, especially in reference to the Diptera (Hilsenhoff 1975, Olive and Smith 1975, Oliver 1971). Identifications were facilitated by the use of the taxonomic keys found in Eddy and Hodson (1957), Hilsenhoff (1975), Mason (1973), Pennak (1953), and Usinger (1956). One group of organisms often requiring special preparation for correct identification was the dipteran (midge) larvae, especially those larvae belonging to the Family Chironomidae (Tendipedidae) (Lindsay and Herdendorf 1975, Mason 1973). Head squashes were accomplished by removing the head capsules of many dipteran larvae and exposing the ventral structural features necessary for proper identification.

The number of taxa and the number of benthic invertebrates per taxon were recorded for each sample. All samples were represerved in 5% formalin.

Data Analysis

Simple linear and multiple correlations were obtained using the computer program Multiple Regression/Correlation (Contributed Program BASIC, MULREG, A 404-36178 A) which performs multiple linear correlation and regression on data using the model $Y = B_0 + B_1X_1 + B_2X_2 + \ldots + B_nX_n$. This program was modified in order to accommodate 41 observations, 16 variables, and 16 regressions (Appendix II). Twenty-two selected parameters of the macrobenthic fauna of Navigation Pool No. 8 were correlated with average physical-chemical parameters of the pool for each sampling period. Levels of significance were assigned at the 0.01 and 0.05 levels.

DESCRIPTION OF STUDY AREA

With a length of 2552 miles (4116.13 km), the Mississippi River is the largest river in the United States. The drainage basin of the Mississippi River and its 164 tributaries encompasses an area of 1,250,000 square miles (3.24 X 10^6 km^2) or 40% of the total area of the United States. The waters from 31 states and two Canadian provinces drain into the Mississippi River.

The section of the Mississippi River from Lake Itasca to Cairo, Illinois, the mouth of the Ohio River, is defined as the Upper Mississippi River. From 1930 to 1940, a series of 27 dams was constructed on this reach of the river by the U. S. Army Corps of Engineers for purposes of commercial navigation. Two other dams were privately built. The resulting impoundments can be divided into two distinct ecological areas (Fremling 1970). Immediately downstream from the dams are the tailwaters which essentially represent the unmodified river. The pools upstream from the dams resemble open lake-type systems whose sediments are largely composed of silt. These two areas are separated by transitional, shallower marshy areas.

Navigation Pool No. 8 is the result of a project authorized by the River and Harbors Act of 3 July 1930. This act provided for a navigable channel with a minimum depth of nine feet and a minimum width of 400 feet. Lock and Dam No. 8 was completed in 1937 and its closure created at immediate 11 foot rise in the water level of the upstream pool (Claflin 1973). The pool is impounded by Lock and Dam No. 8 located at Genoa, Wisconsin, and is 679.2 river miles upstream from Cairo, Illinois. The pool extends northward to Lock and Dam No. 7

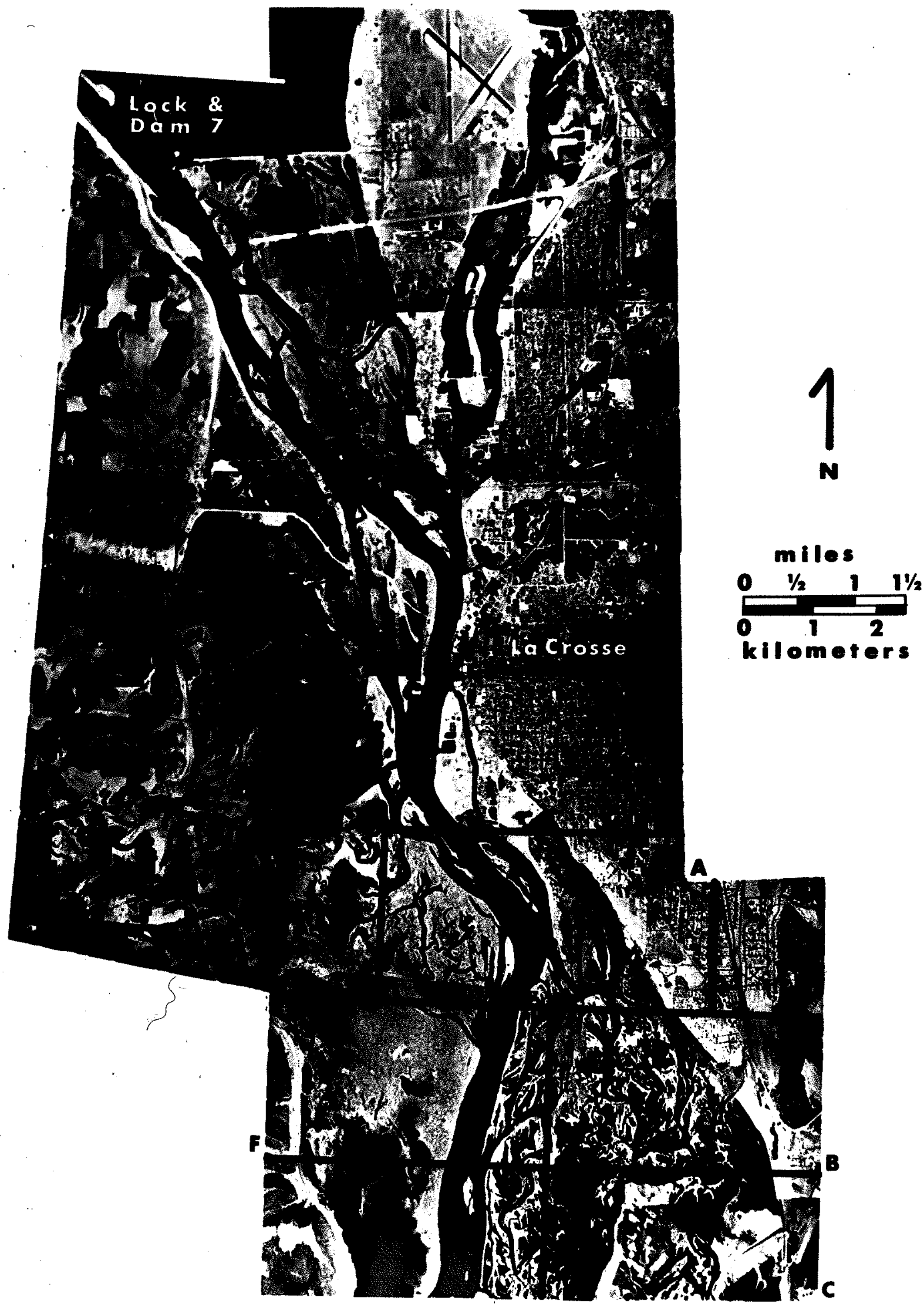
located at Dresbach, Minnesota (river mile 702.5) (Figs. 1 and 2). Pool 8 is bordered by La Crosse and Vernon Counties in Wisconsin and by Winona and Houston Counties in Minnesota. The major tributaries to the Mississippi River in Pool 8 are the La Crosse River, which enters from the east at river mile 698.1, and the Root River, which enters from the west at river mile 693.8.

Environmental Setting

Wisconsin can be divided into two regions: the Driftless Area and the Glaciated Region, with Navigation Pool No. 8 lying in the Driftless Area. This area was once thought to represent a lake bed having deposits of fine silt or loess. The deposits of loess are now known to be chiefly wind-blown. The loess, a silt intermediate in particle size between clay and sand, forms a cover or "cap" which overlies other parental, residual soils typical of weathering processes acting on limestone, sandstone, and crystalline rocks. A uniform, homogeneous substrate is thus present for the development of vegetation. Martin (1965) reported that the thicker loess deposits are usually within 10 to 20 miles (16 to 32 km) of the Mississippi River and average 10 to 15 feet (3.05 to 4.57 m) in thickness. These deposits can attain thicknesses of 60 feet (18.29 m) near the Mississippi River. Thinner deposits of loess are found 50 to 80 miles (80 to 128 km) from the river and have an average thickness of less than one foot (0.305 m).

Navigation Pool No. 8 has an elevation of approximately 640 feet (195.07 m). The pool has a length of 23.3 river miles (37.5 km), a maximum width of 2.9 miles (4.7 km), and a surface area of 20,810 acres

Fig. 1. Aerial photograph, 1974, of the northern half of Navigation Pool No. 8 of the Upper Mississippi River, including rectangular insets which indicate the location of sampling areas.


Lock &
Dam 7
La Crosse
A
B
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F
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miles
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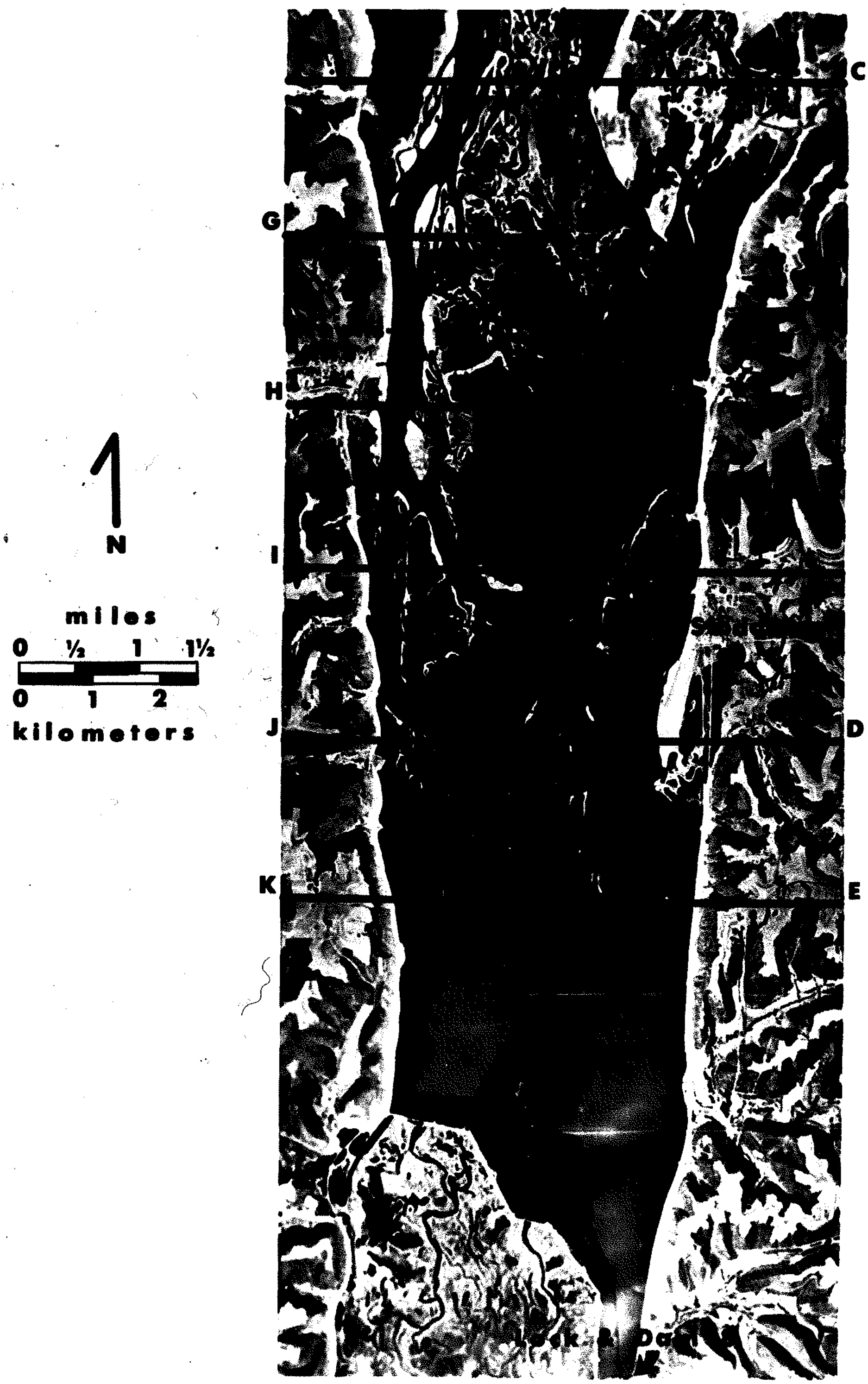
kilometers

Fig. 2. Aerial photograph, 1974, of the southern half of Navigation Pool No. 8 of the Upper Mississippi River, including rectangular insets which indicate the location of sampling areas.


C
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kilometers

(8,425.10 ha). The shoreline (perimeter) and the federal land above the flat pool involve 85 miles (136 km) and 10,282 acres (4,162.75 ha), respectively. Discharge typically averages between 5700 cubic feet per second (cfs) to 286,000 cfs during periods of flooding. The pool has an average annual incoming sediment load of 3,655,000 tons. Pool 8 has an estimated trapping efficiency of 27%, resulting in the deposition of 987,000 tons of sediment annually (U. S. Army Corps of Engineers, St. Paul District 1974).

Clay, silt, loam, and occasionally sand constitute the floodplain material (Martin 1965); a dark color is imparted by organic matter. The floodplain material is 10 to 30 inches (25.4 to 76.2 cm) thick and is underlain by several feet of sand, which often grades into coarse gravel 3 to 6 feet (0.91 to 1.83 m) below the surface (Martin 1965). In Wisconsin the floodplain slopes southward from an elevation of about 677 feet (206.35 m) at Prescott to 592 feet (180.44 m) at Dubuque, Iowa (Martin 1965). The Mississippi River thus descends 85 feet (25.91 m) between Prescott and Dubuque (259 river miles; 417.74 km) and has a grade in Wisconsin of less than four inches (10.2 cm) per mile (Martin 1965). Pool 8 thus descends approximately 7.75 feet (2.36 m) from North to South.

In Wisconsin high waters typically occur during the months of April or May and possibly October. Low waters prevail during December, January, and February with a secondary low stage often occurring during the summer. High waters did occur during the months of June and July, 1975.

Pool 8 demonstrates great ecological diversity due partly to the inundation of large, diverse land areas. Low-lying marsh, meadow, and low wetland forest areas were inundated producing large-scale changes in the habitats within the affected area (Claflin 1973). Habitats range from the very eutrophic backwater areas to the less eutrophic areas of the main channel.

Description of the Forty-one Study Areas

Forty-one areas in Navigation Pool No. 8 were designated for investigation during the summer of 1975. According to Claflin (1977), these areas possessed the widest ranges of the parameters that could be encountered in the entire pool. The differences found between these ecotypes or study areas were assumed to typify the differences found between similar ecotypes contained within the entire pool. These areas were defined on the basis of chemical and physical parameters and were numbered in order of increasing current velocity. Current velocity was believed to be the most important parameter influencing all other physical and chemical parameters (Claflin 1977). The average values for all chemical and physical parameters for all 41 study areas (Claflin 1977) are given in Table 2.

The following descriptions, modified from Sefton (1976), include descriptions of the predominant aquatic macrophytes in each of the 41 study areas. Relative biomasses (%) of the major aquatic macrophytes occurring in each area were calculated by dividing the total dry weight of a species in an area by the total dry weight of all species in an area (Sefton 1976). Figures 3-13 are enlargements of the delineated sections of Navigation Pool No. 8 shown in Figs. 1 and 2.

Areas 1-5. These areas were located above the Goose Island area in the midsection of the pool (Fig. 4). They were small, eutrophic marsh openings of similar size. The areas were differentiated on the basis of the size of the central opening of water. There was no measurable current velocity in any of the five areas and the turbidity was low. Nitrate and organic nitrogen levels were much higher than the levels in the majority of other areas. The clay-size fraction (fraction #6) dominated the sediments. All areas contained large amounts of emergent vegetation. Area 1 had the largest central opening of water. The mean depth was 1.70 m. *Ceratophyllum demersum* (17.4%) was the predominant species in the opening. Patches of *Nuphar variegatum* (16.9%) occurred along the edges of the emergent *Sagittaria latifolia* (43.7%) surrounding the area. Area 2 had a mean depth of 1.20 m. *Ceratophyllum demersum* (11.7%) and *Nuphar variegatum* (11.4%) were found in the opening. Dense stands of *Sagittaria latifolia* (66.9%) bordered the opening. The mean depth of area 3 was 1.10 m. Area 3 contained emergent and floating-leaved communities. The major emergent macrophytes were *Sagittaria rigida* (32.0%), *Sagittaria latifolia* (23.6%), and *Sparganium eurycarpum* (18.6%). The floating-leaved community was dominated by *Nymphaea tuberosa* (5.3%). The buildup of Lemnaceae (12.3%) was marked during the summer. The mean depths of areas 4 and 5 were 1.00 m and 0.90 m, respectively. Areas 4 and 5 had dense stands of *Sagittaria* consisting of 92.2% and 98.5% *Sagittaria latifolia*, respectively.

Area 6. Area 6 was located in a side channel along the east side of upper Raft Channel (Fig. 12). The mean depth was 1.08 m. The current velocity measured 0.015 m/sec. Relative to those areas with greater current velocities, the turbidity was low and the organic nitrogen and nitrate levels were somewhat higher. The clay-size fraction (69.40%) was the major constituent of the sediment. The center of the area was open, but the margins possessed stands of *Sagittaria latifolia* (57.2%), *Sagittaria rigida* (17.6%), and *Nelumbo pentapetala* (11.4%).

Area 7. Located south of the main channel above the "S" curve below Brownsville, Minnesota (Fig. 12), area 7 had a mean depth of 0.61 m and a current velocity of 0.016 m/sec which was due to its proximity to the channel. The clay-size fraction constituted 61.28% of the sediment; the silt-size fraction constituted 35.43%. The area contained a stand of *Sagittaria latifolia* (75.9%) surrounded by *Nelumbo pentapetala* (8.0%), *Potamogeton nodosus* (4.5%), and *Nymphaea tuberosa* (3.7%).

Area 8. This area was east of upper Raft Channel and was separated from it by a thin land mass (Fig. 11). The mean depth was 0.98 m. The current velocity averaged 0.019 m/sec. The clay-size fraction constituted 60.06% of the sediment. This was predominantly a floating-leaved community containing *Nelumbo pentapetala* (37.7%), *Nymphaea tuberosa* (23.9%), and associated submergent species. *Sagittaria rigida* (6.95%) and *Sagittaria latifolia* (6.2%) were found near the shoreline.

Area 9. This area was located 1.7 km downstream from the head of Running Slough (Fig. 4). The mean depth was 1.60 m. The current velocity averaged 0.020 m/sec and was a result of currents coming from Running Slough. Clay (74.16%) was the main constituent of the sediment. No quantitatively significant amount of vegetation was present due to the depth of the water.

Area 10. Located immediately downstream from study area 8 (Fig. 11), area 10 was not separated from area 8 by any obvious chemical or physical barriers. Area 10 had a mean depth of 0.96 m and a current velocity of 0.030 m/sec. The clay-size fraction constituted 55.60% of the sediment. The silt-size fraction constituted 40.22% of the sediment. This was predominantly a floating-leaved community containing *Nymphaea tuberosa* (5.9%) and *Nelumbo pentapetala* (4.1%). The perimeter of the area possessed emergent *Scirpus validus* (27.6%) and *Sagittaria latifolia* (21.5%).

Area 11. Located immediately off Running Slough at the downstream end of area 35 (Fig. 3), area 11 had a mean depth of 0.51 m and a mean current velocity of 0.034 m/sec. The sediment consisted of clay (69.32%) and silt (28.32%). *Potamogeton nodosus* (21.3%), *Ceratophyllum demersum* (13.8%), and Lemnaceae (10.3%) were predominant in the open water. Emergent macrophytes were *Sagittaria latifolia* (37.1%) and *Sagittaria rigida* (9.7%).

Area 12. This area is referred to as Ebner's Gravel Pit and is located east of area 11 (Fig. 3). The mean depth and current velocity values were 4.91 m and 0.039 m/sec, respectively. The silt-size fraction constituted 50.60% of the sediment; the clay-size fraction constituted 44.68%. Due to the depth, vegetation was restricted to the shallower circumference of the area and consisted predominantly of *Ceratophyllum demersum* (43.6%) and *Vallisneria* (43.4%).

Area 13. Area 13 opened at its lower end into area 11 (Fig. 3). The mean depth was 1.50 m. The mean current velocity was 0.042 m/sec. The sediment consisted of medium sand (30.91%). Area 13 was long and slender. It was too deep and turbid to support an appreciable amount of aquatic vegetation. Emergent vegetation was not present. Submergent *Ceratophyllum demersum* (64.35%) and *Potamogeton foliosus* (21.4%) were the predominant macrophyte species encountered.

Area 14. Situated in the upper end of the Stoddard stump field (Fig. 6), area 14 had a mean depth of 1.61 m with a mean current velocity of 0.078 m/sec. The water currents were best characterized as being slow sheeting movements that were uniform throughout the entire area. The sediments were composed of silt (11.23%), fine sand (13.96%), and clay (66.05%). Deep-water submergent communities typical of the southern portion of the pool were present. The primary macrophytes were *Vallisneria americana* (35.9%), *Ceratophyllum demersum* (22.9%), and *Elodea canadensis* (20.5%).

Area 15. Area 15 was contiguous with and located below area 14 (Fig. 6). The mean depth was 1.73 m. The current velocity averaged 0.102 m/sec. As in area 14, the water currents were categorized as uniform, slow sheeting movements. Silt (16.67%) and clay (41.88%) characterized the sediments. Typical of the southern portion of the pool, deep-water submergent communities were present. The primary macrophytes were *Vallisneria americana* (66.3%), *Ceratophyllum demersum* (16.8%), and *Potamogeton nodosus* (11.6%).

Area 16. Located below area 6 just east of Raft Channel (Fig. 12), area 16 had a mean depth of 1.22 m and a current velocity of 0.116 m/sec. The increased current velocity was the result of a chute off Raft Channel located near the downstream end of area 6. The clay-size fraction composed 46.44% of the sediment. The central portion of this area was deep and open. Floating-leaved and emergent vegetation was present along the periphery and consisted of *Sagittaria latifolia* (50.5%), *Sagittaria rigida* (27.7%), and *Nymphaea tuberosa* (14.2%).

Area 17. Located below area 16 (Fig. 12), this area had a mean depth of 1.35 m with a current velocity of 0.134 m/sec. As in area 16, this increased current velocity was due to the chute off Raft Channel. Clay and silt constituted 53.64% and 30.65%, respectively, of the sediment. The center of area 17 was open and deep. Floating-leaved and emergent vegetation was present along the edges. *Sagittaria latifolia* (56.7%), *Nymphaea tuberosa* (20.1%), and *Ceratophyllum* (12.5%) were present.

Area 18. Situated west of the main channel, downstream from the "S" curve below Brownsville, Minnesota (Fig. 12), area 18 had a mean depth of 0.95 m. The current velocity was 0.136 m/sec. An inflow of water from the main channel caused the currents in study area 18. The sediment was largely composed of clay (61.39%). A deep-water submergent community dominated by *Vallisneria americana* (90.9%) was found here.

Area 19. Area 19 was situated downstream from area 12 (Fig. 3). Both areas 12 and 19 contained deep, dredged portions. The mean depth was 6.10 m. The current velocity was 0.140 m/sec. Silt composed 57.10% of the sediment, while clay composed 27.39% of the sediment. The central portion of the area was too deep to support aquatic vegetation. The shallower peripheral areas supported *Ceratophyllum demersum* (67.6%), Lemnaceae (16.7%), and *Heteranthera dubia* (8.9%).

Area 20. This area was located in the upper Goose Island backwaters (Fig. 4). The area was characterized as being pond-like with a mean depth of 0.81 m and a current velocity of 0.159 m/sec. Small feeder channels connected to Running Slough supplied an inflow of water to the area. The sediments were primarily composed of fine sand (40.07%), clay (20.93%), and medium sand (20.26%). Emergent, floating-leaved, and shallow-water submergent communities typical of the midsection of Pool 8 were supported. *Sagittaria latifolia* (36.8%) and *Sagittaria rigida* (28.7%) were the major emergent macrophytes. The floating-leaved *Nelumbo pentapetala* (8.0%) and the submergent *Ceratophyllum demersum* (9.8%) were also present.

Area 21. Located at the lower end of the Stoddard stump field (Fig. 6), study area 21 had a mean depth of 2.64 m with a current velocity of 0.206 m/sec. The sediments were composed of fine sand (49.67%) and silt (51.19%). Area 21 was similar to areas 14 and 15; however, fewer landforms were present to protect it from the currents of the main channel. The dominant macrophytes in this deep-water submergent community were *Vallisneria americana* (63.8%), *Potamogeton nodosus* (20.1%), and *Ceratophyllum* (7.6%).

Area 22. Study area 22 was situated at the upper end of Crosby

Slough (Fig. 9). It had a mean depth of 2.26 m with a current velocity of 0.218 m/sec. Fine sand and medium sand constituted 58.15% and 34.73%, respectively, of the sediments. Macrophyte growth was not favored because of the depth, swift current, and sediments of the channel. The shallower, peripheral areas, however, could support plant communities in which the dominant species were *Sagittaria latifolia* (49.2%), *Ceratophyllum demersum* (16.2%), *Nelumbo* (15.4%), and *Sagittaria rigida* (6.5%).

Area 23. Situated immediately downstream from area 22 (Fig. 10), area 23 had a mean depth of 1.84 m. The current velocity of 0.235 m/sec was slightly higher than that of area 22 probably due to the shallower depth found in area 23. A high influx of sediments caused the downstream end to be fairly shallow. The sediment was mainly composed of clay (30.86%) and silt (28.84%). Area 23 supported a macrophyte population which was more dense than area 22. The major shoreline macrophytes were *Sagittaria latifolia* (54.3%), *Sagittaria rigida* (15.0%), and *Elodea canadensis* (10.1%).

Area 24. This area was located immediately above area 21 in the Stoddard stump field (Fig. 6). The mean depth was 1.71 m. A current velocity of 0.282 m/sec was present. The sediments were largely composed of fine sand (40.92%) and silt (46.77%). Areas 21 and 24 resembled one another in general ecological characteristics and vegetation. *Vallisneria americana* (66.9%), *Nymphaea tuberosa* (13.2%), and *Heteranthera dubia* (8.2%) were the dominant macrophytes.

Area 25. Study area 25 was located with its downstream end at the lower end of Running Slough (Fig. 5). Numerous small, meandering channels fed this large lake-type area. The mean depth was 0.61 m with a current velocity of 0.292 m/sec. The sediments were composed largely of silt (54.68%), fine sand (21.26%), and clay (14.79%). Although the area was shallow, the growth of most aquatic macrophytes could not be supported. A few patches of *Potamogeton nodosus* (6.5%) were present. *Sagittaria latifolia* (67.2%) and *Sagittaria rigida* (20.3%) dominated the stands of emergent species which bordered the area.

Area 26. This area was located immediately below area 18 (Fig. 13). Similar to area 25, area 26 was also a large lake-type area with a mean depth of 1.02 m and a current velocity of 0.301 m/sec. The relatively high current velocity can be attributed to the main channel bordering on the eastern boundary of area 26 and the numerous feeder channels off Raft Channel to the west. Fine sand (18.04%), silt (38.10%), and clay (23.02%) comprised most of the sediment. A deep-water submergent community dominated by *Vallisneria americana* (80.2%) and *Heteranthera dubia* (9.8%) was present.

Area 27. Located off Running Slough (Fig. 4), area 27 was a small side channel with a mean depth of 2.34 m and a current velocity of 0.305 m/sec. The sediments were mainly composed of fine sand (61.52%) and medium sand (26.22%). Vegetation was only present in the shallower, peripheral waters. *Sagittaria latifolia* (67.5%), *Sagittaria rigida* (15.7%), and *Nymphaea tuberosa* (6.6%) were predominant.

Area 28. Situated in the main channel with its upstream end bordering the mouth of Crosby Slough (Figs. 9 and 10), study area 28 had a mean depth of 4.73 m. The current velocity averaged 0.344 m/sec. Fine sand (67.47%) and medium sand (32.20%) predominated in the sediments. The area possessed vegetation mainly on the shallow borders, with *Vallisneria americana* (59.0%), *Potamogeton pectinatus* (26.0%), and *Potamogeton nodosus* (13.3%) being predominant.

Area 29. Study area 29 was located along the west side of the main channel at the lower end of the "S" curve (Fig. 12). The mean depth was 1.63 m with a current velocity of 0.352 m/sec. Fine sand (30.70%), silt (29.23%), and clay (27.71%) largely composed the sediments. Large stands of emergent *Sagittaria latifolia* bordered the area. The predominant macrophytes were *Vallisneria americana* (54.0%), *Nymphaea tuberosa* (31.6%), and *Potamogeton nodosus* (14.4%).

Area 30. This area was located a short distance downstream from the entrance to Raft Channel (Fig. 11). This area was relatively deep (mean depth, 1.57 m) and open with a gradual slope on the eastern shore. The mean current velocity was 0.385 m/sec. Silt comprised 59.31% of the sediments. The dominant macrophytes along the shoreline were *Sagittaria latifolia* (48.8%), *Sagittaria rigida* (18.8%), and *Nelumbo pentapetala* (7.2%). *Potamogeton nodosus* (14.1%) also occurred on a sandbar near the eastern shore of the area.

Area 31. Located at the downstream end of area 27 along with some flow from lower Running Slough (Fig. 4), study area 31 was a small channel system consisting of relatively deep (mean depth, 1.48 m), swift (mean current velocity, 0.393 m/sec), and open channels. The sediments were composed of fine sand (36.85%), medium sand (22.32%), and silt (16.02%). Stands of *Sagittaria latifolia* (74.1%), *Ceratophyllum demersum* (6.8%), *Sagittaria rigida* (5.0%), *Nymphaea tuberosa* (4.6%), and *Potamogeton nodosus* (3.4%) were found along the periphery of the area.

Area 32. Study area 32 bordered the downstream edge of area 30 and included the widest part of Raft Channel (Fig. 12). The mean depth was 2.01 m. The current velocity averaged 0.407 m/sec. Fine sand and medium sand comprised 62.17% and 27.95%, respectively, of the sediments. The relatively deep and open western portion of the area supported a small amount of *Vallisneria americana* (9.6%). The shallower eastern shore was dominated by *Sagittaria latifolia* (64.6%), *Ceratophyllum demersum* (12.5%), and *Nymphaea tuberosa* (3.3%).

Area 33. This area was located in the main channel at the downstream end of the "S" curve (Fig. 6). The mean depth was 6.71 m with a mean current velocity of 0.411 m/sec. Sediment-size fraction #4 (fine sand) composed 80.11% of the sediments. No aquatic macrophytes were present.

Area 34. Area 34, located in the middle reach of Running Slough (Figs. 3 and 4), had a mean depth of 2.41 m and a current velocity of 0.448 m/sec. Sediment-size fractions #3 (medium sand) and #4 (fine sand) composed 40.63% and 41.56%, respectively, of the sediments. The general ecological characteristics of this area and upper Running Slough (area 35) were very similar. Area 34 had a slightly slower current velocity, however, because of the side channels branching off at the downstream end of area 35. *Nymphaea tuberosa* (100%) was the only macrophyte sampled along the periphery.

<u>Area 35</u>. Located in the upper secion of Running Slough (Fig. 3), area 35 was relatively deep (mean depth, 2.91 m) and was quite channelled. The current velocity was 0.463 m/sec. Fine sand and medium sand made up 35.03% and 46.35%, respectively, of the sediment. The main channel provided the area with its water flow. Aquatic macrophytes could be supported only along the shallower shoreline areas. *Ceratophyllum demersum* (70.4%) was the dominant species.

<u>Area 36</u>. Located off the east side of the main channel and a short distance downstream from the entrance to Running Slough (Fig. 8), area 36 received its primary inflow of water from the main channel. It flowed back into the main channel approximately 350 meters downstream from its origin. The mean depth was 1.33 m. The current velocity averaged 0.470 m/sec. Sediment-size fractions #4 and #5 comprised 49.71% and 32.13%, respectively, of the sediments. Aquatic macrophytes could not be supported in the central portion of the area. Despite the relatively shallow water, the high current velocity and sand-like sediments were not conduscive to macrophyte growth. Along the shoreline, the dominant macrophytes were *Sagittaria latifolia* (44.7%), *Sagittaria rigida* (20.2%), *Potamogeton nodosus* (14.9%), and *Heteranthera dubia* (11.3%).

<u>Area 37</u>. This area, located downstream from the Stoddard stump field and bordered on its western side by the main channel (Fig. 7),

received heavy flow from the main channel. Area 37 had a mean depth of 1.33 m and a current velocity of 0.527 m/sec. The sediments were composed of fine sand (31.72%) and silt (52.60%). Large beds of submergent vegetation were supported. The dominant species were *Vallisneria americana* (64.4%), *Potamogeton nodosus* (16.7%), and Lemnaceae (12.0%).

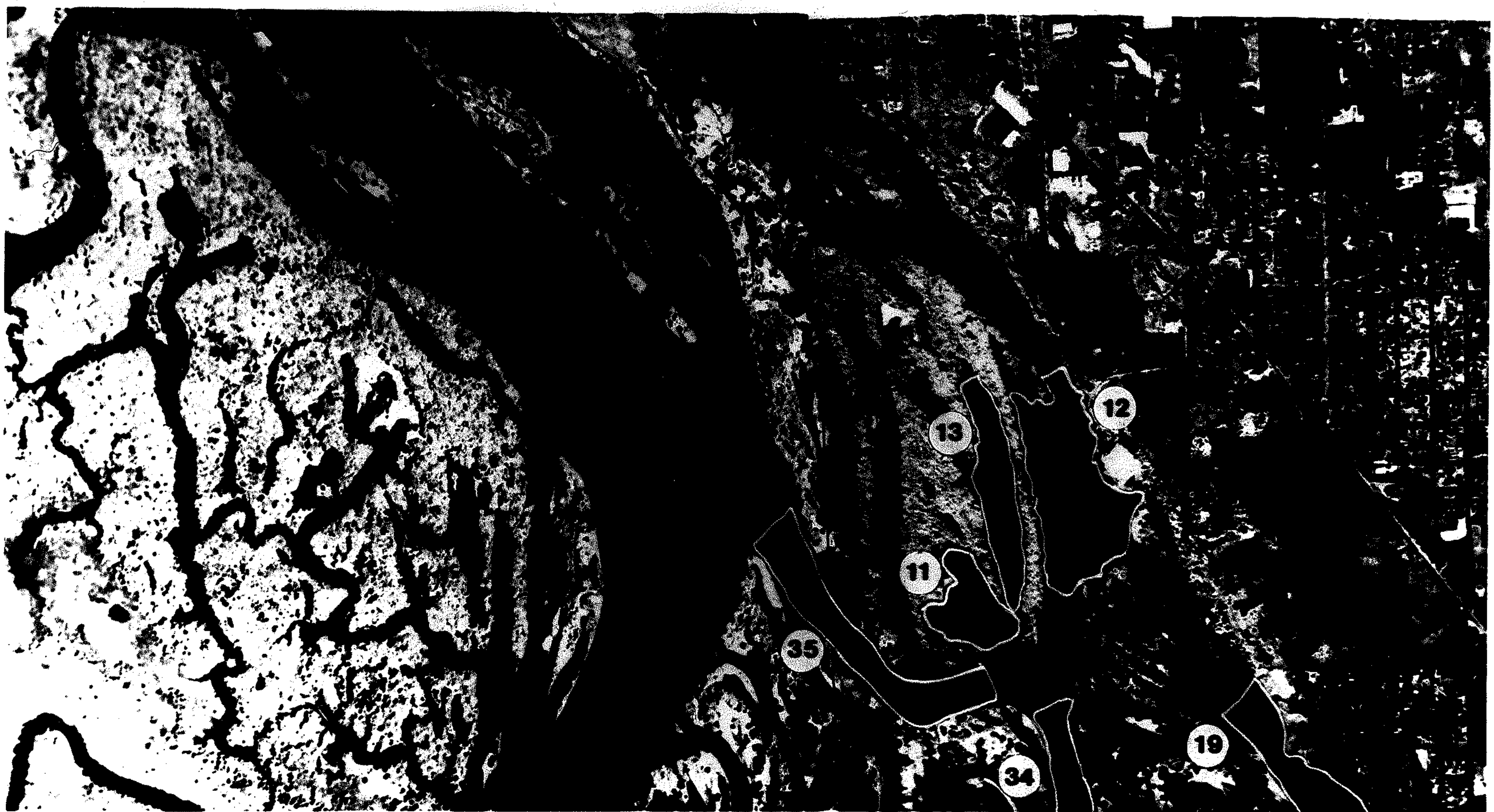
Area 38. Situated in the farthest downstream portion of Running Slough that was sampled (Fig. 4), study area 38 was a channelled area with a mean depth of 1.89 m and a current velocity of 0.534 m/sec. The sediments were composed of medium sand (36.22%) and fine sand (52.57%). Vegetation occurred mainly along the shoreline areas. The dominant shoreline species were *Potamogeton nodosus* (28.95%), *Sagittaria rigida* (18.8%), *Nymphaea tuberosa* (13.3%), and *Sagittaria latifolia* (12.1%).

Area 39. Area 39 was situated below area 32 (Fig. 12). This study area was the farthest downstream portion of Raft Channel that was sampled. The depth averaged 2.33 m with a mean current velocity of 0.578 m/sec. Sediment-size fraction #4 (fine sand) comprised 80.11% of the sediment. Due to the depth and current velocity, very little vegetation was present. *Sagittaria latifolia* (54.1%) and *Potamogeton nodosus* (13.0%) were the predominant species along the shallow eastern boundary and along the centrally located island.

Area 40. Located in the uppermost portion of Raft Channel (Fig. 11), area 40 had a mean depth of 1.90 m and a current velocity of 0.587 m/sec. The high current velocity was caused by the direct flow from the main channel. The sediments were largely composed of sediment-size fraction #4 (82.07%). Most of area 40 was open with the majority of macrophytes restricted to the peripheral areas. *Sagittaria latifolia* (84.0%), *Potamogeton pectinatus* (10.9%), and *Ceratophyllum demersum* (3.1%) predominated.

Area 41. Study area 41 was a narrow chute located along an outside curve of the main channel (Fig. 6). The area was relatively deep (mean depth, 3.70 m). The current velocity averaged 0.720 m/sec. Area 41 had the highest current velocity of all areas. Fine sand (51.64%) and medium sand (44.00%) were the main constituents of the sediments. Aquatic vegetation was absent in the open areas of the chute. The major species bordering the area were *Vallisneria americana* (56.6%), *Nymphaea tuberosa* (11.5%), and *Potamogeton richardsonii* (8.4%).

Fig. 3. Aerial photograph, 1974, of upper Running Slough and adjoining backwater areas in Navigation Pool No. 8 of the Upper Mississippi River.



A

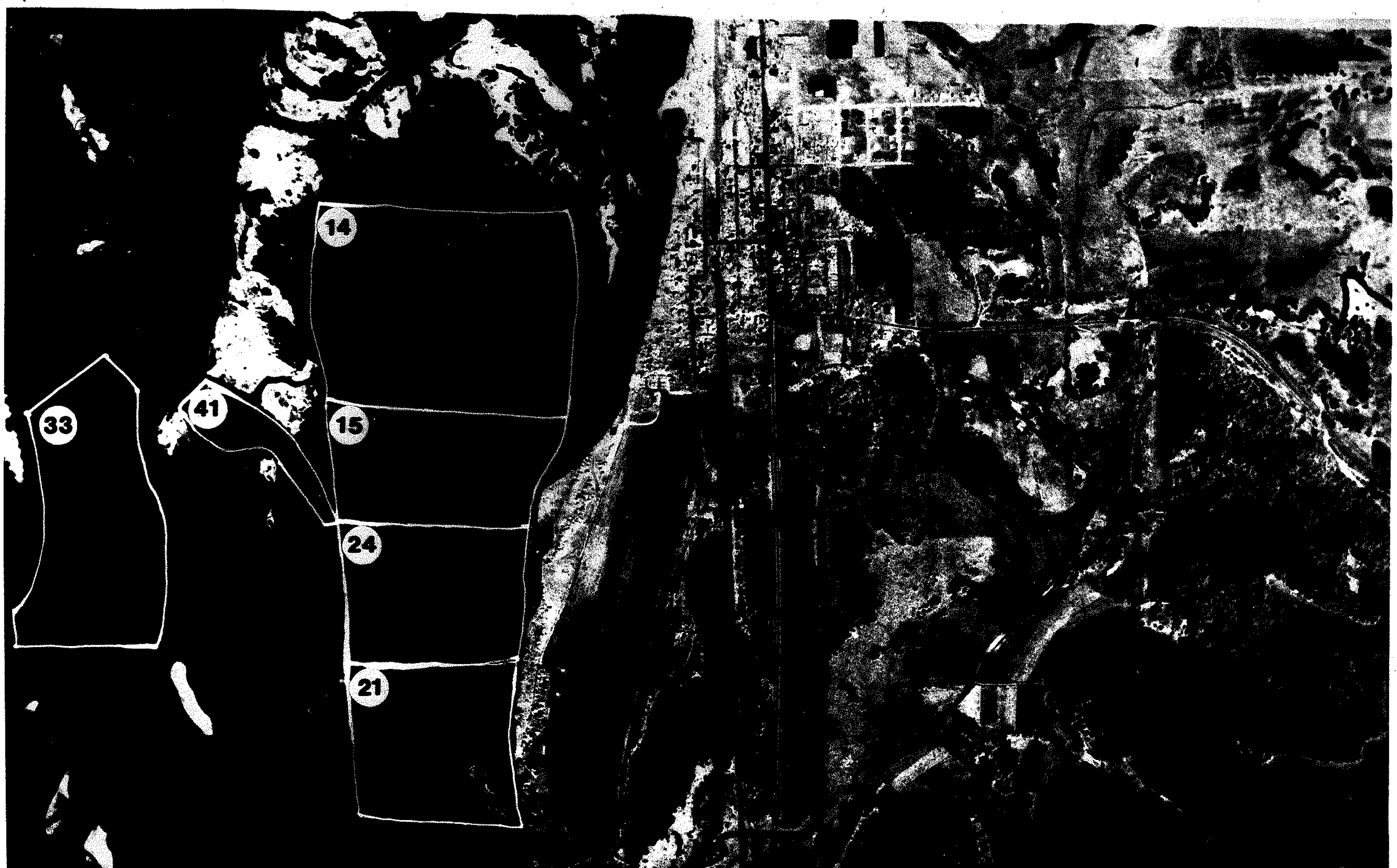
Fig. 4. Aerial photograph, 1974, of middle Running Slough and adjoining backwaters of the upper Goose Island area in Navigation Pool No. 8 of the Upper Mississippi River.

B

Fig. 5. Aerial photograph, 1974, of lower Running Slough and adjoining backwaters of the Goose Island area in Navigation Pool No. 8 of the Upper Mississippi River.

C

Fig. 6. Aerial photograph, 1974, of the Stoddard stump fields east of the main channel, adjacent to Stoddard, Wisconsin, in Navigation Pool No. 8 of the Upper Mississippi River.

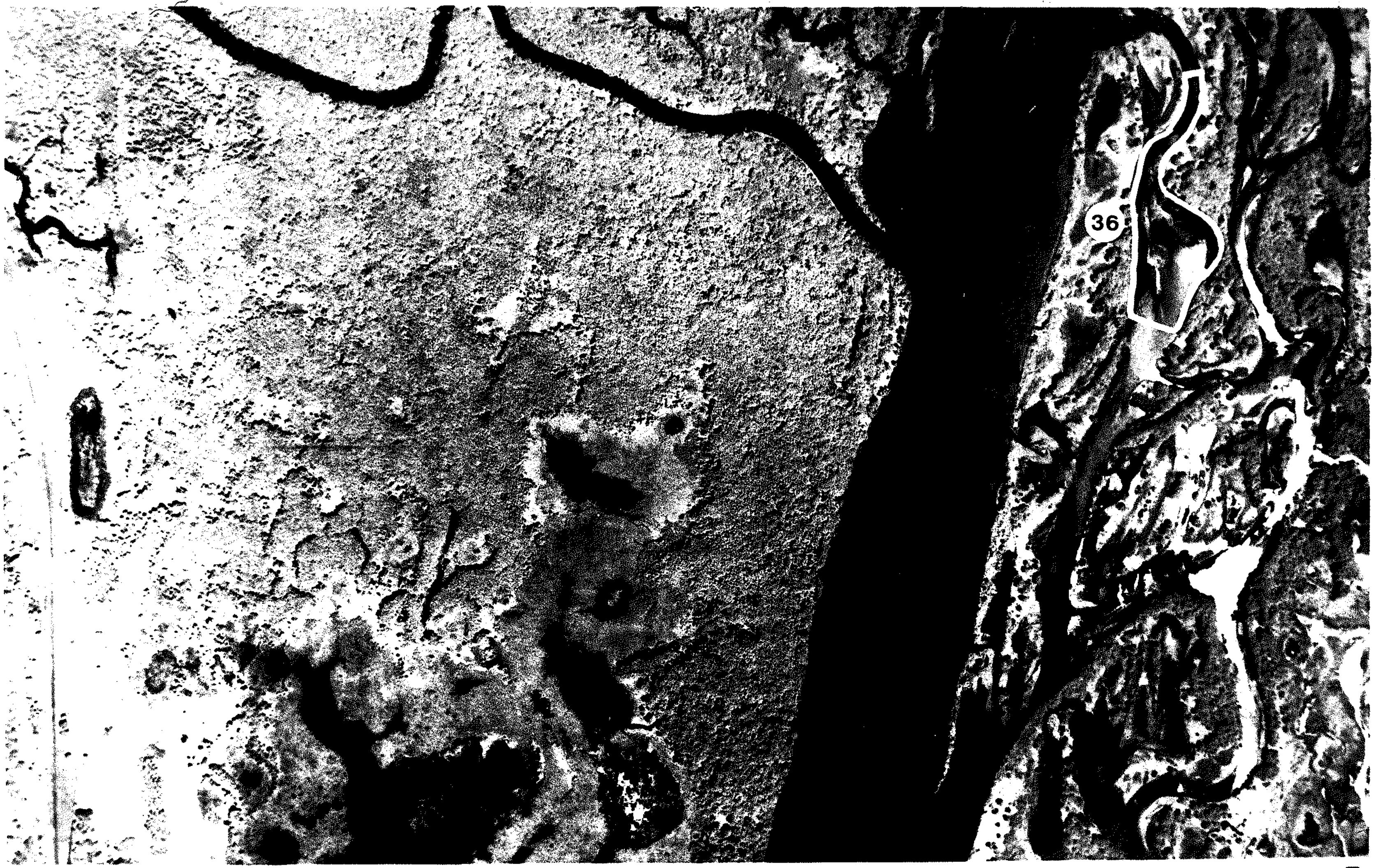


D

Fig. 7. Aerial photograph, 1974, east of the main channel in Navigation Pool No. 8 of the Upper Mississippi River immediately downstream from Stoddard, Wisconsin.

E

Fig. 8. Aerial photograph, 1974, of the main channel and backwaters immediately downstream from the mouth of Running Slough with the mouth of the Root River on the west side of the main channel in Navigation Pool No. 8 of the Upper Mississippi River.



F

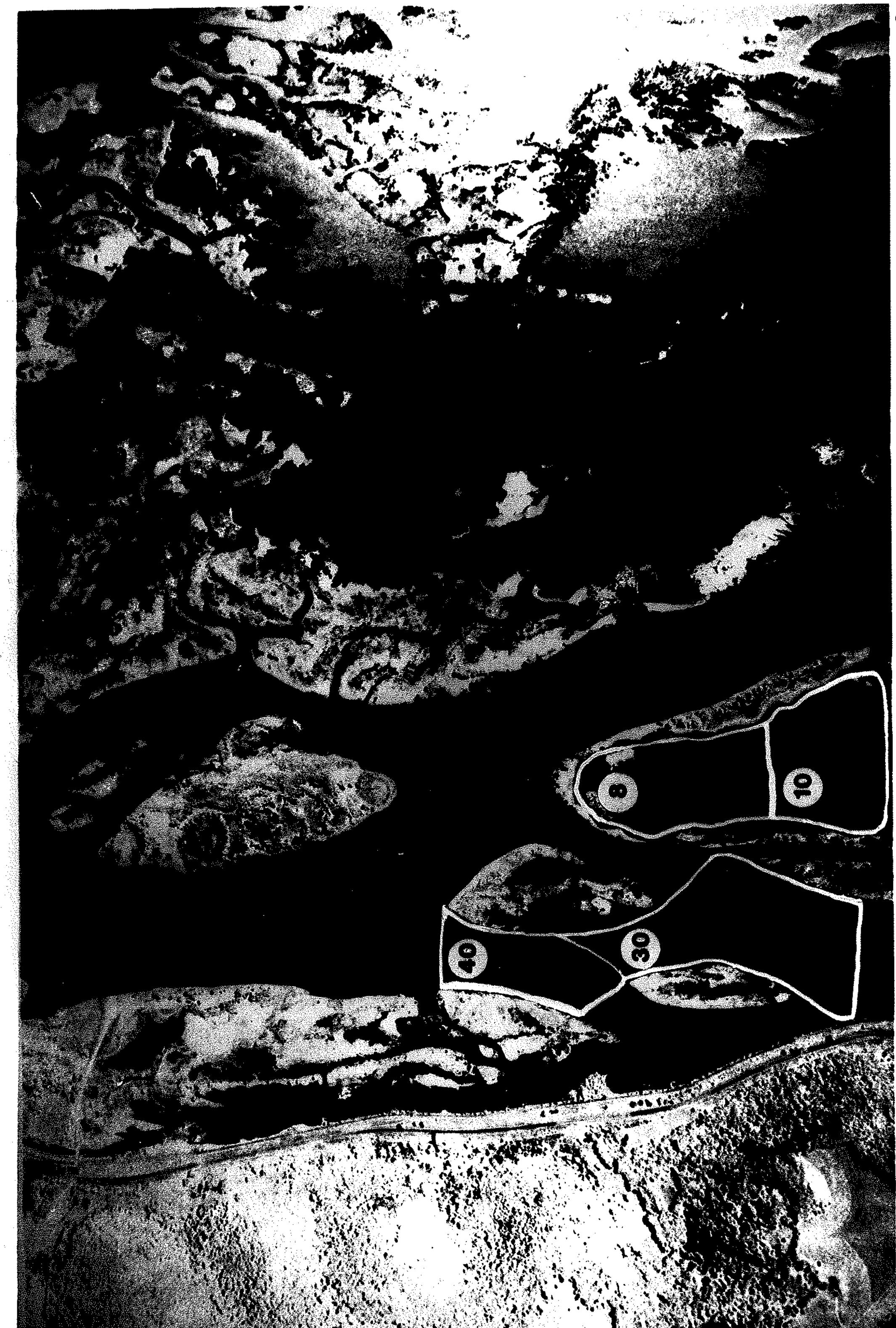
Fig. 9. Aerial photograph, 1974, of the main channel and upper Crosby Slough in Navigation Pool No. 8 of the Upper Mississippi River.

G

Fig. 10. Aerial photograph, 1974, of the main channel and lower Crosby Slough in Navigation Pool No. 8 of the Upper Mississippi River.

H

Fig. 11. Aerial photograph, 1974, of the confluence of Raft Channel and the main channel, immediately below Brownsville, Minnesota, in Navigation Pool No. 8 of the Upper Mississippi River.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10
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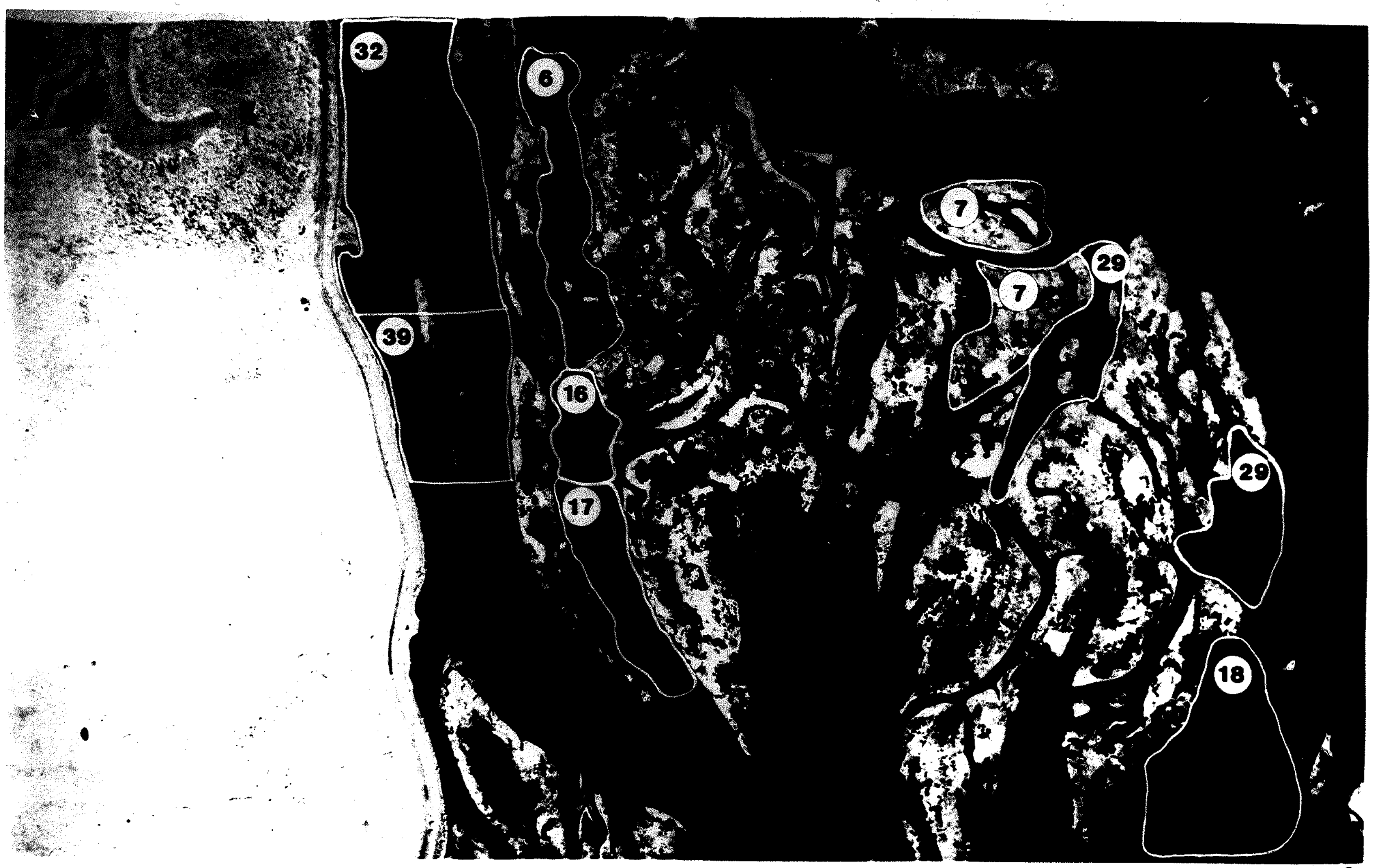
40

Fig. 12. Aerial photograph, 1974, of middle Raft Channel and associated backwater areas below Brownsville, Minnesota, in Navigation Pool No. 8 of the Upper Mississippi River.



32
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Fig. 13. Aerial photograph, 1974, of the lower reaches of Raft Channel and associated backwater areas, downstream from Brownsville, Minnesota, in Navigation Pool No. 8 of the Upper Mississippi River.

K

RESULTS

An inventory of the benthic fauna of Navigation Pool No. 8 of the Upper Mississippi River was prepared by sampling the 41 study areas twice during the summer of 1975 (Table 1). Copies of the original data are on file at the University of Wisconsin-La Crosse River Studies Center. The taxa collected per sample, the number of individuals per taxon, the total number of collected organisms per sample, and the total wet weights for each sample are included.

One hundred forty-four taxonomic categories were found in the 616 bottom collections. A total of 90,693 representatives of the Phyla Platyhelminthes, Nematoda, Annelida, Arthropoda, and Mollusca were counted, weighed, and identified.

The qualitative and quantitative compositions of the benthic communities varied among the 41 study areas. Habitat preferences of particular benthic forms were reflected in the distributional relationships between the benthic macroinvertebrates and the chemical, physical, and biological conditions. Members of the Class Oligochaeta were ubiquitous while the spatial and temporal distributions of many other benthic forms were sporadic.

Chemical-Physical Water Quality

Chemical-physical water quality data for the 41 study areas are summarized in Table 2. A trend toward decreasing eutrophy occurred from area 1 to area 41. The trophic status of each area was primarily based on current velocity, turbidity, dissolved oxygen levels, sediment

Table 1. Benthic macroinvertebrates collected from all study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

PLATYHELMINTHES

Turbellaria

NEMATODA

ANNELIDA

Oligochaeta
Hirudinea

ARTHROPODA

Crustacea

Malacostraca

ISOPODA

Asellus militaris Hay

AMPHIPODA

Gammarus fasciatus Say
Hyalella azteca (Saussure)

DECAPODA

Arachnoidea

HYDRACARINA

Unidentified Hydracarina
Arrenurus
Hydrachna

Insecta

PLECOPTERA

Perlidae

Perlesta placida (Hagen)

EPHEMEROPTERA

Unidentified Ephemeroptera

Table 1. (cont'd)

Siphlonuridae

Unidentified Siphlonuridae
Isonychia Eaton
Siphlonurus Eaton

Heptageniidae

Unidentified Heptageniidae
Stenonema Traver

Tricorythidae

Tricorythodes Ulmer

Caenidae

Unidentified Caenidae
Brachycercus Curtis
Caenis Stephens

Ephemeridae

Unidentified Ephemeridae
Hexagenia Walsh
Hexagenia bilineata (Say)
Hexagenia limbata (Serville)
Pentagenia Walsh

Polymitarcidae

Ephoron Williamson

ODONATA

Lestidae

Lestes Leach

Coenagrionidae

Unidentified Coenagrionidae
Enallagma Charpentier

Gomphidae

Dromogomphus Selys
Gomphus Leach
Ophiogomphus Selys

Table 1. (cont'd)

Aeshnidae

Anax Leach

HEMIPTERA

Notonectidae

Buenoa Kirkaldy
Notonecta Linnaeus

Corixidae

Unidentified Corixidae
Unidentified Corixidae female
Trichocorixa Kirkaldy

MEGALOPTERA

Unidentified Megaloptera

Corydalidae

Chauliodes Latreille

Sialidae

Sialis Latreille

TRICHOPTERA

Unidentified Trichoptera larva
Unidentified Trichoptera pupa

Polycentropodidae

Cyrnellus Banks
Neureclipsis McLachlan
Phylocentropus Banks
Polycentropus Curtis

Hydropsychidae

Unidentified Hydropsychidae larva
Unidentified Hydropsychidae pupa
Cheumatopsyche Wallengren
Hydropsyche Pictet

Table 1. (cont'd)

Hydroptilidae

Unidentified Hydroptilidae pupa
Hydroptila Dalman
Stactobiella Martynov

Leptoceridae

Unidentified Leptoceridae larva
Unidentified Leptoceridae pupa
Leptocerus Leach
Nectopsyche Müller
Oecetis McLachlan
Trianenodes McLachlan

LEPIDOPTERA

Pyralidae

Nymphula Schrank
Paraponyx Hubner

COLEOPTERA

Gyrinidae

Dineutus MacLeay
Gyrinus (Geoffroy in) Müller

Hydrophilidae

Helophorus Fabricius

Elmidae

Dubiraphia Sanderson
Stenelmis Dufour

Chrysomelidae

Donacia Fabricius

DIPTERA

Nematocera

Unidentified Nematocera larva

Table 1. (cont'd)

Psychodidae

Psychoda Latreille

Chaoboridae

Chaoborus Lichtenstein

Simuliidae

Unidentified Simuliidae pupa
Eusimulium Roubaud
Simulium Latreille

Chironomidae

Unidentified Chironomidae larva
Unidentified Chironomidae pupa
Unidentified Tanypodinae larva
Chironomus Meigen
Cryptochironomus Kieffer
Cryptocladopelma
Demicryptochironomus
Dicrotendipes Kieffer
Einfeldia Thienemann
Endochironomus Kieffer
Glyptotendipes Kieffer
Harnischia Goetghebuer
Microtendipes Kieffer
Parachironomus Lenz
Paracladopelma
Paralauterborniella Lenz
Paratendipes Kieffer
Polypedilum Kieffer
Pseudochironomus Malloch
Stenochironomus Kieffer
Stictochironomus Kieffer
Xenochironomus Kieffer
Paratanytarsus Bause
Rheotanytarsus Bause
Stempellina Bause
Tanytarsus Van der Wulp
Sympotthastia
Cardiocladius Kieffer
Cricotopus Van der Wulp
Epoicocladius Zavrel
Eukiefferiella Zavrel
Psectrocladius Kieffer
Smittia Holmgren
Clinotanypus Kieffer

Table 1. (cont'd)

Coelotanypus Kieffer
Pentaneura Philippi
Procladius (Skuse) Edwards
Psectrotanypus Kieffer
Tanypus Meigen

Ceratopogonidae

Unidentified Ceratopogonidae larva
Unidentified Ceratopogonidae pupa
Atrichopogon Kieffer
Bezzia Kieffer
Dasyhelea Kieffer
Palpomyia Meigen

Brachycera

Stratiomyiidae

Euparyphus Gerstaecker

Tabanidae

Chrysops Meigen

MOLLUSCA

Gastropoda

Unidentified Gastropoda

CTENOBRANCHIATA

Amnicolidae

Amnicola Gould and Haldeman

Pleuroceridae

Pleurocera Rafinesque

Valvatidae

Valvata Müller
Valvata sincera Say
Valvata tricarinata (Say)

Table 1. (cont'd)

Viviparidae

Campeloma Rafinesque
Lioplax Troschel
Viviparus Montfort

PULMONATA

Lymnaeidae

Stagnicola emarginata (Say)

Physidae

Aplexa Fleming
Physa Draparnaud

Planorbidae

Gyraulus Charpentier
Helisoma Swainson

Pelecypoda

Unionidae

Amblema rariplicata Rafinesque
Anodonta Lamarck
Anodontoides Simpson
Carunculina parva (Barnes)
Fusconaia undata Ortmann
Lampsilis Rafinesque
Lasmigona Lea
Ligumia Swainson
Obliquaria reflexa (Rafinesque)
Quadrula metanevra (Rafinesque)
Quadrula pustulosa (Lea)
Quadrula quadrula (Rafinesque)
Truncilla truncata (Rafinesque)

Sphaeriidae

Unidentified Sphaeriidae
Musculium Link
Pisidium Pfeiffer
Sphaerium Scopoli

Table 2. Mean values for all physical-chemical parameters for all study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

Study Area	Physical-Chemical Parameter									Sediment Particle Size Fraction (%)					
	Depth (m)	Current Velocity (m/sec)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Temperature (°C)	Organic Nitrogen (μg/g)	NO_3^- (μg/g)	NO_2^- (μg/g)	PO_4^{3-} (μg/g)	1	2	3	4	5	6
1	1.70	0.000	8	0.40	22.0	734.0	25.30	0.06	0.73	1.31	10.26	21.12	13.25	10.74	43.32
2	1.20	0.000	9	1.00	25.0	753.0	16.84	0.09	0.15	1.02	1.93	6.33	18.72	17.60	54.40
3	1.10	0.000	8	1.30	26.0	267.3	21.27	0.30	0.35	2.06	4.07	1.34	1.18	18.31	73.04
4	1.00	0.000	8	1.80	25.0	734.0	27.90	0.25	0.21	1.20	8.40	12.18	10.26	14.46	53.51
5	0.90	0.000	9	2.60	25.5	387.3	15.15	0.16	0.27	3.07	8.30	14.90	15.13	12.63	45.96
6	1.08	0.015	11	3.05	21.5	452.1	17.42	0.17	0.32	0.40	0.48	2.54	5.85	21.32	69.40
7	0.61	0.016	11	3.20	25.8	429.4	23.58	0.53	0.49	0.60	0.52	0.56	1.60	35.43	61.28
8	0.98	0.019	12	4.05	21.5	688.6	21.15	0.20	0.35	0.28	1.07	4.16	19.94	14.49	60.06
9	1.60	0.020	14	2.35	25.8	753.0	16.50	0.33	0.20	2.21	7.10	9.43	8.14	9.23	74.16
10	0.96	0.030	12	2.55	21.5	762.7	26.34	0.19	0.38	0.48	0.56	0.96	2.19	40.22	55.60
11	0.51	0.034	12	2.80	24.0	156.8	13.53	0.16	0.14	0.28	0.69	0.40	0.69	28.32	69.32
12	4.91	0.039	18	5.30	25.0	118.0	8.20	0.29	0.17	0.06	0.44	0.95	3.09	50.60	44.68
13	1.50	0.042	14	4.70	24.5	102.8	9.31	0.20	0.19	3.05	11.02	30.91	23.62	15.94	15.45
14	1.61	0.078	15	3.90	24.0	659.9	34.68	0.14	0.38	0.42	4.51	3.83	13.96	11.23	66.05
15	1.73	0.102	17	4.10	25.0	621.3	26.69	0.34	0.42	12.61	5.09	11.76	12.00	16.67	41.88
16	1.22	0.116	17	3.70	22.0	571.8	20.40	0.23	0.41	7.86	8.23	11.08	18.84	7.53	46.44
17	1.35	0.134	17	4.10	22.0	259.8	19.99	0.37	0.48	1.21	4.86	5.38	4.26	30.65	53.64
18	0.95	0.136	19	4.30	22.0	426.1	28.56	0.40	0.33	1.53	5.75	7.49	7.71	16.31	61.39
19	6.10	0.140	20	3.30	24.0	105.6	10.97	0.15	0.29	2.25	3.78	4.34	5.15	57.10	27.38
20	0.81	0.159	14	3.80	24.5	254.2	10.68	1.88	0.35	0.29	8.40	20.26	40.07	10.05	20.93
21	2.64	0.206	26	2.75	21.7	166.1	18.35	0.35	0.36	4.48	3.69	12.93	49.67	51.19	18.04
22	2.26	0.218	25	6.55	24.0	18.8	2.17	0.11	0.10	0.20	2.66	34.73	58.15	4.15	0.08
23	1.84	0.235	25	5.75	25.0	28.4	4.86	0.16	0.12	2.79	6.83	11.59	19.09	28.84	30.86
24	1.71	0.282	31	3.95	23.2	370.0	24.67	0.31	0.62	0.12	2.79	7.07	40.92	46.77	4.93
25	0.61	0.292	26	4.60	24.0	167.1	14.14	0.23	0.45	1.94	1.82	5.51	21.26	54.68	14.79
26	1.02	0.301	27	2.30	23.0	439.6	33.67	0.42	0.83	0.40	5.44	14.10	18.04	38.10	23.02
27	2.34	0.305	29	5.90	25.0	149.0	9.08	0.30	0.37	0.00	0.36	26.22	61.52	11.66	0.21
28	4.73	0.344	33	7.30	23.5	2.2	0.73	0.06	0.00	1.20	1.81	32.20	67.47	7.07	0.24
29	1.63	0.352	37	5.10	24.0	399.2	18.02	0.19	0.35	0.64	2.95	8.77	30.70	29.23	27.71
30	1.57	0.385	36	5.30	24.0	126.4	1.77	0.08	0.25	0.57	2.20	2.82	16.86	59.31	18.25
31	1.48	0.393	31	6.30	25.0	9.4	8.14	0.12	0.13	8.91	10.52	22.32	36.85	16.02	5.38
32	2.01	0.407	30	6.10	24.0	304.8	6.13	0.23	0.20	0.32	0.64	27.95	62.17	8.54	0.40
33	6.71	0.411	30	6.95	23.0	44.2	2.62	0.40	0.61	0.12	0.36	7.20	80.11	11.32	0.83
34	2.41	0.448	19	6.25	25.0	33.2	7.21	0.25	0.45	4.51	11.54	40.63	41.56	1.74	0.08
35	2.91	0.463	27	5.40	25.0	18.2	4.13	0.16	0.20	1.49	14.51	46.35	35.03	1.85	0.71
36	1.33	0.470	28	4.20	25.0	66.5	4.56	0.16	0.42	0.12	1.92	5.60	49.71	32.13	10.53
37	1.35	0.527	27	3.50	19.9	346.7	22.68	0.36	0.46	1.28	1.98	4.35	31.72	52.60	8.47
38	1.89	0.534	27	6.45	20.0	200.0	8.38	0.19	0.37	1.04	1.97	36.22	52.57	6.99	1.20
39	2.33	0.578	27	6.50	24.0	357.6	13.50	0.15	0.53	0.12	0.36	7.20	80.11	11.32	0.38
40	1.90	0.587	28	7.00	24.0	96.6	3.76	0.13	0.33	0.04	0.12	10.00	82.07	7.02	0.76
41	3.70	0.720	25	5.30	25.0	102.8	17.37	0.19	0.42	0.48	0.64	44.00	51.64	3.00	0.24

organic nitrogen and nitrate, sediment particle size, and macrophyte biomass. The more eutrophic areas (areas 1-18) were characterized by undetectable or low current velocities, low turbidities, low dissolved oxygen levels, high sediment organic nitrogen and nitrate concentrations, and fine sediments. These more eutrophic areas also supported larger amounts of macrophyte biomass than did the less eutrophic areas (Sefton 1976). Sefton reported that areas 9, 12, 19, 22-36, and 38-41 did not support any significant macrophyte biomass.

Depth ranged from 0.51 m (area 11) to 6.71 m (area 33). Current velocities increased from undetectable (areas 1-5) to 0.720 m/sec (area 41). Turbidity was lowest in the most eutrophic areas (areas 1-5) and ranged from values of 11 NTU and 12 NTU to 37 NTU in the less eutrophic areas. Dissolved oxygen measurements ranged from 0.40 mg/l (area 1) to 7.30 mg/l (area 28). Water temperatures were relatively constant within a range of 19.9 C (area 37) to 26.0 C (area 3). Sediment organic nitrogen and nitrate levels were generally higher in the more eutrophic areas. Nitrite measurements ranged from 0.06 μg/g (areas 1 and 28) to 1.88 μg/g (area 20). Sediment phosphorus levels ranged from 0 μg/g (area 28) to 0.83 μg/g (area 26). A trend toward decreasing sediment particle size was observed from the less eutrophic areas to the more eutrophic areas. The bulk of the sediments in the more eutrophic areas was composed of sediment particle size fraction #6 (clay). Simple linear correlations (r) relating these mean physical-chemical parameters are given in Table 3.

According to Claflin (1973), total hardness levels in Navigation Pool No. 8 rarely exceeded 175 mg/l $CaCO_3$ except in areas of emergent

Table 3. Simple linear correlations (r)* relating mean physical-chemical parameters in all study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

										Sediment Particle Size Fraction					
	Depth	Current Velocity	Turbidity	Dissolved Oxygen	Temperature	Organic Nitrogen	NO_3^-	NO_2^-	PO_4^{3-}	1	2	3	4	5	6
Depth	1•	.302	.356••	.439•	.054	-.455•	-.447•	-.140	-.090	-.076	-.157	.218	.393••	.005	-.413•
Current Velocity	.302	1•	.798•	.693•	-.088	-.566•	-.449•	-.099	.153	-.116	-.167	.456•	.761•	-.112	-.835•
Turbidity	.356••	.798•	1•	.719•	-.094	-.587•	-.479•	-.150	.021	-.075	-.224	.266	.656•	.167	-.782•
Dissolved Oxygen	.439•	.693•	.719•	1•	.033	-.684•	-.683•	-.101	-.233	-.023	-.170	.443•	.711•	-.253	-.718•
Temperature	.054	-.088	-.094	.033	1•	-.190	-.245	.045	-.326••	.116	.216	.116	-.043	-.188	.021
Organic Nitrogen	-.455•	-.566•	-.537•	-.684•	-.190	1•	.769•	.015	.261	.058	.013	-.406•	-.482•	-.059	.667•
NO_3^-	-.447•	-.449•	-.479•	-.683•	-.245	.769•	1•	.090	.503•	.106	.048	-.401•	-.554•	.153	.600•
NO_2^-	-.140	-.099	-.150	-.101	.045	.015	.090	1•	.181	-.057	.128	-.028	-.004	-.017	.023
PO_4^{3-}	-.090	.153	.021	-.233	-.326••	.261	.503•	.181	1•	-.084	-.063	-.173	.046	.153	-.059
Sediment Particle Size Fraction															
1	-.076	-.116	-.075	-.023	.116	.058	.106	-.057	-.084	1•	.462•	.107	-.170	-.099	.039
2	-.157	-.167	-.224	-.170	.216	.013	.048	.128	-.063	.462•	1•	.426•	-.229	-.315••	.012
3	.218	.456•	.266	.443•	.116	-.406•	-.401•	-.028	-.173	.107	.426•	1•	.476•	-.599•	-.615•
4	.393••	.761•	.656•	.711•	-.043	-.482•	-.554•	-.004	.046	-.170	-.229	.476•	1•	-.373••	-.831•
5	.005	-.112	.167	-.253	-.188	-.059	.153	-.017	.153	-.099	-.315••	-.599•	-.373••	1•	.093
6	-.413•	-.835•	-.782•	-.718•	.021	.667•	.600•	.023	-.059	.039	.012	-.615•	-.831•	.093	1•

•--Significant at the 0.01 level
••--Significant at the 0.05 level
*--39 degrees of freedom

ground water. Alkalinity levels were relatively constant and deviated slightly from 175 mg/l (Claflin 1973). Alkaline pH values were obtained during most of the year (Claflin 1973). Dissolved organic substances leached from the forest floor of the watershed imparted a brown color to the water.

Biological Water Quality

Area 1

Sampling Period I. Two bottom samples composed of single dredge hauls were randomly collected. Only two taxonomic categories were found and examined. The dominant macroinvertebrates belonged to the Class Oligochaeta which averaged 75.5 individuals per sample and composed 99.34% of the benthic fauna. The other taxon was poorly represented by the dipteran *Tanypus* which accounted for 0.66% of the benthic community. An average of 76 individuals per bottom collection was calculated. The average wet weight per sample was 0.23222 g.

Sampling Period II. Two bottom samples composed of double dredge hauls were randomly collected. The benthic fauna was represented by 24 taxa and consisted of mostly pollution-tolerant and pollution-facultative macroinvertebrates. The dominant oligochaetes constituted 73.90% of the organisms collected in this area. The amphipod *Hyalella azteca* composed 14.29% of the benthic community. Twelve dipteran genera were present. The major dipteran representatives included *Polypedilum* (3.17%), *Pentaneura* (2.39%), *Cryptocladopelma* (1.16%), *Cryptochironomus* (1.00%), and *Endochironomus* (1.00%). The remaining 17 taxa constituted 3.09% of the organisms collected. Five mayfly taxa were present with *Hexagenia limbata* predominating. The average number of individuals per sample and the average wet weight per sample were 647.5 and 0.77285 g, respectively.

Area 2

Sampling Period I. Three taxa, representing 49 macroinvertebrates and having a total wet weight of 0.11303 g, were present. The oligochaetes (71.43%) and the dipteran *Chironomus* (26.53%) accounted for over 98% of the macroinvertebrates collected. The third taxon was represented by one individual of the dipteran genus *Endochironomus* (2.04%).

Sampling Period II. Ten taxa were found in two random bottom collections. The oligochaetes and the amphipod *Hyalella azteca* were the major benthic macroinvertebrates comprising 64.39% and 28.41%, respectively, of the collected benthic community. Leeches (3.03%), nematodes (1.14%), and the dipteran *Endochironomus* (1.14%) accounted for less than 6% of the benthic fauna. The remaining five taxa constituted 1.89% of the collected organisms. The total number of organisms per sample averaged 132 individuals. The average wet weight per sample was 0.1626 g.

Area 3

Sampling Period I. Sixteen taxa were collected in three random bottom samples. An average of 435.3 organisms were collected per sample. Each benthic collection had an average wet weight of 0.16334 g. The benthic fauna was dominated by the oligochaetes (92.34%). *Hyalella azteca*, members of the Class Hirudinea and Phylum Nematoda accounted for 2.60%, 1.15%, and 1.00%, respectively, of the collected benthic fauna. Eight dipteran genera were present. The major dipteran was *Endochironomus* which comprised 1.15% of the bottom community. The remaining eleven taxa (1.76%) included seven dipterans, *Asellus militaris*, *Gyrinus*, *Stactobiella*, and *Hexagenia limbata*.

Sampling Period II. Four random benthic collections were taken. The benthic fauna was composed of 26 taxa which were dominated by *Hyalella azteca* (46.36%) and members of the Class Oligochaeta (37.82%). Of the nine dipteran genera present, *Polypedilum* predominated and accounted for 1.88% of the organisms collected. Members of the Class Hirudinea and Phylum Nematoda constituted 8.73% and 1.33%, respectively, of the benthic fauna. The remainder of the bottom community was comprised of 21 taxa (3.88%). Three mayfly genera were present with *Hexagenia limbata* being dominant. The average number of individuals per sample and the average wet weight per sample were 412.5 and 0.86745 g, respectively.

Area 4

Sampling Period I. Oligochaetes (88.99%) and leeches (6.88%) dominated the benthic fauna. The remaining six taxa included *Chironomus* (1.15%), *Endochironomus* (0.92%), *Procladius* (0.92%), *Hyalella azteca* (0.69%), *Chrysops* (0.23%), and *Cryptochironomus* (0.23%). A total of 8 taxa were collected in the two random samples. Each bottom collection had an average of 218 macroinvertebrates and an average total wet weight of 0.21054 g.

Sampling Period II. Fourteen taxa were found in two randomly collected benthic samples. Four taxa occurred more frequently in the benthic community and accounted for over 98% of the organisms collected. These organisms included members of the Classes Oligochaeta (75.93%) and Hirudinea (1.11%), the amphipod *Hyalella azteca* (20.19%), and the dipteran *Pentaneura* (0.83%). The remaining ten taxa, including four dipteran genera, composed 1.94% of the benthic fauna. The average total number of organisms per sample was 361.5. The average wet weight per sample was 0.40825 g.

Area 5

Sampling Period I. Two bottom samples composed of single dredge hauls were randomly collected. The benthic fauna was represented by eight taxa. The average number of individuals and wet weight per sample were 81.5 and 0.02246 g, respectively. Members of the Classes Oligochaeta (95.09%) and Hirudinea (1.23%) accounted for over 96% of the benthic fauna. The remaining six taxa included the amphipods *Gammarus fasciatus* (0.61%) and *Hyalella azteca* (0.61%), the dipterans *Cryptocladopelma* (0.61%), *Endochironomus* (0.61%) and *Polypedilum* (0.61%), and a member of the Phylum Nematoda (0.61%). This is one of the few occasions that the scud *Gammarus fasciatus* appeared.

Sampling Period II. The benthic fauna was randomly collected and consisted of 19 taxa. The average number of organisms per sample was 223. The wet weight per sample averaged 0.3494 g. The oligochaetes, *Hyalella azteca*, *Endochironomus*, leeches, and *Polypedilum* constituted 70.18%, 13.23%, 8.74%, 2.02%, and 1.57%, respectively, of the macroinvertebrate community. The remaining 14 taxa (4.26%) were dominated by six dipteran genera.

Area 6

Sampling Period I. The 24 benthic taxa were dominated by pollution-tolerant and facultative forms. Pollution-tolerant forms accounted for over 82% of the benthic fauna and included oligochaetes (68.42%), *Chironomus* (8.12%), *Musculium* (3.74%), and leeches (2.24%). The crustaceans *Hyalella azteca* (3.77%) and *Asellus militaris* (1.39%) were the dominant facultative forms. The major pollution-sensitive macroinvertebrate was *Hexagenia limbata* (7.69%). Seventeen taxa accounted for the remaining collected organisms (4.63%). Representatives of these remaining 17 taxa were dominated by six dipteran genera. The average number of invertebrates and wet weight per sample were 312.1 and 2.26658 g, respectively.

Sampling Period II. Thirty-nine taxa were collected. The average number of organisms per sample was 256.9 and the average wet weight per sample was 1.29521 g. The fauna was dominated by oligochaetes (63.45%), *Hyalella azteca* (16.70%), *Hexagenia limbata* (5.23%), *Chironomus* (4.33%), *Sphaerium* (2.72%), and Nematoda (2.25%). The remainder of the benthic fauna (33 taxa) accounted for 5.32% of the collected macroinvertebrates. These 33 taxa were dominated by ten genera belonging to the Order Diptera.

Area 7

Sampling Period I. Representatives of 18 taxa were collected in six random bottom samples. The average benthic collection had 130.8 individuals and a wet weight of 0.40775 g. The benthic fauna was primarily composed of oligochaetes (74.78%), *Hyalella azteca* (9.94%), Hirudinea (5.61%), *Hexagenia limbata* (2.55%), and *Asellus militaris* (2.42%). The remaining 13 taxa included eight genera of the Order Diptera and accounted for 4.71% of the organisms sampled.

Sampling Period II. Representatives of the Classes Oligochaeta (81.05%), Hirudinea (2.76%), and Turbellaria (1.63%) and Phylum Nematoda (1.51%), the amphipod *Hyalella azteca* (6.46%), and the mayfly *Hexagenia limbata* (1.44%) dominated the 30 taxa collected in the six random collections. Nine midge genera, two mayfly genera, and three caddisfly genera dominated the remaining 24 taxa which constituted 5.14% of the benthos taken. The benthic fauna averaged 265.7 individuals per sample and 0.82542 g wet weight per sample.

Area 8

Sampling Period I. Eight taxa dominated the 28 taxa of benthic fauna, accounting for almost 95% of the sampled community. Oligochaetes (69.57%) predominated at all stations. *Chironomus* (6.58%), *Hyalella azteca* (5.65%), leeches (4.39%), *Hexagenia limbata* (3.99%), *Sphaerium* (2.46%), *Musculium* (1.20%), and nematodes (1.13%) were also relatively abundant. The remainder of the macroinvertebrate assemblage was composed of 20 taxa which constituted 5.05% of the individuals sampled. Of these remaining 20 taxa, ten taxa represented the Order Diptera. The number of organisms per sample averaged 250.8. The average bottom grab weighed 1.48897 g wet weight.

Sampling Period II. Twenty-five taxa were surveyed in the six random bottom collections. The average number of macroinvertebrates per sample and the average wet weight per sample were 363 and 1.8664 g, respectively. The oligochaetes (75.39%) and *Hyalella azteca* (8.08%) dominated the invertebrate fauna. Representatives of *Sphaerium* (5.19%), *Chironomus* (2.25%), Hirudinea (2.25%), and *Musculium* (0.83%) were abundant. *Hexagenia limbata* accounted for 2.25% of the organisms collected in this area. Eighteen taxa, including seven dipteran taxa, represented the rest of the benthos and constituted 8.20% of the investigated faunal forms.

Area 9

Sampling Period I. Four random samples, averaging 175.3 individuals and 0.97212 g per sample, were collected. The macrobenthic community, characterized by 18 taxa, consisted primarily of oligochaetes, *Hexagenia limbata*, nematodes, and leeches which accounted for 82.17%, 6.42%, 4.14%, and 2.14%, respectively, of the assemblage. Eight dipteran genera dominated the remaining 14 taxa which constituted 5.14% of those organisms collected in the area.

Sampling Period II. Twenty-two taxa were collected in four random samples. Representatives of the Class Oligochaeta (72.50%) and the pelecypod *Musculium* (5.70%) predominated in the benthic fauna. The dipteran *Chaoborus* and the pelecypod *Sphaerium* constituted 4.70% and 3.60%, respectively, of the sampled benthos. The remainder of the collection was composed of 18 taxa (13.50%) which were dominated by eight dipteran and four mayfly taxa. *Hexagenia limbata* was the dominant mayfly and constituted 5.30% of the benthos. An average of 250 individuals and 1.4289 g wet weight were observed for each sample.

Area 10

Sampling Period I. The benthic fauna was composed of a wide variety of dipteran taxa involving 13 genera which included *Chironomus* (14.39%), *Endochironomus* (5.39%), *Glyptotendipes* (4.88%), and *Cricotopus* (1.65%). Representatives of the Oligocaheta (35.83%) and *Hyalella azteca* (18.07%) were the major macroinvertebrates present in the benthos. Hirudinea (6.09%), *Hexagenia limbata* (2.22%), *Asellus militaris* (1.52%), *Sphaerium* (1.33%), *Musculium* (1.27%), and Turbellaria (1.14%) were relatively abundant. Of the 32 taxa surveyed, 20 taxa accounted for 6.22% of the macroinvertebrates inventoried. An average of 262.8 organisms were collected per sample. Each benthic collection had an average wet weight of 1.36168 g.

Sampling Period II. During this sampling interval, a total of 27 taxa were inventoried. The average sample had 105.3 individuals and a wet weight of 1.25032 g. The benthic fauna was dominated by oligochaetes (36.71%), *Chironomus* (18.83%), *Hyalella azteca* (10.13%), *Sphaerium* (5.54%), leeches (4.43%), and *Asellus militaris* (3.64%). Of the remaining 21 taxa, which constituted 20.73% of the fauna, 11 genera representing the Order Diptera were present with *Chironomus* and *Endochironomus* (3.80%) being prevalent. Four taxa of Ephemeroptera were present and dominated by *Hexagenia limbata* and *H. bilineata* which constituted 5.54% and 2.53%, respectively, of the total collection for the area.

Area 11

Sampling Period I. Thirty-one taxa, including 18 representatives of the Order Diptera, were collected in six bottom samples. An average of 292.5 organisms were collected per sample. Each benthic collection had an average wet weight of 1.03064 g. Representatives of the Class Oligochaeta and the dipteran *Endochironomus* predominated, accounting for 40.74% and 30.31%, respectively, of the benthic fauna. Other dominant invertebrates included *Hexagenia limbata* (6.27%), *Hyalella azteca* (5.36%), Hirudinea (3.02%), *Glyptotendipes* (2.74%), *Chironomus* (2.28%), Nematoda (1.54%), *Polypedilum* (1.48%), and *Dicrotendipes* (0.85%). The remainder of the benthic fauna was composed of 21 taxa, accounting for 5.41% of the community.

Sampling Period II. The benthic fauna was dominated by the oligochaetes (70.37%), leeches (10.80%), *Hexagenia limbata* (5.24%), and the dipteran *Chironomus* (3.10%). Of the 20 taxa collected, 16 taxa (10.48%) composed the remainder of the sampled community. Apart from *Chironomus*, six genera of the Order Diptera were represented. Only one live specimen of *Physa* was collected for the entire area at sampling station 11-1-2. At this same station numerous empty shells of *Physa* were present. The average number of organisms and wet weight per sample were 155.8 individuals and 1.3377 g, respectively.

Area 12

Sampling Period I. Twenty-seven taxa, including 13 dipteran taxa, constituted the benthic fauna. The average number of organisms per sample was 166.9. The wet weight averaged 0.28206 g per sample. The Oligochaeta and *Chironomus*, accounting for 75.23% and 8.99%, respectively, dominated the collected benthos. *Procladius* (3.93%) and *Palpomyia* (2.86%) were other dominant dipterans. The remaining 23 taxa accounted for 8.99% of the organisms inventoried. Three representatives of the Order Ephemeroptera were present with *Hexagenia limbata* (2.60%) prevailing.

Sampling Period II. The benthic fauna consisted of a wide variety of macroinvertebrates. Of the 39 taxa surveyed, 19 taxa were represented by members of the Order Diptera and four by the Order Ephemeroptera. The bottom community was dominated by the oligochaetes (75.45%). *Pentaneura* (3.37%), *Chironomus* (3.19%), *Hexagenia limbata* (3.14%), *Procladius* (2.22%), *Chaoborus* (1.90%), *Coelotanypus* (1.71%), Nematoda (1.48%), Hirudinea (0.83%), and *Hyalella azteca* (0.74%) occurred more frequently relative to the other 29 taxa which constituted 5.96% of the investigated fauna. The averages of 240.3 individuals per sample and 0.55823 g wet weight per sample were observed.

Area 13

Sampling Period I. The benthic fauna was composed of 27 taxa, including 14 dipteran and three mayfly taxa, and was dominated by the Oligochaeta (58.51%) and *Chironomus* (16.52%). Of the 14 dipteran taxa, *Chironomus*, *Palpomyia* (3.07%), *Procladius* (3.07%), and *Cryptocladopelma* (2.05%) were most abundant. The dominant mayfly was *Hexagenia limbata* which accounted for 6.02% of the investigated benthic assemblage. The remaining 21 taxa constituted 10.76% of the collected organisms. The average number of individuals per sample and the average wet weight per sample were 86.8 and 0.44902 g, respectively.

Sampling Period II. Thirty-four taxa, representing an average of 142.9 individuals per sample and an average wet weight of 0.67852 g per sample, were inventoried in the eight collected samples. Four taxa constituted over 85% of the benthic fauna and included the oligochaetes (75.42%), *Hyalella azteca* (4.64%), *Chironomus* (3.06%), and *Chaoborus* (2.27%). Seventeen dipteran genera dominated the remaining 30 taxa which accounted for 14.61% of the collected fauna.

Area 14

Sampling Period I. The benthic fauna was represented by 29 taxa, including seven genera belonging to the Order Diptera. All three arbitrary levels of pollution tolerance were approximately equally represented. The pollution-tolerant component accounted for over 38% of the collected benthos and was dominated by the following four taxa: The Oligochaeta (26.48%), *Musculium* (5.43%), the Hirudinea (4.29%), and *Chironomus* (2.55%). Pollution-facultative organisms, constituting about 43% of the invertebrate community, were dominated by five taxa which included *Sphaerium* (22.14%), *Asellus militaris* (14.27%), the nematodes (3.26%), *Hyalella azteca* (1.74%), and the pelecypod *Pisidium* (1.30%). *Hexagenia limbata* (4.94%) and the gastropods *Amnicola* (4.77%) and *Valvata tricarinata* (3.20%) were the three dominant taxa composing the pollution-sensitive rank. The remainder of the benthic community was an assemblage of 17 taxa, accounting for 5.64% of the total fauna collected. The average sample was characterized by 204.8 macroinvertebrates and a wet weight of 3.29989 g.

Sampling Period II. The dominant benthic fauna accounted for over 93% of the organisms collected and included *Sphaerium* (35.32%), oligochaetes (23.88%), nematodes (8.01%), *Chironomus* (7.55%), *Musculium* (6.18%), leeches (5.60%), *Valvata tricarinata* (3.03%), *Asellus militaris*

(2.06%), and *Amnicola* (1.44%). Of the 41 taxa sampled, the remaining 32 taxa accounted for 6.92% of the surveyed benthos and included 12 genera belonging to the Order Diptera, excluding *Chironomus*. The average number of organisms per sample was 285.7. The wet weight averaged 4.57335 g per sample.

Area 15

Sampling Period I. A relatively large number of taxa (43) were collected in nine bottom samples. The average number of individuals per sample and the average wet weight per sample were 183.3 and 3.83017 g, respectively. The dominant pollution-facultative organisms accounted for approximately 54% of the collected benthos. These macroinvertebrates were represented by the pelecypod *Sphaerium* (27.82%), the crustaceans *Hyalella azteca* (14.55%) and *Asellus militaris* (5.70%), members of the Phylum Nematoda (4.36%), and the dipteran *Polypedilum* (1.39%). Members of the Classes Oligochaeta (22.18%) and Hirudinea (4.30%) and the pelecypod *Musculium* (3.64%) were the dominant representatives of the pollution-tolerant level, accounting for 30.12% of the benthic inventory in this area. Major pollution-sensitive macroinvertebrates were *Xenochironomus*, *Hexagenia limbata*, and *Amnicola*, constituting 2.61%, 2.18%, and 1.94%, respectively, of the collected benthos. The dipteran *Xenochironomus* was collected at only one sampling station (site 15-3-1) in the entire area. The remaining 32 taxa composed 9.33% of the benthic inventory and included nine representatives of the Order Diptera.

Sampling Period II. The benthic fauna consisted of 43 taxa, including 12 dipteran taxa. Eleven taxa accounted for approximately 91% of the community and included *Sphaerium* (32.95%), oligochaetes (14.49%), *Musculium* (8.52%), *Hyalella azteca* (7.11%), *Tanytarsus* (6.38%), leeches (5.06%), *Asellus militaris* (4.56%), *Amnicola* (3.69%), *Chironomus* (2.87%), *Valvata tricarinata* (2.83%), and members of the Phylum Nematoda (2.10%). The remainder of the faunal assemblage consisted of 32 taxa, representing 9.43% of the collected benthos. Averages of 243.8 individuals per sample and 5.41902 g wet weight per sample were obtained.

Area 16

Sampling Period I. The 25 benthic taxa were dominated primarily by the oligochaetes (82.73%) and secondarily by the mayfly nymph *Hexagenia limbata* which accounted for 5.49% of the benthic organisms collected in this area. Other relatively abundant forms included the pelecypod *Musculium* (2.53%), *Hyalella azteca* (1.42%), leeches (1.26%), *Chironomus* (1.23%), *Asellus militaris* (0.95%), *Sphaerium* (0.95%), and members of the Nematoda (0.91%). Sixteen taxa constituted the remainder of the benthic assemblage and accounted for 2.53% of the bottom inventory. Nine of these remaining taxa represented the Order Diptera. The average number of organisms was 281.1 per sample. The average wet weight per sample was 0.99482 g.

Sampling Period II. The bottom community consisted of 44 taxa, including 16 genera of Diptera and four taxa belonging to Ephemeroptera. The Oligochaeta (70.80%), *Hexagenia limbata* (11.06%), and *Sphaerium* (4.03%) were dominant. The remaining 41 taxa accounted for 14.11% of the collected organisms. The average number of individuals per sample and the average wet weight per sample were 181.9 and 2.81027 g, respectively.

Area 17

Sampling Period I. The oligochaetes, accounting for 57.81% of the collection, dominated the 32 taxa of benthic fauna. The other dominant macrobenthic invertebrates were *Hexagenia limbata* (16.14%), nematodes (7.20%), *Musculium* (4.76%), the crustaceans *Asellus militaris* (2.25%) and *Hyalella azteca* (1.74%), the pelecypod *Sphaerium* (1.80%), and leeches (1.48%). The remainder of the bottom fauna (24 taxa) accounted for 6.82% of the collected macroinvertebrates. These 24 taxa were dominated by nine genera and three taxa belonging to the Orders Diptera and Ephemeroptera, respectively. Averages of 172.8 individuals per sample and 2.55521 g wet weight per sample were calculated.

Sampling Period II. Benthic collections, averaging 97.3 individuals and 1.22285 g wet weight, consisted of 37 taxa of which 11 represented dipterans and four involved mayflies. Three macroinvertebrates were most prevalent and included the oligochaetes (77.85%), *Hexagenia limbata* (6.74%), and *Hyalella azteca* (3.42%). The remaining 34 taxa accounted for 11.99% of the community.

Area 18

Sampling Period I. Thirty-two taxa, including 12 dipteran genera and three mayfly taxa, were found in six random bottom collections. Representatives of the Class Oligochaeta were the major benthic macroinvertebrates, comprising 83.15% of the collected benthic community.

Hyalella azteca (3.74%), *Hexagenia limbata* (3.38%), leeches (2.12%), *Asellus militaris* (1.33%), turbellarians (1.01%), and *Valvata tricarinata* (0.50%) accounted for approximately 12% of the fauna. Less than 5% (4.78%) of the sampled macroinvertebrates consisted of 25 taxa. The total number of organisms averaged 464 per sample. The average wet weight per sample was 1.53392 g.

Sampling Period II. The six random bottom samples consisted of 40 taxa and had an average of 691.3 organisms per sample and an average wet weight of 2.79548 g. Pollution-tolerant and facultative macroinvertebrates, representing over 91% of the fauna, dominated the benthic inventory. These macroinvertebrates included the pollution-tolerant oligochaetes (73.19%), leeches (2.36%), and *Physa* (1.69%) and the pollution-facultative *Hyalella azteca* (7.21%), *Sphaerium* (4.48%), nematodes (1.37%), and turbellarians (0.77%). The major pollution-sensitive organism was *Hexagenia limbata* (2.22%). Thirty-two taxa constituted the remainder (6.70%) of the benthic community and included 11 genera belonging to the Order Diptera.

Area 19

Sampling Period I. The benthic fauna consisted mainly of oligochaetes (84.07%), nematodes (2.95%), *Procladius* (2.58%), and *Hyalella azteca* (2.03%). *Hexagenia limbata* constituted 1.75% of the macroinvertebrate community. Of the 32 taxa sampled, the remaining 27 taxa (6.63%) were dominated by 16 dipteran genera and five mayfly taxa. The average number of organisms per sample was 120.7. The wet weight per sample averaged0.15508 g.

<u>Sampling Period II</u>. The benthic fauna consisted of 32 taxa and was dominated by the oligochaetes (64.50%), *Hexagenia limbata* (9.75%), *Polypedilum* (3.90%), and *Pentaneura* (3.51%). The remaining 28 taxa included 22 dipteran genera and three mayfly taxa and accounted for 18.34% of the faunal inventory. Averages of 96.1 individuals and 0.43492 g wet weight were calculated.

Area 20

<u>Sampling Period I</u>. Representatives of 34 taxa were surveyed in ten bottom collections. The average benthic sample had 91.6 macro-invertebrates and a wet weight of 0.93892 g. The dominant macroinvertebrates were oligochaetes (37.12%), *Endochironomus* (13.32%), *Hyalella azteca* (11.57%), *Hexagenia limbata* (10.26%), *Musculium* (6.00%), leeches (4.91%), *Asellus militaris* (3.71%), nematodes (2.73%), *Sphaerium*(1.64%), and *Simulium* (1.53%). The remainder of the benthic community was an assemblage of 24 taxa which included 15 dipteran genera and accounted for 7.20% of the total collected fauna.

<u>Sampling Period II</u>. The dominant benthic fauna accounted for over 90% of the organisms collected and included the Oligochaeta (47.98%), *Hyalella azteca* (9.55%), *Hexagenia limbata* (9.07%), the Nematoda (7.11%), the Hirudinea (4.11%), the Turbellaria (3.07%), *Polypedilum* (3.00%), *Asellus militaris* (2.58%), *Endochironomus* (1.95%), and *Sphaerium* (1.88%). Of the 47 taxa sampled, the remaining 37 taxa accounted for 9.69% of the surveyed benthos and included 20 genera belonging to the Order Diptera, excluding *Polypedilum* and *Endochironomus*. The average number of organisms per sample was 143.4. The wet weight averaged 0.81236 g per sample.

Area 21

Sampling Period I. Over half (53.96%) of the benthic fauna consisted of the pelecypod *Sphaerium*. The Oligochaeta (17.45%), *Musculium* (6.09%), *Amnicola* (5.48%), nematodes (3.66%), and turbellarians (2.71%) were relatively prevalent in the inventory which encompassed 36 taxa. *Cricotopus* (2.11%), one of 11 dipteran genera, dominated the remaining 30 taxa which made up 10.64% of the community. The respective averages for the number of organisms and wet weight per sample were 200.6 and 2.38241 g.

Sampling Period II. Thirty-four taxa were collected in nine bottom grabs which had an average of 172.1 macroinvertebrates and 5.52486 g wet weight per sample. No macroinvertebrates were taken at site 21-2-3. The benthic fauna consisted mostly of *Sphaerium* and oligochaetes, accounting for 36.99% and 18.66%, respectively, of the assemblage. The other dominant macroinvertebrates were *Amnicola* (10.85%), *Musculium* (7.62%), nematodes (6.78%) leeches (3.87%), *Asellus militaris* (3.10%), *Pisidium* (2.45%), *Valvata tricarinata* (1.61%), *Hyalella azteca* (1.29%), and *Hexagenia limbata* (0.84%). Twenty-three taxa accounted for the remaining benthos collection which encompassed 5.94% of the total.

Area 22

Sampling Period I. Forty-one taxa, each represented by few macroinvertebrates, were examined in the benthic fauna. The average bottom collection sampled only 21.8 organisms and weighed 0.09112 g wet weight. Oligochaetes accounted for 33.64% of the organisms collected. *Palpomyia* (12.23%), *Hyalella azteca* (7.65%), *Polypedilum* (7.03%), Corixidae females (5.20%), *Cheumatopsyche* (4.89%), and *Atrichopogon* (1.83%) were prevalent. *Palpomyia* and *Atrichopogon* were present in the majority of samples and were the dominant faunal forms in the central areas of the aquatic environment. As in other areas, the mayfly *Brachycercus* was often associated with these dipterans. In these open waters, only one representative of the Class Oligochaeta was taken. The remaining 34 taxa, including 12 dipterans, four mayflies, and three caddisflies, accounted for 27.52% of the benthic survey.

Sampling Period II. Fifteen bottom samples, averaging only 28.7 invertebrates and 0.02768 g wet weight per sample, resulted in the collection of 39 poorly-represented taxa. Of the 39 taxa, the Orders Diptera, Ephemeroptera, and Trichoptera respectively comprised 20, 4, and 2 taxa. *Palpomyia* (32.95%) and *Atrichopogon* (25.06%), collectively accounting for over 58% of the faunal conglomeration, dominated the benthos. Often associated with these two dipterans, *Brachycercus* constituted 4.18% of the community. Less than 11% (10.44%) of the investigated fauna included the oligochaetes. The remaining 35 taxa comprised 27.38% of the total collection.

Area 23

Sampling Period I. The benthic fauna consisted of mostly the oligochaetes (53.96%), *Hyalella azteca* (7.19%), *Palpomyia* (6.12%), and *Hexagenia limbata* (5.76%). Of the 31 taxa collected, the remaining 27 taxa formed 26.98% of the benthos. A wide variety of dipterans

(13 taxa), excluding *Palpomyia*, predominated in these taxa. Averages of 30.9 individuals and 0.27428 g per sample were calculated.

<u>Sampling Period II</u>. Representatives of 34 taxa were collected in nine bottom samples. The average benthic collection had 37.4 invertebrates and a wet weight of 0.46584 g. The benthic fauna was dominated by oligochaetes (45.40%), leeches (13.65%), and *Xenochironomus* (4.45%). The remaining 31 taxa (36.50%) contained 16 genera belonging to the Order Diptera. Few taxa and few individuals per taxon were found in the central waters of the area. *Atrichopogon*, *Palpomyia*, oligochaetes, *Stictochironomus*, and *Brachycercus* were the more abundant macroinvertebrates in these waters.

<u>Area 24</u>

<u>Sampling Period I</u>. The pelecypods *Sphaerium* (38.86%), *Musculium* (10.17%), and *Pisidium* (1.36%), accounting for over 50% of the organisms collected, dominated the macrobenthic conglomeration. Members of the Classes Oligochaeta (26.59%) and Hirudinea (2.16%), *Amnicola* (6.31%), nematodes (2.67%), *Hexagenia limbata* (2.16%), turbellarians (1.70%), and *Valvata tricarinata* (1.42%) were common. Less than 7% (6.59%) of the fauna encompassed 31 taxa, 11 of which were dipterans. The average number of macroinvertebrates per sample and the average wet weight per sample were 195.6 and 4.60769 g, respectively.

<u>Sampling Period II</u>. The 41 benthic taxa were dominated by the pelecypods *Sphaerium* (55.57%) and *Musculium* (14.10%) which accounted for 69.67% of the fauna. Other dominant taxa were the oligochaetes (6.91%), *Asellus militaris* (5.70%), leeches (3.68%), and the gastropod

Amnicola (1.97%). The remaining 35 taxa included 11 dipteran genera and constituted 12.07% of the organisms sampled. The average benthic collection contained 202.6 individuals and weighed 8.48620 g.

Area 25

Sampling Period I. Twenty-five taxa were surveyed in nine bottom collections. The most abundant invertebrates accounted for approximately 87% of the benthic inventory and included the Oligochaeta (66.60%), *Hexagenia limbata* (13.87%), and *Musculium* (6.09%). Twenty-two taxa, encompassing ten dipteran genera, constituted the remaining 13.45% of the benthic fauna. Bottom samples taken in the central portions of the area were generally characterized by possessing fewer taxa and fewer representatives per taxon. No macroinvertebrates were collected at site 25-1-2. Collectively the bottom samples averaged 52.9 individuals and 0.22430 g per sample.

Sampling Period II. Forty-six taxa, representing an average of 79.4 individuals per sample and an average wet weight of 1.12192 g per sample, were inventoried in the nine bottom collections. Dominant macroinvertebrates constituted over 84% of the benthic fauna and included the oligochaetes (64.90%), *Atrichopogon* (6.43%), *Polypedilum* (3.36%), *Hexagenia limbata* (2.94%), Ceratopogonidae pupae (2.66%), *Hyalella azteca* (2.38%), and *Xenochironomus* (1.54%). Fourteen dipteran genera were prevalent in the remaining 39 taxa which accounted for 15.80% of the collected fauna. No macroinvertebrates were collected at site 25-1-2.

Area 26

Sampling Period I. The benthic fauna was randomly collected and consisted of 40 taxa. Averages of 299.5 individuals per sample and 1.59373 g wet weight per sample were calculated. The oligochaetes (70.34%) predominated. *Hyalella azteca* (8.68%), *Sphaerium* (3.73%), *Hexagenia limbata* (2.50%), nematodes (2.39%), turbellarians (1.67%), leeches (1.61%), *Musculium* (1.39%), *Amnicola* (1.06%), and *Valvata tricarinata* (0.95%) were common. The remainder (5.67%) of the macroinvertebrate community was characterized by 30 taxa, including 11 members of the Order Diptera.

Sampling Period II. The benthic fauna consisted of a wide variety of macroinvertebrates encompassing a total of 59 taxa which included 18 dipteran genera, seven caddisfly genera, and four mayfly taxa. This was the largest number of taxa inventoried. The average bottom collection had 248.2 invertebrates and a wet weight of 4.76095 g. The Class Oligochaeta, accounting for 45.74% of the surveyed community, was dominant. Unidentified *Hexagenia* nymphs (9.67%), *Sphaerium* (4.77%), members of the Phylum Nematoda (4.63%), *Hyalella azteca* (3.16%), *Hexagenia limbata* (2.08%), *Pleurocera* (2.08%), *Physa* (1.75%), *Asellus militaris* (1.54%), *Xenochironomus* (1.41%), and *Amnicola* (1.28%) were other common macrobenthic invertebrates. Forty-eight taxa made up the remainder (21.90%) of the bottom collection.

Area 27

Sampling Period I. Nine bottom samples, quantitatively ranging in size from one organism to 43 organisms, were collectively composed of 14 taxa and averaged 16.7 macroinvertebrates and 0.06521 g wet weight per sample. The number of taxa per sample ranged from one to eight with the number of organisms per taxon ranging from one to 39. The oligochaetes and dipteran *Endochironomus* accounted for 56.00% and 21.33%, respectively, of the investigated benthos. *Hyalella azteca* (5.33%), *Glyptotendipes* (4.67%), and *Palpomyia* (1.33%) composed 11.33% of the total community. Nine taxa made up the remainder (11.33%) of the total fauna which contained five dipteran and three tricopteran taxa.

Sampling Period II. Thirteen dipteran taxa, five mayfly taxa, and three trichopteran taxa were contained in the 32 taxa which were dominated by the oligochaetes (34.72%). The major dipteran representatives included *Xenochironomus* (13.99%), *Palpomyia* (4.66%), *Paratendipes* (4.66%), *Polypedilum* (3.11%), *Atrichopogon* (2.59%), and *Glyptotendipes* (2.59%). The trichopterans *Hydropsyche* and *Cheumatopsyche* constituted 5.70% and 3.63%, respectively, of the fauna. The beetle larvae of *Stenelmis* accounted for 3.63% of the collected organisms. The remainder (20.73%) of the benthic inventory consisted of 22 taxa. Averages of 21.4 organisms per sample and 0.14904 g per sample were obtained. The number of organisms per sample ranged from three to 50 individuals. The number of taxa per sample ranged for two to 12 with the number of organisms per taxon ranging from one to 44.

Area 28

Sampling Period I. Fifteen bottom samples, quantitatively ranging in size from zero organisms to 31 organisms, were collectively composed of 15 taxa and averaged only 11.8 macroinvertebrates and 0.00600 g wet weight per sample. The number of taxa per sample ranged from zero to eight with all taxa being present at low densities. No faunal representatives were collected at site 28-5-1. The benthic fauna consisted mainly of oligochaetes (29.38%), *Palpomyia* (25.42%), and *Atrichopogon* (21.47%). *Brachycercus* accounted for 10.73% of the fauna collected. Eleven taxa, including five dipterans, comprised the remainder (12.99%) of the benthos.

Sampling Period II. The benthic fauna consisted of 32 poorly represented taxa, including 14 dipteran genera and five mayfly taxa, and was dominated by facultative pollution-tolerant organisms. The major macroinvertebrates accounted for almost 84% of the benthic assemblage and included the oligochaetes (29.65%), *Palpomyia* (16.98%), *Atrichopogon* (10.51%), *Hexagenia limbata* (7.55%), *Brachycercus* (6.20%), *Cheumatopsyche* (6.20%), *Paratendipes* (4.85%), and *Xenochironomus* (1.62%). The remainder of the faunal conglomeration consisted of 24 taxa, representing 16.44% of the collected benthos. Averages of 24.7 individuals per sample and 0.07561 g wet weight per sample were calculated.

Area 29

Sampling Period I. The benthic fauna consisted of 27 taxa, including eight dipteran and three mayfly representatives, and was dominated by the oligochaetes which composed 91.51% of the surveyed community. Members of the Phylum Nematoda (2.20%), *Hexagenia limbata* (1.86%), *Hyalella azteca* (1.19%), *Sphaerium* (0.82%), and leeches (0.40%)

were relatively abundant. Approximately 2.02% of the benthos consisted of the remaining 21 taxa. The average number of individuals and wet weight per sample were 272.8 and 0.39395 g, respectively.

Sampling Period II. Representatives of the Class Oligochaeta, accounting for 87.87% of the fauna, dominated the benthos which consisted of 39 taxa, including 15 genera belonging to the Order Diptera. The major dipteran representatives included *Cryptochironomus* (0.73%) and *Stictochironomus* (0.49%). Members of the Phylum Nematoda (3.20%), unidentified early instars of *Hexagenia* (2.59%), *Hyalella azteca* (0.83%), and *Hexagenia limbata* (0.56%) were common. The remaining 32 taxa constituted 3.72% of the organisms collected. The average bottom sample yielded 340.8 macroinvertebrates and weighed 0.39233 g wet weight.

Area 30

Sampling Period I. Representatives of the Class Oligochaeta (47.15%) and the caddisfly *Cheumatopsyche* (30.89%) composed over 78% of the collected community. Seven dipteran genera and four mayfly taxa contributed most to the remaining 16 taxa which included 21.95% of the total benthos. Averages of 20.5 individuals and 0.01468 g per sample were calculated. Numbers of organisms and taxa per sample ranged from five to 58 and two to nine, respectively. All taxa were poorly represented in terms of numbers of individuals per taxon.

Sampling Period II. Five taxa dominated the 35 taxa of benthic fauna. These macroinvertebrates accounted for over 92% of the sampled benthos and included the oligochaetes (78.87%), the trichopterans

Hydropsyche (5.12%) and *Cheumatopsyche* (2.40%), and the dipterans *Polypedilum* (3.38%) and *Xenochironomus* (2.40%). The remainder of the macroinvertebrate assemblage was composed of 30 taxa which constituted 7.84% of in the individuals sampled. Of these remaining 30 taxa, 14 represented the Order Diptera. One hundred fifty-three invertebrates constituted the average benthos sample which had a wet weight of 0.15855 g.

Area 31

Sampling Period I. Representatives of 17 benthic taxa were collected in five random samples. The average bottom sample had 50 invertebrates and a wet weight of 0.20172 g. No macroinvertebrates were collected at site 31-1. The benthic fauna was primarily composed of oligochaetes (80.40%). Six percent of the collected benthos was composed of the mayfly nymph *Hexagenia limbata*. The remaining 15 taxa, accounting for 13.60% of the organisms sampled, included ten dipteran genera of which *Cryptochironomus* was the dominant representative.

Sampling Period II. The benthic fauna consisted of 20 taxa, including eight dipteran genera and four mayfly taxa. The dominant macroinvertebrates included the Class Oligochaeta (37.66%), the trichopteran *Cheumatopsyche* (25.97%), and the dipteran *Xenochironomus* (13.64%). The remainder of the benthic community was an assemblage of 17 taxa, accounting for 22.73% of the total fauna collected. The average number of organisms per sample was 30.8. The wet weight averaged 0.04002 g per sample.

Area 32

Sampling Period I. Benthic collections, averaging 99.7 individuals and 0.77749 g wet weight, consisted of 34 taxa of which the Orders Diptera, Ephemeroptera, and Trichoptera were represented by 11, 6, and 3 taxa, respectively. Two macrobenthic taxa accounted for over 80% of the organisms collected and included the Oligochaeta (57.36%) and *Cheumatopsyche* (22.91%). The remaining 32 taxa made up 19.73% of the collection.

Sampling Period II. Oligochaetes (72.73%) dominated the 28 taxa of benthic fauna. Of the 16 representatives of the Order Diptera, *Polypedilum* (5.00%) and *Harnischia* (3.33%) were the most abundant. The mayfly *Hexagenia limbata* accounted for 3.48% of the benthic inventory. Twenty-four taxa constituted the remaining benthos collection which encompassed 15.45% of the total. The respective averages for the number of organisms and wet weight per sample were 110 and 0.31268 g.

Area 33

Sampling Period I. Because of the depth (6.71 m) and current velocity (0.411 m/sec) of this area, a valid representative bottom sample could not be collected during this sampling interval.

Sampling Period II. Nine bottom samples, averaging 305.9 invertebrates and 2.17551 g wet weight per sample, resulted in the collection of 38 taxa of which 14 taxa involved representatives of the Order Diptera. Seven benthic collections contained fewer than 165 macroinvertebrates, while sites 33-1-3 and 33-3-1 collected 632 and 1622 organisms, respectively. The oligochaetes predominated, composing 87.58% of the fauna. Other dominant macroinvertebrates included the nematodes (3.05%), unidentified early instars of *Hexagenia* (1.45%), leeches (1.45%), and *Sphaerium* (1.42%). The remaining 33 taxa constituted 5.05% of the total benthic inventory for this area.

Area 34

Sampling Period I. Twelve bottom samples averaged only 15.8 faunal representatives and 0.02271 g per sample, with most samples possessing fewer than 40 invertebrates and ten taxonomic categories. No macrobenthic invertebrates were collected in the central open waters except at sampling site 34-2-2 at which a sole specimen representing the Family Ceratopogonidae (Order Diptera) was inventoried. The 31 surveyed taxa included 14 dipteran genera, six mayfly taxa, and three caddisfly taxa. All taxa were poorly represented in terms of numbers of individuals per taxon. The dominant benthic forms, constituting 67.89% of the sampled benthos, included the Oligochaeta (39.47%), the caddisfly *Cheumatopsyche* (13.68%), and the dipterans *Endochironomus* (8.95%) and *Glyptotendipes* (5.79%). The remainder of the sampled community (32.11%) consisted of 27 taxa.

Sampling Period II. All benthic samples and taxa were poorly represented. The average number of specimens and wet weight per sample were 11 and 0.00998 g, respectively. The number of taxa per sample ranged from one to nine with a range of one to 22 representatives per taxon in each sample. The four dominant taxa accounted for 71.59% of the collection and included oligochaetes (37.50%), the dipterans

Atrichopogon (15.91%) and *Palpomyia* (12.50%), and the mayfly *Brachycercus* (5.68%). The remaining 17 taxa (28.41%) included six genera belonging to the Order Diptera.

Area 35

Sampling Period I. Thirty-four poorly represented taxa, including 15 dipteran, five mayfly, and two trichopteran taxa, were inventoried in nine bottom collections. The dominant benthic invertebrates included the Oligochaeta (27.55%), the dipterans *Glyptotendipes* (8.67%) and *Chironomus* (6.12%), the trichopteran *Cheumatopsyche* (9.69%) and the mayfly *Hexagenia limbata* (7.14%). The ceratopogonids *Atrichopogon* and *Palpomyia* were present in most samples, often being the dominant or sole organisms collected. Including these two dipterans, 29 taxa composed the remaining 40.82% of the benthos. Averages of 21.8 individuals and 0.09650 g total wet weight were calculated.

Sampling Period II. Members of the Class Oligochaeta constituted 45.95% of the benthic assemblage. Representatives of the Phylum Nematoda (7.44%), *Hexagenia limbata* (7.28%), unidentified early instars of *Hexagenia* (4.85%), *Polypedilum* (4.69%), *Cheumatopsyche* (4.05%), *Hyalella azteca* (3.24%), *Pentaneura* (3.07%), *Sphaerium* (2.27%), *Brachycercus* (1.94%), and *Hydropsyche* (1.94%) were relatively abundant and accounted for almost 41% of the benthic survey. Of the 38 taxa sampled, 27 taxa composed less than 14% (13.28%) of the total benthic collection. These 27 taxa were dominated by 14 genera of Diptera. The average benthic collection contained 68.7 individuals and weighed 0.14363 g.

Area 36

Sampling Period I. The oligochaetes were the dominant macrobenthic invertebrates and constituted 84.24% of the benthic fauna. The remaining 17 taxa were dominated by ten representatives of the Order Diptera and accounted for 15.76% of the community. All benthic samples and taxa were poorly represented. The average benthic collection sampled 23.6 represenatatives of the fauna and had a wet weight of 0.10177 g. The number of macroinvertebrates and taxa per sample respectively ranged from zero (site 36-2-3) to 127 and zero (site 36-2-3) to 11. Two samples (36-2-2 and 36-3-2) were entirely composed of only two oligochaetes each. In each sample the minimum and maximum numbers of individual representatives per taxon were one and 114, respectively.

Sampling Period II. Oligochaetes (37.04%), *Palpomyia* (12.96%), *Atrichopogon* (10.19%), and *Cheumatopsyche* (8.33%) dominated the 24 benthic taxa. Twenty taxa constituted the remainder (31.48%) of the bottom community. All bottom collections and taxonomic categories were poorly represented. Averages of 15.4 individuals and 0.01152 g per sample were obtained.

Area 37

Sampling Period I. The 43 taxa of benthic fauna consisted mostly of oligochaetes (47.57%). *Sphaerium* (10.57%), *Cricotopus* (8.76%), and *Hyalella azteca* (3.76%) were the other major macroinvertebrates. *Hyalella azteca* occurred more abundantly in the central portions of this area. Fourteen dipteran genera and four caddisfly taxa were the main components of the remaining 39 taxa (29.35%). The average number of specimens per sample was 79.9. The total wet weight per collection averaged 1.06906 g.

Sampling Period II. The Oligochaeta (51.23%) dominated the investigated benthos (36 taxa). Other principal benthic constituents accounted for almost 33% of the faunal elements collected and included *Hyalella azteca* (14.62%), *Sphaerium* (9.43%), the Nematoda (5.05%), and *Pisidium* (3.83%). Specimens of *Hyalella azteca* were more prevalent in the central regions of the area. Twelve members of the Order Diptera made up the bulk of the remaining 31 taxa (15.85%). The average number of organisms and wet weight per sample were 81.3 individuals and 0.97234 g, respectively.

Area 38

Sampling Period I. The principal components of the community were members of the Class Oligochaeta (41.83%) and *Cheumatopsyche* (18.93%). Seventeen dipteran genera, four mayfly taxa, and four caddisfly taxa formed the largest taxonomic categories contained with the 35 sampled taxa. The five dominant representatives of Diptera accounted for over 24% of the benthos and included *Glyptotendipes* (7.94%), *Polypedilum* (4.73%), *Simulium* (4.27%), *Endochironomus* (4.12%), and *Rheotanytarsus* (3.21%). Twenty-eight taxa comprised the remainder (14.81%) of the surveyed assemblage. The quantitative and qualitative compositions of the bottom collections varied widely. Collections taken in the central open waters were generally devoid of macroinvertebrates (site 38-1-2) or contained few representatives of the macroinvertebrate fauna. The four samples taken in these portions of this area collectively consisted of nine organisms including five specimens of *Palpomyia*, three of *Atrichopogon*, and one oligochaete. Samples collected near shore also varied quantitatively and qualitatively. The average benthic sample contained 59.5 invertebrates and weighed 0.05647 g.

Sampling Period II. Forty-six taxa were collected in 12 bottom grabs which averaged 55.2 macroinvertebrates and 0.68254 g wet weight per sample. The benthic fauna consisted mostly of oligochaetes and *Hyalella azteca*, accounting for 43.50% and 16.31%, respectively, of the collected organisms. Other dominant macroinvertebrates were *Cheumatopsyche* (7.70%), *Stenelmis* (3.47%), *Endochironomus* (2.57%), *Palpomyia* (2.57%), *Hexagenia limbata* (2.27%), and representatives of the Class Hirudinea (1.96%). Thirty-eight taxa, including 15 dipteran, six mayfly, and four caddisfly taxa, accounted for the remaining benthos collection which encompassed 19.64% of the total. Samples taken in the central portions of the area contained few organisms and collectively were composed of the ceratopogonids *Palpomyia* and *Atrichopogon*, the mayfly *Brachycercus*, the dipteran *Paratendipes*, an unidentified early instar of *Hexagenia*, one oligochaete, and one nematode.

Area 39

Sampling Period I. The oligochaetes (77.53%) and the pelecypod *Musculium* (3.75%) accounted for over 81% of the benthos. The mayfly nymphs *Brachycercus* (3.75%) and *Hexagenia limbata* (3.56%), and the pelecypod *Sphaerium* (2.81%) were common. The remainder (8.61%) of the benthos consisted of 21 taxa, including five dipteran genera.

Averages of 89 individuals and 0.56703 g per sample were calculated.

Sampling Period II. The benthic fauna (22 taxa) consisted mostly of oligochaetes (83.10%). Approximately 13% of the fauna was composed of *Harnischia* (2.84%), *Hexagenia* early instars (2.84%), *Brachycercus* (2.41%), *Stictochironomus* (1.99%), *Hexagenia limbata* (1.28%), and *Palpomyia* (1.14%). The remaining 15 taxa, including nine specimens of Diptera, accounted for 4.40% of the collected organisms. The average benthic sample was characterized by 117.3 macroinvertebrates and a wet weight of 0.08528 g.

Area 40

Sampling Period I. The Oligochaeta (80.75%), *Simulium* (5.16%), and *Hexagenia limbata* (3.57%) accounted for over 89% of the fauna. Less than 11% (10.52%) of the remaining bottom collection consisted of 20 taxa which included eight representatives of the Order Diptera. Eighty-four macroinvertebrates, averaging 1.24728 g total wet weight, constituted the typical benthic sample.

Sampling Period II. The bottom community consisted of 21 taxa, including 12 dipteran genera. The average number of organisms per sample was 18.3. The total wet weight averaged 0.00820 g. *Palpomyia* (29.09%), oligochaetes (20.00%), *Atrichopogon* (14.55%), *Brachycercus* (6.36%), and *Xenochironomus* (5.45%) accounted for 75.45% of the total benthic inventory. Approximately one-fourth (24.55%) of the remaining macroinvertebrate fauna consisted of 16 taxa.

Area 41

Sampling Period I. Representatives of 36 taxa were surveyed in nine bottom collections. The average benthic sample had 67.2 macroinvertebrates and a wet weight of 0.76156 g. The dominant benthic representatives accounted for over 81% of the organisms collected and included the Oligochaeta (38.18%), the Nematoda (16.86%), *Hyalella azteca* (8.93%), *Asellus militaris* (4.79%), the Turbellaria (4.30%), *Xenochironomus* (3.14%), the Hirudinea (2.81%), and *Polypedilum* (2.31%). The remaining 28 taxa, accounting for 18.68% of the surveyed benthos, included ten specimens characterizing the Order Diptera.

Sampling Period II. The benthic fauna consisted of a wide variety of macroinvertebrates encompassing a total of 54 taxa which included 19 dipteran genera, five caddisfly taxa, and four mayfly taxa. This was the second largest number of taxa found. The average bottom collection had 195.1 organisms and a wet weight of 2.28926 g. Oligochaetes, accounting for 59.05% of the investigated community, were dominant. Other major macrobenthic invertebrates included nematodes (6.66%), *Hyalella azteca* (4.84%), *Xenochironomus* (4.61%), *Sphaerium* (2.16%), *Cheumatopsyche* (2.11%), turbellarians (1.82%), leeches (1.71%), *Pentaneura* (1.42%), *Hexagenia limbata* (1.25%), *Dicrotendipes* (1.20%), *Amnicola* (1.08%), *Physa* (1.08%), and *Asellus militaris* (1.03%). Forty taxa made up the remainder (9.96%) of the bottom collection.

Table 4 and Figs. 14 and 15 summarize the total number of benthic taxa collected in each area. During sampling period I, areas 15 and 37 and areas 1, 2, 4, and 5, respectively, supported the largest and smallest numbers of taxa. Areas 26 and 41, supporting 59 and 54 taxa, respectively, yielded the largest number of taxa collected during

Table 4. Total number of taxa, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, 1975.

Study Area	Number of Taxa	
	Sampling Period I	Sampling Period II
1	2	24
2	3	10
3	16	26
4	8	14
5	8	19
6	24	39
7	18	30
8	28	25
9	18	22
10	32	27
11	31	20
12	27	39
13	27	34
14	29	41
15	43	43
16	25	44
17	32	37
18	32	40
19	32	32
20	34	47
21	36	34
22	41	39
23	31	34
24	41	41
25	25	46
26	40	59
27	14	32
28	15	32
29	27	39
30	18	35
31	17	20
32	34	28
33	--	38
34	31	21
35	34	38
36	18	24
37	43	36
38	35	46
39	26	22
40	23	21
41	36	54

Fig. 14. Number of benthic taxa per area, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period I, 1975.

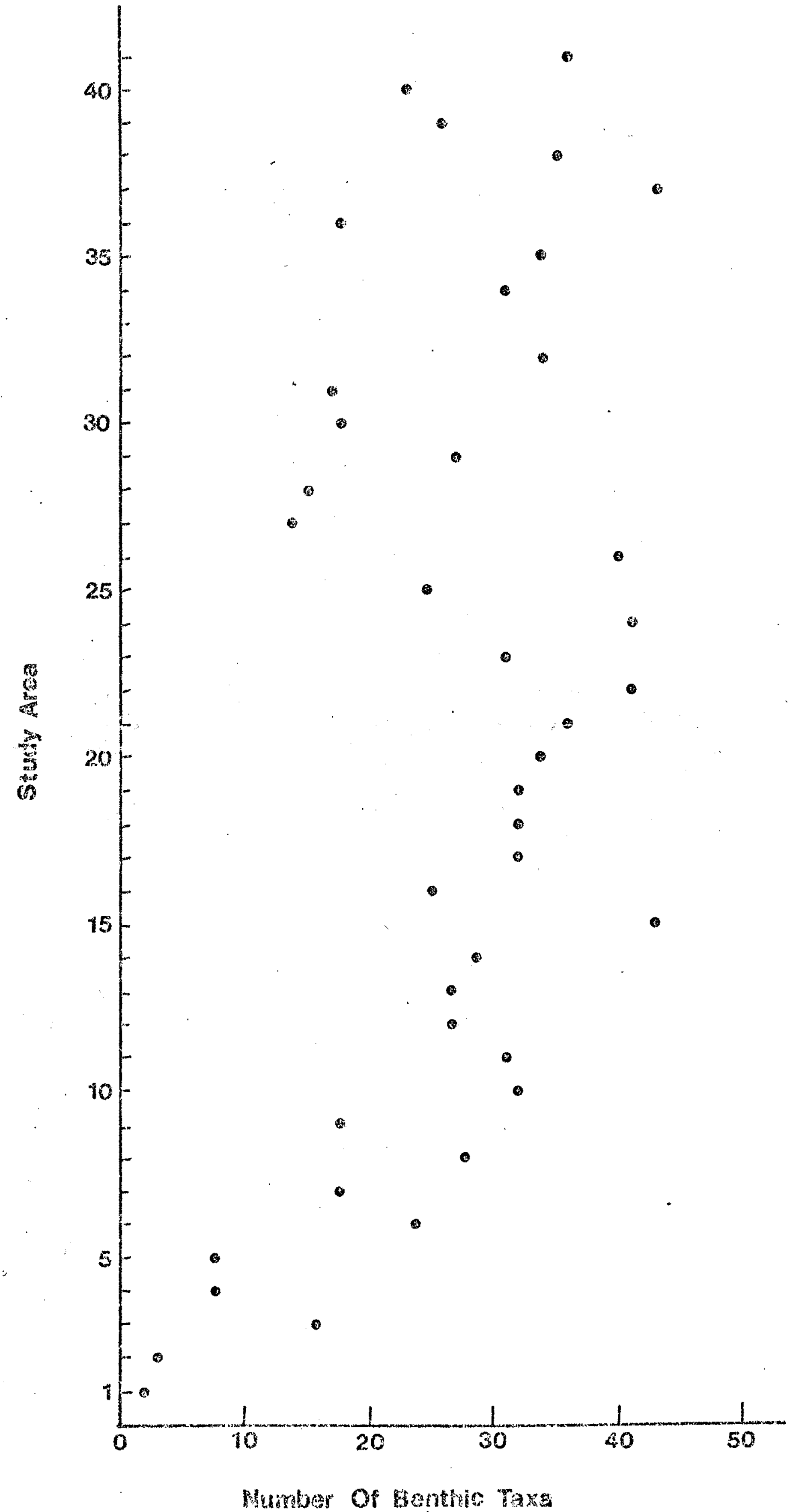
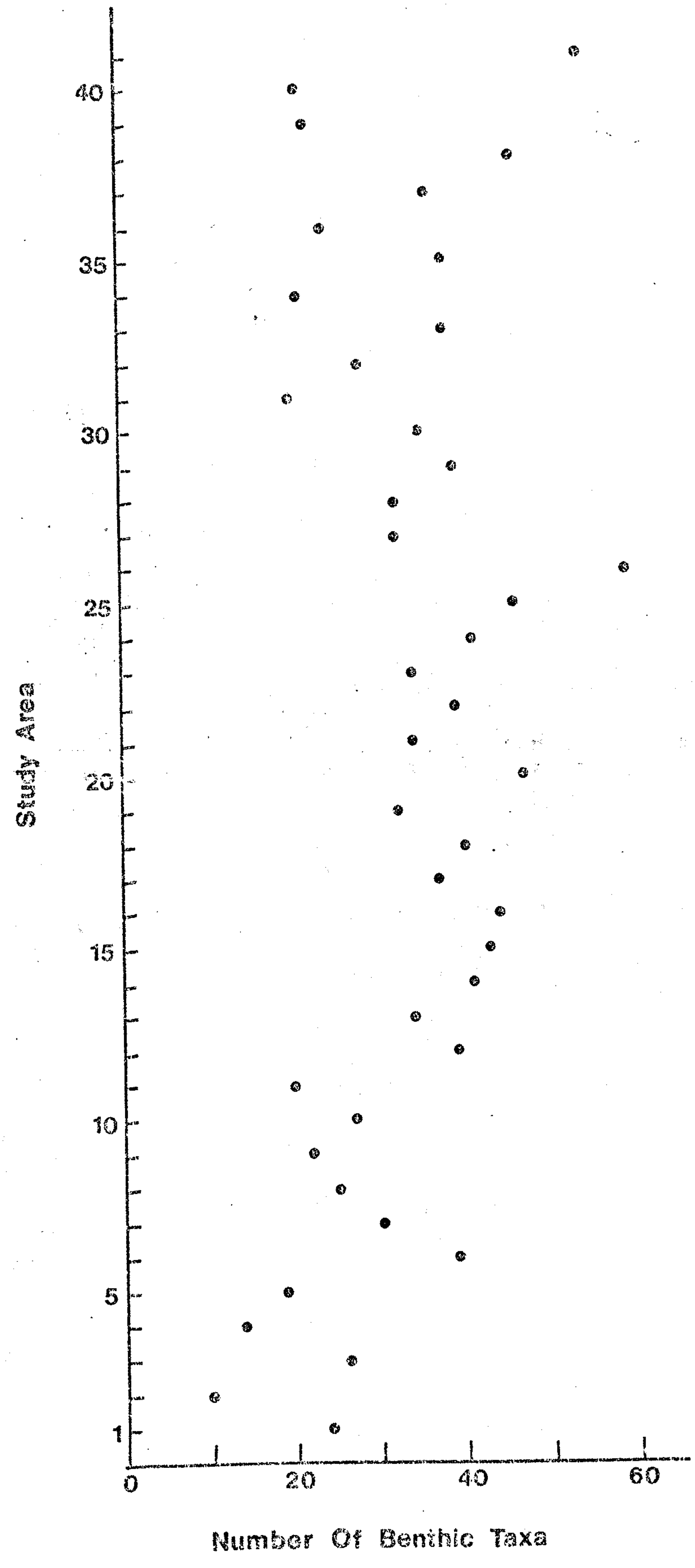

Study Area
40
35
30
25
20
15
10
5
1
0
10
20
30
40
50
Number Of Benthic Taxa

Fig. 15. Number of benthic taxa per area, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period II, 1975.


Study Area
40
35
30
25
20
15
10
5
1
0
20
40
60
Number Of Benthic Taxa

sampling period II. The smallest numbers of taxa were collected in areas 2 and 4 during the second sampling period. The most eutrophic areas generally yielded fewer numbers of taxa per area. Greater numbers of taxa typically occurred in the less eutrophic areas. Within each area, the number of taxa collected at each sampling site varied and presumably reflected the relationships existing between localized chemical-physical conditions and the specific habitat preferences of the benthic macroinvertebrates.

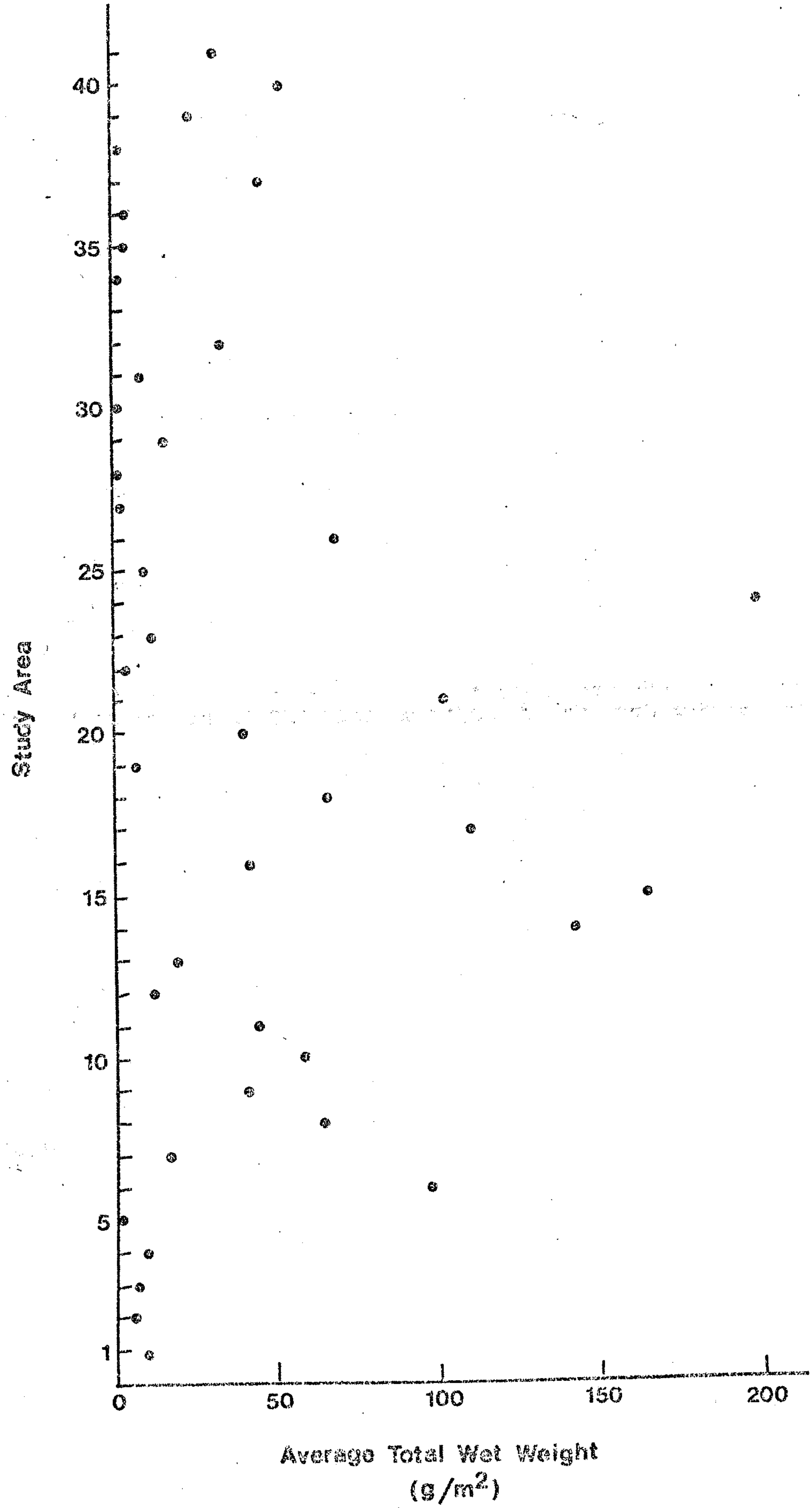
Data concerning the average total wet weight per square meter in each study area are summarized in Table 5 and Figs. 16 and 17. The largest standing crops during the first sampling interval were recorded in areas 15 and 24 which yielded values of 164.88881 g and 198.36105 g, respectively. Areas 5, 28, 30, and 34 supported the smallest standing crops. During the second sampling interval, the greatest biomasses occurred in areas 15 (116.67150 g), 21 (118.95024 g), and 24 (182.70788 g). Minimum average biomass values of 0.21487 g, 0.24803 g, and 0.17655 g were respectively found in areas 34, 36, and 40. The more eutrophic areas generally tended to support larger standing crops of macroinvertebrates. The majority of low biomass measurements were recorded in the less eutrophic areas (areas 27-41). Within each area, the standing crop collected at each sampling site varied, depending on the localization of stable habitats which were least affected by such factors as wind, current velocity, and fluctuating water levels.

Greater numbers of organisms per square meter were generally found in the more eutrophic study areas in Navigation Pool No. 8 (Table 6, Figs. 18 and 19). During both sampling periods, area 18

Table 5. Average total wet weight per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, 1975.

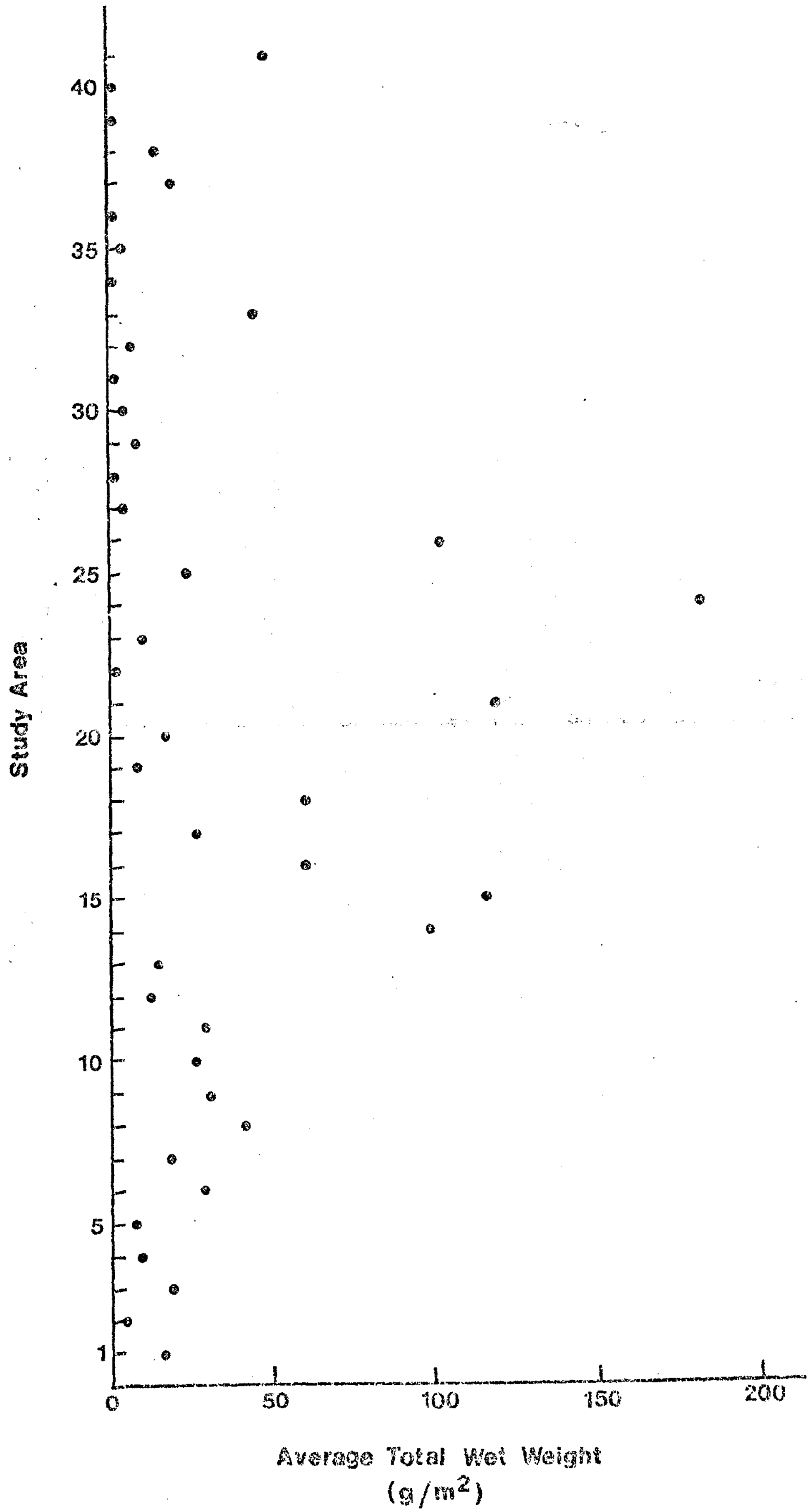
Study Area	Average Total Wet Weight (g/m^2)	
	Sampling Period I	Sampling Period II
1	9.99707	16.64946
2	4.86594	3.50078
3	7.03179	18.67620
4	9.06375	8.78962
5	0.96690	7.52258
6	97.57627	27.88587
7	17.55364	17.77129
8	64.10016	40.18359
9	41.84977	30.76422
10	58.62032	26.91939
11	44.36905	28.80068
12	12.14268	12.01869
13	19.33031	14.60854
14	142.06026	98.46423
15	164.88881	116.67150
16	42.82700	60.50511
17	110.00179	26.32796
18	66.03526	60.18668
19	6.67619	9.36383
20	40.42051	17.49011
21	102.56275	118.95024
22	3.92271	0.59595
23	11.80775	10.02954
24	198.36105	182.70788
25	9.65612	24.15494
26	68.61008	102.50325
27	2.80729	3.20883
28	0.25830	1.62788
29	16.95955	8.44686
30	0.63197	3.41358
31	8.68405	0.86163
32	33.47094	6.73200
33	---------	46.83873
34	0.97767	0.21487
35	4.15433	3.09235
36	4.38120	0.24803
37	46.02303	20.93448
38	2.43103	14.69509
39	24.41064	1.83608
40	53.69540	0.17655
41	32.78516	49.28777

Fig. 16. Average total wet weight per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period I, 1975.



Study Area
40
35
30
25
20
15
10
5
1
0
50
100
150
200
Average Total Wet Weight
(g/m²)

Fig. 17. Average total wet weight per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period II, 1975.



Study Area
40
35
30
25
20
15
10
5
1
0
50
100
150
200
Average Total Wet Weight
(g/m2)

Table 6. The mean number of macroinvertebrates per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, 1975.

Study Area	Mean Number of Macroinvertebrates	
	Sampling Period I	Sampling Period II
1	3271.8	13940.7
2	2109.5	2842.0
3	18739.7	8881.1
4	9384.9	7783.1
5	3508.6	4801.2
6	13435.9	5531.1
7	5630.9	5720.5
8	10796.9	7815.4
9	7546.7	5382.5
10	11313.5	2267.1
11	12592.1	3354.4
12	7185.0	5173.7
13	3736.7	3076.6
14	8816.6	6151.1
15	7891.1	5249.0
16	12101.4	3916.3
17	7439.0	2094.9
18	19975.2	14883.7
19	5196.1	2069.0
20	3943.4	3087.4
21	8635.8	3705.3
22	938.5	617.9
23	1330.2	805.2
24	8420.6	4362.0
25	2277.3	1709.5
26	12893.5	5343.7
27	718.9	460.7
28	508.0	531.8
29	11744.0	7337.4
30	882.5	3294.1
31	2152.5	663.1
32	4292.1	2368.3
33	-------	6586.0
34	680.2	236.8
35	938.5	1479.1
36	1016.0	331.6
37	3439.7	1750.4
38	2561.5	1188.5
39	3831.5	2525.5
40	3616.2	394.0
41	2893.0	4200.5

Fig. 18. Average number of organisms per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period 1, 1975.

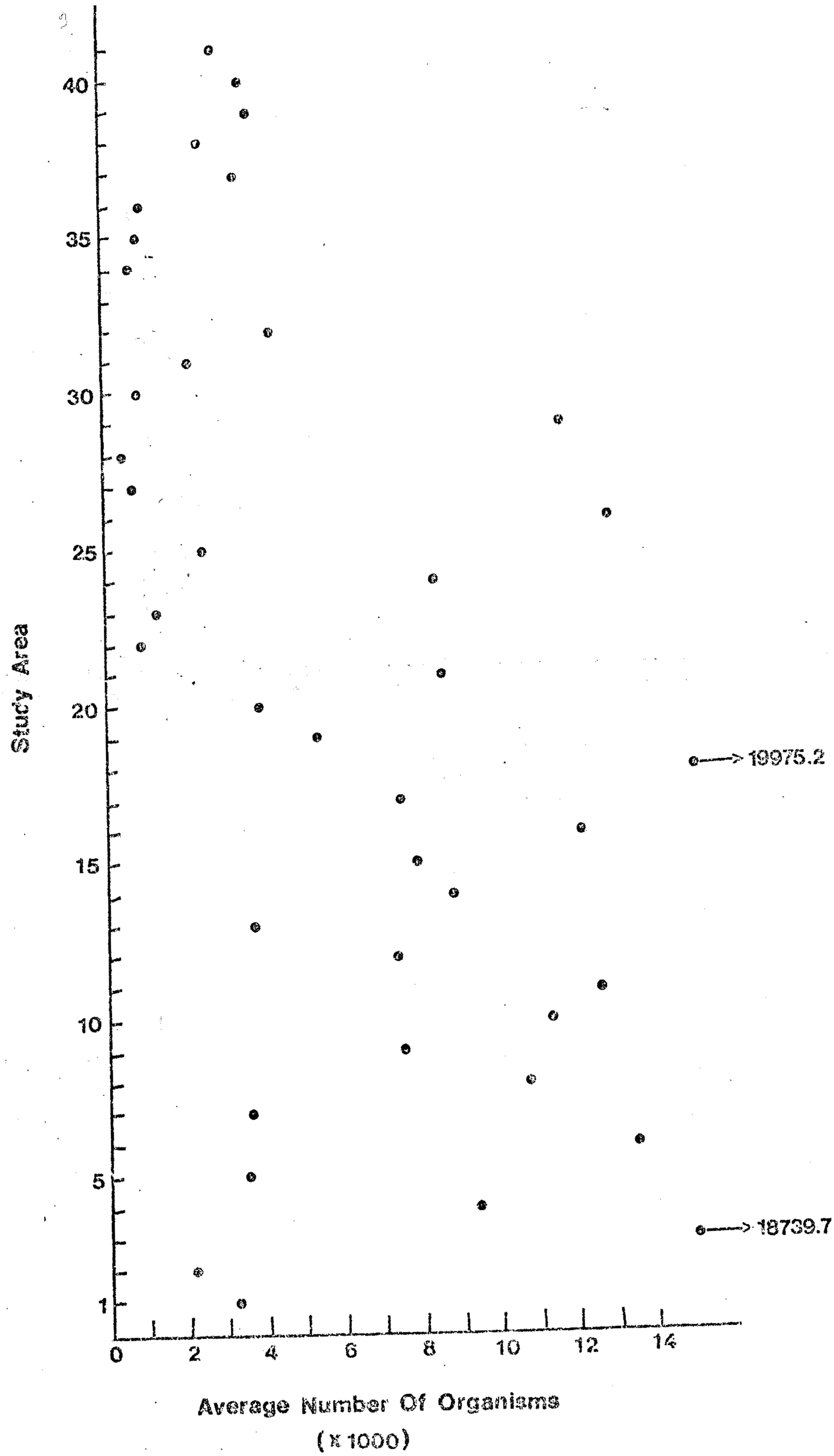
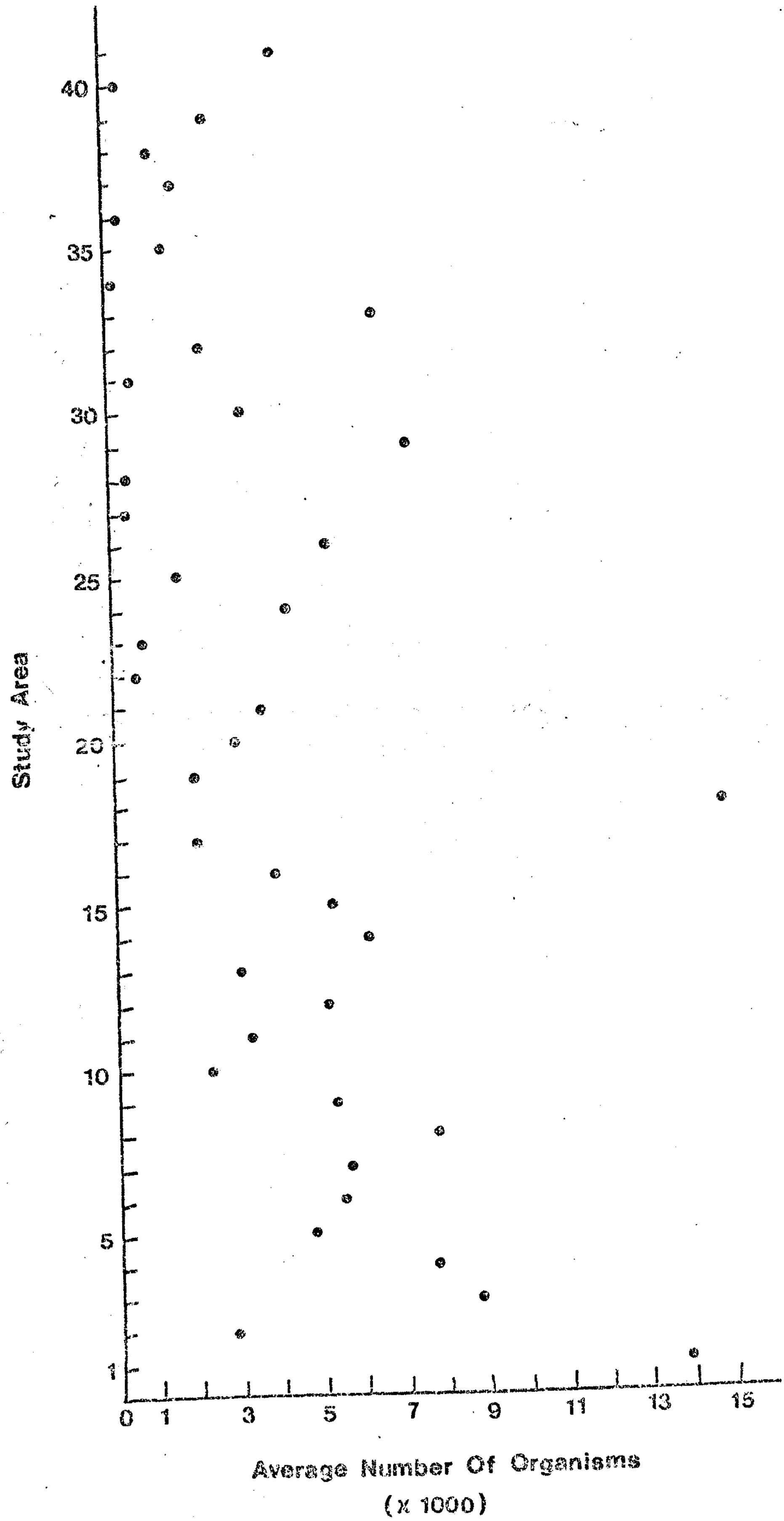

Study Area
Average Number Of Organisms
(x 1000)
19975.2
18739.7
0
2
4
6
8
10
12
14
1
5
10
15
20
25
30
35
40

Fig. 19. Average number of organisms per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period II, 1975.



Study Area
40
35
30
25
20
15
10
5
1
0
1
3
5
7
9
11
13
15
Average Number Of Organisms
(x 1000)

yielded the largest average number of organisms per square meter. Other high readings of 18,739.7 and 13,940.7 organisms per square meter were recorded in areas 3 (Sampling Period I) and 1 (Sampling Period II), respectively. The smallest numbers of benthic organisms were collected in areas 28 (Sampling Period I) and 34 (Sampling Period II). Within each study area, the number of macroinvertebrates collected at each site varied. Greater numbers were typically collected from the more stable habitats of the area.

Simple linear and multiple correlations related various chemical-physical parameters with characteristics of the inventoried benthic community (Tables 7 and 8). Simple correlation coefficients were low and ranged from -0.534 to 0.686 (Sampling Period I) and from -0.568 to 0.608 (Sampling Period II). Most of these simple correlation coefficients were not significant at the 0.01 or 0.05 levels. All multiple correlation coefficients (multi-r) were significant at the 0.01 level and ranged from 0.539 to 0.869 (Sampling Period I) and from 0.520 to 0.928 (Sampling Period II).

Dominant Groups of Benthic Macroinvertebrates

Tables 9 and 10 partially summarize the benthic macroinvertebrate composition of each study area and depict habitat preferences. The dominant benthic fauna and those organisms of particular interest are included and shall be discussed.

Class Turbellaria (Phylum Platyhelminthes). Flatworms inhabited many ecologically diverse areas and were more frequently found in

Table 7. Simple linear* and multiple$^{\Phi}$ correlations of selected benthic dependent variables with mean physical-chemical parameters in all study areas, Navigation Pool No. 8, *Upper Mississippi River*, Sampling Period I, 1975.

Benthic Dependent Variable	Physical-Chemical Parameter									Sediment Particle Size Fraction						Multi-r
	Depth	Current Velocity	Turbidity	Dissolved Oxygen	Temperature	Organic Nitrogen	NO_3^-	NO_2^-	PO_4^{3-}	1	2	3	4	5	6	
Number of taxa/area	.128	.332··	.336··	.317··	-.353··	-.245	.079	.234	.178	.081	-.110	.140	.136	.186	-.287	.760·
Mean total biomass/m^2	-.184	-.163	-.058	-.174	-.306	.353··	.573·	.138	.380··	.185	-.130	-.314··	-.141	.159	.231	.739·
Mean # of macroinvertebrates/m^2	-.321··	-.483·	-.384··	-.482·	-.244	.464·	.669·	.094	.209	.021	-.100	-.516·	-.534·	.112	.686·	.859·
Turbellaria	-.024	.035	.188	-.062	-.241	.088	.264	-.011	.123	.091	-.179	-.163	-.070	.349··	.044	.680·
Nematoda	.005	-.054	-.053	-.220	-.060	.173	.486·	.149	.314··	.134	-.070	-.126	-.228	.070	.280	.797·
Oligochaeta	-.268	-.417·	-.352··	-.421·	-.103	.383··	.509·	.042	.142	-.026	-.056	-.433·	-.485·	.003	.624·	.780·
Hirudinea	-.434·	-.517·	-.529·	-.439·	-.200	.607·	.671·	.158	.108	-.016	-.092	-.418·	-.503·	.034	.629·	.846·
Asellus militaris	-.118	-.201	-.198	-.089	-.047	.337··	.511·	.070	.137	.111	-.018	-.196	-.226	-.097	.343··	.700·
Hyalella azteca	-.311··	-.308	-.310··	-.319··	-.222	.409·	.520·	.190	.262	.090	-.182	-.303	-.408·	.138	.410·	.694·
Hexagenia	-.323··	-.349··	-.297	-.174	-.368··	.270	.348··	.169	.123	-.042	-.070	-.386··	-.422·	.024	.541·	.812·
Cheumatopsyche	.042	.323··	.303	.316··	-.131	-.107	-.294	-.062	-.118	-.117	-.155	.313··	.308··	-.145	-.319··	.606·
Oecetis	.140	.218	.298	-.151	-.278	-.033	.340··	.090	.415·	.107	-.107	-.047	.061	.461·	-.228	.853·
Chironomus	-.129	-.425·	-.417·	-.242	-.282	.364··	.183	-.106	-.126	-.144	-.225	-.286	-.360··	.131	.399·	.729·
Cryptochironomus	-.050	.191	.189	.216	-.083	-.013	-.134	.066	-.163	.144	-.069	.058	.138	-.019	-.182	.539·
Endochironomus	-.224	-.191	-.222	-.174	-.001	-.062	-.010	.060	-.181	-.124	-.152	-.181	-.212	.051	.265	.584·
Polypedilum	-.068	.014	-.044	.011	-.217	-.054	.100	.030	-.038	.077	-.189	.064	-.154	-.026	.118	.679·
Xenochironomus	.104	.102	-.021	.053	.151	.106	.186	.017	.110	.560·	-.040	.161	-.019	-.148	-.031	.856·
Coelotanypus	-.141	-.036	-.041	-.141	-.139	.067	.316··	.112	.152	.199	-.090	-.360··	-.221	.375··	.140	.646·
Pentaneura	-.208	-.216	-.186	-.115	-.186	.127	.339··	-.054	.084	-.067	-.229	-.332··	-.384··	.152	.402·	.679·
Palpomyia	.490·	-.052	.098	.394··	.061	-.349··	-.416·	-.167	-.464·	-.153	-.112	.222	.080	-.011	-.152	.779·
Amnicola	.017	-.066	.043	-.162	-.195	.148	.431·	.029	.192	.185	-.011	-.121	-.001	.180	.088	.831·
Sphaerium	.030	-.056	.126	-.151	-.198	.118	.357··	.060	.253	.264	-.050	-.135	.076	.290	-.035	.864·

·--Significant at the 0.01 level
··--Significant at the 0.05 level
*--38 degrees of freedom
Φ--24 degrees of freedom

Table 8. Simple linear* and multiple♦ correlations of selected benthic dependent variables with the mean physical-chemical parameters in all study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period II, 1975.

Benthic Dependent Variable	Physical-Chemical Parameter															Multi-r
										Sediment Particle Size Fraction						
	Depth	Current Velocity	Turbidity	Dissolved Oxygen	Temperature	Organic Nitrogen	NO_3^-	NO_2^-	PO_4^{3-}	1	2	3	4	5	6	
Number of taxa/area	.143	.249	.338··	.208	-.294	-.188	.157	.313··	.359··	§	-.072	.178	.034	.160	-.221	.860·
Mean total biomass/m^2	-.059	-.123	.028	-.237	-.245	.287	.589·	.119	.469·	.229	-.044	-.201	-.110	.228	.123	.819·
Mean # of macroinvertebrates/m^2	-.142	-.472·	-.429·	-.511·	-.130	.549·	.608·	.062	.327··	-.050	.111	-.304	-.431·	-.057	.571·	.785·
Turbellaria	-.216	-.035	-.122	-.094	-.017	.096	.386··	.541·	.213	-.127	-.025	-.032	-.184	-.040	.200	.819·
Nematoda	.084	.017	.027	-.109	-.082	.147	.457·	.297	.292	-.095	-.039	-.061	-.046	-.021	.132	.814·
Oligochaeta	-.073	-.387··	-.355··	-.374··	-.137	.453·	.402·	.020	.238	-.159	.091	-.256	-.350··	-.088	.482·	.698·
Hirudinea	-.231	-.412·	-.434·	-.402·	.132	.202	.429·	.120	.024	.076	-.054	-.355··	-.391··	-.013	.551·	.793·
Asellus militaris	-.154	-.182	-.063	-.209	-.094	.318··	.558·	.245	.317··	.276	-.038	-.184	-.159	.176	.153	.766·
Hyalella azteca	-.248	-.419·	-.543·	-.568·	.081	.324··	.363··	.007	.105	-.009	.129	-.181	-.369··	-.130	.476	.722·
Hexagenia	-.083	-.258	-.160	-.252	-.193	.254	.318··	.326··	.222	-.026	.142	-.174	-.341··	.014	.360··	.718·
Cheumatopsyche	.107	.504·	.443·	.386··	.047	-.404·	-.325··	-.135	-.135	.217	.152	.415·	.232	-.100	-.422·	.696·
Oecetis	.061	.130	.285	-.136	-.315··	.030	.430·	.112	.484·	.071	-.051	-.105	.023	.353··	-.087	.870·
Chironomus	-.120	-.358··	-.320··	-.163	-.221	.414·	.415·	-.097	-.003	-.044	-.194	-.307··	-.340··	.083	.426	.591·
Cryptochironomus	.140	.073	.108	-.206	-.171	.111	.128	-.125	.425·	-.129	.077	.105	.004	.084	-.120	.715·
Endochironomus	-.186	-.299	-.384··	-.330··	.090	.202	.103	.016	.039	.037	.252	.019	-.184	-.119	.179	.520·
Polypedilum	-.041	-.219	-.252	-.409·	.013	.224	.077	0	.217	-.064	.286	.070	-.192	-.064	.131	.702·
Xenochironomus	.097	.503·	.365··	.244	.156	-.277	-.098	-.081	.080	.073	-.036	.365··	.202	-.076	-.345··	.721·
Coelotanypus	.197	-.134	.047	-.016	-.115	.047	.309··	.135	.155	-.081	-.060	-.228	-.269	.301	.163	.730·
Pentaneura	.068	-.349··	-.358··	-.437·	-.099	.316··	.348··	.007	.293	-.134	.226	-.038	-.370··	.019	.308··	.715·
Palpomyia	.157	.287	.290	.493·	.039	-.334··	-.497·	-.207	-.309··	-.195	-.169	.371··	.496·	-.281	-.426·	.717·
Amnicola	.034	-.030	.092	-.159	-.200	.066	.329··	.099	.186	.361··	-.015	-.056	.050	.242	-.013	.928·
Sphaerium	-.063	-.135	.025	-.128	-.128	.285	.503·	.040	.256	.236	-.024	-.189	-.068	.151	.116	.741·

·—Significant at the 0.01 level
··—Significant at the 0.05 level
*—39 degrees of freedom
♦—25 degrees of freedom
§—Correlation could not be calculated. A square of a negative argument was obtained.

Table 9. The mean number of selected macroinvertebrates per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period I, 1975.

Study Area	Taxon						
	Tur.	Nem.	Oligo.	Hir.	A. mil.	H. azt.	G. fasc.
1			3250.28				
2			1506.75				
3		186.41	17306.10	215.25	57.26	487.76	
4			8351.70	645.75		64.58	
5		21.53	3336.38	43.05		21.53	21.53
6	33.58	124.41	9193.76	301.35	186.41	507.13	
7	28.84	78.78	4211.58	315.56	136.47	559.65	
8	14.21	121.83	7512.23	473.55	43.05	610.02	
9		312.11	6199.20	71.89		10.76	
10	129.15	28.84	4054.02	688.80	172.20	2044.88	
11	7.32	193.73	5130.27	380.13		674.59	
12	4.74	18.94	5405.36	9.47		18.94	
13		43.05	2186.08	47.79		18.94	
14	76.63	287.14	2334.17	377.98	1257.92	153.26	
15	105.04	344.40	1750.84	339.66	449.44	1148.14	
16	14.21	110.21	10011.71	153.26	114.94	172.20	
17	4.74	535.54	4300.26	110.21	167.46	129.15	9.47
18	201.04	150.68	16609.98	423.18	265.62	746.06	
19		153.26	4366.99	14.21	9.47	105.04	
20		107.63	1463.70	193.73	146.37	456.33	
21	234.19	315.56	1506.75	76.63	61.99	47.79	
22	8.61		315.56	3.01	11.62	71.89	
23		4.74	717.64		47.79	95.57	
24	143.36	224.72	2238.60	181.67	61.99	71.89	
25		24.11	1516.22	9.47	38.31	9.47	
26		308.67	9069.34	207.93	50.37	1119.30	
27			401.66			38.31	
28			149.38			11.62	
29	21.53	261.74	10748.29	46.49	10.76	139.91	
30	215.25		416.29		7.32	35.73	
31		25.83	1730.61				8.61
32	21.53	43.05	2461.17	28.84	43.05	14.21	7.32
33							
34		3.44	269.06	7.32		18.08	14.21
35		24.11	258.30			9.47	
36	12.48		854.97			6.03	
37	9.47	33.58	1635.90	76.63	33.58	129.15	
38		11.62	1072.38	3.87		27.55	
39		21.53	2970.45			43.05	7.32
40		50.37	2920.08	21.53			
41	119.68	487.76	1105.09	33.58	138.62	258.30	

Table 9. (cont'd)

Study Area	Deca.	Hydra.	P. plac.	Siph.	Steno.	Tri.	Brach.
1							
2							
3							
4							
5							
6		4.74					
7							
8						7.32	
9							
10							
11							
12							14.21
13							
14							4.74
15							
16							47.79
17							18.94
18						7.32	
19							14.21
20			4.31				8.61
21							
22						3.01	14.21
23							9.47
24				14.21			
25							4.74
26		7.32				7.32	
27			4.74				
28							54.67
29							21.53
30					7.32		7.32
31							17.22
32					7.32		14.21
33							
34					7.32		10.76
35		4.74	9.47	4.74			14.21
36							12.48
37							
38			11.62		7.75		31.43
39				7.32	7.32		143.36
40							
41							9.47

Table 9. (cont'd)

Study Area	Taxon						
	Hex.	Eph.	Enal.	Ophio.	Corix.	Sialis	Neur.
1							
2							
3	14.21						
4							
5							
6	1195.93				9.47		
7	150.68						
8	552.33		14.21		35.73		
9	516.60						
10	373.24		14.21		7.32		
11	789.11						
12	234.19						
13	244.09					9.47	
14	554.91						
15	181.67	4.74				4.74	
16	750.79						
17	1334.55			4.74	4.74		
18	767.58		7.32				
19	110.21	4.74					
20	426.20		4.31				
21	28.84		4.74		4.74		
22		3.01			48.65		8.61
23	86.10	9.47			52.52		
24	186.41						9.47
25	320.29	4.74					
26	437.82			7.32			
27		9.47			9.47		4.74
28		8.61			8.61		
29	236.78			14.21			
30	7.32						
31	129.15				8.61		
32	172.20	21.53					28.84
33							
34	3.44	28.84					7.32
35	71.89	28.84					
36					6.03		
37	86.10		4.74		4.74		4.74
38	19.37	3.87			11.62		11.62
39	186.41				14.21		
40	172.20				35.73		
41	43.05				9.47		

Table 9. (cont'd)

Study Area	Taxon							
	Cheum.	Hydro.	Stacto.	Oec.	Nym.	Sten.	Chao.	Simu.
1								
2								
3			28.84					
4								
5								
6								
7								
8	7.32							
9	10.76							
10			14.21					
11			14.21				14.21	
12				4.74			33.58	
13								
14						4.74		
15	9.47	4.74	4.74	9.47	18.94	4.74		
16	14.21		4.74					28.84
17	9.47							
18								
19			4.74	4.74			4.74	
20	12.92							60.27
21			18.94	18.94		4.74		
22	46.06			3.01		5.60		5.60
23				4.74		4.74		9.47
24	4.74			14.21		4.74		4.74
25								
26	7.32			21.53	7.32			7.32
27	14.21		9.47					
28								
29	3.44			3.44				
30	272.51	7.32						7.32
31								
32	982.83	14.21						
33								
34	93.42	3.44						
35	90.84	4.74				14.21		
36								
37	38.31		14.21	18.94				
38	485.17	23.68	27.55			7.75		109.78
39	39.73							
40								50.37
41	43.05			9.47		38.31		

Table 9. (cont'd)

Study Area	Taxon						
	Chiro.	Crypto.	Endo.	Glypto.	Poly.	Xeno.	Tany.
1							
2	559.65		43.05				
3			215.25	86.10	14.21		
4	107.63	21.53	86.10				
5			21.53		21.53		
6	1090.46	18.94			33.58		
7	7.32		7.32		21.53		7.32
8	717.64	7.32	64.58	21.53	21.53		
9	21.53		21.53		32.29		
10	1628.58	64.58	610.02	552.43	28.84		
11	287.14	21.53	3817.24	344.40	186.41		
12	641.01	14.21			24.11		14.21
13	626.81	9.47	52.52		14.21		4.74
14	224.72				47.79		
15	61.99	14.21	9.47		110.21	205.78	4.74
16	148.09	24.11			18.94		
17	47.79	14.21	4.74		57.26	4.74	
18	7.32		28.84	43.05	28.84		
19	14.21	14.21	18.94	9.47	38.31		33.58
20	38.75	30.14	525.21	17.22	30.14		
21	33.58	4.74	24.11		18.94		
22	28.84		17.22	8.61	74.48	3.01	
23	38.31				18.94		9.47
24	61.99	4.74	14.21		18.94		
25	57.26	14.21			4.74		4.74
26			7.32		64.58		
27		9.47	157.99	33.58	4.74		
28		3.01			8.61		
29	18.08	24.97			28.84		
30		14.21	7.32		14.21		
31	17.22	68.88			8.61		
32		71.89			50.37		
33							
34	3.44	3.44	61.13	39.61	14.21	3.44	3.44
35	57.26	14.21	14.21	81.36	28.84		9.47
36	6.03	12.48	12.48	12.48	6.03		
37	47.79	9.47	86.10	4.74	57.26		4.74
38	7.75	15.50	105.47	211.50	121.40	11.62	3.87
39	7.32	28.84					
40	7.32	7.32					
41	33.58	18.94		9.47	67.16	105.04	

Table 9. (cont'd)

Study Area	Taxon							
	Coelo.	Pent.	Atrich.	Palp.	Physa	Amni.	Musc.	Sphaer.
1								
2								
3	14.21							
4								
5								
6	4.74	38.31		14.21	4.74		502.39	114.94
7	35.73	28.84					7.32	14.21
8		35.73		64.58			129.15	265.62
9		10.76		21.53			129.15	21.53
10	14.21	39.73		43.05	39.73	14.21	143.35	150.68
11		114.94		39.73			43.05	21.53
12		33.58		205.78			57.26	
13	4.74	14.21		114.94			18.94	24.11
14	18.94	52.52		4.74	9.47	421.03	478.29	1951.46
15	9.47	33.58		9.47	90.84	153.26	287.14	2195.55
16	9.47	14.21				4.74	306.09	114.94
17	4.74	57.26					393.87	133.89
18	7.32	28.84			50.37	78.78	100.31	114.94
19	14.21	14.21		18.94			9.47	
20	4.31				34.44		236.78	64.58
21	14.21					473.55	526.07	4658.87
22	3.01	3.01	17.22	114.94		5.60	3.01	3.01
23	9.47	4.74	14.21	81.36		9.47	4.74	
24		24.11		4.74	14.21	53.08	856.26	3271.80
25	9.47	18.94				4.74	138.62	14.21
26		50.37		39.73	28.84	136.47	179.52	480.87
27				9.47				
28			108.92	132.16				
29	10.76	10.76					14.21	96.86
30			14.21	7.32		7.32		
31	17.22	25.83		17.22				
32		28.84	21.53	39.73		7.32	39.73	57.26
33								
34	3.44			10.76	7.32			
35		18.94	33.58	38.31			4.74	
36	6.03		18.51	12.48				
37	38.31	14.21		4.74		67.16	43.05	363.34
38		7.75	15.50	43.05				
39	7.32	14.21	7.32	14.21			143.35	107.63
40		14.21	39.73	14.21			7.32	14.21
41		18.94	14.21	28.84		28.84	4.74	38.31

Table 10. The mean number of selected macroinvertebrates per square meter, 41 study areas, Navigation Pool No. 8, Upper Mississippi River, Sampling Period II, 1975.

Study Area	Taxon						
	Tur.	Nem.	Oligo.	Hir.	A. mil.	H. azt.	G. fasc.
1		21.53	10302.11	53.83		1991.53	
2		32.30	1830.05	86.12	10.77	807.38	
3		118.42	3358.68	775.08	10.77	4117.61	
4			5909.99	86.12	10.77	1571.69	
5		21.53	3369.45	96.89	21.53	635.14	
6	16.79	124.44	3509.39	50.16	28.63	925.79	
7	93.22	86.12	4636.05	157.81	39.40	369.67	
8	3.66	60.93	5892.12	175.90	35.96	631.47	
9		32.30	3902.31	10.77		16.15	
10		21.53	832.57	100.55	82.56	229.73	
11	25.19	10.77	2361.20	362.35	32.30	68.25	
12		76.65	3904.03	45.43	19.16	38.32	
13	5.38	8.18	2319.86	29.71		142.74	
14	35.96	492.82	1468.78	344.48	126.81	35.96	
15	14.43	110.02	760.65	265.46	239.20	373.11	
16	12.06	38.32	2772.63	28.63	7.10	45.43	
17	12.06	31.00	1631.54	4.74	2.37	71.69	
18	132.84	204.54	10894.18	351.58	107.65	1072.84	
19	5.38	29.71	1334.86	26.91		16.15	
20	94.73	219.61	1481.26	127.03	79.66	294.96	
21		251.26	691.33	143.61	114.75	47.80	
22		20.02	64.59	4.31		4.31	
23	2.37	23.90	366.01	110.02		14.43	
24	21.53	62.22	301.42	160.18	248.89	47.80	
25	9.47	16.79	1110.09	9.47	2.37	40.69	
26	43.06	247.60	2443.66	28.63	82.56	168.58	
27		12.06	160.18		2.37	4.74	
28		5.81	157.81	2.80			
29	26.91	235.11	6448.24	25.84	5.38	60.93	
30		14.43	2598.03	7.10		3.66	
31			249.75	4.31			
32		35.96	1722.40	7.10			
33		200.87	5767.67	95.59	2.37	21.53	
34		2.80	88.92	8.18	2.80	5.38	
35		110.02	679.49	2.37	4.74	47.80	
36			122.94	15.29		3.01	
37	9.47	88.49	897.16	40.69	4.74	255.99	
38	10.77	16.15	516.72	23.25	3.66	193.77	
39			2099.18				
40		10.77	79.02	3.66			
41	79.02	279.89	2480.69	71.69	43.06	203.24	

Table 10. (cont'd)

Study Area	Taxon						
	Deca.	Hydra.	P. plac.	Siph.	Steno.	Tri.	Brach.
1							
2							
3	5.38						
4							10.77
5							
6		3.66					
7							
8							
9						5.38	
10						3.66	3.66
11							
12							2.37
13							
14							
15		2.37					
16							
17					2.37	2.37	
18					3.66		
19							10.77
20		2.15					6.46
21							
22							25.84
23							9.47
24							
25							4.74
26							21.53
27							7.10
28					1.51	1.51	32.94
29							16.15
30					3.66	7.10	14.43
31					4.31		4.31
32							17.87
33							21.53
34							13.56
35					2.37		28.63
36					3.01		9.26
37		2.37					
38					16.15		5.38
39							60.93
40							25.19
41							7.10

Table 10. (cont'd)

Study Area	Taxon						
	Hex.	Eph.	Enal.	Ophio.	Corix.	Sialis	Neur.
1	107.65						
2							
3	86.12					16.15	
4	10.77		10.77				
5	21.53						
6	322.95		2.37	2.37	2.37	2.37	
7	114.75			3.66			
8	229.73				3.66	3.66	
9	387.54					59.21	
10	68.25				21.53		
11	233.17						
12	246.30				2.37	7.10	
13	118.42					5.38	
14	52.53				4.74		9.47
15	35.96		4.74		2.37		12.06
16	526.19			2.37		2.37	
17	167.50		2.37	2.37		2.37	
18	412.73		3.66	3.66	7.10		
19	239.63	2.80				2.80	2.80
20	342.33		4.31		6.46	2.15	4.31
21	35.96						
22	8.61				11.41		
23	40.69				4.74		
24	45.43						
25	76.65				2.37		2.37
26	628.03	3.66			7.10		3.66
27	12.06	2.37					
28	48.87			2.80			
29	235.11			1.72	1.72		
30	17.87				3.66		
31	4.31				4.31		25.84
32	129.18						
33	119.71						
34	2.80						
35	193.77	2.37				12.06	
36							
37	31.00		7.10				2.37
38	39.40	1.72					3.66
39	103.99						
40							
41	71.69		7.10		4.74		4.74

Table 10. (cont'd)

Study Area	Cheum.	Hydro.	Stacto.	Oec.	Nym.	Sten.	Chao.	Simu.
1					10.77			
2								
3					21.53			
4					21.53			
5					10.77			
6	2.37		2.37	4.74	2.37			
7	3.66			3.66	7.10			
8							7.10	
9		10.77					252.98	
10								
11							3.66	
12			2.37	4.74			98.18	
13				2.80			69.97	
14			2.37	12.06			2.37	
15			7.10	14.43		2.37	9.47	
16	4.74			7.10		2.37	2.37	
17	4.74			4.74		2.37	2.37	
18			17.87	25.19		3.66		
19	2.80			2.80			64.59	
20	8.61	4.31						
21				43.06			4.74	
22	4.31		1.51			1.51	1.51	
23				7.10			2.37	
24	2.37			26.27		2.37	9.47	
25	23.90						7.10	2.37
26	21.53		3.66	50.16		17.87	7.10	
27	16.79	26.27				16.79	4.74	
28	32.94	4.31					2.80	
29				9.04			3.66	
30	79.02	168.58		7.10				
31	172.24					8.61		
32				3.66			3.66	
33	19.16			16.79			16.79	
34	8.18		5.38					
35	59.85	28.63		2.37		2.37	12.06	
36	27.77			3.01			3.01	
37				16.79	4.74		2.37	
38	91.50	9.04	1.72	1.72		41.34		
39	7.10							
40						10.77		
41	88.49	2.37		14.43	2.37	21.53	12.06	

Table 10. (cont'd)

Study Area	Taxon						
	Chiro.	Crypto.	Endo.	Glypto.	Poly.	Xeno.	Tany.
1		139.95	139.95	21.53	441.37		
2			32.30				
3			37.68	10.77	166.86		
4			21.53		32.30		
5			419.84		75.36		
6	239.20	2.37			12.06		
7	3.66		7.10		14.43		
8	175.90	3.66		3.66	28.63		
9		5.38			80.74	5.38	
10	426.94	14.43	86.12		28.63		
11	103.99	25.19			7.10		
12	157.81	14.43	9.47	4.74	31.00		4.74
13	94.30	5.38	18.95		21.53		2.80
14	464.19	4.74			2.37		7.10
15	150.71	2.37	7.10		2.37		335.01
16	28.63	23.90			28.63	43.06	2.37
17	9.47	4.74	9.47	2.37			
18	7.10	7.10	17.87				
19	8.18	40.48		2.80	80.74	2.80	
20	8.61	10.77	60.28		92.58	8.61	2.15
21	19.16	16.79			4.74	2.37	
22	1.51	14.43	2.80		14.43	5.81	2.80
23	14.43	9.47	2.37		4.74	35.96	12.06
24	52.53	21.53			4.74		
25		33.59	7.10	2.37	57.49	26.27	
26	17.87	50.16	7.10		14.43	75.36	14.43
27	4.74	7.10	4.74	12.06	14.43	64.59	
28	1.51	8.61			7.10	8.61	1.51
29	23.25	53.83			28.63	5.38	5.38
30	3.66	25.19	3.66		111.31	79.02	
31		8.61			17.22	90.43	
32	28.63	43.06			118.42		3.66
33	2.37	23.90	2.37		7.10	2.37	2.37
34			2.80			5.38	
35		14.43	7.10		69.33	14.43	4.74
36		9.26		6.24	9.26	6.24	
37	21.53	7.10	2.37	4.74	12.06		
38	1.72	1.72	30.57	3.66	10.77	17.87	
39	3.66	17.87			7.10	14.43	10.77
40		7.10		3.66	7.10	21.53	3.66
41	23.90	47.80	2.37	21.53	33.59	193.77	7.10

Table 10. (cont'd)

Study Area	Taxon							
	Coelo.	Pent.	Atrich.	Palp.	Physa	Amni.	Musc.	Sphaer.
1		333.72						
2		10.77						
3		43.06						
4		64.59						
5		10.77		21.53				
6	4.74	14.43		7.10	2.37	2.37	52.53	150.71
7	21.53	39.40		3.66		7.10	7.10	43.06
8	21.53	50.16				3.66	64.59	405.41
9		64.59					306.80	193.77
10	14.43	28.63		39.40			50.16	125.52
11		68.25			3.66		14.43	10.77
12	88.49	174.61		4.74	2.37		12.06	28.63
13		48.44		13.56	2.80		5.38	56.62
14	31.00	31.00			2.37	88.49	380.44	2172.16
15	16.79	14.43			28.63	191.40	447.39	1729.50
16	9.47	35.96		2.37		4.74	59.85	157.81
17	7.10	23.90					16.79	38.32
18	111.31	132.84			251.26	82.56	75.36	667.43
19	53.83	72.77		8.18				21.53
20	12.92	40.91	2.15	4.31		10.77	32.30	60.28
21	9.47	7.10			7.10	401.97	282.26	1370.82
22	2.80		155.02	213.79				2.80
23	14.43	4.74	23.90	28.63				12.06
24	38.32	43.06		2.37		86.12	614.90	2423.42
25	4.74	7.10	110.02	12.06		2.37	9.47	7.10
26	75.36	103.99		3.66	93.22	68.25	17.87	254.70
27		4.74	12.06	21.53				2.37
28		7.10	55.98	90.43		2.80	1.51	2.80
29	9.04	28.63		10.77		1.72	3.66	10.77
30	7.10	3.66	7.10	17.87				7.10
31	12.92		4.31					
32	25.19	32.30		17.87			7.10	39.40
33	16.79	16.79	26.27	9.47		14.43	4.74	93.22
34			37.68	29.71				
35	12.06	45.43	7.10	28.63			4.74	
36			33.80	43.06				
37	2.37	4.74				31.00	31.00	165.14
38	5.38	7.10	16.15	37.68	12.49	1.72	1.72	3.66
39	3.66	3.66	14.43	28.63				3.66
40			57.49	114.75				
41	7.10	66.96	9.47	16.79	45.43	45.43	7.10	90.86

areas 10 to 26 (Appendix Fig. I-1). The greatest densities were recorded in areas 21 (Sampling Period I) and 18 (Sampling Period II). High densities were evident in both extremes of eutrophy.

Phylum Nematoda. Representatives of the Phylum Nematoda were found in all study areas except 4 and 36 (Appendix Fig. I-2). High densities were recorded in a wide variety of habitats and under a wide range of ecological conditions. Areas 17 and 41 (Sampling Period I) and area 14 (Sampling Period II) supported the largest standing crops of nematodes. The larger standing crops were generally distributed more frequently in those areas having intermediate current velocities.

Class Oligochaeta (Phylum Annelida). The oligochaetes were ubiquitous (Appendix Fig. I-3) and were by far the most abundant and dominant benthic organisms inventoried. The general distribution of these macroinvertebrates favored the more eutrophic areas (areas 1-18). Greatest densities were recorded in areas 3 and 18 (Sampling Period I) and areas 1 and 18 (Sampling Period II). This distribution agrees with the general ecological characteristics of the oligochaetes which can thrive in habitats having fine sediments high in organic matter, low current velocities, and low dissolved oxygen levels.

Class Hirudinea (Phylum Annelida). All areas except 27 and 39 supported benthic communities having leeches. The more eutrophic areas (areas 1-18) favored larger standing crops of leeches (Appendix Fig. I-4). Areas 4 and 10 (Sampling Period I) and area 3 (Sampling Period II) supported the greatest densities during the respective sampling intervals. This distributional pattern corresponds to the general preference of leeches for shallow habitats having undetectable or low current velocities and sufficient debris and plant material to afford concealment and adequate substrate for attachment.

Order Isopoda (Phylum Arthropoda, Class Crustacea). *Asellus militaris* was the only benthic representative of the Order Isopoda to be collected. Representatives of this species occurred in all benthic assemblages except those found in areas 1, 9, 13, 28, 31, 36, 39, and 40. The general distribution of *Asellus militaris* favored those areas of intermediate eutrophic status (areas 14-26) (Appendix Fig. I-5). Area 14 supported the greatest density of *A. militaris* (1257.92 individuals/ m^2) during the first sampling period. The greatest densities during the second sampling period were recorded in areas 24 (248.89 individuals/m^2) and 15 (239.20 individuals/m^2). Greater numbers of *A. militaris* were generally found in shallower habitats supporting sufficient vegetation and debris which could furnish protection, concealment, and substrates for attachment.

Order Amphipoda (Phylum Arthropoda, Class Crustacea). The Order Amphipoda was represented by two species, *Gammarus fasciatus* and *Hyalella azteca*. *Hyalella azteca* was by far the dominant amphipod. No specimens of *Gammarus fasciatus* were taken during Sampling Period II. During Sampling Period I, representatives were taken in only six areas (areas 5, 17, 31, 32, 34, and 39). The greatest density (21.53 individuals/m^2) of this amphipod was recorded in area 5. *Hyalella azteca* was present in all areas except areas 31 and 40 (Appendix Fig. I-6). Those areas numbered lower than 20 supported the largest standing crops of *H. azteca*. These areas supported large biomasses of vegetation (*Sagittaria latifolia*, *Potamogeton crispus*, and *Ceratophyllum demersum*) and debris which afforded protection and concealment. Greatest densities were recorded in area 10 during Sampling Period I and areas 1 and 3 during Sampling Period II.

Order Decapoda (Phylum Arthropoda, Class Crustacea). Only one representative of this order was collected and consisted of an unidentified, partial specimen. This representative was taken during the second sampling period in area 3.

Order Hydracarina (Phylum Arthropoda, Class Arachnoidea). Three representatives of this order were surveyed and included *Arrenurus*, *Hydrachna*, and an unidentified representative. These water mites, present in low densities, were represented in only six areas (areas 6, 15, 20, 26, 35, and 37). The greatest densities were supported in areas 26 (Sampling Period I) and 6 (Sampling Period II).

Order Plecoptera (Phylum Arthropoda, Class Insecta). *Perlesta placida* was the sole representative of this order and was poorly represented in only four areas characterized by being less eutrophic and having current velocities greater than or equal to 0.159 m/sec (areas 20, 27, 35, and 38). The greatest density of 11.62 individuals per m^2 was recorded in area 38. No representatives were taken during the second sampling period.

Order Ephemeroptera (Phylum Arthropoda, Class Insecta). Representatives of the Family Siphlonuridae were *Isonychia*, *Siphlonurus*, and an unidentified specimen. All representatives were obtained during the first sampling period in areas 24, 35, and 39. Area 24 supported the greatest density (14.21 specimens/m^2).

Stenonema occurred in the less eutrophic areas (areas 17, 18, 28, 30, 31, 32, 34, 35, 36, 38, and 39) and most frequently in those areas having current velocities greater than or equal to 0.385 m/sec. Densities during Sampling Period I were constant at approximately 7.32 individuals/m^2. Area 38 supported the greatest density (16.15 individuals/m^2) during Sampling Period II.

Areas 8, 18, 22, and 26 supported representatives of *Tricorythodes* during Sampling Period I. The density of this mayfly was constant at approximately 7.32 organisms/m^2. *Tricorythodes* was collected from areas 9, 10, 17, 28, and 30 during the second sampling period. The greatest density was recorded in area 30.

The general distribution of *Brachycercus* favored the less eutrophic, sandy areas. Area 39 yielded the highest densities during both sampling periods.

Species belonging to the genus *Hexagenia* included *H. bilineata* and *H. limbata*. Many early instars of *Hexagenia* were encountered and could not be categorized as belonging definitely to either of the two species. Representatives of *Hexagenia* were found in all study areas except areas 2 and 36 (Appendix Fig. I-7). The distribution pattern of *Hexagenia* tended to be localized between areas 5 and 21 which provided suitable substrates and debris for burrowing. High densities of 1334.55 representatives/m^2 and 1195.93 representatives/m^2 were respectively recorded in areas 17 and 6 during Sampling Period I. Areas 16 and 26 supported high densities of 526.19 and 628.03 mayflies per m^2, respectively, during Sampling Period II.

The largest standing crops of *Ephoron* occurred in areas 34 and 35 (Sampling Period I) and 26 (Sampling Period II). *Ephoron* occurred most frequently in those areas numbered higher than 15.

<u>Order Odonata</u> (Phylum Arthropoda, Class Insecta). Two of the dominant representatives of the Order Odonata were *Enallagma* and *Ophiogomphus*, both of which are typically associated with submerged vegetation. The distribution of *Enallagma* favored the more eutrophic areas numbered lower than 21. Areas 8 and 10 yielded the greatest standing crops during the first sampling period. During the second sampling period, area 4 had the highest density of *Enallagma* (10.77 macroinvertebrates/m^2). High densities were also supported in areas 37 and 41 during this second sampling interval. *Ophiogomphus* was collected more frequently in those areas numbered lower than 30. The greatest densities were found in area 29 (Sampling Period I) and areas 7 and 18 (Sampling Period II).

<u>Order Hemiptera</u> (Phylum Arthropoda, Class Insecta). Unidentified females belonging to the Family Corixidae (water boatmen) were the dominant true bugs. Representatives were taken most frequently from those areas having an intermediate trophic status. Areas 22 and 23 (Sampling Period I) and areas 10 and 22 (Sampling Period II) supported the largest standing crops. Relatively high densities were also supported in areas 8 and 40 during Sampling Period I.

<u>Order Megaloptera</u> (Phylum Arthropoda, Class Insecta). *Sialis*, the dominant megalopteran, was most frequently found in the more

eutrophic areas (areas 3 to 20) whose fine sediments were suitable for burrowing. *Sialis* was collected from only two areas (areas 13 and 15) during the first sampling period. High densities of 16.15 and 59.21 megalopterans/m^2, respectively, were supported in areas 3 and 9 during the second sampling period.

Order Trichoptera (Phylum Arthropoda, Class Insecta). The distribution of *Neureclipsis* tended to favor the less eutrophic areas with higher current velocities which helped to billow the trumpet-shaped silken nets which are constructed by this organism. The greatest densities were found in areas 32 (Sampling Period I) and 31 (Sampling Period II).

Cheumatopsyche (Appendix Fig. I-8) and *Hydropsyche* were the dominant representatives of the Family Hydropsychidae. Both genera were most frequently found in the less eutrophic areas where current velocities were sufficiently high to billow their silken catch nets. *Cheumatopsyche* was most abundant in areas 32 and 38 (Sampling Period I) and areas 31, 38, and 41 (Sampling Period II). Areas 38 (Sampling Period I) and 30 (Sampling Period II) supported the largest numbers of *Hydropsyche*. *Cheumatopsyche* was more widely distributed than was *Hydropsyche* and occurred more frequently in areas of greater eutrophy and having lower current velocities. No representatives of either *Cheumatopsyche* or *Hydropsyche* were found in the stagnant waters of areas 1-5.

The Family Hydroptilidae was primarily represented by *Stactobiella*. *Stactobiella* was sporadically distributed in a wide variety of lentic and lotic habitats and under diverse ecological conditions. The greatest densities during Sampling Period I were recorded in areas 3 (28.84 representatives/m^2), 21 (18.94 representatives/m^2), and 38 (27.55 representatives/m^2). Area 18 yielded the greatest density (17.87 representatives/m^2) during the second sampling period.

Oecetis (Family Leptoceridae) was more abundant in the less eutrophic areas numbered higher than 12 (Appendix Fig. I-9). The largest standing crops were supported in areas 21, 26, and 37 (Sampling Period I) and area 26 (Sampling Period II).

Order Lepidoptera (Phylum Arthropoda, Class Insecta). *Nymphula*, along with *Paraponyx*, was one of the dominant representatives of the Order Lepidoptera. The general distribution of this taxon favored the most eutrophic areas (areas 1-7). In these areas *Nymphula* was closely associated with various vegetation including emergent *Sagittaria latifolia* and *S. rigida*, submergent *Potamogeton crispus*, *P. nodosus*, and *Ceratophyllum demersum*, and floating-leaved *Nymphaea tuberosa* and *Nelumbo pentapetala*. During Sampling Period I, *Nymphula* was collected only in areas 15 (18.94 aquatic caterpillars/m^2) and 26 (7.32 representatives/m^2). *Nymphula* was collected in areas 1, 3, 4, 5, 6, 7, 37, and 41 during the second sampling period. Areas 3 and 4 (21.53 representatives/m^2) and areas 1 and 5 (10.77 representatives/m^2) yielded the greatest numbers of *Nymphula*.

Order Coleoptera (Phylum Arthropoda, Class Insecta). *Stenelmis* (Family Elmidae) was a representative member of the Order Coleoptera and occurred in those less eutrophic areas numbered higher than 14. The largest standing crops were found in areas 35 and 41 (Sampling

Period I) and areas 26, 27, 38, and 41 (Sampling Period II).

Order Diptera (Phylum Arthropoda, Class Insecta). The general distribution of *Chaoborus* (Family Chaoboridae) favored those areas numbered between 7 and 20. *Chaoborus* was collected from only three areas (areas 11, 12, and 19) during the first sampling period. Area 12 supported the greatest density (33.58 phantom midges/m^2). The largest standing crop (252.98 phantom midges/m^2) was collected in area 9 during the second sampling period. Areas 12, 13, and 19 yielded relatively high densities.

Simulium (Family Simuliidae) was collected only from area 25 (2.37 black flies/m^2) during Sampling Period II. The general distribution during Sampling Period I favored the less eutrophic, lotic areas. Greatest concentrations occurred in areas 20, 38, and 40.

Midges belonging to the Family Chironomidae were the dominant dipterans and occurred in every area and under diverse ecological conditions. The general distribution of *Chironomus* favored the more eutrophic areas (areas 1-16) (Appendix Fig. I-10). The greatest densities of *Chironomus* were recorded in areas 6 and 10 (Sampling Period I) and areas 10 and 14 (Sampling Period II). Densities in the less eutrophic areas (areas 17-41) did not exceed 61.99 midges/m^2. *Cryptochironomus* was collected in every area except areas 2, 3, 5, and 7 (Appendix Fig. I-11). *Cryptochironomus* was equally distributed in all types of habitats although larger standing crops were generally recorded in areas 10, 31, and 32 (Sampling Period I) and areas 1, 26, 32, and 41 (Sampling Period II). The general distribution of *Endochironomus* favored the more eutrophic areas numbered lower than 20 (Appendix Fig. I-12).

Greatest densities were recorded in areas 10 (610.02 representatives/m^2), 11 (3817.24 representatives/m^2), and 20 (525.21 representatives/m^2) during the first sampling period. Areas 1, 5, and 10 respectively yielded high densities of 139.95, 419.84, and 86.12 representatives/m^2 during Sampling Period II. *Glyptotendipes* was sporadically distributed and was most abundant in areas 10, 11, and 38 (Sampling Period I) and areas 1 and 41 (Sampling Period II). *Polypedilum* was collected in all areas and its general distribution did not appear to favor any particular type of habitat (Appendix Fig. I-13). Areas 11, 15, and 38 (Sampling Period I) and areas 1, 3, 20, and 30 (Sampling Period II) maintained the largest standing crops. *Xenochironomus* was generally more abundant in the less eutrophic areas numbered higher than 22 (Appendix Fig. I-14). *Xenochironomus* was collected in only six areas during the first sampling period. Areas 15 and 41 supported the largest standing crops of 205.78 and 105.04 midges/m^2, respectively. *Xenochironomus* was most abundant in areas 31 and 41 during the second sampling period. *Tanytarsus* was generally more frequently encountered in those areas having an intermediate trophic status and was most abundant in areas 19 (Sampling Period I) and 15 (Sampling Period II). The general distribution of *Coelotanypus* centered around the areas having intermediate eutrophic states and was greatest in areas 7 and 37 (Sampling Period I) and areas 12, 18, and 26 (Sampling Period II) (Appendix Fig. I-15). The general distribution of *Pentaneura* favored the more eutrophic areas (areas 1-20) (Appendix Fig. I-16). *Pentaneura* was taken in all areas except areas 34 and 36 and was most abundant in study area 11 (Sampling Period I) and areas 1, 12, and 18 (Sampling

Period II).

The ceratopogonids *Atrichopogon* and *Palpomyia* (Appendix Fig. I-17) were typically more common and could compete better in the less eutrophic areas having sandy sediments and higher mean current velocities. The greatest densities of *Atrichopogon* were supported in area 28 (Sampling Period I) and areas 22 and 25 (Sampling Period II). *Palpomyia* was most abundant in areas 12, 13, 22, and 28 (Sampling Period I) and areas 22, 28, and 40 (Sampling Period II). Both of these biting midges were more concentrated in the deeper, central portions in each area where the current velocities were greatest, the sediments were of a sandier nature, and few competitors were present. *Palpomyia* was more widely distributed than was *Atrichopogon* and occurred in the more eutrophic areas numbered between 5 and 19.

Class Gastropoda (Phylum Mollusca). *Physa* and *Amnicola* were representative gastropods. *Physa*, whose mantle cavity serves as a lung, abounded in the more eutrophic areas and was most dense in areas 15 and 18 (Sampling Period I) and area 18 (Sampling Period II). The general distribution of *Amnicola*, which possesses an operculum and gills, favored those areas having intermediate eutrophic states (areas 14-24) (Appendix Fig. I-18). The greatest densities of *Amnicola* were maintained in areas 14, 21, and 24 (Sampling Period I) and areas 15 and 21 (Sampling Period II).

Class Pelecypoda (Phylum Mollusca). The fingernail clams *Musculium* and *Sphaerium* were widely distributed and were by far the most common bivalve mollusks. Both clams were not present in the most eutrophic, stagnant areas 1-5. The general distributions of *Musculium* and *Sphaerium* favored those areas numbered between 6 and 27. *Musculium* abounded in areas 6, 14, 17, 21, and 24 (Sampling Period I) and areas 9, 14, 15, 21, and 24 (Sampling Period II). The greatest densities of *Sphaerium* were recorded in areas 14, 15, 21, and 24 (Sampling Period I) and areas 14, 15, 21, and 24 (Sampling Period II) (Appendix Fig. I-19).

DISCUSSION

The benthic community of a body of water consisted of those life forms which are associated with the bottom sediments during some stage in their life history. Turbellarians, nematodes, annelids, crustaceans, insects, and mollusks are the principal taxonomic constituents of fresh-water benthos. In a well-balanced ecological system, benthic macroinvertebrates occupy three major trophic levels (herbivore, omnivore, carnivore) and include deposit and detritus feeders, parasites, scavengers, grazers, and predators.

Benthic macroinvertebrates, representing the Phyla Platyhelminthes, Nematoda, Annelida, Arthropoda, and Mollusca, of Navigation Pool No. 8 of the Upper Mississippi River were inventoried and typified the three arbitrary ranks of pollution tolerance and the three major trophic levels. Members of the Class Oligochaeta (Phylum Annelida) were ubiquitous and were the dominant benthic macroinvertebrates in most study areas. Distribution of other benthic organisms was more or less restricted and tended to reflect habitat preference.

The Phylum Platyhelminthes was represented by the free-living turbellarian flatworms which are generally considered to be pollution-facultative (Weber 1973). The collected representatives of the Class Turbellaria were widely distributed throughout the 41 study areas and were generally more abundant in those areas demonstrating intermediate trophic states (Tables 9 and 10, Appendix Fig. I-1). Large standing crops of submergent *Vallisneria americana* and *Ceratophyllum demersum* were present in most of these areas (Sefton 1976) to offer concealment for these negatively phototactic turbellarians. Turbellarian distribution and density were highly correlated with the average physical-chemical parameters encountered in Pool 8 (Sampling Period I: multi-r = .680, $P < 0.01$; Sampling Period II: multi-r = .819, $P < 0.01$). Fresh-water turbellarians can be found everywhere and are usually on or closely associated with any kind of substrate where there is an appropriate food supply (Pennak 1953). This lack of preference for particular substrate types is supported by the low correlations obtained between the number of turbellarians/m^2 in each area and the six sediment particle size fractions (Tables 7 and 8). Although turbellarians are typically characteristic of the shallows, no such relationship between depth and turbellarian abundance could be proposed. Wetzel (1975) reported that an inverse relationship exists between turbellarian abundance and current velocity. Turbellarians, as well as many other benthic forms, cannot withstand the mechanical abrasion of shifting substrates found in lotic streams and in littoral zones where breaking waves occur. No such relationship occurred in the present investigation (Tables 7 and 8).

Free-living nematodes have been categorized as pollution-facultative macroinvertebrates (Weber 1973). Pennak (1953) stated that nematodes are ecologically and physiologically perhaps the most highly adaptable among all the metazoan phyla. The results collected in the present investigation tend to agree with Pennak's statement. Nematodes were widely distributed throughout the 41 study areas and their densities in each of the areas were strongly correlated with the existing physical-chemical parameters (Sampling Period I: multi = .797, $P < 0.01$; Sampling Period II: multi-r = .814, $P < 0.01$). Larger standing crops were generally collected from those areas having intermediate trophic states (Tables 9 and 10, Appendix Fig. I-2).

Two major groups belonging to the Phylum Annelida are represented in fresh water: the Classes Oligochaeta (aquatic earthworms) and Hirudinea (leeches). The oligochaetes were ubiquitous and were by far the most abundant and dominant macroinvertebrates in the present investigation. As shown in Tables 7 and 8, oligochaete distribution and density were strongly correlated with the average physical-chemical values obtained for the study areas in Navigation Pool No. 8. The general distribution of the oligochaetes favored the more eutrophic areas having undetectable or low current velocities, low dissolved oxygen levels, and silt or clay sediments high in organic matter (Tables 9 and 10, Appendix Fig. I-3). Significant, negative relationships at the 0.01 and 0.05 levels were obtained between oligochaete abundance and current velocity, turbidity, dissolved oxygen, and sediment particle sizes #3 and #4. Oligochaete density was positively correlated at the two levels of significance with sediment organic nitrogen, sediment nitrate, and sediment particle size #6. During Sampling Period I, a relatively strong positive correlation ($r = .624$, $P < 0.01$) between oligochaete abundance and sediment particle size #6 (clay) was obtained. Similar observations have been made by Pennak (1953). He stated that aquatic oligochaetes, common in the mud and debris substrates of stagnant ponds and pools and in streams and lakes everywhere, are capable of surviving under near anaerobic conditions and may be able to withstand the complete absence of oxygen for extended time intervals. Oligochaetes are thus categorized as being pollution-tolerant and their presence in an aquatic environment is often considered an indication of organic contamination. Goodnight and Whitley (1960), studying a drainage ditch southeast of Lafayette, Indiana, reported the possibility of using the abundance of oligochaetes in relation to the total benthic community as a fast, simple biological indication of the degree of pollution in streams or drainage ditches. Smith (1975) pointed out the importance of oligochaetes, especially the Naididae and Tubificidae, in monitoring water quality since large populations may occur under organically polluted situations where predators and competitors have been eliminated. He also stated that proper identification is needed since different oligochaete species have different ecological requirements. Brinkhurst (1965) has been more reluctant to use oligochaetes, specifically members of the Family Tubificidae, as indicators of organic pollution. He has termed such schemes of pollution detection and assessment naive since oligochaetes are exceedingly nonrandom in distribution, a situation causing large sampling variability. Brinkhurst further stated that the distribution, habitat requirements, and competitive relationships between oligochaete species must be more intensely analyzed before the group can be fully used in pollution detection and assessment since the number of unidentified oligochaete species, or the proportion of all oligochaetes in the fauna, and pollution are not simply or numerically related.

The general distribution of leeches favored the more eutrophic, shallow habitats having undetectable or low current velocities and sufficient debris and plant material to afford concealment and adequate substrate for attachment (Tables 9 and 10, Appendix Fig. I-4). These areas supported the largest total macrophyte biomasses (Sefton 1976). This distribution was highly correlated with the average physical-chemical conditions existing in the 41 study areas (Sampling Period I: multi-r = .846, $P < 0.01$; Sampling Period II: multi-r = .793, $P < 0.01$). Significant, negative correlations were obtained with depth, current velocity, turbidity, dissolved oxygen, and sediment particle sizes #3 (medium sand) and #4 (fine sand). Significant, positive correlations between leech abundance and sediment organic nitrogen, sediment nitrate, and sediment particle size #6 (clay) were obtained (Tables 7 and 8). Several investigators have independently made similar observations. Although the abundance of leeches is highly variable in different habitats, leech abundance and the productivity of an aquatic habitat are directly related (Wetzel 1975). Areas of greater productivity generally provide leech populations with increasingly diverse plant and sediment substrates and greater food availability. Pennak (1953) reported that while leeches generally demonstrate little habitat preference, greatest densities typically occur in warm, protected shallows where wave action is absent and adequate substrate for concealment and adhesion is present. Although he reported leeches usually cannot survive on pure mud or clay substrates, relatively high, significant correlations (Sampling Period I: $r = .629$, $P < 0.01$; Sampling Period II: $r = .551$, $P < 0.01$) were obtained between leech abundance and sediment particle size #6 (clay) in the present investigation. Klemm (1971,1972) surveyed 40 species of leeches in Washtenaw County, Michigan. Water velocity, depth, and substrate were the major factors limiting the distribution and abundance of leeches. The scouring, depositing, and disrupting phenomena causing substrate instability under lotic conditions were not favorable to leech survival. Depths greater than 1.5 m were reported to restrict leech abundance due to the lack of vegetation and substrate for attachment, low dissolved oxygen levels, and insufficient food. Klemm also found that leeches favored those areas which provided some type of substrate, such as rocks, vegetation, and litter, which could be used for attachment.

The dominant phylum in terms of diversity was the Phylum Arthropoda which was represented by the Classes Crustacea, Arachnoidea, and Insecta. The dominant arthropods belonged to the Class Insecta, more specifically to the Order Diptera. The Chironomidae was the most diverse dipteran family.

The Orders Isopoda (aquatic sow bugs) and Amphipoda (scuds, sideswimmers) were the most abundant crustaceans. The only isopod to be collected was *Asellus militaris*. Similar observations were made by Pennak (1953) who stated that in the same habitat only one isopod species is typically found and it is very unusual to find two or more species. *Asellus militaris*, often classified as a pollution-facultative species (Weber 1973), had a wide distribution in Navigation Pool No. 8, centering around those areas having intermediate eutrophic states (Tables 9 and 10, Appendix Fig. I-5). As shown in Tables 7 and 8, the distribution of *Asellus militaris* was highly correlated with the average physical-chemical conditions measured in the present investigation (Sampling Period I: multi-r = .700, $P < 0.01$; Sampling Period II: multi-r = .766, $P < 0.01$). Although isopods are generally found in shallow habitats (< 1 m), depth did not appear to be a limiting factor

(Sampling Period I: $r = -.118$, $P > 0.05$; Sampling Period II: $r = -.154$, $P > 0.05$) and small numbers of isopods were collected in the present investigation from the three deepest areas which had depths of 4.91 m, 6.10 m, and 6.71 m. Great depths presumably restrict isopod abundance due to the lack of vegetation and debris available for protection and insufficient food. Isopods, usually absent from open waters, are typically found under debris, rocks, and aquatic macrophytes. Submergent macrophytic communities, often including *Vallisneria americana* and *Ceratophyllum demersum*, were present in those areas favoring populations of *Asellus militaris*.

Amphipods are generally restricted to the sediments and are frequently associated with aquatic vegetation. *Gammarus fasciatus* and *Hyalella azteca* were collectively most abundant in the more eutrophic areas supporting large standing crops of vegetation such as *Sagittaria latifolia*, *Potamogeton crispus*, and *Ceratophyllum demersum* (Tables 9 and 10, Appendix Fig. I-6). Highly significant correlations between the number of *Hyalella azteca*/m^2 in each area and the physical-chemical conditions encountered in each area (Sampling Period I: multi-r = .694, $P < 0.01$; Sampling Period II: multi-r = .722, $P < 0.01$) were obtained. Bousfield (1958) reported that while the distribution of *Gammarus fasciatus* favors lakes and large, lentic rivers that are relatively turbid and warm in the summer, *Hyalella azteca* can be found in all permanent fresh water that exceeds a monthly mean temperature of 10 C in the summer. Although high levels of dissolved oxygen are usually required for the maintenance of amphipod populations, a negative, significant relationship existed between amphipod abundance and dissolved oxygen levels (Sampling Period I: r = -.319, $P < 0.05$; Sampling Period II: r = -.568, $P < 0.01$). Significant, negative correlations also occurred with depth, current velocity, turbidity, and sediment particle size #4 (Tables 7 and 8). Sediment organic nitrogen, sediment nitrate, and sediment particle size #6 were significantly and positively correlated with the density of *Hyalella azteca*.

The Order Hydracarina (water mites) represented the Class Arachnoidea. *Arrenurus*, *Hydrachna*, and unidentified specimens were infrequently and sporadically distributed among rooted vegetation and typically in water less than two meters deep (Tables 9 and 10).

The dominant, diverse Class Insecta was represented by the Orders Plecoptera (stoneflies), Ephemeroptera (mayflies), Odonata (dragon-flies, damselflies), Hemiptera (true bugs), Megaloptera (alderflies, fishflies, dobsonflies), Trichoptera (caddisflies), Lepidoptera (aquatic caterpillars), Coleoptera (beetles), and Diptera (flies, mosquitoes, midges). The Order Plecoptera was not well represented in Navigation Pool No. 8. The general distribution of the only stonefly representa-tive, *Perlesta placida*, favored the peripheral areas of the less eutrophic, lotic habitats having sediments of a coarser nature, relatively high dissolved oxygen levels, and sufficient shoreline vegetation (Tables 9 and 10). Comparable results have been collected by Cummins and Lauff (1969). Although the nymphs were shown to tolerate slower current velocities, they classified *Perlesta placida* as a fast-water species which is usually found among coarse substrate materials. White (1974) studied the distribution of stoneflies in the Salt River of Kentucky. He too found *Perlesta placida* to be the most abundant stonefly and most commonly collected it from small, intermittent streams having bottom materials of bedrock, sand, gravel, and large stones. White further found that the extensive beds of water willow (*Justicia americana*) located in his study area were not necessary for the survival of *Perlesta placida*. Where this vegetation was present, the adults of *P. placida* did use it for a site for mating and egg deposition.

Members of the Order Ephemeroptera are widely distributed throughout a variety of habitats in Wisconsin (Hilsenhoff 1975). Similar results were obtained in the present investigation. Although mayfly nymphs typically prefer shallow streams and the littoral zones of lakes, where oxygen is abundant, water movements and the nature of the substrate often restrict many species to particular types of habitat. Some occur only associated with vegetation and debris, burrowed in mud bottoms, hidden under or between rocks, or confined to lotic or lentic environments. Considerable morphological variations and adaptations of the nymphs reflect these habitat preferences.

The mayflies examined in the present investigation can be divided into two basic groups on the basis of habitat preferences: those generally favoring lentic environments and those most commonly collected in and adapted to lotic habitats. Those nymphs most abundant in lentic habitats can be further divided into the following three subgroups: climbers, bottom sprawlers, and burrowers. Climbers are associated with submerged vegetation and are capable of rapid movements. *Siphlonurus* (Siphlonuridae), the only representative of this subgroup, was collected from only three areas which had current velocities greater than or equal to 0.282 m/sec, sediments primarily composed of fine sand, and significant shoreline submergent communities of macrophytes often composed of *Ceratophyllum demersum*, *Potamogeton nodosus*, or *Vallisneria americana* (Table 9). The Families Caenidae (*Brachycercus*, *Caenis*) and Tricorythidae (*Tricorythodes*) were representative bottom sprawlers. Although bottom sprawlers are typically found slowly crawling over all types of substrate in both lentic and lotic habitats (Pennak 1953), the general distribution of *Brachycercus* favored the less eutrophic, sandy areas having high current velocities (Tables 9 and 10). Burrowing mayflies, widely distributed in the study areas of Navigation Pool No. 8, were the dominant mayflies and were represented by unidentified early instars of *Hexagenia*, *H. bilineata*, *H. limbata*, and *Pentagenia* of the Family Ephemeridae and by *Ephoron* of the Family Polymitarcidae. Similar results have been reported by Fremling (1970). He has stated that burrowing mayflies are abundant along the Mississippi River and are dominated by *Hexagenia bilineata*, *H. limbata*, and *Pentagenia vittigera*. In the present study several representatives of *Ephoron* were collected and were more commonly taken from areas having high current velocities and coarse sediments composed largely of medium-sized sand (Tables 9 and 10). These results do not exactly agree with Hilsenhoff (1975) who has reported that the nymphs of *Ephoron* are relatively uncommon in Wisconsin and are typically found under rocks in rapid, medium-sized streams. High standing crops of *Hexagenia* species were generally supported in those habitats having finer sediments and low or intermediate current velocities (Tables 9 and 10, Appendix Fig. I-7). Strong, positive correlations between *Hexagenia* abundance and the physical-chemical parameters in the study areas of the pool

(Sampling Period I: multi-r = .812, P < 0.01; Sampling Period II: multi-r = .718, P < 0.01) were obtained. As shown in Tables 7 and 8, significant, negative correlations occurred between the density of *Hexagenia* and depth (Sampling Period I), current velocity (Sampling Period I), temperature (Sampling Period I), and sediment particle sizes #3 (Sampling Period I) and #4 (Sampling Periods I and II). Positive correlations coefficients of .541 (P < 0.01) and .360 (P < 0.05) for Sampling Periods I and II, respectively, were obtained with sediment particle size #6 (clay). This apparent preference for fine, undisturbed sediments was also stated by Eriksen (1968). He further concluded that *Hexagenia* does not burrow into coarse substrates. Such a conclusion cannot be drawn from the results of this investigation since representatives of *Hexagenia* were collected from a wide variety of substrates which were encountered throughout the 41 study areas. *Hexagenia limbata* was the dominant species collected in Pool 8. This observation contradicts Fremling (1960) whose findings indicated that *H. limbata* is generally less abundant than *H. bilineata* on the Upper Mississippi River although it does become more abundant in the northern sections of the river.

Mayfly nymphs favoring lotic environments can be categorized as being free-ranging species of rapid waters or clinging species (Pennak 1953). The free-ranging species often cling to substrates but are capable of rapid movements despite the swift current. *Isonychia* (Siphlonuridae) was the only collected representative of this subgroup. Although poorly represented in Navigation Pool No. 8, it is commonly found throughout Wisconsin in a variety of streams (Hilsenhoff 1975). The only collected clinging mayfly belonged to the genus *Stenonema* (Heptageniidae). *Stenonema* was most abundant in the less eutrophic areas having current velocities greater than or equal to 0.385 m/sec. The largest standing crop of *Stenonema* was collected in area 38 which had a current velocity of 0.534 m/sec (Tables 9 and 10).

The Order Odonata was represented by the Families Coenagrionidae (*Enallagma*), Gomphidae (*Dromogomphus*, *Gomphus*, *Ophiogomphus*), Lestidae (*Lestes*), and Aeshnidae (*Anax*). *Enallagma* and *Ophiogomphus* were the dominant odonate nymphs and were collected most frequently from lentic habitats which were shallow (< 1 m) and which had sufficient vegetation and fine sediments (Tables 9 and 10). The examined odonate nymphs fell into two ecological categories: climbers and burrowers. In agreement with the descriptions given by Pennak (1953), the climbers, which included the Families Aeshnidae, Coenagrionidae, and Lestidae, tended to favor those lentic habitats or portions of those habitats having dense vegetation and fine sediments. Burrowing odonate nymphs, including members of the Gomphidae family, burrow into silt, mud, or sand substrates.

The large Order Hemiptera is primarily terrestrial and is one of the few orders in which some of the adults are adapted to aquatic habitats. This order was represented in Navigation Pool No. 8 by the aquatic Families Notonectidae and Corixidae, both of which are excellent swimmers and which cling to submerged objects and vegetation. The notonectids (back swimmers) *Buenoa* and *Notonecta* were taken infrequently. This study, therefore, does not support Hilsenhoff (1975) who reported that they are commonly found throughout the state of

Wisconsin and are associated with emergent vegetation. Unidentified females and *Trichocorixa* represented the Family Corixidae (water boatmen) which was widely distributed throughout most of the study areas. The general distribution of the unidentified females favored those areas having intermediate eutrophic states (Tables 9 and 10). Representatives were not collected from the five stagnant, eutrophic marsh openings (areas 1-5), although Pennak (1953) has reported that they can be found in muddy stagnant pools.

The Megaloptera, commonly found in both lentic and lotic environments, can be frequently collected from littoral zones and from underneath rocks in streams. The order can be divided into the two Families Sialidae (alderflies) and Corydalidae (dobsonflies, fishflies). Corydalidae was represented by a few specimens of the fishfly larva *Chauliodes*, which is typically associated with vegetation. The alderfly *Sialis* (Sialidae), the dominant megalopteran, was infrequently collected (Tables 9 and 10) and was most abundant in the more lentic, eutrophic areas whose silt and clay sediments were possibly conducive to burrowing (Hilsenhoff 1975). Comparable observations were made by Cummins and Lauff (1969) who classified *Sialis vagans* as a slow-water species which is typically associated with detritus and aquatic macrophytes. They further reported that the larvae preferentially select sediment particle sizes in the gravel range but are able to tolerate silty sediments.

The trichopteran fauna was represented by larvae and pupae belonging to the Families Hydropsychidae, Hydroptilidae, Leptoceridae, and Polycentropodidae. The dominant caddisflies were *Cheumatopsyche*, *Hydropsyche*, *Neureclipsis*, *Oecetis*, and *Stactobiella*. *Hydropsyche* and *Cheumatopsyche* are perhaps the most abundant and widespread caddisflies in Wisconsin (Hilsenhoff 1975). The four families, collectively representing 12 genera, can be divided into the following two simple, basic groups: net spinners and case builders. Case builders, such as Leptoceridae, often construct intricate cases from available substrate particles, debris, and leaf material. They are usually restricted to lentic habitats having low or moderate current velocities. Hydropsychidae, Hydroptilidae, and Polycentropodidae construct nets which trap microorganisms and detritral particles in flowing waters.

Although caddisflies are generally found in all types of freshwater habitats, Edington (1965) stated that the lentic and lotic habitats in any one stream are often occupied by different species. The present study appears to support this statement. The distribution of *Oecetis*, a case builder, was highly correlated with the average physical-chemical parameters encountered in each area (Sampling Period I: multi-r = .853, $P < 0.01$; Sampling Period II: multi-r = .870, $P < 0.01$) and favored those areas having intermediate current velocities (Tables 9 and 10, Appendix Fig. I-9). Those caddisflies that construct silken catch nets, such as *Cheumatopsyche* (Appendix Fig. I-8), *Hydropsyche*, and *Neureclipsis*, are typically restricted to lotic habitats (Tables 9 and 10). The distribution of *Cheumatopsyche* and current velocity were significantly correlated (Sampling Period I: $r = .323$, $P < 0.05$; Sampling Period II: $r = .504$, $P < 0.01$). Similar observations concerning *Neureclipsis bimaculata* and *Hydropsyche angustipennis* were made by Jaag and Ambühl (1963). The running waters aid in the distension of the nets and permit those nets to properly function in trapping food particles. Correlation coefficients of .606 ($P < 0.01$) and .696 ($P < 0.01$) were obtained during Sampling Periods I and II, respectively, between the abundance of *Cheumatopsyche* and the existing physical-chemical conditions (Tables 7 and 8).

According to Scott (1958), substrate and food distribution as well as current velocity are the major controlling factors governing trichopteran larval distribution. He reported that densities of trichopteran populations tended to increase with increasing sediment particle size primarily due to the greater varieties of microhabitats and greater stability during flooding afforded by substrates of a coarser nature. When the total trichopteran fauna is considered, this trend seemed evident in the present investigation. This trend does not appear as obvious when each trichopteran genus or species is considered separately. *Cheumatopsyche* was negatively correlated with sediment particle size #6 (Sampling Period I: $r = -.319$, $P < 0.05$; Sampling Period II: $r = -.422$, $P < 0.01$) and positively correlated with sediment size fraction #3 (Sampling Period I: $r = .313$, $P < 0.05$; Sampling Period II: $r = .415$, $P < 0,01$).

The Order Lepidoptera (aquatic caterpillars, moths) is predominantly terrestrial and is widely distributed over the United States. Only a few species of the Family Pyralididae have immature states that have become adapted to aquatic habitats. These habitats are typically lentic, shallow and densely overgrown with vegetation. Present observations support this general statement. Representatives of *Nymphula*, the dominant lepidopteran, and *Paraponyx* were generally taken from the most eutrophic, lentic areas which had large stands of the emergent *Sagittaria latifolia* and *S. rigida*, submergent *Potamogeton crispus*, *P. nodosus*, and *Ceratophyllum demersum*, and floating-leaved *Nymphaea tuberosa* and *Nelumbo pentapetala* (Tables 9 and 10). Both *Nymphula* and *Paraponyx* build cases out of plant material and can be frequently found feeding on the undersides of floating leaves. Little is known about the Lepidoptera of Wisconsin (Hilsenhoff 1975).

Beetles belong to the largest order of insects, the Coleoptera. This very diverse order is similar to the Order Hemiptera in that the adults of a few species, as well as the immature stages, have become adapted to aquatic situations. Wetzel (1975) reported that those beetles having both larval and adult aquatic stages are phylogenetically more primitive than the other coleopteran groups. Larval forms from the following four families were collected in the present investigation: Chrysolmelidae (leaf beetles), Elmidae (riffle beetles), Gyrinidae (whirligig beetles), and Hydrophilidae (water scavenger beetles). The Elmidae were frequently encountered in Navigation Pool No. 8. The other three families were represented by only a few specimens.

Although Chrysomelidae is a very large terrestrial family, aquatic larvae of the sluggish *Donacia* were uncommon in the study areas of Pool 8. Hilsenhoff (1975) has stated comparable findings throughout the state of Wisconsin. *Donacia* is typically associated with aquatic vegetation, especially water lilies, from which it obtains oxygen. It possesses nine pairs of spiracles, the last pair being functional and located at the base of two caudal spines. These spines are used to penetrate into the plant tissues of submerged roots and stems.

The dominant Family Elmidae was represented by *Dubiraphia* and *Stenelmis*. Members of this family are typically found slowly crawling on the substrate in lotic habitats. Supportive evidence was given in the present study. *Stenelmis* was collected most frequently from those less eutrophic areas having high current velocities (Tables 9 and 10).

The small Family Gyrinidae is well adapted to the aquatic environment. The larval forms, unlike the adults, are completely independent of the surface for respiration. *Dineutus* and *Gyrinus* were infrequently collected in the present investigation but have been reported to be common inhabitants of Wisconsin waters (Hilsenhoff 1975). These two genera are widely distributed throughout the United States and are generally associated with shallow environments having submerged vegetation.

The Hydrophilidae was uncommon in Navigation Pool No. 8 and was represented by one genus, *Helophorus*. Most of the hydrophilids are extremely sluggish crawlers, favoring shallow quiet pools having abundant vegetation.

Although mostly terrestrial, the large, diverse, holometabolous Order Diptera formed a major component of the benthic community in both lentic and lotic aquatic habitats. Members of the Family Chironomidae were particularly widespread. Navigation Pool No. 8 supported a rich dipteran fauna consisting of two suborders, seven families, and 46 genera. The Suborder Brachycera was uncommon in Pool 8 and was represented by the two Families Stratiomyidae (soldier flies) and Tabanidae (horse flies and deer flies). Each of these families was represented by a single genus: Stratiomyidae--*Euparyphus* and Tabanidae--*Chrysops*.

Suborder Nematocera, encompassing five families and 44 genera, included most of the aquatic Diptera. With 36 genera the Chironomidae was the most diverse and ubiquitous dipteran family. Many chironomids were very selective in their choice of habitat. Paine and Gaufin (1956), in their study of Lytle Creek, Ohio, reported similar observations. They found that chironomid representatives could adapt to many different stream habitats, some species demonstrating a high degree of habitat selectivity. Oliver (1971) stated that the Chironomidae has radiated into may different habitat types. Chironominae, Orthocladinae, and Tanypodinae, the dominant subfamilies in Navigation Pool No. 8, have been reported to be the most common subfamilies in the United States and to have a world-wide distribution (Mason 1975, Oliver 1971).

The distribution and abundance of dipteran larvae are often restricted by current velocity, substrate type, depth, the degree of organic contamination, and food availability. Wene (1940) reported that soil type, texture, and organic matter content were important factors influencing the abundance of chironomids. He found that loam and clay-loam types of soil with high organic content supported the greatest biomass of chironomids. The chironomid populations found in sandy soils of low organic content were generally small. In the present investigation parallel observations were made when all collected chironomids were considered as a unit. However, when each genus was examined separately, habitat preferences became apparent and the positive relationship between population density and sediment organic content and texture was not obvious. Some chironomids, such as *Cryptochironomus* and *Polypedilum*, showed no obvious habitat preferences and were widely distributed throughout the 41 study areas. The distribution of other chironomids often favored those areas having an intermediate trophic status and moderate current velocities (*Coelotanypus* and *Tanytarsus*), the less eutrophic, lotic areas (*Palpomyia*, *Simulium*, and *Xenochironomus*), or the more eutrophic, lentic areas (*Chironomus*, *Endochironomus*, and *Pentaneura*).

The general distributions of *Chironomus* and the average physical-chemical parameters in Navigation Pool No. 8 were significantly correlated (Sampling Period I: multi-r = .729, $P < 0.01$; Sampling Period II: multi-r = .691, $P < 0.01$). The more eutrophic areas having fine sediments and undetectable or low current velocities supported the largest standing crops of *Chironomus* (Tables 9 and 10, Appendix Fig. I-10). A significant, negative correlation was obtained between the abundance of *Chironomus* and current velocity (Sampling Period I: $r = -.425$, $P < 0.01$; Sampling Period II: $r = -.358$, $P < 0.05$). As shown in Tables 7 and 8, significant, positive correlations were obtained with sediment organic nitrogen, sediment nitrate, and sediment particle size #6 (clay). Apparently, therefore, the population density of *Chironomus* appeared directly proportional to the productivity of the study area and inversely proportional to the sediment texture.

The general distribution of *Simulium* (Family Simuliidae) favored the less eutrophic, lotic areas (Tables 9 and 10). The largest populations of these black flies generally occurred in those study areas having current velocities greater than 0.50 m/sec. Wu (1931) has collected comparable data. Larvae of *Simulium*, generally found in the shallows of swift streams, have a definite, inherent requirement for current (Wu 1931). Upon transplantation to habitats having slower current velocities than the original habitats, some *Simulium* larvae have been reported by Wu to voluntarily desert the new locality in search for a more favorable habitat having a higher current velocity.

The aquatic species of Ceratopogonidae have been reported to inhabit a wide variety of lentic habitats in Wisconsin (Hilsenhoff 1975). In the present study, however, the dominant ceratopogonids *Atrichopogon* and *Palpomyia* (Appendix Fig. I-17) were most abundant in the less eutrophic areas having sandy, organically poor sediments and higher average current velocities (Tables 9 and 10). Within each of these areas, higher densities of these biting midges were recorded in the deeper, central locations where the ceratopogonids presumably received little competition. These habitats supported little, if any, vegetation and few benthic macroinvertebrates due to the swift current velocities, sandy substrates, and depth. The distribution of *Palpomyia* was strongly correlated with the distribution of the physical-chemical parameters in the 41 study areas (Sampling Period I: multi-r = .779, $P < 0.01$; Sampling Period II: multi-r = .717, $P < 0.01$). As shown in Tables 7 and 8, significant, positive correlations were obtained between the abundance of *Palpomyia* and depth, dissolved oxygen, and sediment particle sizes #3 (medium sand) and #4 (fine sand). *Palpomyia* abundance was negatively correlated at the significance levels of 0.01 and 0.05 with sediment organic nitrogen, sediment nitrate, sediment phosphate, and sediment particle size #6 (clay).

The Phylum Mollusca can be divided into two classes, the univalve Gastropoda (snails, limpets) and the bivalve Pelecypoda (clams, mussels). Almost every type of fresh-water habitat, including Navigation Pool No. 8, supports a characteristic gastropod population. Snails are usually found feeding on the substrates in shallow, hard waters typically less than three meters deep. At greater depths food availability is presumably not conducive to gastropod growth. While hard waters are generally more favorable environments for gastropod, as well as pelecypod, survival and growth (Shoup 1943), it is very difficult to separate the importance of water quality from geographical distribution, the physical characteristics of the habitat, and food availability as factors promoting species abundance at any locality (Boycott 1936). The sum of the ecological factors may override the importance of calcium in determining the distribution of the Gastropoda (Shoup 1943). Shoup (1943) reported, however, that there is a general tendency for more alkaline or harder waters to support greater standing crops of gastropods. Calcium carbonate is the essential building block used by mollusks in shell construction. He found that habitats having total methyl orange alkalinities within a range of 140 to 180 ppm supported the richest gastropod bottom faunas. Alkalinity levels in Navigation Pool No. 8 are relatively constant and average 175 mg $CaCO_3$/ 1 (Claflin 1973).

The gastropods of Navigation Pool No. 8 can be grouped into two categories according to their means of respiration, those gastropods which have internal gills and those which obtain oxygen through a pulmonary cavity or "lung". The Order Ctenobranchiata possesses internal gills or ctenidium which are specialized folds of the mantle. An exception is *Valvata* which has delicate, plumose, external gills. Ctenobranchiata was the dominant order in the present study and was represented by *Amnicola* (Amnicolidae), the river snail *Pleurocera* (Pleuroceridae), the round-mouth snail *Valvata* (Valvatidae), and *Campeloma*, *Lioplax*, and *Viviparus* (Viviparidae). Due to the use of gills in aquatic respiration, most members of this order, as well as other gill-breathing benthic forms, are usually restricted to cleaner habitats (Gaufin and Tarzwell 1956). In Navigation Pool No. 8 the general distribution of *Amnicola*, one of the dominant ctenobranchiates, favored those areas having intermediate eutrophic states (Tables 9 and 10, Appendix Fig. I-18). This distribution was strongly correlated with the distribution of the mean physical-chemical parameters encountered in the pool (Sampling Period I: multi-r = .831, $P < 0.01$; Sampling Period II: multi-r = .928, $P < 0.01$).

The Order Pulmonata does not possess gills or opercula. Respiration is accomplished by means of an internal saclike "lung" or pulmonate cavity which is a specialized, air-filled, highly vascularized portion of the mantle cavity. The pulmonate snails collected from Navigation Pool No. 8 belonged to the three families Lymnaeidae (pond snails), Physidae (pouch snails), and Planorbidae (orb snails). Physidae was the dominant family and included *Physa*, which was the dominant pulmonate, and *Aplexa*. *Helisoma* and *Gyraulus* were representative planorbids. *Stagnicola emarginata* was the only lymnaeid. Most pulmonate snails are capable of thriving under polluted conditions as a consequence of their direct accessibility to atmospheric oxygen. *Physa*, which abounded in the more eutrophic study areas of Pool 8 (Tables 9 and 10), was found by Gaufin and Tarzwell (1956) to be a major component of the pollution-tolerant communities in Lytle Creek, Ohio. Working specifically with *Physa integra*, Gaufin and Tarzwell reported that the ability of this snail to directly utilize atmospheric oxygen enabled it to benefit from the abundant food supplies in the enriched portions of the aquatic habitat. The snail was much more abundant in the polluted zones as compared to the cleaner areas of Lytle Creek. Similar explanations can presumably to advanced to account for the preference of *Physa* for the more eutrophic habitats in Pool 8.

All members of the Class Pelecypoda, the dominant mollusks in Navigation Pool No. 8, are entirely aquatic. This is unlike the Class Gastropoda which includes a few terrestrial species. Pelecypods have been reported to occur more frequently in unpolluted shallows of large rivers where they burrow into the sediments often until the excurrent and incurrent siphons are the only structures visible above the substrate. Stable sediments generally support the largest mussel populations, while shifting sediments and environments of high turbidity are not conducive to the growth of these gill-breathing, filter-feeding bivalves.

Navigation Pool No. 8 supported pelecypods belonging to the Families Unionidae (pearly mussels or naiads) and Sphaeriidae (fingernail clams, seed shells). More genera were collected from the Unionidae family and included *Amblema rariplicata*, *Anodonta*, *Anodontoides*, *Carunculina parva*, *Fusconaia undata*, *Lampsilis*, *Lasmigona*, *Ligumia*, *Obliquaria reflexa*, *Quadrula metanevra*, *Q. pustulosa*, *Q. quadrula*, and *Truncilla truncata*. These unionids appeared sporadically and were often represented by a sole specimen. No habitat preferences could therefore be legitimately postulated. Sphaeriidae was represented by greater numbers of individuals and included *Musculium*, *Pisidium*, and *Sphaerium*. *Musculium* and *Sphaerium* (Appendix Fig. I-19), the dominant pelecypods, were widespread throughout the 41 study areas but did not occur in the five stagnant, marshy openings (areas 1-5). Their general distribution favored those intermediate eutrophic areas having intermediate current velocities and fine sediments. Presumably, these sediments were sufficiently stable so as not to interfere with the gill-breathing and filter-feeding activities of these pelecypods. The distribution of *Sphaerium* was significant in relation to the physical-chemical parameters (Sampling Period I: multi-r = .864, $P < 0.01$; Sampling Period II: multi-r = .741, $P < 0.01$). The composition of the substrate is one factor determining the ecological distribution of sphaeriid clams (Gale 1971, Heard 1963). Under experimental conditions Gale (1971) reported that the fingernail clam *Sphaerium transversum* preferred mud, sandy mud, and sand substrates over hard clay, rock, and pebble sediments. He further concluded that under natural conditions in Pool 19 of the Mississippi River this substrate preference was found to be modified by such factors as predation, competition, disease, and/or parasitism.

The qualitative and quantitative compositions of the benthic communities collected from the 41 study areas in Navigation Pool No. 8 varied. The more eutrophic areas generally supported fewer taxa (Table 4, Figs. 14 and 15), greater biomasses or wet weights (Table 5

Figs. 16 and 17), and greater numbers of macroinvertebrates (Table 6, Figs. 18 and 19). One or possibly two species were dominant in these areas. These dominants composed most of the bottom community and usually belonged to the Class Oligochaeta. Similar results were obtained by de March (1976) and Olive and Smith (1975). Olive and Smith assumed these results to be attributable to low oxygen concentrations and uniform, unstable fine sediments which probably eliminated competitors and possible predators. The silt-clay, depositional-type sediments were possibly too unstable for those forms which cling to stable, erosional-type substrates (Olive and Smith 1975). According to Hynes (1960), depositing substrates, primarily composed of silt or mud, occur mostly in lentic waters and typically have low oxygen levels. Eroding substrates of rock, stone, or gravel are principally found in lotic environments and are well oxygenated. According to de March (1976), the reduced number of species or taxa present was the result of fewer habitats or interstices available in fine sediments. De March also reported that the lack of interstices in fine, silty sediments could limit the total numbers of macrobenthic organisms present. This observation was contradicted in the present investigation. Greater numbers of benthic macroinvertebrates were collected from fine sediments. More taxa, smaller biomasses, and fewer macroinvertebrates, indicative of ecologically more stable conditions (Patrick 1950), were yielded from the less eutrophic areas where presumably competition for food and space was greater. Consequently no one macroinvertebrate could become dominant (Gaufin and Tarzwell 1956, Patrick 1950).

As shown in Tables 7 and 8, strong, positive correlations existed between the average physical-chemical conditions encountered in the pool during the summer of 1975 and the number of taxa/area (Sampling Period I: multi-r = .760, $P < 0.01$; Sampling Period II: multi-r = .860, $P < 0.01$), the mean total biomass/m^2 (Sampling Period I: multi-r = .739, $P < 0.01$; Sampling Period II: multi-r = .819, $P < 0.01$), and the mean number of macroinvertebrates/m^2 (Sampling Period I: multi-r = .869, $P < 0.01$; Sampling Period II: multi-r = .785, $P < 0.01$). Certain physical-chemical parameters, especially current velocity and substrate type, significantly influence the occurrence and distribution of benthic inhabitants in rivers (Brusven and Prather 1974, Gaufin and Tarzwell 1956, Hynes 1960, Patrick 1962). Nielsen (1950) stated that fast-water benthic communities are composed of few species. No such correlation seemed strongly evident in the present investigation (Tables 7 and 8). Correlation coefficients of .332 ($P < 0.05$) and .249 ($P > 0.05$) were respectively obtained during Sampling Periods I and II between the number of taxa/area and the average current velocity in each area. Although depth and temperature have been reported as being important physical factors influencing the compositon of the benthic community (Hynes 1960, Patrick 1962), most of the observed benthic variables were not significantly correlated with these two parameters (Tables 7 and 8). Dissolved oxygen, sediment organic nitrogen and sediment nitrate, in addition to current velocity and sediment particle size, appeared to be the dominant governing factors, especially when correlated with the mean number of macroinvertebrates/m^2. The values obtained for the mean number of macroinvertebrates/m^2 in each area were significantly correlated with current velocity, turbidity, dissolved oxygen, sediment organic nitrogen, sediment nitrate, sediment particles sizes #3, #4, and #6. Greater numbers of macroinvertebrates/m^2 were found in fine, organically rich, depositional-type sediments. These results, previously obtained in terms of biomass/m^2 by Claflin (1973) in Navigation Pool No. 8, tend to contradict those obtained by de March (1976) and Scott (1958). Scott concluded that, primarily due to the greater variety of habitats and greater stability during flooding offered by large stones, the density of the general bottom fauna increases with increasing sediment particle size.

Impoundments result in the production of extensive, shallow backwater areas. Claflin (1973) reported that the closure of Lock and Dam No. 8, creating an 11-foot rise in the upstream pool, resulted in the inundation of many large, diverse habitats and an increase in the surface area of the pool. The energy flux in these shallow, eutrophic areas typically having silty, organically rich sediments is high and consequently productivity at all trophic levels is high (Claflin 1973). Production, in terms of benthic biomass and number, was generally higher in these areas in the present investigation. Diversity, in terms of the number of different taxa, however, was lower. Macroinvertebrates, especially oligochaetes, capable of surviving under reduced oxygen conditions tended to dominate the benthic communities.

Population densities can be used as indices of water quality (Olive and Smith 1975). Organically polluted or enriched areas generally support the largest macroinvertebrate populations which are typically composed of oligochaetes and chironomids (Hynes 1960, Olive and Smith 1975). Although the macroinvertebrate densities varied considerably among the 41 study areas in Navigation Pool No. 8 and within each study area, macroinvertebrate density appeared directly proportional to the productivity of the area. The more eutrophic areas (areas 1-18) supported the largest macroinvertebrate populations. These populations were dominated by pollution-tolerant organisms, such as oligochaetes, certain chironomids (e.g., *Chironomus*), and leeches, which could benefit from the abundant food supplies and the absence of severe competition and predation. Most competitors and predators cannot sustain robust populations due to the low dissolved oxygen levels and the fine, uniform sediments which do not provide firm substrates allowing for movement and the maintenance of position.

The benthic faunas inhabiting the more productive areas in Navigation Pool No. 8 were typically pollution-tolerant worm or worm-like organisms capable of surviving and burrowing into the silty, depositional-type sediments. Most of these organisms had low oxygen requirements or, like *Physa*, possessed special adaptations for obtaining atmospheric oxygen. The oligochaetes were dominant and ubiquitous throughout the 41 study areas but their absolute abundance and their abundance in relation to the total benthic community tended to decrease from the more productive areas to the less productive areas. Chironomids, especially *Chironomus*, *Endochironomus*, and *Glyptotendipes*, leeches, the pelecypods *Sphaerium* and *Musculium*, and the mayfly *Hexagenia* were often capable of maintaining healthy populations in the more eutrophic areas. The amphipod *Hyalella azteca*, which is not generally considered a pollution-tolerant organism and which requires large concentrations of dissolved oxygen for its survival, often composed a large proportion of the total benthic community in these more productive areas. Similar finding were reported by Olive and Smith (1975). They concluded that the release of phosphates, nitrates, and other plant nutrients from digested organic material indirectly contributes to the high densities of caddisflies as well as amphipods. These amphipods and caddisflies are abundant in plant communities of filamentous algae and aquatic vascular plants. The release of phosphates, nitrates, and other plant nutrients stimulates the growth of these plant communities which in turn provides more living space for the amphipods and caddisflies. In the present investigation, *Hyalella azteca* was positively correlated at the 0.01 significance level with sediment organic nitrogen and phosphate (Tables 7 and 8).

Small macroinvertebrate populations were supported in the less eutrophic areas having stable, erosional-type substrates. More taxa were present presumably due to the more severe levels of competition and predation operating in these habitats. The benthic communities in these areas contained greater numbers of pollution-sensitive forms which are usually eliminated from organically enriched areas because of inadequate oxygen concentrations, habitat destruction caused by siltation, and the presence of toxic substances, such as ammonia, which are frequently found in organic pollution (Hynes 1960). More benthic macroinvertebrates dependent on gill breathing and filter feeding as the primary modes of respiration and feeding were in these areas as compared to the more eutrophic areas. This was partially the result of an increase in the number of immature stages of insects in these areas. A few of the more abundant insect representatives included the mayfly *Brachycercus*, the caddisflies *Cheumatopsyche* and

Hydropsyche, and the dipterans *Atrichopogon*, *Cricotopus*, *Harnischia*, *Palpomyia*, *Simulium*, and *Xenochironomus*. Unlike the burrowers found in the more eutrophic, lentic study areas of Navigation Pool No. 8, many of these so-called "clean-water" forms were adapted to clinging to stable substrates in lotic habitats.

The separation of the more eutrophic and the less eutrophic study areas in terms of the fauna characteristic to each of these two habitat types is not distinct. Many benthic macroinvertebrates are capable of tolerating a wide variety of physical-chemical parameters. These transitional or pollution-facultative organisms can survive under both extremes of trophic status or under an intermediate trophic status. In the present investigation, such forms were typified by nematodes, turbellarians, the isopod *Asellus militaris*, the dipterans *Cryptochironomus* and *Polypedilum*, and the gastropod *Amnicola*. The delineations between the faunas of the more productive and the less productive areas are further blurred since the fauna characteristic of one of these types of area may occur in the benthic community of the other type of area. The presence or absence of a macroinvertebrate in a particular benthic community may depend more on environmental conditions, such as substrate or current velocity, rather than on trophic status. Oligochaetes and *Physa*, both regarded as pollution-tolerant organisms, were also collected in the less eutrophic areas in the present investigation (Tables 9 and 10). Although the caddisflies *Cheumatopsyche*, *Hydropsyche*, and *Stactobiella* were more abundant in the less eutrophic, lotic study areas, they were occasionally present in the more productive study areas (Tables 9 and 10).

Role of Macrobenthic Invertebrates in Pool 8

Apart from their roles as biological indicators, macroinvertebrates serve other functions. As a vital component of the food web (Cummins 1973), macrobenthic organisms are an important source of food for fish in Navigation Pool No. 8 (Thiel 1977, Wynes 1976). The Chironomidae (Mason 1975), Ephemeroptera (Britt 1975, Fremling 1964), and Mollusca (Heard 1963, Pennak 1953, Wetzel 1975) may serve as significant food sources for fish, birds, and other aquatic and terrestrial life. Benthic inhabitants are also potential contributors to public health and recreational problems, pest and parasite nuisances, and nutrient recycling. Many macroinvertebrates, such as snails, serve as intermediate hosts for parasites of fish and birds and act as vehicles for the transmission of diseases. Clams are capable of concentrating bacteria and viruses (Grimes 1977). Many, especially the Diptera, are pests as biters. Emergences of large numbers of dipterans and ephemeropterans create simple nuisance situations. These emergences of benthic invertebrates may aid in the transport of nutrients to other zones of the aquatic environment (Wetzel 1975). Wetzel has also reported that the burrowing activities of several benthic organisms may disrupt the sediment-water interface and significantly alter the oxidized microzone of the bottom substrate. The effect of this physical disruption on nutrient exchange and cycling is unclear and is probably insignificant in relation to the dominant chemical-microbial regulatory processes. The role that the excretion of nutrients by macrobenthic invertebrates plays in the regeneration of nutrients is also uncertain (Wetzel 1975). Some benthic organisms, especially pelecypods, are of economic importance. The use of mussels in the button and pearl industries, although once important, has been declining as the result of synthetic substitutes and the degradation of mussel beds. Human influences, such as damming, dredging, and agricultural runoff, have eliminated much of the mussel habitat by causing increased siltation.

Man's Impact

Man has had a serious impact on the benthic communities of the Upper Mississippi River (Brigham 1971, Ellis 1931), as well as on those communities of other river systems (Kaplan et al. 1974, La Roe 1972, Mills 1966). The impoundment of the upper section of the Mississippi River has promoted an increase in the deposition of suspended materials, a natural result of decreasing the current velocity of the river. These unstable, shifting silt sediments have a high organic content and place a large oxygen demand on the aquatic system. As a consequence, those pollution-tolerant benthic organisms capable of surviving under poor oxygen conditions, including certain oligochaetes, chironomids, and pulmonate snails, become abundant and replace the clean-water forms which require more stable substrates having high oxygen contents. As mentioned previously, the increased siltation has resulted in the elimination of once-important commercial mussel populations. These changes in the benthic fauna may have adverse effects on the fish communities which may be limited to those fish which can utilize the tolerant macrobenthic invertebrates as food items. Duck populations which feed on mollusks may also experience unfavorable repercussions (Brigham 1971).

The graded condition of the Mississippi River is also aggravated by increased agricultural tillage and dredging. Dredging has had many adverse effects on benthic assemblages (Brigham 1971, Kaplan et al. 1974, La Roe 1972). These effects can be divided into three categories, immediate effects, transitory or semipermanent effects, and permanent changes (Kaplan et al. 1974). Immediate effects include increased siltation, the removal from the water column of planktonic organisms which serve as food items for macrobenthic filter feeders, and changes in the chemical water quality as substances are released from the dredged substrates and dissolved. Dredging also causes increased, irregular suspension of materials which reduce light penetration and, therefore, photosynthesis. These suspended materials also interfere with the filter-feeding mechanisms of many benthic organisms. Transitory effects include the mechanical removal of the benthic fauna and changes in the substrate type. Benthic organisms, capable of surviving on the resulting substrate, will eventually recolonize the previously dredged area. Kaplan et al. (1974) noted however that the benthic communities prior to dredging operations generally had larger biomasses, greater numbers and greater numbers of species. Disruption of the existing current patterns and velocities cause permanent ecological changes.

Human activities tend to exert a monotypic influence on aquatic environments. Damming, dredging, pollution, and careless agricultural practices often cause the simplification of the environment and the elimination niches. The "healthy" community (Patrick 1950), which is composed of many taxa, small biomasses, and few numbers due to balanced, severe competition, is placed under stress and is gradually replaced by a community having fewer taxa, greater biomasses, and greater numbers. Many species are eliminated and the few that survive are able to freely multiply due to the reduced competition.

SUMMARY AND CONCLUSIONS

One hundred forty-four macrobenthic taxa, identified in most cases to the generic level, were found in this survey of 41 study areas in Navigation Pool No. 8 of the Upper Mississippi River during the summer of 1975. Over half of the collected taxa were insect nymphs and larvae. The mollusks were second in importance in terms of the number of taxa examined. A total of 90,693 representatives of the Phyla Platyhelminthes, Nematoda, Annelida, Arthropoda, and Mollusca were counted, weighed, and identified. Members of the Class Oligochaeta were by far the most ubiquitous and dominant macroinvertebrates found in the 616 bottom collections. Spatial distribution of many other benthic forms varied and reflected habitat preference.

Pool 8 demonstrates great ecological diversity due partly to the inundation of large, diverse land areas caused by the closure of Lock and Dam No. 8. Habitats range from the very eutrophic backwater areas to the less eutrophic areas of the main channel and adjacent waters. Although habitat preferences of specific macroinvertebrates were apparent and were often governed by particular physical-chemical parameters, such as current velocity and substratum, these ecologically diverse habitats supported characteristic benthic macroinvertebrate communities. Proceeding from the more eutrophic areas to the less eutrophic areas, the following trends in the benthic macrofauna were observed:

1. The number of taxa per area increased.
2. Benthic production, in terms of the total wet weight/m^2 and the mean number of macroinvertebrates/m^2 in each area, decreased.

3. The relative abundance of pollution-tolerant forms which have low oxygen requirements or which have special adaptations to obtain atmospheric oxygen decreased.
4. An increase in the abundance of pollution-sensitive forms occurred.
5. The number of gill breathers and filter feeders increased.
6. There was an increase in the relative number of insects, including caddisflies, mayflies, stoneflies, and dipterans.
7. Burrowing organisms adapted to lentic, silty habitats tended to be replaced by macroinvertebrates favoring lotic habitats and found clinging to erosional-type sediments.

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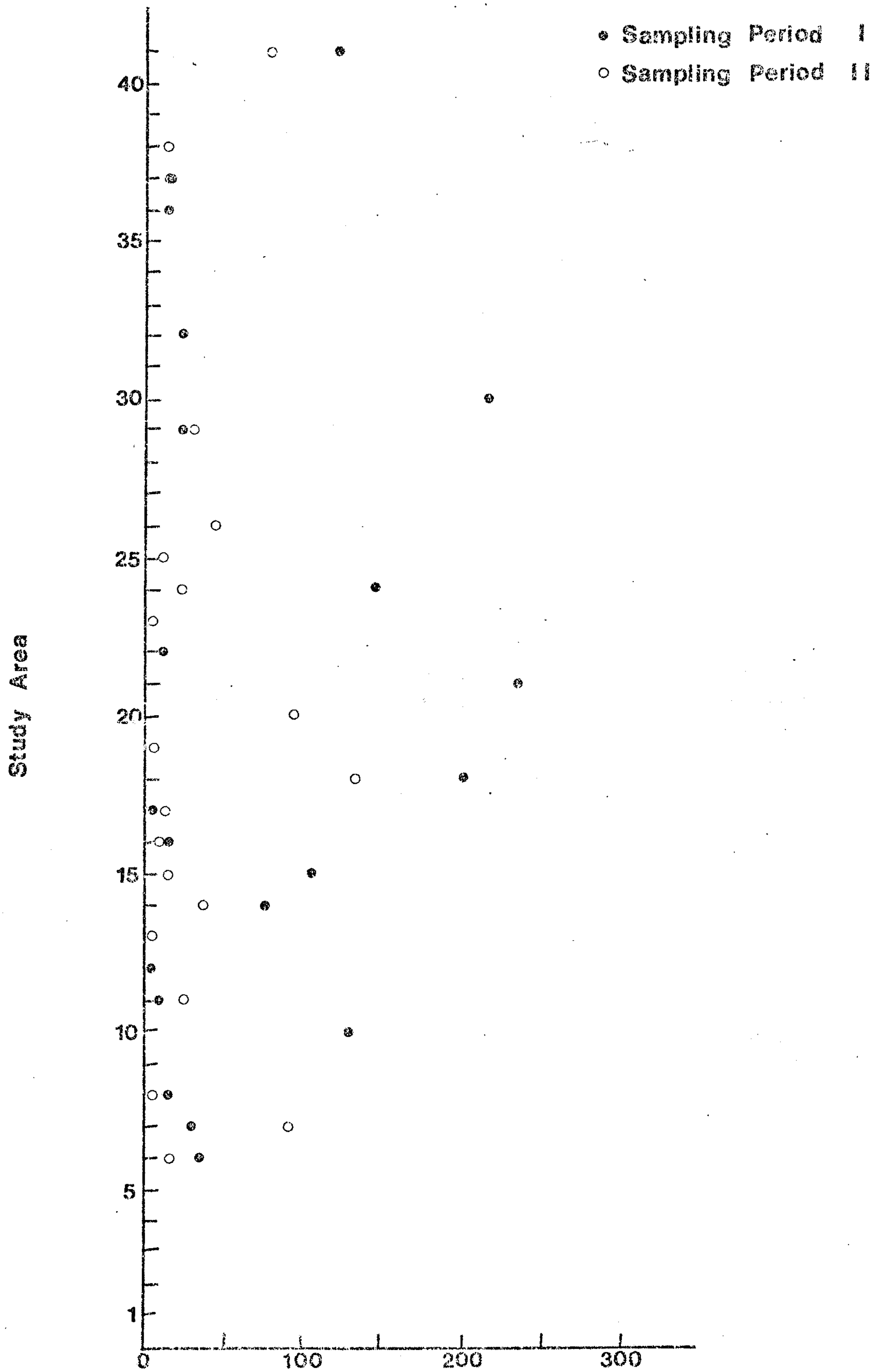
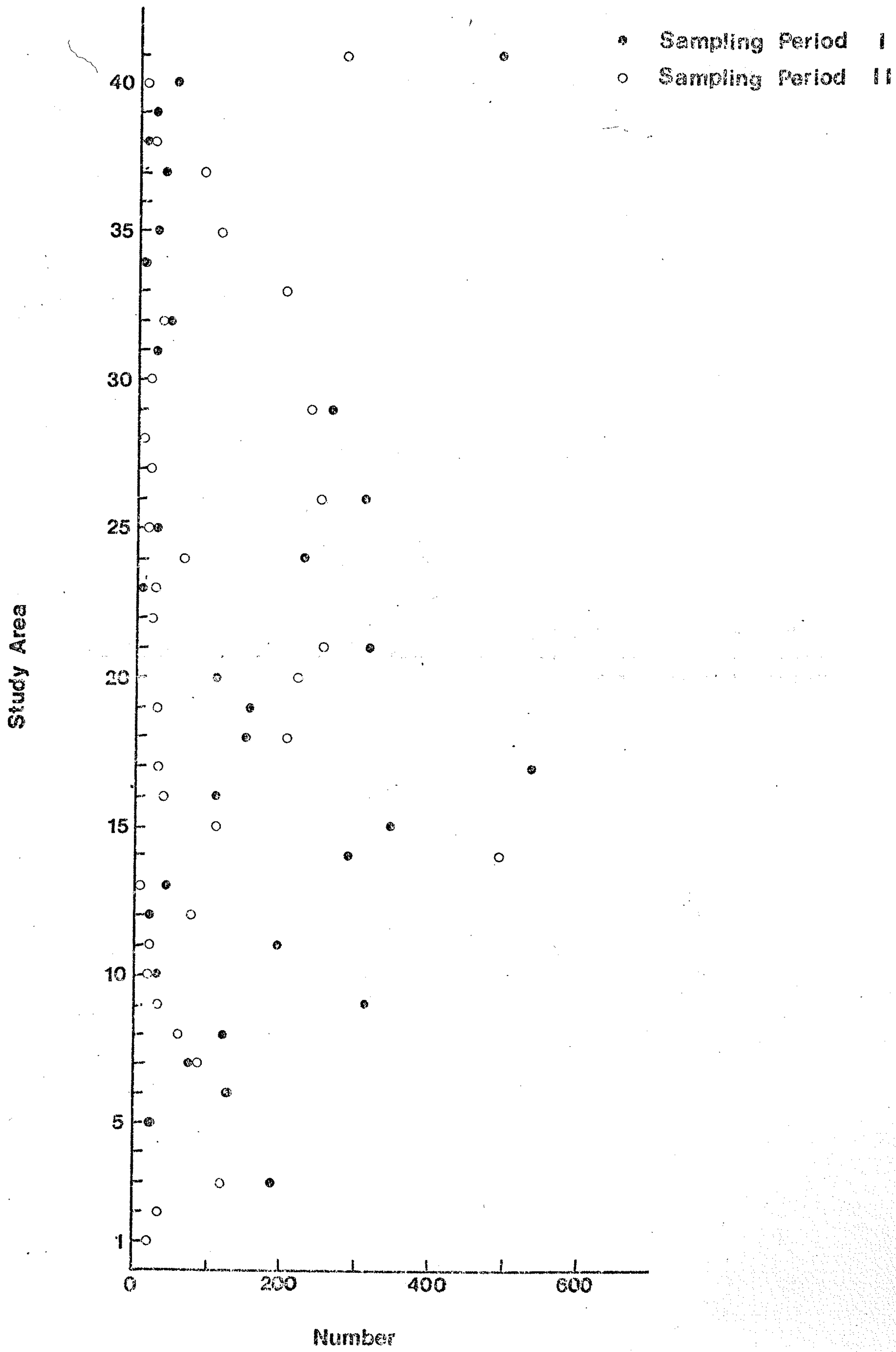
Appendix I. Distribution of selected macrobentic invertebrates in all study areas of Navigation Pool No. 8 of the Upper Mississippi River during the summer of 1975.

Appendix Fig. I-1. Average number of organisms per square meter (Turbellaria), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



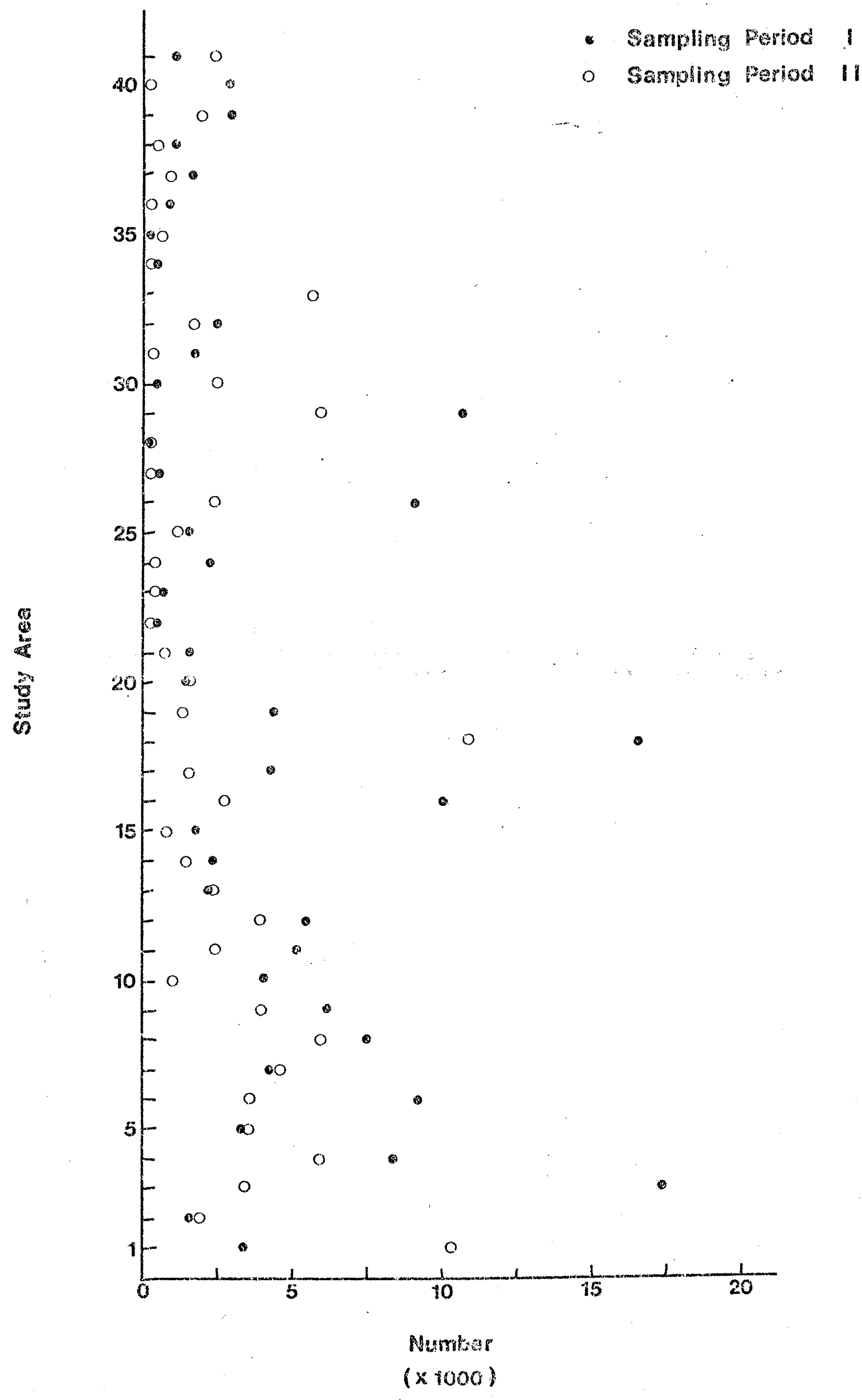
Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
Number
0
100
200
300

Appendix Fig. I-2. Average number of organisms per square meter (Nematoda), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



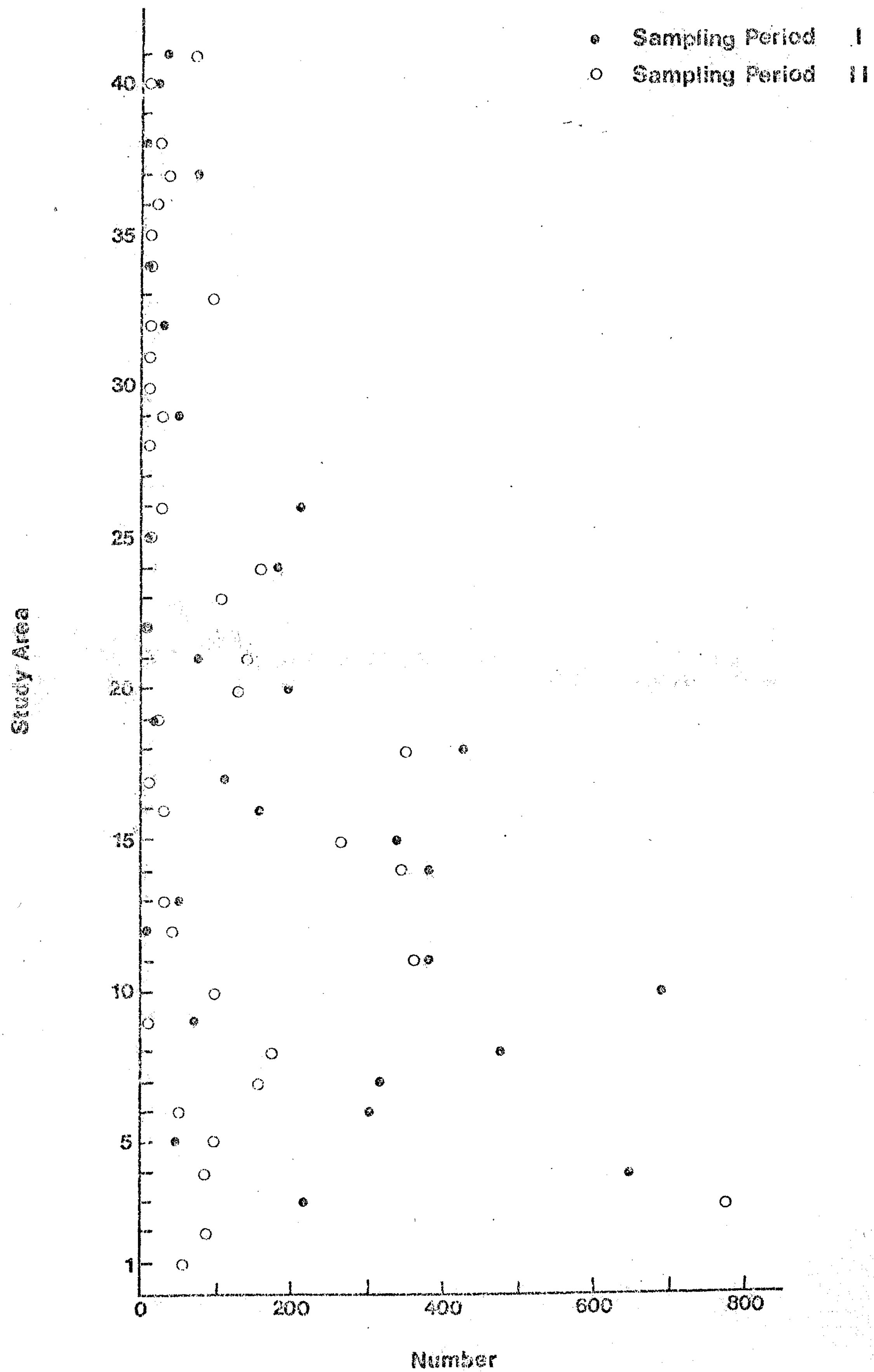
Sampling Period I
Sampling Period II
Study Area
1
5
10
15
20
25
30
35
40
0
200
400
600
Number

Appendix Fig. I-3. Average number of organisms per square meter (Oligochaeta), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



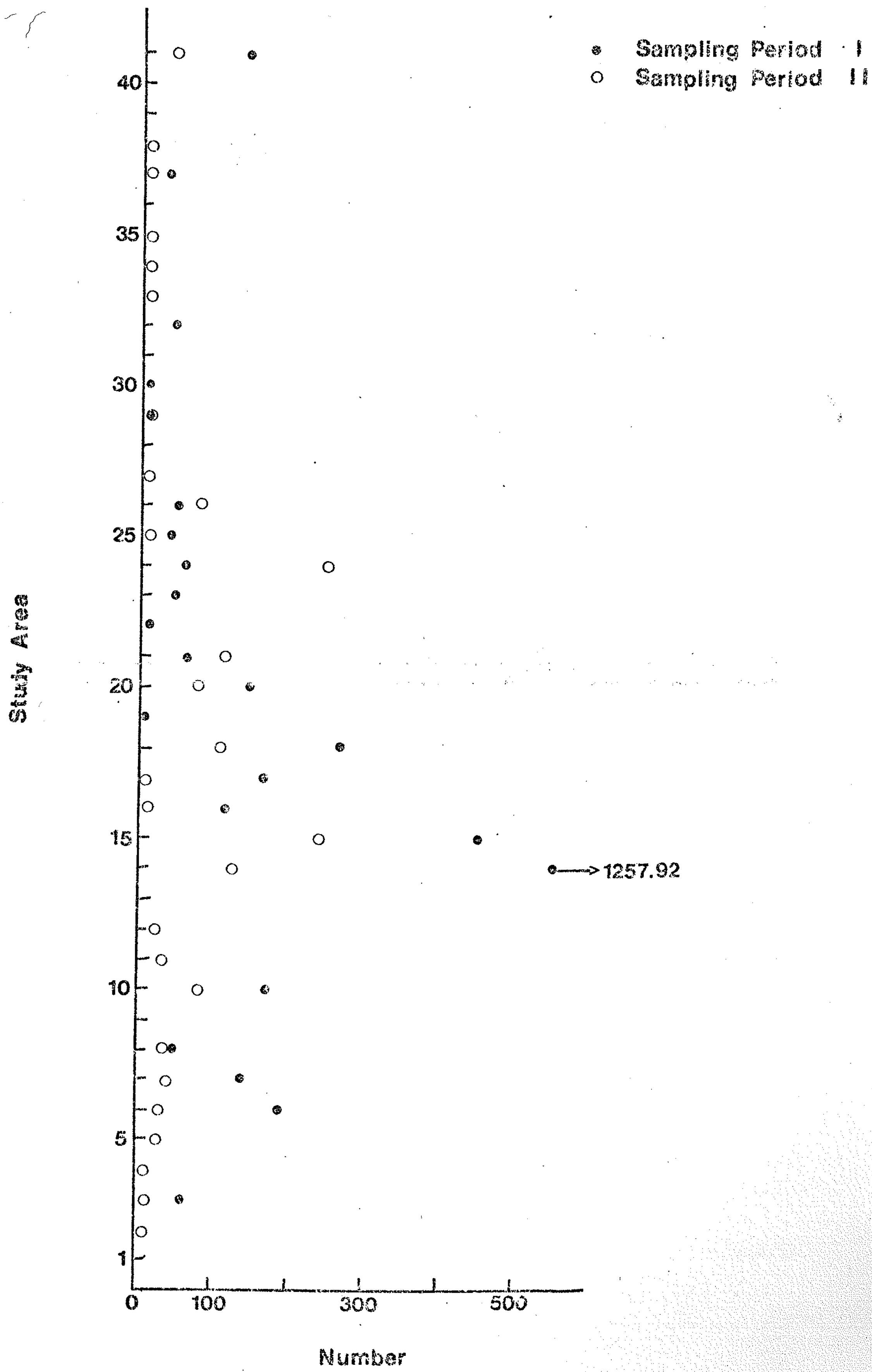
Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
5
10
15
20
Number
(x 1000)

Appendix Fig. I-4. Average number of organisms per square meter (Hirudinea), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



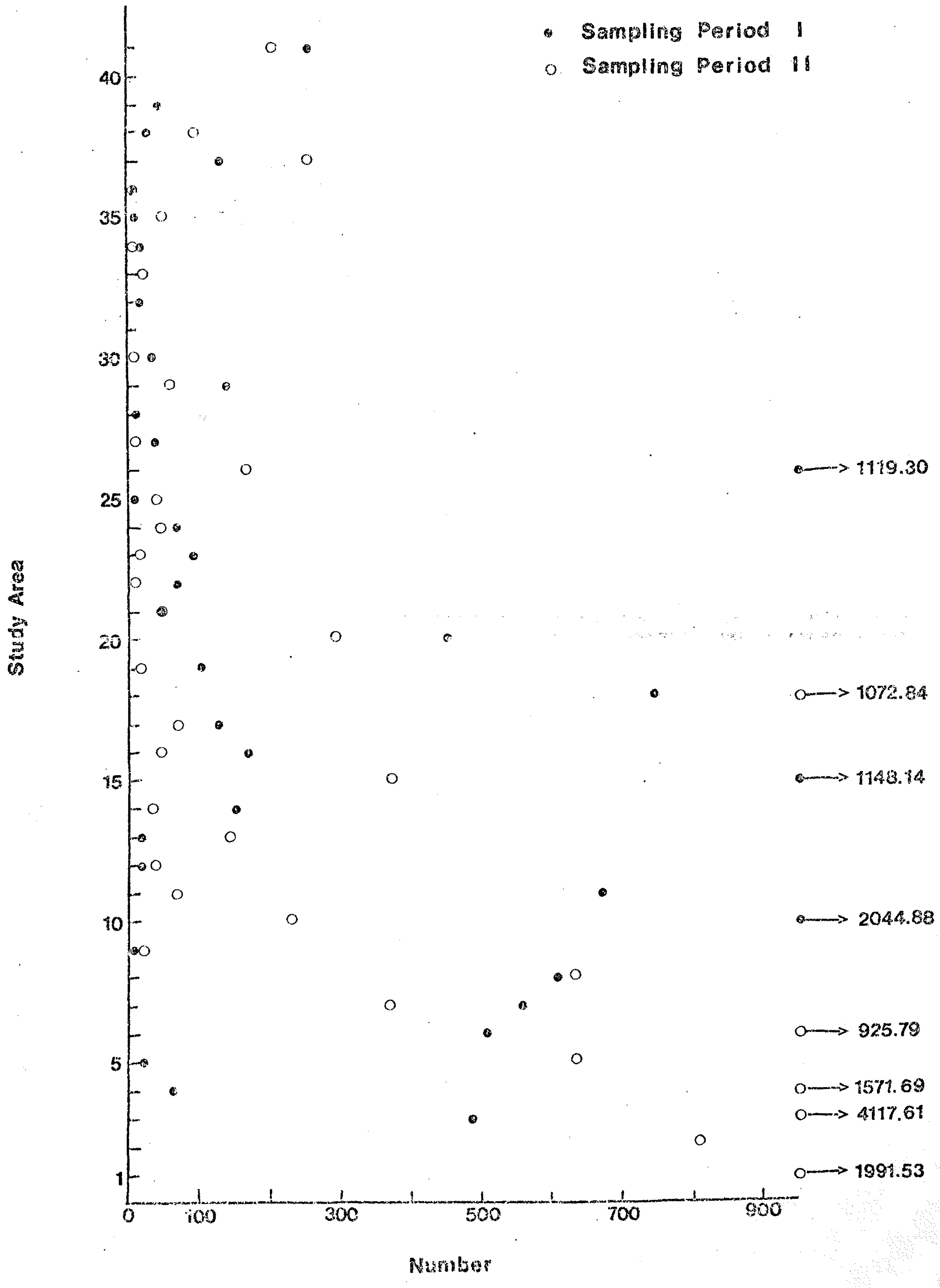
Sampling Period I
Sampling Period II
Study Area
1
5
10
15
20
25
30
35
40
0
200
400
600
800
Number

Appendix Fig. I-5. Average number of organisms per square meter (*Asellus militaris*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



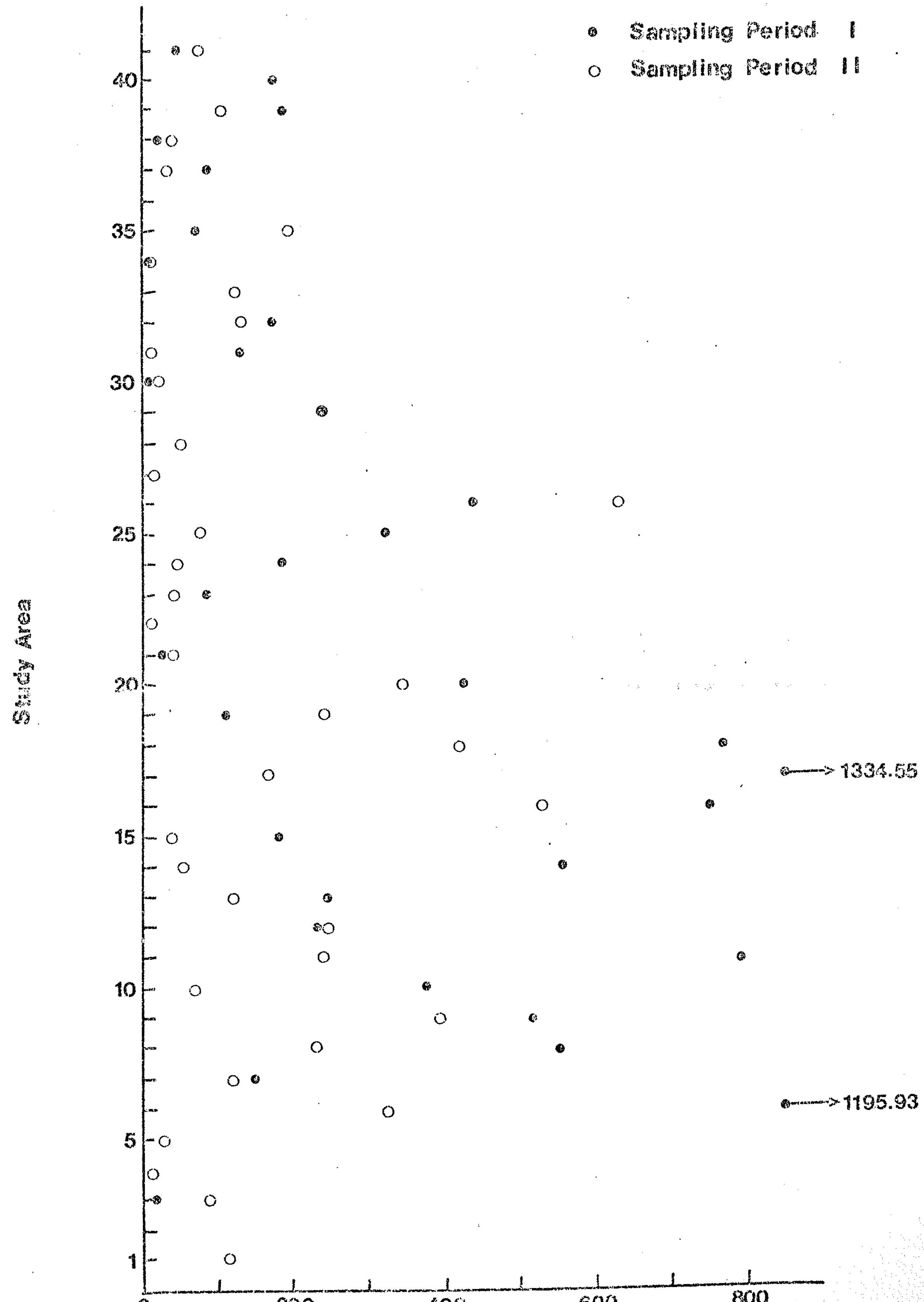
Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
100
300
500
Number
1257.92

Appendix Fig. I-6. Average number of organisms per square meter (*Hyalella azteca*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

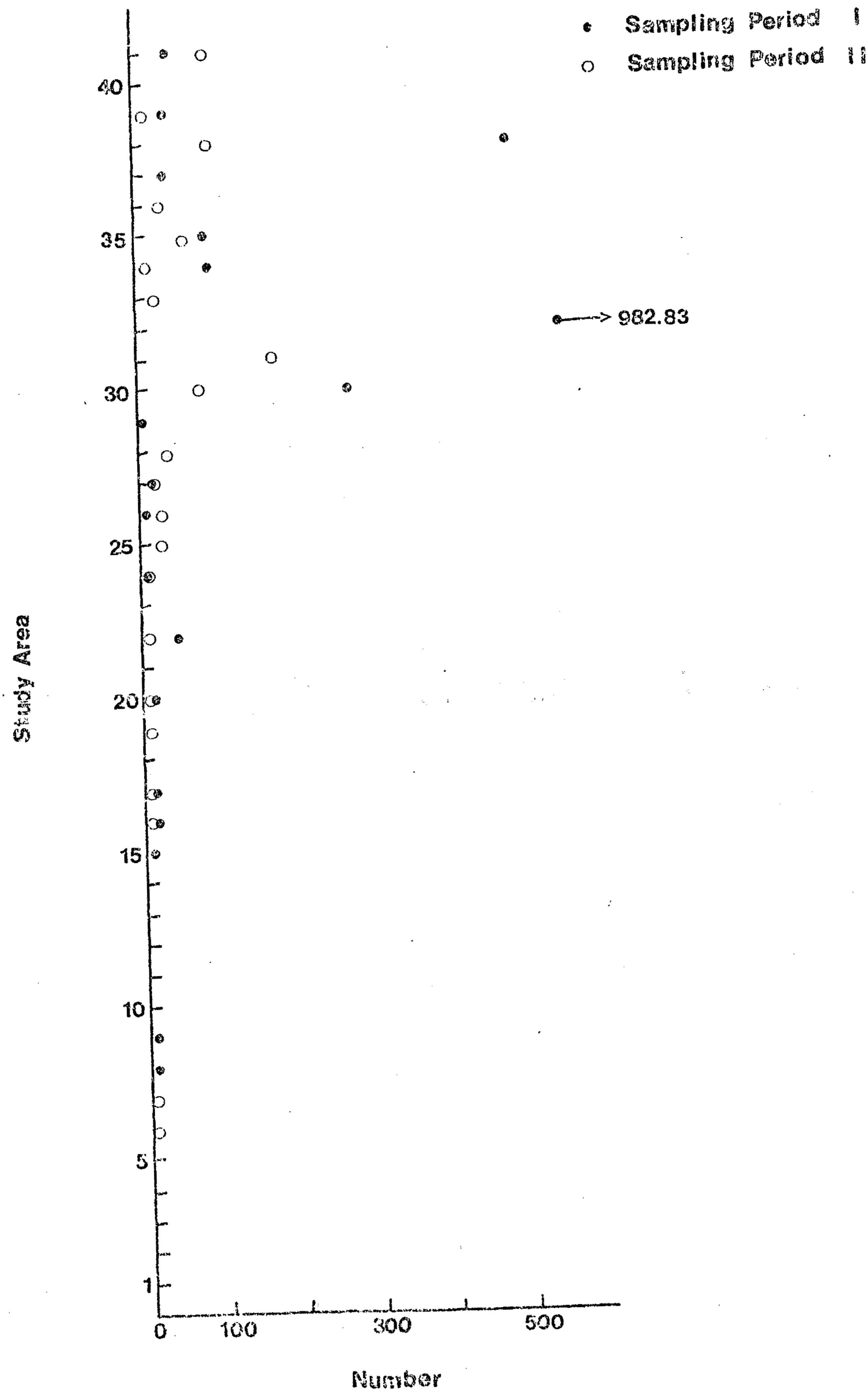


Sampling Period I
Sampling Period II
Study Area
Number
0
100
300
500
700
900
1
5
10
15
20
25
30
35
40
1119.30
1072.84
1148.14
2044.88
925.79
1571.69
4117.61
1991.53

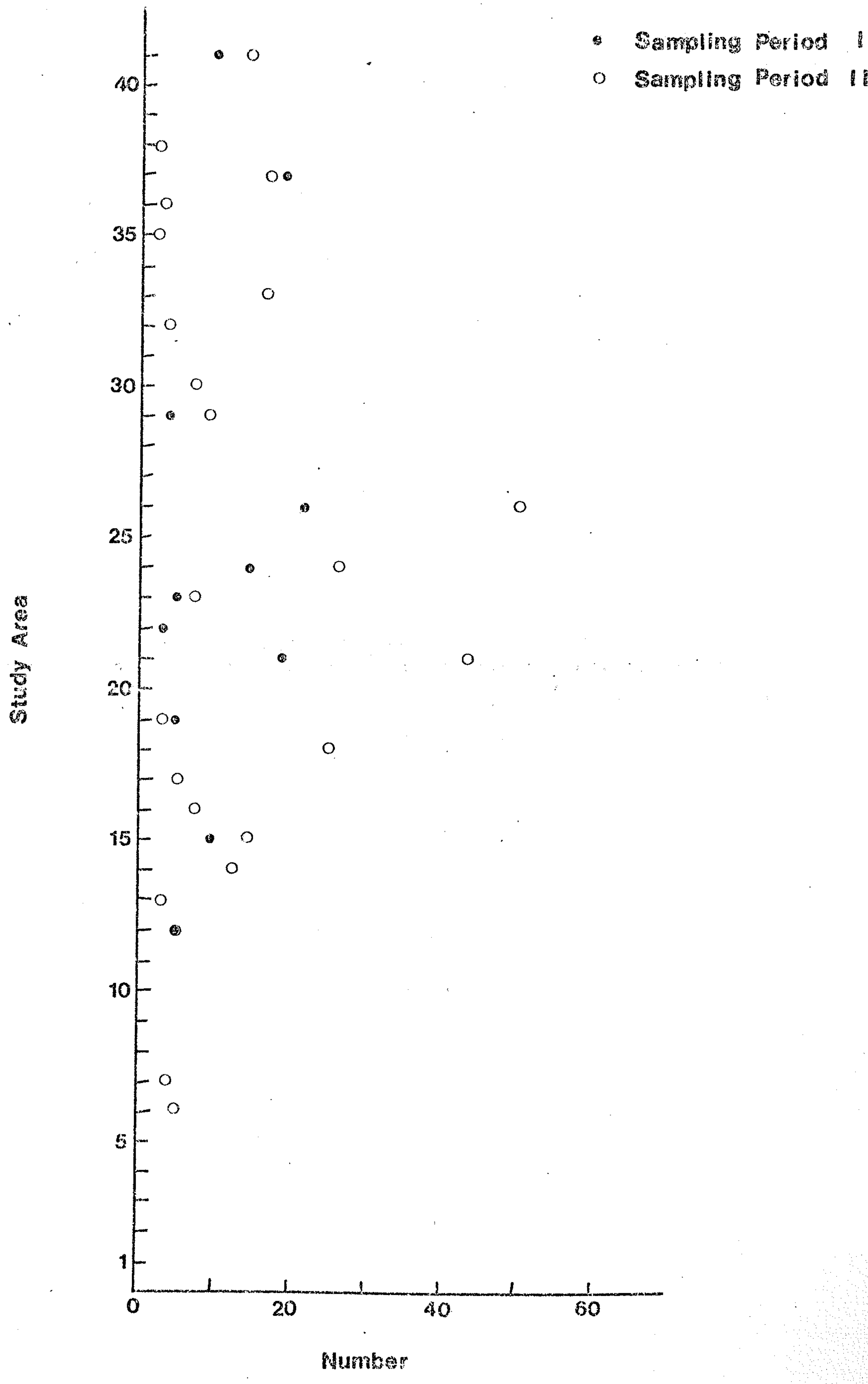
Appendix Fig. I-7. Average number of organisms per square meter (*Hexagenia*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.


Sampling Period I
Sampling Period II
Study Area
Number
1334.55
1195.93
0
200
400
600
800
1
5
10
15
20
25
30
35
40

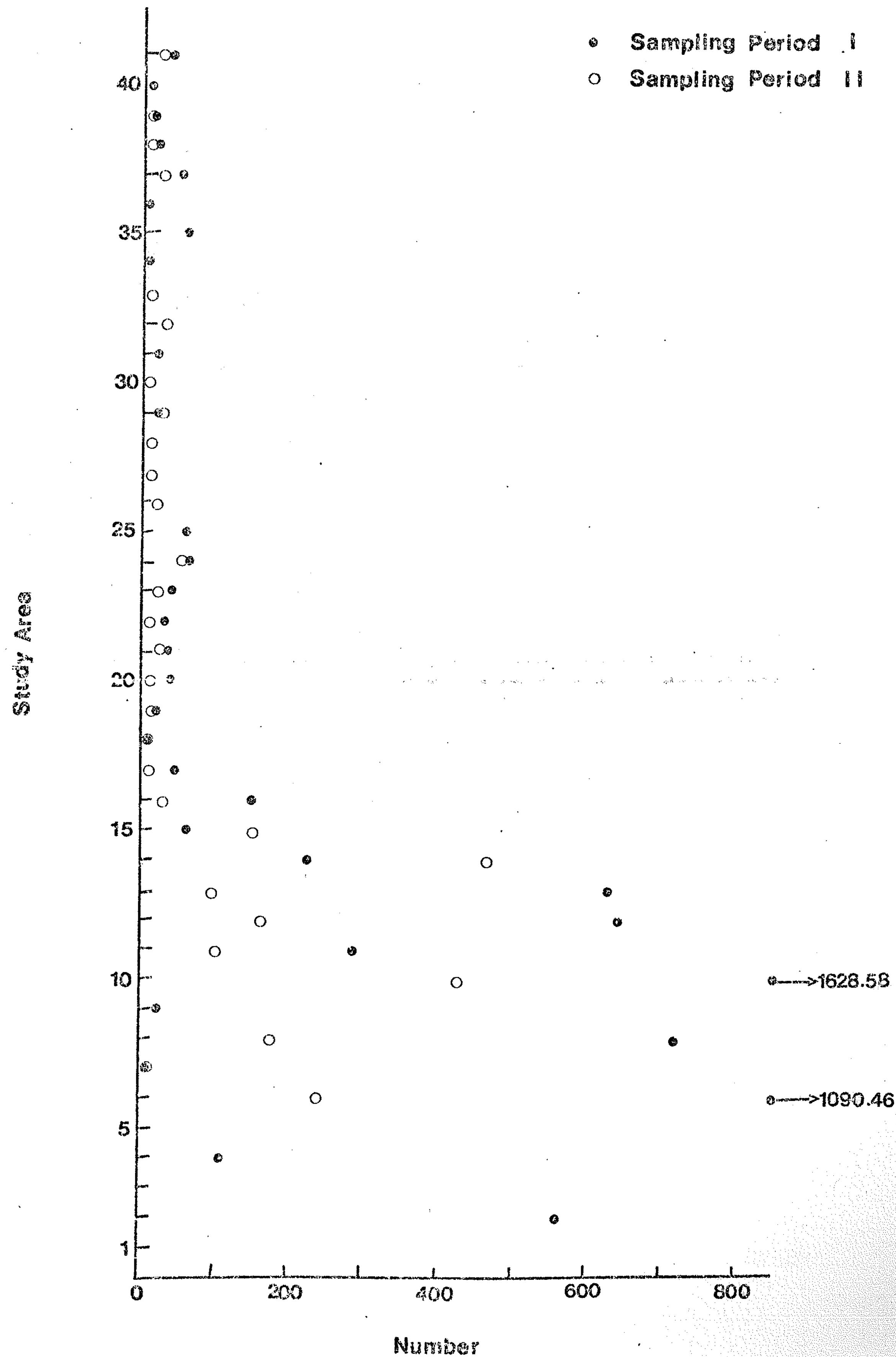
Appendix Fig. I-8. Average number of organisms per square meter (*Cheumatopsyche*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer 1975.


Sampling Period I
Sampling Period II
982.83
Study Area
40
35
30
25
20
15
10
5
1
0
100
300
500
Number

Appendix Fig. I-9. Average number of organisms per square meter (*Oecetis*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

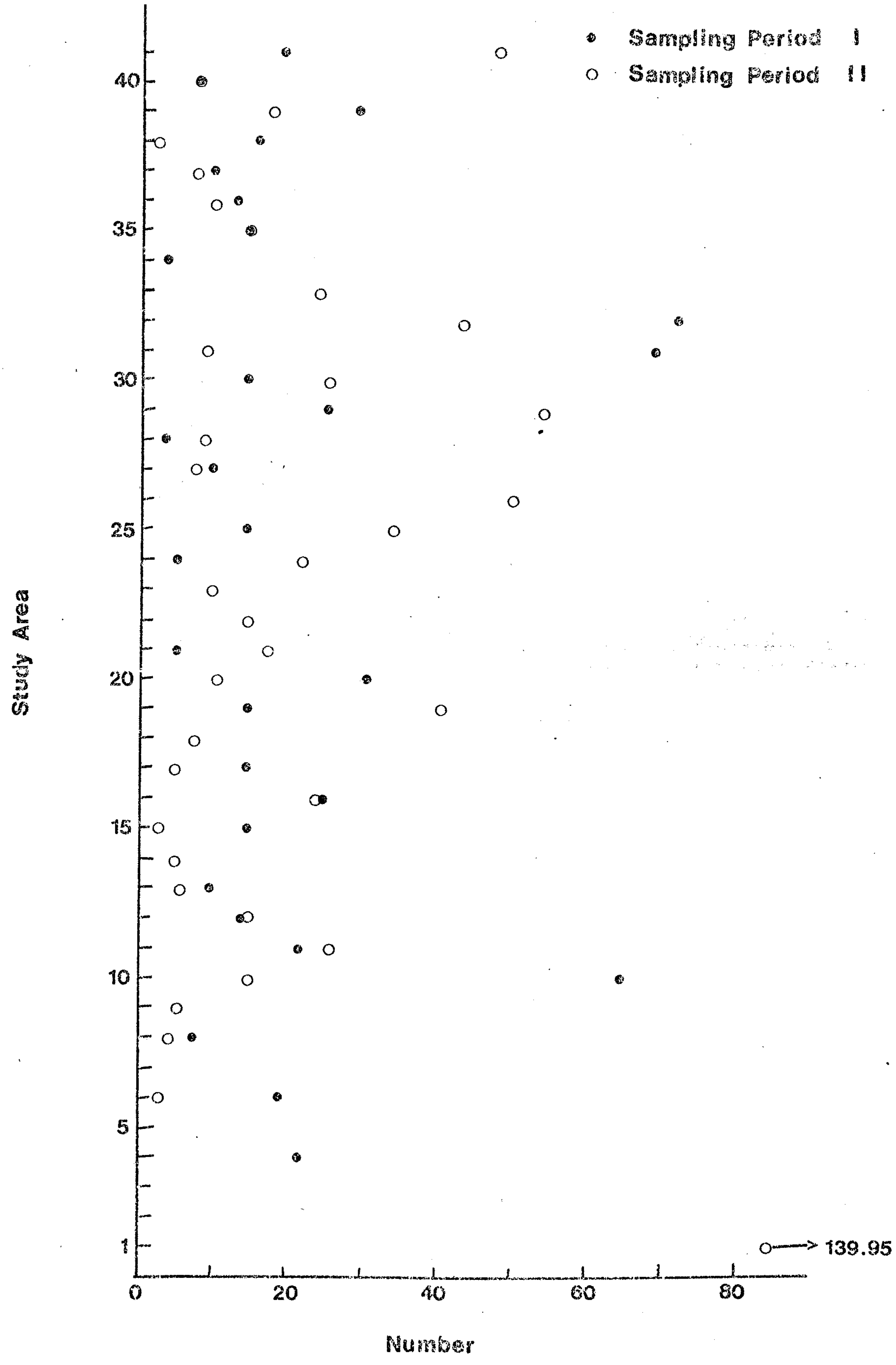

Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
20
40
60
Number

Appendix Fig. I-10. Average number of organisms per square meter (*Chironomus*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

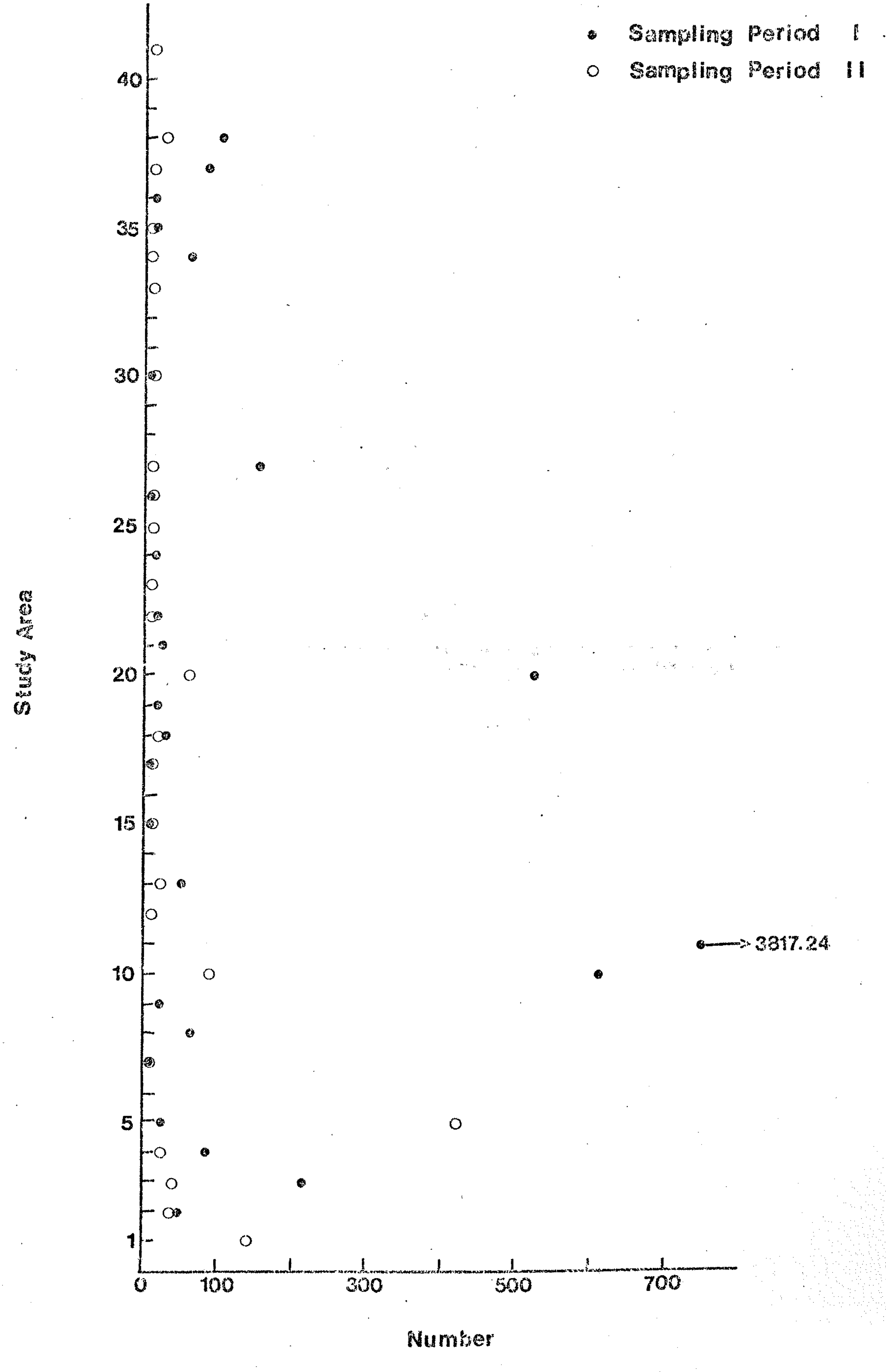


Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
200
400
600
800
Number
>1628.58
>1090.46

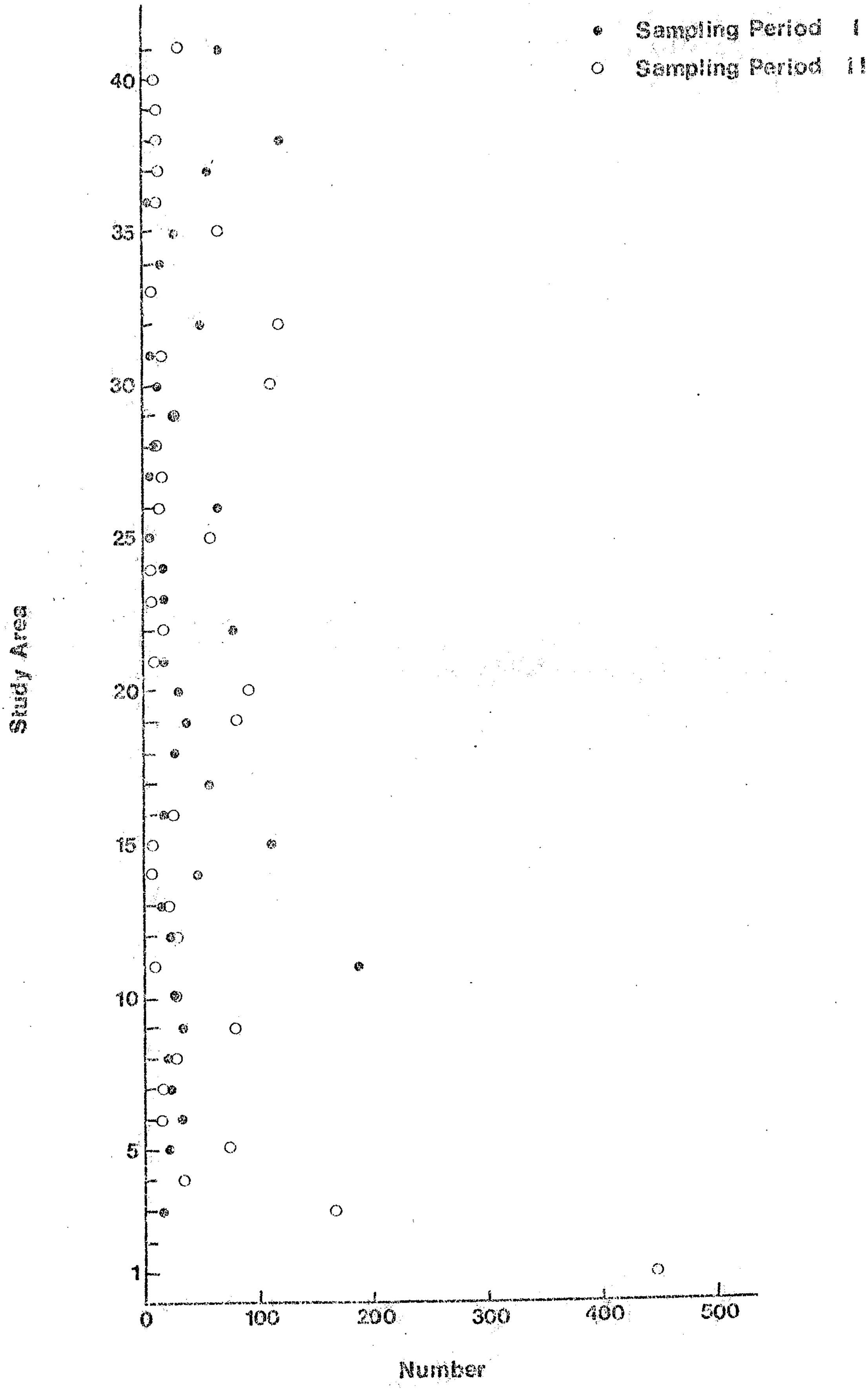
Appendix Fig. I-11. Average number of organisms per square meter (*Cryptochironomus*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.


Sampling Period I
Sampling Period II
Study Area
Number
139.95
0
20
40
60
80
1
5
10
15
20
25
30
35
40

Appendix Fig. I-12. Average number of organisms per square meter (*Endochironomus*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

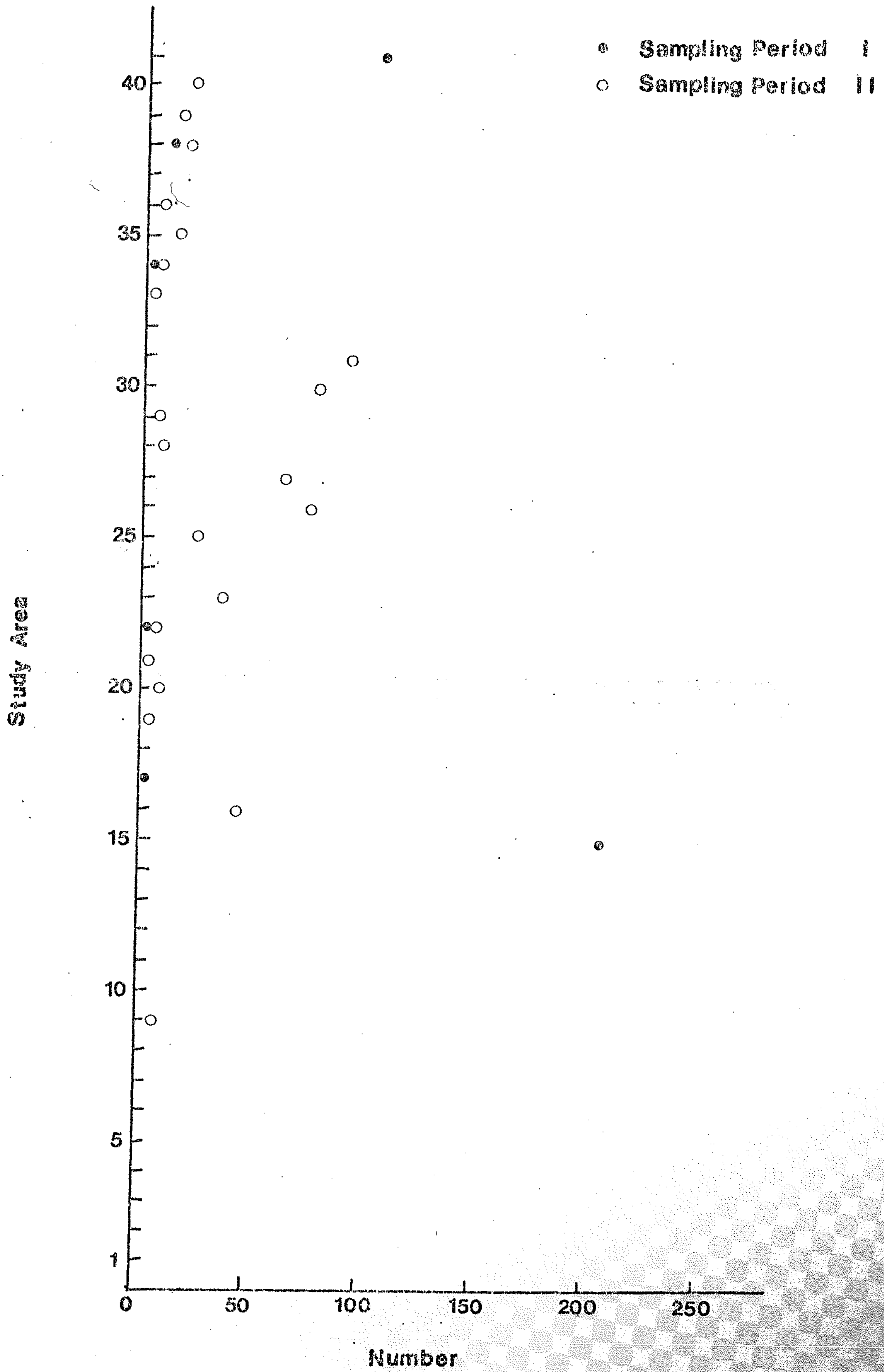

Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
3817.24
0
100
300
500
700
Number

Appendix Fig. I-13. Average number of organisms per square meter (*Polypedilum*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



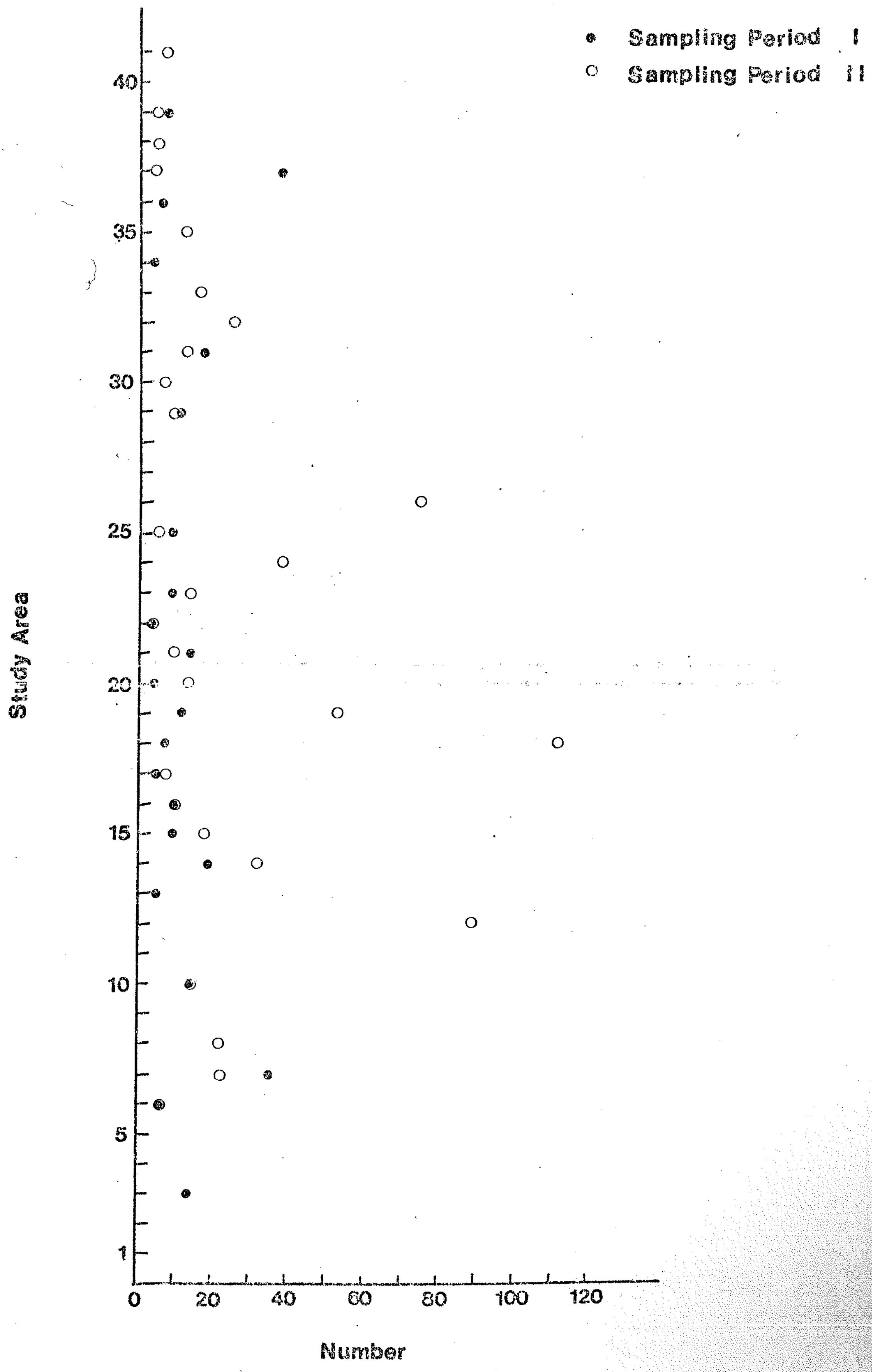
Sampling Period I
Sampling Period II
Study Area
Number
1
5
10
15
20
25
30
35
40
0
100
200
300
400
500

Appendix Fig. I-14. Average number of organisms per square meter (*Xenochironomus*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



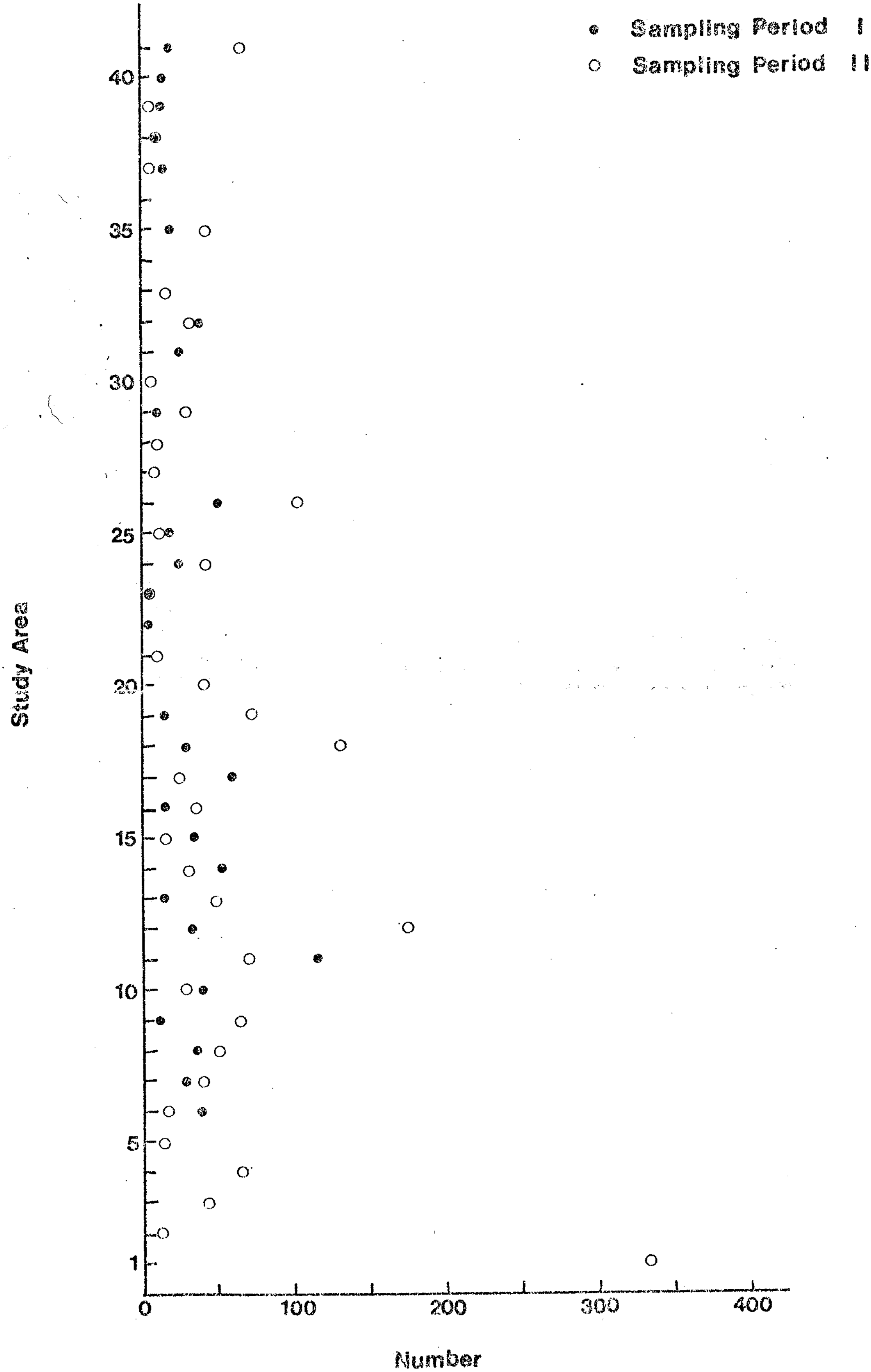
Sampling Period I
Sampling Period II
Study Area
Number
0
50
100
150
200
250
1
5
10
15
20
25
30
35
40

Appendix Fig. I-15. Average number of organisms per square meter (*Coelotanypus*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

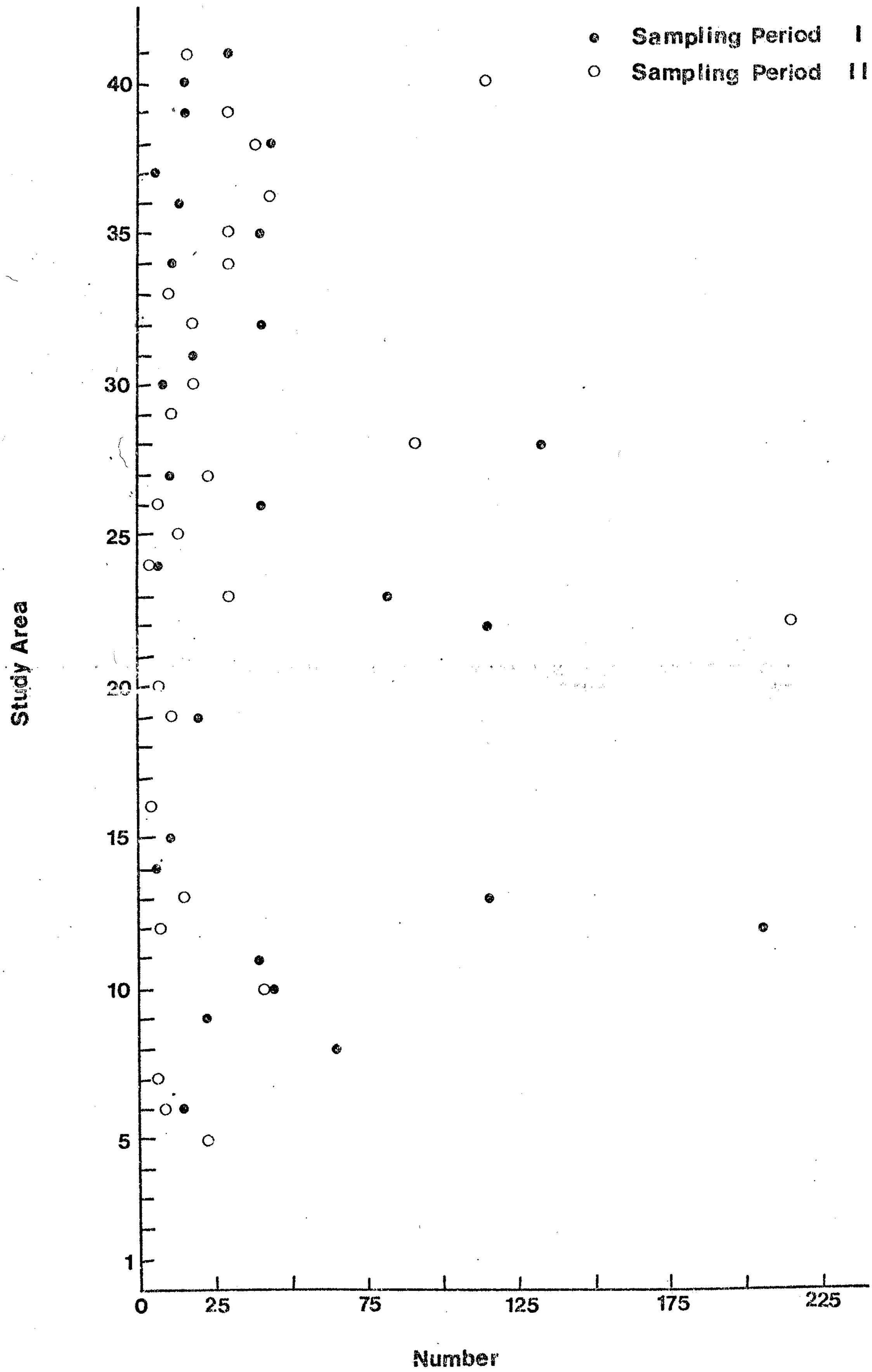


Sampling Period I
Sampling Period II
Study Area
Number
1
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120

Appendix Fig. I-16. Average number of organisms per square meter (*Pentaneura*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.

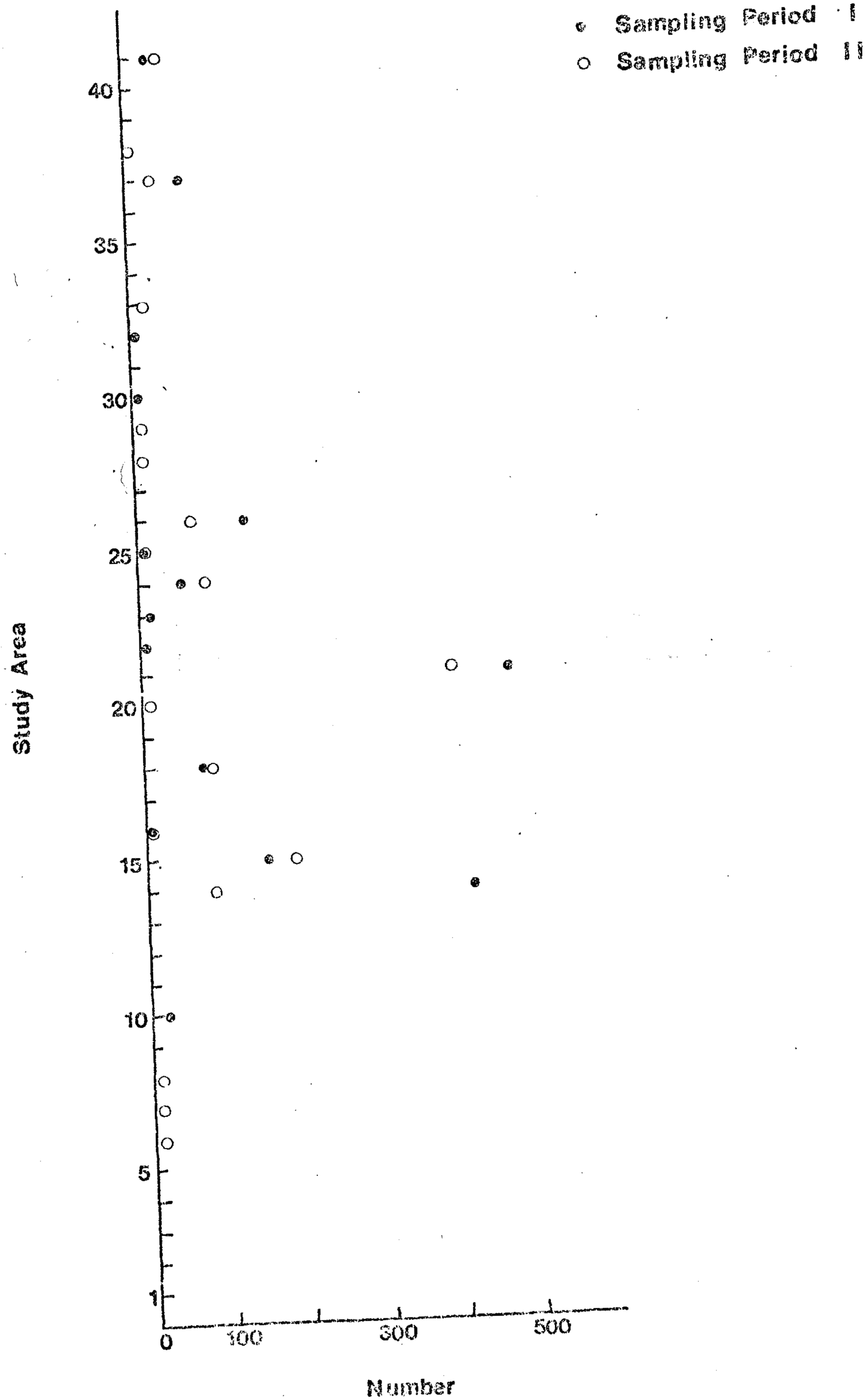

Sampling Period I
Sampling Period II
Study Area
Number
0
100
200
300
400
1
5
10
15
20
25
30
35
40

Appendix Fig. I-17. Average number of organisms per square meter (*Palpomyia*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



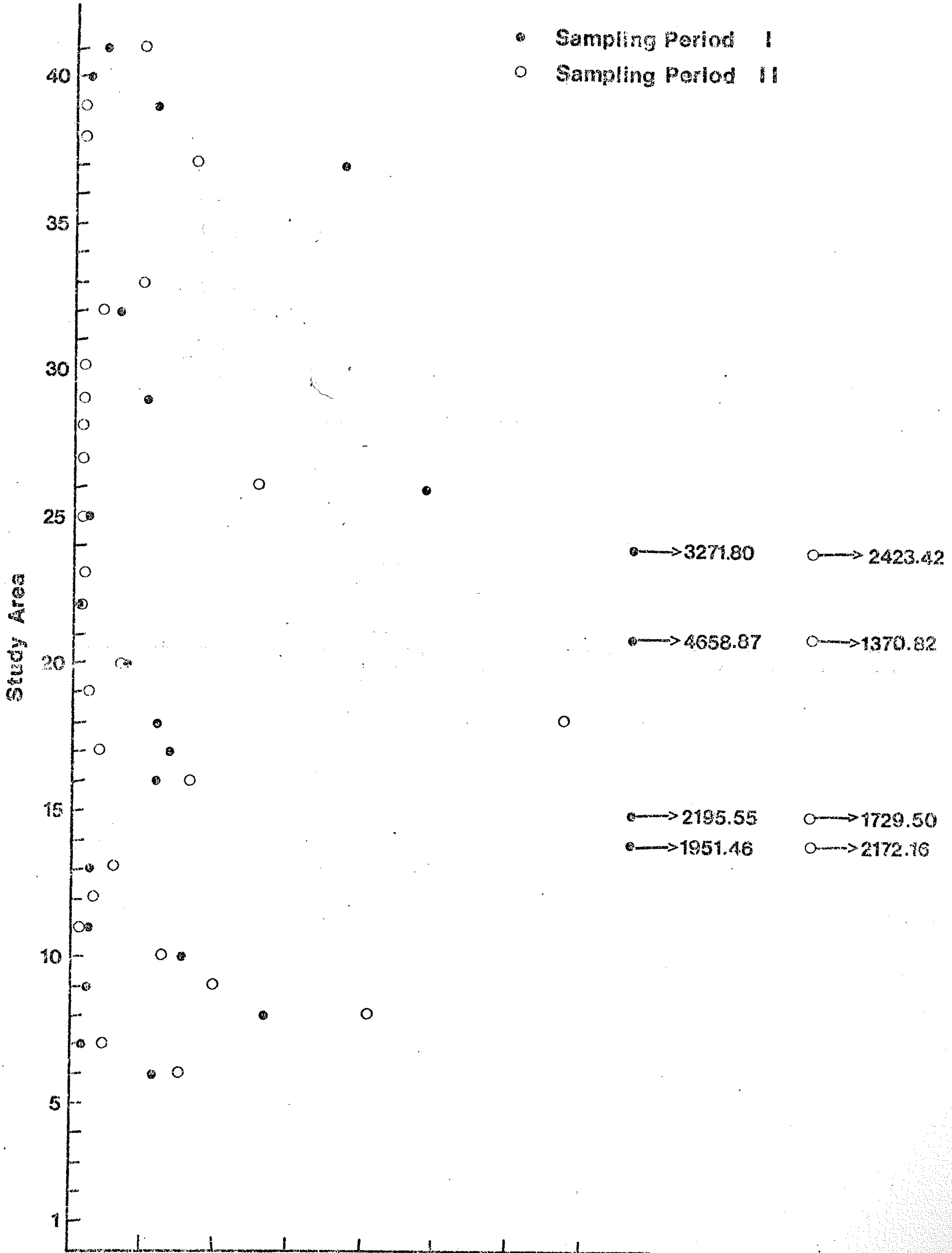
Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
25
75
125
175
225
Number

Appendix Fig. I-18. Average number of organisms per square meter (*Amnicola*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



Sampling Period I
Sampling Period II
Study Area
40
35
30
25
20
15
10
5
1
0
100
300
500
Number

Appendix Fig. I-19. Average number of organisms per square meter (*Sphaerium*), 41 study areas, Navigation Pool No. 8, Upper Mississippi River, summer, 1975.



Sampling Period I
Sampling Period II
Study Area
Number
40
35
30
25
20
15
10
5
1
0
100
300
500
700
→3271.80
→2423.42
→4658.87
→1370.82
→2195.55
→1729.50
→1951.46
→2172.16

Appendix II. Computer Program

```
LIST-P
MULREG

10  REM  ***  HP TIME-SHARED BASIC PROGRAM LIBRARY  *****************
20  REM            MULREG:  36178  (A404)  REV A --9/71
30  REM  ***  CONTRIBUTED PROGRAM * MULTIPLE REGRESSION/CORRELATION *
40  DIM X[19,19],A[19,19],D[42,19],Y[19],M[19],S[19]
50  DIM T[19],B[19],U[19,19],R[19,19],C[19,19],Q[42],E[19]
60  READ N,V,G
70  FOR I=2 TO N+1
80  FOR J=2 TO V
90  READ D[I,J]
100  NEXT J
110  NEXT I
120  FOR I=2 TO N+1
130  LET D[I,1]=1
140  NEXT I
145  FOR I=2 TO N+1
146  READ D[I,V+1]
147  NEXT I
150  READ H,K,P1,P2
160  LET M=K+1
170  FOR I=2 TO M+1
180  READ E[I]
190  NEXT I
200  PRINT "**REGRESSION NUMBER"H";DEPENDENT VARIABLE IS"E[M+1]
210  PRINT
220  IF H>1 THEN 370
230  FOR I=1 TO V+1
240  FOR J=1 TO V+1
250  LET X=0
260  FOR L=2 TO N+1
270  LET X=X+D[L,I]*D[L,J]
280  NEXT L
290  LET X[I,J]=X
300  LET C[I,J]=X
310  NEXT J
320  LET T[I]=X[1,I]/X[1,1]
330  LET B[I]=0
340  IF I=1 THEN 360
350  LET B[I]=SQR(X[I,I]/(N-1)-X[1,I]*X[1,I]/(N*(N-1)))
360  NEXT I
370  PRINT "INDEX","MEANS","STANDARD DEVIATIONS"
380  FOR I=2 TO M+1
390  LET M[I]=T[E[I]+1]
400  LET S[I]=B[E[I]+1]
410  PRINT E[I],M[I],S[I]
420  NEXT I
430  PRINT
440  PRINT
450  PRINT "CORRELATION COEFFICIENTS"
460  IF H>1 THEN 520
470  FOR I=2 TO V+1
480  FOR J=2 TO V+1
490  LET R[I,J]=(N*X[I,J]-X[1,I]*X[1,J])/(N*(N-1)*B[I]*B[J])
500  NEXT J
510  NEXT I
520  FOR I=2 TO M+1
530  FOR J=2 TO M+1
```

```
540  LET U[I,J]=R[E[I]+1,E[J]+1]
550  PRINT U[I,J],
560  NEXT J
570  PRINT
580  PRINT
590  NEXT I
600  PRINT
610  LET E[1]=0
620  FOR I=1 TO K+1
630  LET Y[I]=C[E[I]+1,E[M+1]+1]
640  FOR J=1 TO K+1
650  LET X[I,J]=C[E[I]+1,E[J]+1]
660  NEXT J
670  NEXT I
680  FOR I=1 TO K+1
690  FOR J=1 TO K+1
700  IF I <> J THEN 730
710  LET A[I,J]=1
720  GOTO 740
730  LET A[I,J]=0
740  NEXT J
750  NEXT I
760  FOR I=1 TO K+1
770  IF X[I,I]<.000001 THEN 1510
780  LET Y[I]=Y[I]/X[I,I]
790  FOR J=1 TO K+1
800  LET A[I,J]=A[I,J]/X[I,I]
810  IF J=I THEN 830
820  LET X[I,J]=X[I,J]/X[I,I]
830  NEXT J
840  LET X[I,I]=1
850  FOR L=1 TO K+1
860  IF L=I THEN 940
870  LET Y[L]=Y[L]-X[L,I]*Y[I]
880  FOR J=1 TO K+1
890  LET A[L,J]=A[L,J]-X[L,I]*A[I,J]
900  IF J=I THEN 920
910  LET X[L,J]=X[L,J]-X[L,I]*X[I,J]
920  NEXT J
930  LET X[L,I]=0
940  NEXT L
950  NEXT I
960  LET S6=C[E[M+1]+1,E[M+1]+1]
970  FOR I=1 TO K+1
980  LET S6=S6-Y[I]*C[E[I]+1,E[M+1]+1]
990  NEXT I
1000  LET S7=S6/(N-M)
1010  R2=1-(S6/((S[M+1]^2)*(N-1)))
1020  LET R=SQR(R2)
1030  LET S8=SQR(S7)
1040  IF P1=0 THEN 1060
1050  PRINT "VARIANCE-COVARIANCE MATRIX OF b"
1060  FOR I=1 TO K+1
1070  FOR J=1 TO K+1
1080  LET A[I,J]=A[I,J]*S7
1090  IF P1=0 THEN 1110
1100  PRINT A[I,J],
1110  NEXT J
```

```
1120  IF P1=0 THEN 1150
1130  PRINT
1140  PRINT
1150  NEXT I
1160  PRINT
1170  PRINT "INDEX","B","STD. ERROR","T-RATIO"
1180  FOR I=1 TO K+1
1190  PRINT E[I],Y[I],SQR(A[I,I]),Y[I]/SQR(A[I,I])
1200  NEXT I
1210  PRINT
1220  PRINT "R-SQUARED="R2,"R="R
1230  PRINT
1240  PRINT "STAND. ERROR OF EST.="S8,"D.F.="(N-M)
1250  PRINT
1260  FOR I=2 TO N+1
1270  LET Z=D[I,E[M+1]+1]-Y[1]
1280  FOR J=2 TO K+1
1290  LET Z=Z-Y[J]*D[I,E[J]+1]
1300  NEXT J
1310  LET Q[I]=Z
1320  NEXT I
1330  LET W=0
1340  FOR I=3 TO N+1
1350  LET W=W+(Q[I]-Q[I-1])^2
1360  NEXT I
1370  PRINT
1380  IF P2=0 THEN 1450
1390  PRINT "ACTUAL","PREDICTED","RESIDUAL"
1400  LET I=1
1410  LET I=I+1
1420  PRINT D[I,E[M+1]+1],D[I,E[M+1]+1]-Q[I],Q[I]
1430  IF I=N+1 THEN 1450
1440  GOTO 1410
1450  PRINT
1460  PRINT "DURBIN-WATSON STAT.="W/S6
1470  IF H<G THEN 1490
1480  GOTO 1520
1490  PRINT
1500  GOTO 150
1510  PRINT "CORRELATION MATRIX BECOMING SINGULAR"
1520  PRINT
1530  PRINT "     *****PROBLEM COMPLETED*****"
1540  STOP
9999  END
```