# THE ABUNDANCE AND DISTRIBUTION OF BENTHIC MACROINVERTEBRATES IN THE LUDINGTON PUMPED STORAGE RESERVOIR

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## ABSTRACT

# THE ABUNDANCE AND DISTRIBUTION OF BENTHIC MACROINVERTEBRATES IN THE LUDINGTON PUMPED STORAGE RESERVOIR

By

Daniel Lee Lawson

The benthic macroinvertebrate composition and abundance of the Ludington Pumped Storage Reservoir was investigated during the 1974-1975 seasons. Specific information was sought to answer those questions concerning the rate of colonization since filling in 1973 and its comparative, benthic abundance.

Ponar dredge samples were taken monthly from April to October of each year. Hester-Dendy multiple plate samplers, placed in April along a north-south transect, were removed in June, July and August of each year. Combined information yielded significant results.

Oligochaeta and Chironomidae comprised the major benthic organisms. Amphipoda, Isopoda and Gastropoda, although much less numerous, were collected regularly. The Ephemeroptera, Hydracarina, Ostracoda, and Pelecypoda were encountered rarely.

Significant increases of Oligochaeta, Chironomidae, Amphipoda and Isopoda were found from 1974 to 1975 ($P<0.05$). All remaining taxa showed no significant increases during the present studies.

Numbers of Oligochaeta, Chironomidae, Amphipoda, Isopoda, and Gastropoda have increased since the first year of reservoir operation.

Generic composition of Oligochaeta was dominated by _Tubifex_ sp.,

Limnodrilus sp. and their corresponding immature categories. Potamothrix sp. was first taken in 1974 and appeared to become established in the 1975 collections. Reproductive activity of Tubifex sp. and Limnodrilus sp. was greatest during the spring while decreasing as summer progressed.

The Chironomidae underwent a dynamic shift in generic composition. Chironomus sp., was a major taxa in the mid-1974 collections and dominated the Chironomidae samples in 1975. Chironomus sp. was in greater abundance in the south end of the reservoir; its zonation was attributed to calmer waters and ample food supply.

Species assemblages of Ludington Reservoir Oligochaeta indicated organic enrichment since operation began in 1973. Peloscolex sp., an oligotrophic indicator, was rarely found in the 1974-1975 collections, while the eutrophic indicator Potamothrix sp. became established.

Results indicated an increasingly productive reservoir since filling in 1973. Water currents coupled with organic inputs of fish and invertebrates caused by turbine mortality may have been the causitive agent.

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Daniel Lee Lawson

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# INTRODUCTION

In response to increasing electrical demands, hydroelectric generating facilities have been constructed to insure adequate power production. These facilities require environmental assessment of possible effects to the local ecological balance. In such a case the Consumers Power Company contracted with the Michigan State University, Department of Fisheries and Wildlife in 1971 to assess the effects of the Ludington Pumped Storage Project upon the Lake Michigan biota.

The investigations of benthic macroinvertebrate colonization of the Ludington Reservoir is one phase of a larger study, that includes studies of the effects upon the physio-chemical conditions, as well as fish, benthic and planktonic organisms (Liston and Tack, 1973). A similar study, summarized in depth by Olson (1974,1975), reported the benthic macroinvertebrate colonization of the Ludington Reservoir during the first year of existence in 1973. This research conducted in 1974 and 1975 similarly seeks answers to three fundamental questions.

1. Has the reservoir benthic faunal composition changed since the first year of plant operation?
2. Do the reservoir populations still exhibit expansive, log-phase growth?
3. Generally, how does reservoir benthic abundance compare with that of Lake Michigan?

## DESCRIPTION OF AREA

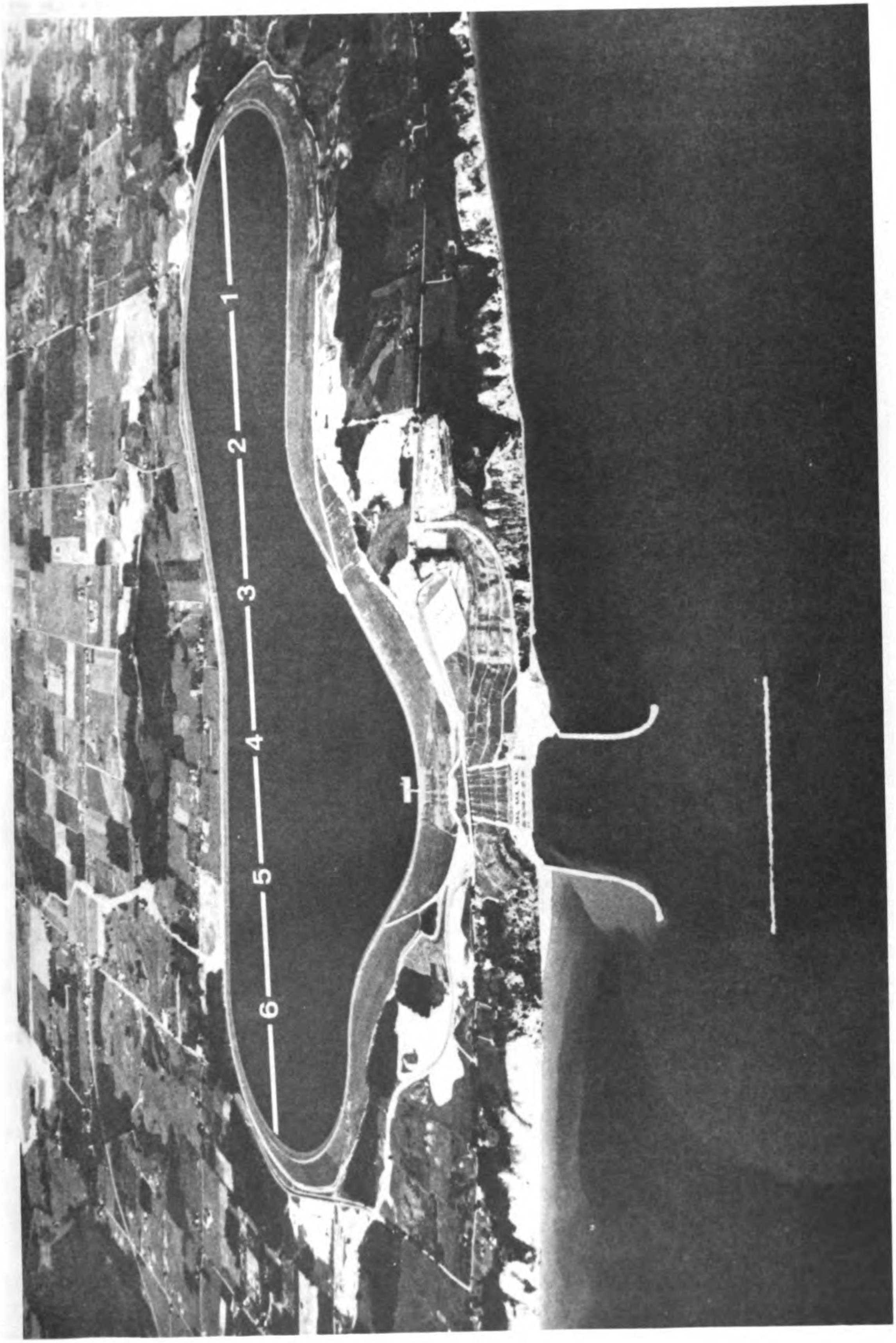
The Ludington Pumped Storage Project is located 4 miles (6.4 km) south of Ludington Michigan on the eastern shore of Lake Michigan. The facilities include six Francis-type reversible pump-turbines each capable of a maximum 12,625 cfs (357.5 $m^3/s$) discharge while generating electricity and 11,139 cfs (315.4 $m^3/s$) during the pumping mode (Comninellis, 1973).

Water transfer between Lake Michigan and the reservoir occurs through six penstocks 1,300 feet (396 m) in length and 28.5 feet (8.7 m) in diameter at the top while tapering to 24 feet (7.3 m) at the lower end.

The reservoir is 2.5 miles (4 km) long, averages .75 miles (1.2 km) in width and has a total surface area of 842 acres (3.4 $km^2$) when full (Figure 1). The reservoir embankment is 108 feet (33 m) in height and has its inside perimeter sealed with asphalt. The reservoir bottom is composed of compacted clay with a 1,200 (365 m) by 800 (244 m) foot scour protection area consisting of limestone rocks in front of the intake structure. Maximum water depths range from 97 feet (29 m) in the south end while increasing to 112 feet (34 m) in the north.

The power plant is protected laterally from potentially destructive wave action by two 1,750 feet (533 m) long and 45 feet (15.3 m) high jetties constructed from large limestone boulders rising to a height of 3 m above the lake level. An outer breakwall 1,700 feet (518 m) long and 45 feet (15.3 m) in height affords similar protection with 1,300 feet

Figure 1. Aerial View of the Ludington Reservoir and Sampling Stations.


1
2
3
4
5
6

(396 m) clearance between the jetties and breakwall allowing uninhibited passage to the plant site. The area between the jetties was dredged uniformly to a depth of 35 feet (10.7 m).

## LITERATURE REVIEW

The colonization of new bodies of water has received considerable attention. Roll et al., (1959), Kruglova (1959), Ozhegova (1962) and Sokolova (1963) studied the benthos of newly impounded reservoirs. These Russian basins are basically large fluviatile impoundments making direct comparison ill-advised.

Several North American studies have focused on existing facilities but few have data from their inception. Burris (1954), Nursall (1952), Fillion (1967) and, more recently, Parterson and Fernando (1969, 1970) studied the benthic colonization of reservoirs soon after filling. These impoundments flooded terrestrial vegetation and a eutrophic-oligotrophic successional period, lasting more than a year, was attributed to the initially high organic content of the sediments. Brinkhurst (1974) discussed the manner in which depth, temperature, food supply, predatory interaction, current and substrate shape benthic distribution and abundance in lakes.

Liston, Tack and Duffy (1974) reported a vertically homothermous reservoir at Ludington where temperatures seasonally mimic those of adjoining inshore Lake Michigan. The chemical parameters, similarly, are not significantly different than those of Lake Michigan, with high dissolved oxygen concentration ranging from 10-12 ppm throughout the season (Liston, Tack and Brazo, 1976).

The dependence of the benthic community upon autochthonous and allochthonous sources of organic material has been well documented

(Deevey, 1941; Rawson, 1942; Jonasson, 1965). Historically, Lake Michigan phytoplankton has been dominated by diatoms, comprising an average of 94% of the total (Davis, 1966). In the Ludington Reservoir diatom populations follow closely those of Lake Michigan with respect to composition and abundance (Liston, Tack and Duffy, 1974). Serchuk (1976) discovered fish mortality associated with both pumping and generating modes of the Ludington Pumped Storage turbines. Unpublished results (Koehler, 1975) revealed passage of larval fish and invertebrates into the Ludington Reservoir with unknown mortality.

Gulvas (1976) outlined the colonization of fishes in the Ludington Reservoir. Although species composition and abundance differ considerably from Lake Michigan collections, resident populations of sculpin, trout perch and carp seem to have become established. Virtually all Lake Michigan species periodically inhabit the reservoir.

Food habits of several Lake Michigan fishes adjacent to the Ludington Plant were investigated (Armstrong, 1973; Brazo, 1973; Chiotti, 1973; Hauer, 1975; Kavetsky, 1975). Those species studied have not yet established significant reservoir populations; consequently, informative Ludington Reservoir food habit data have yet to be obtained.

Several studies have been conducted upon Lake Michigan macro-benthos. Of direct application was a study conducted upon the inshore region of Lake Michigan in conjunction with the Ludington Pumped Storage Project (Olson, 1974). Similar impact studies have been attempted upon the Cook Nuclear Power Plant near Benton Harbor, Michigan (Mozley, 1974; Mozley and Garcia, 1972; Mozley and Winnell, 1975). Other investigations of Lake Michigan macro-benthos have concentrated primarily on the influence of depth and substrate upon species abundance and composition

(Eggleton, 1936; Cook and Powers, 1964; Powers and Robertson, 1965; Robertson and Alley, 1966; Howmiller, 1974; Stimpson et al., 1975).

# METHODS AND MATERIALS

## Field and Laboratory Procedures

A sampling scheme designed to reflect major changes in species abundance and composition was used for this study. The sampling period for each year began in April and subsided in October. A north-south sampling transect was implemented with six sampling stations distributed uniformly along the transect.

The ponar dredge was utilized throughout this study and similarly by Olson (1974). Monthly collections, consisting of four replicate casts, were randomly made in the vicinity of stations one, four and six (Figure 1). Mozley (1974) employed similar replication as increased sampling effort yielded a comparable estimate of the population mean.

Hester-Dendy multiple plate samplers consisting of fourteen 20 cm square hardboard plates mounted vertically on an iron shaft, augmented the dredge information. On April 16, 1974 and April 7, 1975 three Hester-Dendy samplers were located at each of six stations along the north-south transect. One sampler was removed from each station in June, July and August. A total of eighteen samples was collected each year.

Individual ponar and Hester-Dendy samples were returned to the Laboratory for processing. Each replicate was strained through a U.S. Standard #30 sieve, the organisms removed and preserved. The Chironomidae were preserved in 70% ethanol, and identified to genus using a Zeiss phase-contrast compound microscope and several taxonomic keys

(Roback, 1957; Bryce and Hobart, 1972; Mason, 1973). The Oligochaeta were preserved in 10% formalin, identified to genus using Hiltunen (1973) after they were cleared several days in Amman's lactophenol. Miscellaneous organisms were preserved in 70% ethanol and identified to genus using Pennak (1953).

Counts of each taxa were transformed to numbers per square meter for comparative purposes. The ponar dredge, with a total sampling surface area of 529 $cm^2$, required a conversion factor of 18.9; the Hester-Dendy sampler with a 1.12 $m^2$ surface area required a conversion factor of .89.

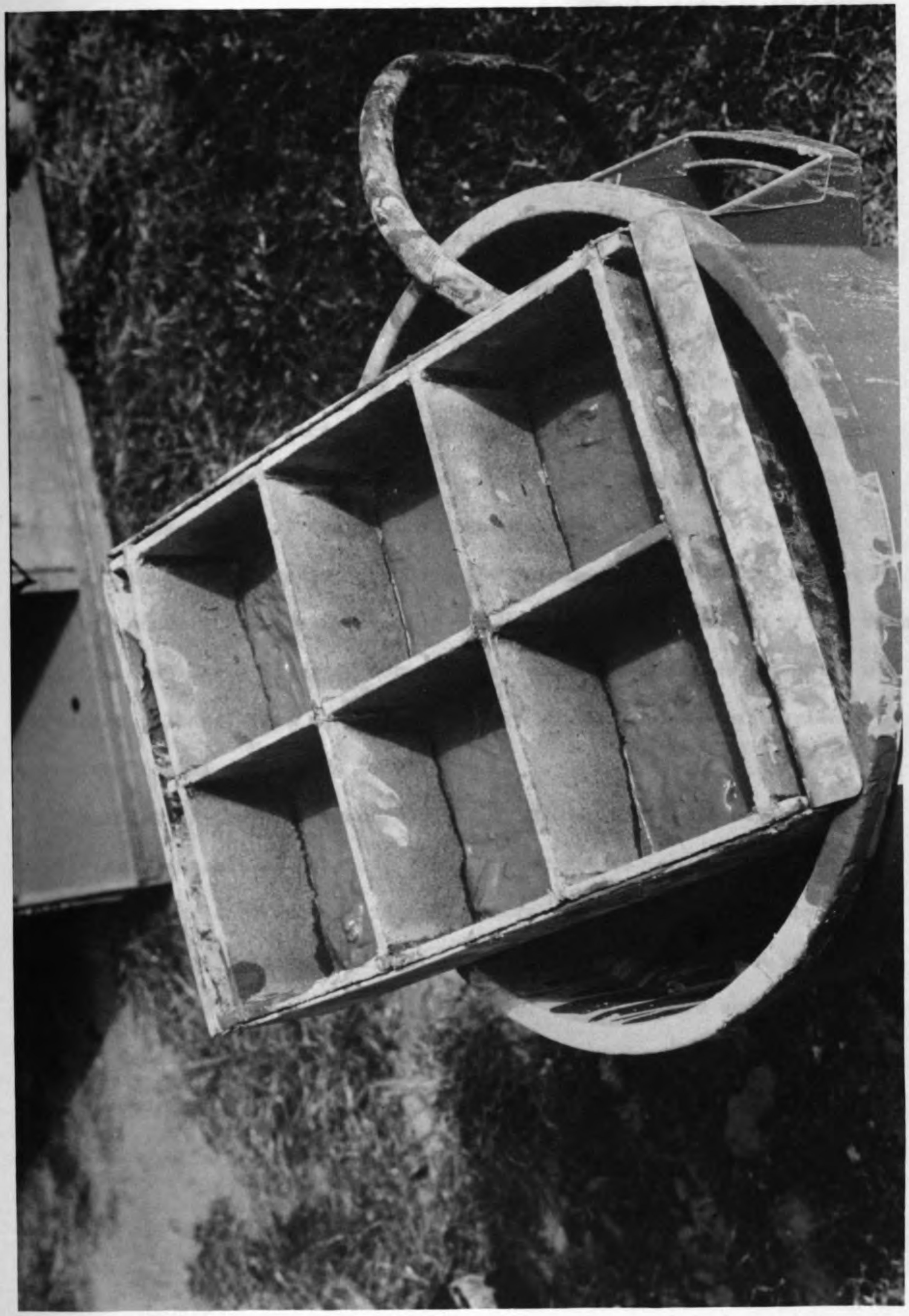
## Subsampling

A subsampling procedure was implemented during the 1975 ponar dredge season due to large numbers of reservoir macrobenthos. Subsampling reduced the processing time and allowed more time for identification and data analysis.

Subsampling is used routinely in field investigations (Mozley, 1974; Lund, Kipling and Le Cren, 1958). When organisms are randomly dispersed between subsamples then the counts are distributed Poisson (Elliott, 1971). A Chi-square procedure is applied to test the hypothesis of randomness and if agreement with the Poisson distribution is reached, a subsample may be used to represent the sample mean (Elliott, 1971).

The 1975 Ludington macrobenthos were subsampled using a modified Wildco ponar dredge washing screen. The entire sample was spread uniformly across the #30 mesh screen and sectioned equally into six subsamples using a compartmented, fiberboard divider (Figure 2). The subsamples were volumetrically reduced by passing water through the screen

Figure 2. Modified Ponar Wash Screen and Compartmented Fiberboard Divider in Place for Subsampling.



retaining organisms for easy removal.

The Chi-square test was applied to the April 24, 1975 dredge samples. The results (Table 1) indicated agreement with the Poisson distribution for a variety of Oligochaeta and the midge *Chironomus* sp.

## Statistical Analysis

As an aid in data analysis, a cross-tabulation procedure recorded the presence or absence of genera for a particular sampling date. Genera which regularly appeared in a year's sampling were selected for analysis of year and station effects. Those genera occuring infrequently were combined within a single category of "Rare Species", and subjected to the identical statistical procedures.

A logarithmic transformation of the original data was used throughout this study. Its use allows the variance to be independent of the mean while in most cases insuring normality of error terms and homogeneity of variances. Transformed data were analyzed by the Analysis of Variance technique (Sokal and Rohlf, 1969).

Bartlett's test for homoscedasticity preceded use of the Analysis of Variance (Steele and Torrie, 1960). When the assumptions of the Analysis of Variance were fulfilled, genera were compared month by month between sampling stations and years. The Student-Neuman-Keuls procedure was employed for post-analysis contrasts of means (Steele and Torrie, 1960). Scheffe's procedure, although less powerful, was used for mean comparisons when Bartlett's test indicated heterogenous variance (Gill, 1972).

Table 1. Counts of Five Taxa of Six Replicate Subsamples.

| Species | 1 | 2 | 3 | 4 | 5 | 6 | Chi-square |
|---|---|---|---|---|---|---|---|
| *Tubifex* sp. | 8 | 5 | 5 | 7 | 4 | 4 | 2.45 |
| Imm. With Hair Setae | 7 | 10 | 15 | 18 | 6 | 8 | 10.81 |
| *Limnodrilus* sp. | 6 | 9 | 4 | 3 | 2 | 2 | 8.68 |
| Imm. Without Hair Setae | 5 | 11 | 10 | 6 | 5 | 3 | 7.47 |
| *Chironomus* sp. | 4 | 6 | 8 | 13 | 6 | 8 | 6.33 |

Data exhibit randomness if Chi-square is less than 11.07 ($p < 0.05$)

## RESULTS AND DISCUSSION

### Ponar Dredge Samples - Major Groups

The Oligochaeta and Chironomidae were the most abundant taxa in the 1974 and 1975 ponar dredge samples. Occasional Hydracarina, Amphipoda, Isopoda, Ostracoda and Gastropoda were collected.

#### Oligochaeta

The April 1974 Oligohcaeta standing crop was 2,784 individuals/$m^2$ (Table 2). A decrease in abundance occurred in May with a modest increase sustained in June and August. Highest densities were in October (6,536/$m^2$) but a further reduction occurred in November. A decrease in abundance in May 1975 samples from a seasonal high in April of 19,121/$m^2$ persisted through the remainder of the 1975 sampling season (Table 3).

The Oligochaeta abundance in 1975 was significantly greater than the 1974 density ($p< 0.05$). The population growth evident in 1974 further accelerated in 1975. Olson (1974, 1975) found a maximum Oligochaeta population of 800/$m^2$. Results from the Ludington Reservoir show Oligochaeta standing crop has increased in each year of study.

The Ludington Reservoir Oligochaeta were in greater densities than similar studies of reservoirs. Nursall (1952) found Oligochaeta in densities of 120/$m^2$ while Fillion (1967) had a maximum of 719/$m^2$. However, Laurel Creek Reservoir sustained Oligochaeta in numbers approximating those of the Ludington Reservoir (7,000 - 12,500/$m^2$). Lake Michigan studies (Eggleton, 1936, 1937; Mozley and Garcia, 1972; Robertson and Alley, 1966; Olson, 1974) recorded lower Oligochaeta populations

Table 2. Monthly Mean Number/$m^2$ of Major Taxonomic Groups in 1974 Ponar Dredge Samples from the Ludington Reservoir.

| Taxon | 1974 | | | | | |
|---|---|---|---|---|---|---|
| | 4/16 | 5/23 | 6/26 | 8/5 | 10/1 | 11/1 |
| Oligochaeta | 2,784 | 277 | 1,128 | 839 | 6,536 | 2,057 |
| Chironomidae | 378 | 150 | 1,485 | 101 | 800 | 1,148 |
| Hydracarina | 20 | 9 | 2 | 3 | 6 | 11 |
| Amphipoda | 3 | 5 | 8 | 14 | 11 | 17 |
| Isopoda | 0 | 0 | 0 | 2 | 3 | 0 |
| Ostracoda | 8 | 9 | 0 | 0 | 0 | 0 |
| Gastropoda | 0 | 0 | 0 | 2 | 9 | 22 |

Table 3. Monthly Mean Number/$m^2$ of Major Taxonomic Groups in 1975 Ponar Dredge Samples from the Ludington Reservoir.

| Taxon | 1975 | | | | | |
|---|---|---|---|---|---|---|
| | 4/24 | 5/29 | 7/7 | 8/4 | 9/16 | 10/14 |
| Oligochaeta | 10,121 | 4,981 | 6,447 | 4,573 | 5,978 | 4,545 |
| Chironomidae | 1,688 | 1,009 | 756 | 829 | 992 | 349 |
| Hydracarina | 0 | 0 | 0 | 0 | 9 | 0 |
| Amphipoda | 19 | 9 | 9 | 0 | 28 | 32 |
| Isopoda | 0 | 0 | 0 | 0 | 9 | 0 |
| Ostracoda | 0 | 0 | 0 | 0 | 0 | 0 |
| Gastropoda | 0 | 0 | 0 | 0 | 76 | 19 |
| Pelecypoda | 0 | 0 | 0 | 76 | 28 | 0 |

($400-2500/m^2$). However, Powers and Robertson (1965), Cook and Powers (1964) and Mozley and Winnell (1975) have shown similar Oligochaeta abundance ranging from $5,000-10,000/m^2$ in productive areas of Lake Michigan.

As primary production and water chemistry are similar between Lake Michigan and the Ludington Reservoir (Liston, Tack and Duffy, 1974), other factors may account for the apparent differences in Oligochaeta abundance. Several explanations are possible.

Predation pressure upon benthic macroinvertebrates may have differed between regions (Hauer, 1974; Kavetsky, 1975). Distinctions in species composition and abundance of fishes between the reservoir and Lake Michigan were apparent (Hauer, 1974; Gulvas, 1976).

Oligochaeta, for the most part, reflect conditions prevalent within the sediments (Jonasson, 1975). The sandy sediments in Lake Michigan are disrupted frequently by wave action while the clay substrate in the reservoir is more stable and thus may be a better habitat.

Allochthonous organics may offer an alternate cause of higher standing crop. Fish mortality from turbine operation added organic material to the Reservoir (Serchuk, 1976). The occurrence of the midge Stempeelina sp. in ponar dredge samples on June 26, 1974 and July 7, 1975 is especially noteworthy. Stempeelina sp. constructs transportable larval cases from available materials. Larvae collected with intact sand-grained cases offered direct evidence of the transportation of invertebrates from Lake Michigan. Organisms were pumped into the reservoir, but the mortality and biomass associated with their passage is unknown (Koehler, 1975).

Organic enrichment of the reservoir is taking place but its extent and impact upon the Ludington Reservoir benthic community is unclear. It is assumed Lake Michigan receives organic inputs in a similar fashion.

However, the size of the respective basin coupled with the erosional conditions outlined, may not permit Oligochaeta abundance to approach that of the Ludington Reservoir.

## Chironomidae

Total Chironomidae fluctuated with apparent peaks occurring in the June and November sampling periods of 1974 ($1,485/m^2$ and $1,148/m^2$ respectively) (Table 2). The high November 1974 abundance was maintained into the 1975 season with comparable values during April and May of 1975 (Table 3). The peaks demonstrated in the 1974 Chironomidae were not apparent in the 1975 collections. A decrease in abundance occurred in October 1975.

Contrasts of total Chironomidae between years were not highly significant although the 1975 density was somewhat greater than 1974 ($p < 0.13$). Olson (1975) found a maximum Chironomidae standing crop of $450/m^2$ in August 1973. Comparison of data revealed an increase of Chironomidae density during the three years of Ludington Reservoir colonization.

Paterson and Fernando (1969) found a Chironomidae population of $6,000 - 14,000/m^2$ a density higher than that reported from the Ludington Reservoir. However, the former study was conducted upon a reservoir covering terrestrial vegetation which supported its benthic abundance. Investigations by Nursall (1952) and Fillion (1967), also done where terrestrial vegetation had been flooded, indicated densities similar to the Ludington Reservoir once the organic material disappeared.

The Ludington Reservoir Chironomidae show a standing crop comparable to that found in adjacent Lake Michigan ranging from 500 to $1,500/m^2$

(Olson, 1974; Mozley and Winnell, 1975). In other Lake Michigan studies lower densities of 200 to $500/m^2$ were reported (Eggleton, 1936, 1937; Robertson and Alley, 1966; Mozley and Garcia, 1972; Cook and Powers, 1964).

The work of Olson (1974, 1975) and the present study may indicate locally productive conditions. The high abundances may be a result of characteristically high inshore densities, local eutrophication or operational effects peculiar to the Ludington Pumped Storage Project.

Jonasson (1975) indicated the Chironomidae are sensitive to those conditions near the sediment-water interface. Increased detrital material resulting from current patterns and fish and invertebrate mortalities may have increased Chironomidae abundance.

### Less Abundant Groups

The occurrences of Hydracarina, Amphipoda, Isopoda, Ostracoda and Gastropoda in 1974 and 1975 samples were sporadic (Tables 2 and 3). Abundances in all groups were low with no significant increases from 1974 to 1975. The occurrences of these groups appear less frequent in 1975. This result may be misleading. The subsampling procedures initiated in 1975 may not adequately represent those taxa collected infrequently.

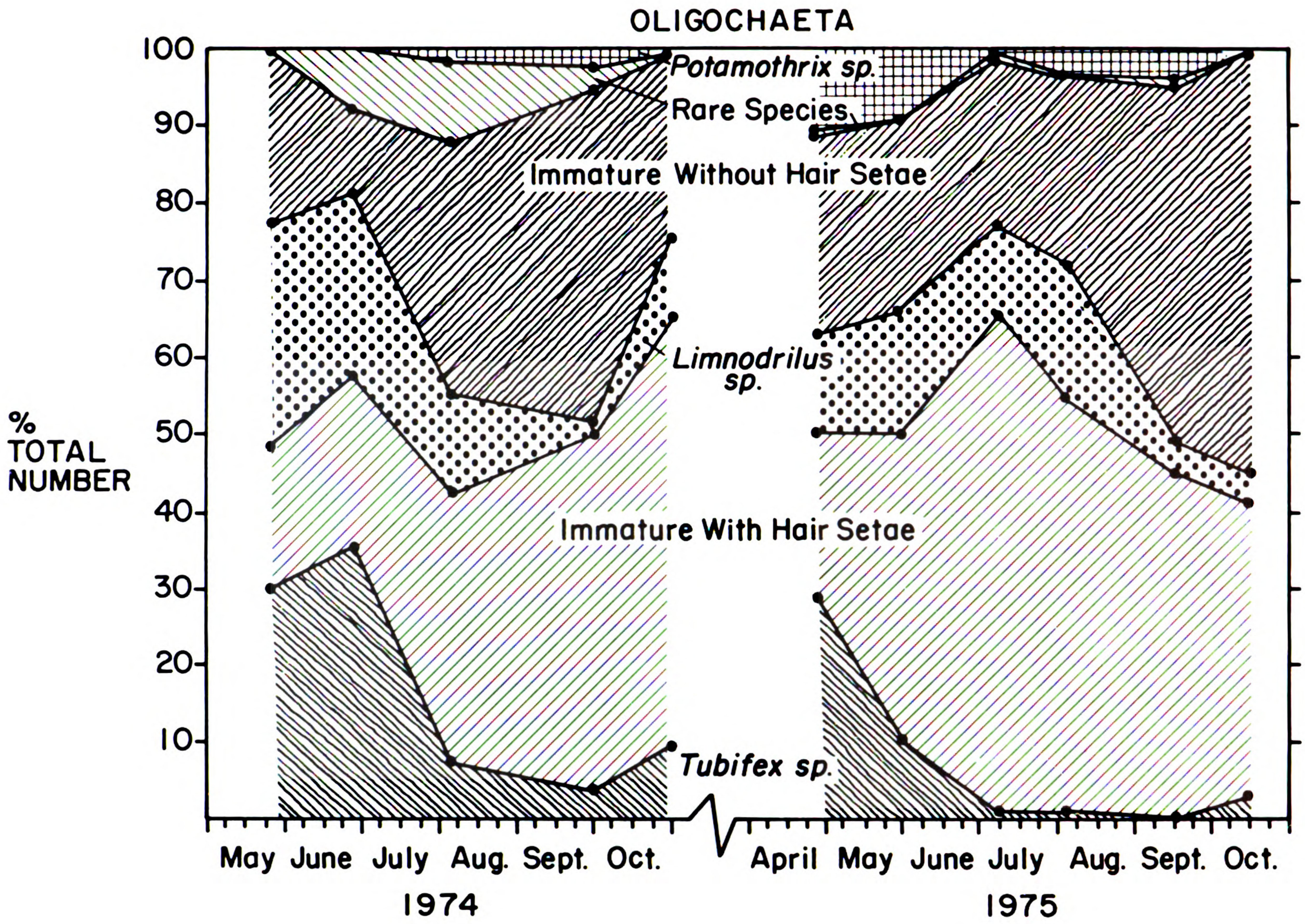
Comparison with 1973 results have shown no increase in standing crop of the minor groups since initial colonization (Olson, 1974, 1975).

## Ponar Dredge Samples - Generic Composition

### Oligochaeta

*Limnodrilus* sp. and *Tubifex* sp. comprised the majority of sexually mature individuals in both 1974 and 1975 (Figure 3). The Immature

Figure 3. Cummulative Percentage of Total Oligochaeta due to each Taxon for each Sampling Interval in the 1974-1975 Ponar Dredge Samples.


OLIGOCHAETA
% TOTAL NUMBER
100
90
80
70
60
50
40
30
20
10
Potamothrix sp.
Rare Species
Immature Without Hair Setae
Limnodrilus sp.
Immature With Hair Setae
Tubifex sp.
May June July Aug. Sept. Oct.
1974
April May June July Aug. Sept. Oct.
1975

With Hair Setae grouping likely represented immature Tubifex sp. while the Immature Without Hair Setae corresponded to both immature Limnodrilus sp. and Potamothrix sp.

The percentage of mature individuals exhibited seasonal periodicity. Limnodrilus sp. and Tubifex sp. each demonstrated a high proportion of mature specimens early in the season. Reproductive activity subsequently declined as the summer progressed. The immature groups correspondingly increased throughout the season. Although a reduction of midsummer Potamothrix sp. occurred, no reproductive maxima was ascertained with the few number of specimens taken.

Hiltunen (1967) and Stimpson et al. (1975) have shown similar reproductive seasonality for Limnodrilus sp. and Tubifex sp. in Lake Michigan. The contribution of Tubifex sp. to the total abundance was greater in the Ludington Reservoir than in the aforementioned studies. Olson (1974, 1975) recorded Peloscolex sp. as a major species. This study noted the absence of Peloscolex sp. and the increase of Potamothrix sp. The decline may be a result of taxonomic confusion of Peloscolex sp. as this form was exceedingly scarce and difficult to discern.

Generic distribution between sampling stations yielded few significant trends (Table 4). The data demonstrated high variation between stations. The abundance of Limnodrilus sp. and both immature groups was significantly less at station 4 during August, September and October 1975 ($p < 0.05$). Overall, the sampling stations were not significantly different during most sampling intervals. The genera appeared to be distributed equally over the reservoir bottom with no apparent north-south preference.

TABLE 4

Taxa and Mean Number/m$^2$ of Oligochaeta in 1974 and 1975 Ponar Dredge Samples from the Ludington Reservoir Sampling Stations

| | | 1974 | | | | | 1975 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Station | 5/23 | 6/26 | 8/5 | 10/1 | 11/1 | 4/24 | 5/29 | 7/7 | 8/4 | 9/16 | 10/14 |
| *Tubifex* sp. | 1 | 5 | 38 | 132 | 432 | 94 | 1492 | 649 | 192 | 0 | 0 | 118 |
| | 4 | 0 | 66 | 19 | 182 | 279 | 3939 | 0 | 113 | 0 | 0 | 0 |
| | 6 | 246 | 854 | 0 | 144 | 218 | 3376 | 1353 | 28 | 151 | 56 | 372 |
| Immature With Hair Setae | 1 | 9 | 19 | 284 | 1587 | 1167 | 1917 | 2501 | 5170 | 4211 | 2721 | 2238 |
| | 4 | 5 | 47 | 346 | 5073 | 2058 | 2036 | 369 | 1162 | 57 | 255 | 0 |
| | 6 | 139 | 521 | 57 | 2373 | 206 | 2547 | 4149 | 6043 | 3061 | 5042 | 2863 |
| *Limnodrilus* sp. | 1 | 0 | 14 | 82 | 170 | 241 | 927 | 529 | 942 | 1671 | 273 | 161 |
| | 4 | 0 | 61 | 145 | 175 | 298 | 1478 | 709 | 255 | 57 | 0 | 0 |
| | 6 | 243 | 574 | 28 | 0 | 103 | 1457 | 1440 | 1011 | 709 | 480 | 399 |
| Immature Without Hair Setae | 1 | 9 | 14 | 189 | 1071 | 501 | 1213 | 605 | 2089 | 1425 | 2577 | 4996 |
| | 4 | 0 | 85 | 227 | 4106 | 370 | 3898 | 1247 | 1077 | 227 | 851 | 85 |
| | 6 | 174 | 190 | 331 | 3296 | 608 | 2561 | 2247 | 973 | 1639 | 4819 | 2376 |
| *Potamothrix* sp. | 1 | 0 | 0 | 0 | 0 | 0 | 377 | 44 | 85 | 0 | 237 | 0 |
| | 4 | 0 | 0 | 19 | 392 | 0 | 1445 | 284 | 113 | 0 | 113 | 0 |
| | 6 | 0 | 0 | 19 | 69 | 22 | 1432 | 1269 | 0 | 478 | 376 | 28 |
| Rare Species | 1 | 0 | 430 | 113 | 0 | 0 | 57 | 0 | 0 | 35 | 106 | 0 |
| | 4 | 0 | 435 | 57 | 396 | 5 | 160 | 0 | 85 | 0 | 0 | 0 |
| | 6 | 0 | 34 | 28 | 142 | 0 | 52 | 0 | 0 | 0 | 28 | 0 |

Several authors (Brinkhurst, 1974; Hiltunen, 1967; Milbrink, 1973) make use of the concept of "species assemblages" to characterize water quality. Their studies attach significance to the occurrence of particular species. Peloscolex ferox was found to be a good indicator of oligotrophic conditions. Ilyodrilus templetoni as well as Aulodrilus pluriseta were associated with those habitats recovering from severe pollution (mesotrophic). Eutrophic waters were inhabited with members of Limnodrilus spp., Tubifex spp. and Potamothrix spp.

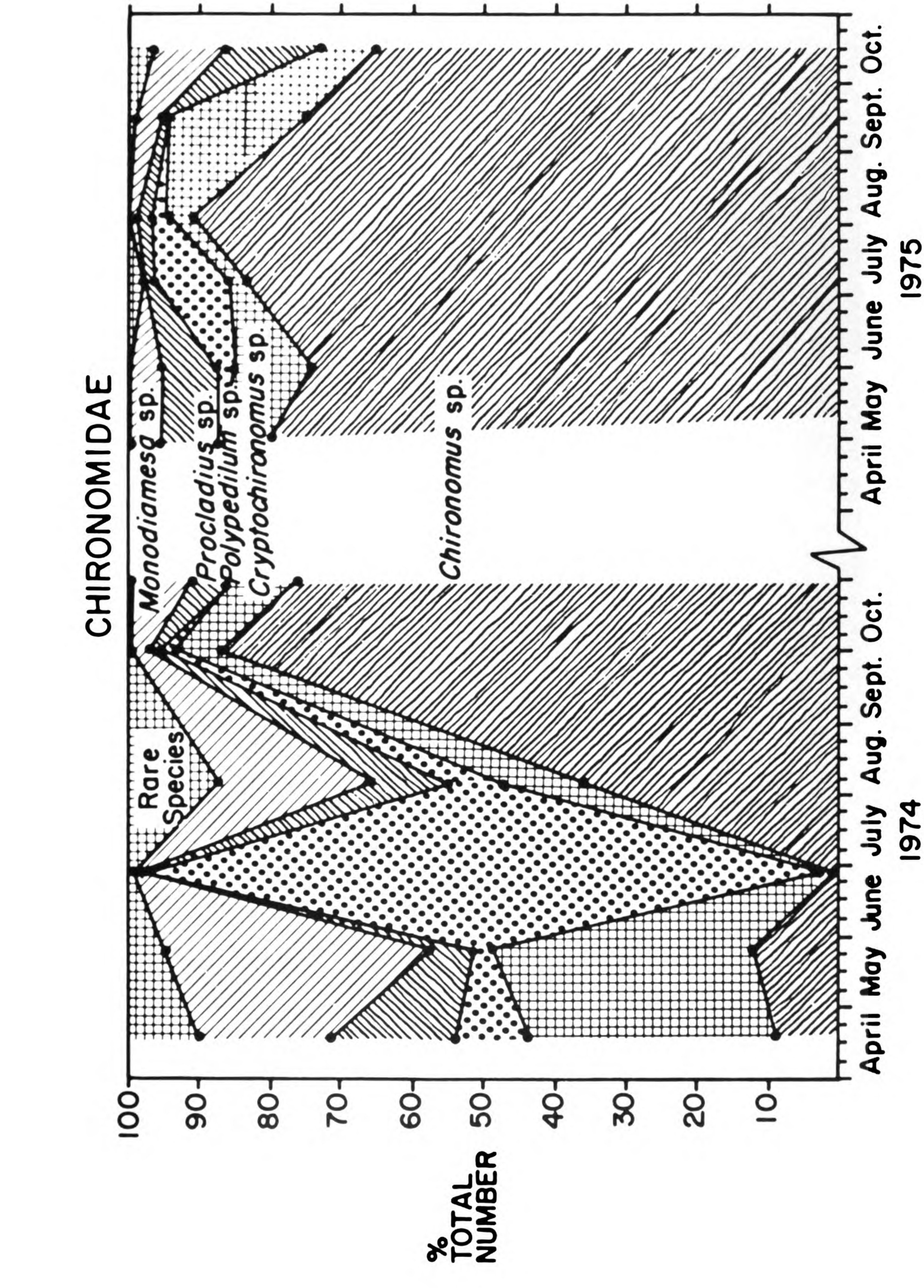
The Ludington Reservoir may have undergone a shift from originally oligotrophic conditions to those of a eutrophic habitat. However, the lack of specific identification may hinder such interpretations. Secondly it is not known what selective advantage is afforded those species capable of inhabiting clay substrate areas.

## Chironomidae

The Chironomidae collections of 1974 and 1975 showed progressive alterations in species composition (Figure 4). Commencing in April 1974, the composition was partitioned between Chironomus sp., Cryptochironomus sp., Polypedilum sp., Procladius sp. and Rare Species. A population increase of Polypedilum sp. occurred in June, 1974. Chironomus sp. became the most abundant genera in August 1974 and remained so through the conclusion of this study.

Similar reservoir investigations (Nursall, 1952; Fillion, 1967; Paterson and Fernando, 1970) revealed the successional dominance of Chironomus sp. A numerical decrease of Chironomus sp. was correlated with the reduction of organic material. Sokolova (1963) noted the increase of Chironomus sp. as a previously reophilic fauna adapted to a

Figure 4. Comulative Percentage of Total Chironomidae due to each Taxon for each Sampling Interval in the 1974-1975 Ponar Dredge Samples.


CHIRONOMIDAE
Rare Species
Monodiamesa sp.
Procladius sp.
Polypedilum sp.
Cryptochironomus sp.
Chironomus sp.
% TOTAL NUMBER
100
90
80
70
60
50
40
30
20
10
April May June July Aug. Sept. Oct.
1974
April May June July Aug. Sept. Oct.
1975

limnetic existence. Olson (1974, 1975) found a Chironomidae composition in the Ludington Reservoir similar to the present investigation before *Chironomus* sp. became dominant.

Inshore Lake Michigan studies (Mozley and Garcia, 1972; Olson, 1974) have shown the proportion of *Chironomus* sp. in relation to other Chironomidae. *Chironomus* sp. comprised at most 50% of the total in the aforementioned studies. The Ludington Reservoir supported *Chironomus* sp. in proportions higher (70 - 90%) than that reported in other Lake Michigan studies.

Chironomidae distribution differed significantly between sampling stations (Table 5). However, *Chironomus* sp. accounted for the majority of station effects.

At Station 1 *Chironomus* sp. had significantly higher densities in August, October and November 1974 than one or both of Stations 4 and 6 ($p < 0.05$). In April, August and October 1975, Station 1 was again significantly greater than one or both of Stations 4 and 6. Remaining genera showed no station differences except for one example: *Cryptochironomus* sp. was in greater abundance at Station 6 than Station 1 during the November 1974 sampling date (p 0.05). *Chironomus* sp. reached greater densities in the southerly regions of the Ludington Reservoir.

Currents and food availability, somewhat interrelated, may be the cause for the southern preference for *Chironomus* sp. *Chironomus* sp. is most often collected in lakes, ponds and in quiet river pools (Curry, 1961). Detritus and diatoms formed the principal food items (Monakov, 1972). The operating mode of the Ludington Pumped Storage Project promoted substantial currents in the north section of the reservoir (Station

TABLE 5

Taxa and Mean Number/m$^2$ of Chironomidae in 1974 and 1975 Ponar Dredge Samples from the Ludington Reservoir Sampling Stations

| | | 1974 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Station | 4/16 | 5/23 | 6/26 | 8/5 | 10/1 | 11/1 | 4/24 | 5/29 | 7/7 | 8/4 | 9/16 | 10/14 |
| *Chironomus* sp. | 1 | 19 | 25 | 5 | 85 | 2046 | 2226 | 2296 | 1497 | 1588 | 2211 | 964 | 595 |
| | 4 | 38 | 9 | 0 | 14 | 5 | 340 | 586 | 340 | 170 | 57 | 510 | 0 |
| | 6 | 0 | 24 | 0 | 13 | 42 | 61 | 1219 | 264 | 142 | 0 | 765 | 86 |
| *Cryptochironomus* sp. | 1 | 76 | 76 | 5 | 0 | 14 | 28 | 85 | 61 | 0 | 0 | 85 | 28 |
| | 4 | 104 | 24 | 38 | 19 | 57 | 146 | 57 | 198 | 0 | 57 | 113 | 0 |
| | 6 | 76 | 71 | 66 | 19 | 66 | 142 | 198 | 57 | 57 | 28 | 368 | 57 |
| *Polypedilum* sp. | 1 | 50 | 0 | 1016 | 9 | 0 | 0 | 0 | 57 | 85 | 0 | 0 | 0 |
| | 4 | 0 | 9 | 917 | 14 | 0 | 0 | 0 | 0 | 57 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 2292 | 0 | 52 | 0 | 0 | 6 | 85 | 57 | 0 | 0 |
| *Procladius* sp. | 1 | 69 | 6 | 14 | 24 | 24 | 66 | 198 | 142 | 28 | 0 | 0 | 85 |
| | 4 | 28 | 9 | 0 | 9 | 14 | 52 | 113 | 57 | 0 | 28 | 0 | 0 |
| | 6 | 0 | 9 | 14 | 0 | 9 | 33 | 113 | 13 | 0 | 28 | 28 | 57 |
| *Monodiamesa* sp. | 1 | 0 | 13 | 0 | 0 | 0 | 0 | 57 | 9 | 0 | 0 | 28 | 57 |
| | 4 | 104 | 24 | 9 | 61 | 38 | 165 | 85 | 85 | 0 | 28 | 28 | 0 |
| | 6 | 57 | 123 | 42 | 6 | 28 | 165 | 57 | 44 | 0 | 0 | 57 | 57 |
| Rare species | 1 | 6 | 0 | 5 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4 | 9 | 5 | 9 | 14 | 0 | 5 | 0 | 0 | 0 | 0 | 28 | 28 |
| | 6 | 113 | 19 | 24 | 6 | 5 | 14 | 0 | 6 | 57 | 0 | 0 | 0 |

6). The prevailing west-southwest winds often developed turbulent wave conditions in the north while it remained relatively calm in the southerly portion of the reservoir. Currents and wave action no doubt influence the rate and location in which food items become available to the benthos. A settling of particles may have occurred in the southern portion of the Ludington Reservoir.

Lacking precise information, *Chironomus* sp. zonation in the south section of the reservoir is likely related to relatively calm waters and ample food supply. The abundance experienced in the south (Station 1) was far greater than any reported account in Lake Michigan (Table 5).

The relatively large sieve size (600 microns) precluded observation of reproductive activity and population dynamics of the Ludington Reservoir Chironomidae. Many early instars were presumably lost while processing (Cummins, 1975).

### Less Abundant Genera

Minor genera taken during the 1974 and 1975 ponar dredge collections are enumerated (Table 6). No significant yearly trends appear visible. A decrease in rare organisms was evident in 1975 indicated in part by *Hygrobates* sp., *Lebertia* sp., *Mideopsis* sp. and the Amphipods *Gammarus* sp. and *Pontoporeia* sp. Again, the subsampling in 1975 may not have adequately represented those genera.

### Hester-Dendy Multiple Plate Samples

Amphipoda (*Gammarus* sp.), Isopoda (*Asellus* sp.) and Gastropoda (*Physa* sp.) were the major organisms found colonizing the Hester-Dendy plate samplers. Chironomidae were frequently collected while the Oligochaeta Hydracarina, Ostracoda (*Candona* sp.) and Ephemeroptera (*Stenonema* sp.),

TABLE 6

Monthly Mean Number/m$^2$ of Taxa in 1974 and 1975 Ponar Dredge Samples from the Ludington Reservoir

| | 1974 | | | | | | 1975 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 4/16* | 5/23 | 6/26 | 8/5 | 10/1 | 11/1 | 4/24 | 5/29 | 7/7 | 8/4 | 9/16 | 10/14 |
| Tubificidae | | | | | | | | | | | | |
| *Aulodrilus* sp. | --- | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 28 | 12 | 9 | 0 |
| *Ilyodrilus* sp. | --- | 0 | 16 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 0 |
| *Limnodrilus* sp. | --- | 81 | 217 | 92 | 115 | 214 | 1287 | 874 | 736 | 812 | 251 | 186 |
| Imm. Without Hair Setae | --- | 61 | 96 | 238 | 2824 | 492 | 2557 | 1354 | 1380 | 1096 | 2748 | 2486 |
| *Peloscolex* sp. | --- | 0 | 3 | 0 | 66 | 2 | 53 | 0 | 0 | 0 | 35 | 0 |
| *Potamothrix* sp. | --- | 0 | 0 | 12 | 154 | 7 | 1084 | 507 | 66 | 160 | 242 | 9 |
| *Tubifex* sp. | --- | 84 | 319 | 57 | 252 | 197 | 2935 | 600 | 111 | 50 | 18 | 163 |
| Imm. With Hair Setae | --- | 51 | 196 | 250 | 3011 | 1144 | 2167 | 2142 | 4125 | 2443 | 2673 | 1700 |
| Naididae | | | | | | | | | | | | |
| *Nais* sp. | --- | 0 | 2 | 7 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Slavina* sp. | --- | 0 | 0 | 38 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chironomidae | | | | | | | | | | | | |
| *Chironomus* sp. | 22 | 19 | 2 | 40 | 698 | 876 | 1367 | 734 | 633 | 756 | 746 | 227 |
| *Cryptochironomus* sp. | 85 | 55 | 36 | 12 | 46 | 106 | 113 | 110 | 19 | 28 | 189 | 28 |
| *Parachironomus* sp. | 9 | 2 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Polypedilum* sp. | 25 | 3 | 1408 | 9 | 17 | 0 | 0 | 22 | 76 | 19 | 0 | 0 |
| *Stictochironomus* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 9 |
| *Cladotanytarsus* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 |
| *Microspectra* sp. | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Stempellina* sp. | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 |
| *Tanytarsus* sp. | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Procladius* sp. | 44 | 9 | 9 | 12 | 16 | 50 | 142 | 76 | 9 | 19 | 9 | 47 |
| *Potthastia* sp. | 0 | 5 | 0 | 0 | 2 | 6 | 0 | 2 | 0 | 0 | 0 | 0 |
| *Monodiamesa* sp. | 44 | 57 | 17 | 24 | 22 | 110 | 66 | 46 | 0 | 9 | 38 | 38 |
| *Heterotrissocladius* sp. | 16 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pupae | 0 | 5 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 76 | 0 | 0 |
| Hydracarina | | | | | | | | | | | | |
| *Lebertia* sp. | 6 | 3 | 0 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hygrobates* sp. | 12 | 6 | 0 | 8 | 2 | 6 | 0 | 0 | 0 | 0 | 9 | 0 |
| *Mideopsis* sp. | 0 | 0 | 2 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Amphipoda | | | | | | | | | | | | |
| *Gammarus* sp. | 2 | 0 | 5 | 9 | 11 | 12 | 19 | 0 | 9 | 0 | 19 | 30 |
| *Pontoporeia* sp. | 2 | 5 | 3 | 5 | 0 | 5 | 0 | 9 | 0 | 0 | 9 | 2 |
| Isopoda | | | | | | | | | | | | |
| *Asellus* sp. | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| Ostracoda | | | | | | | | | | | | |
| *Candona* sp. | 8 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gastropoda | | | | | | | | | | | | |
| *Physa* sp. | 0 | 0 | 0 | 2 | 9 | 22 | 0 | 0 | 0 | 0 | 76 | 19 |
| Pelecypoda | | | | | | | | | | | | |
| *Sphaerium* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 |

* Improper preservation of the April 16, 1974 Oligochaeta samples prevented detailed taxonomic determination.

to a lesser degree, contributed to overall abundance (Table 7).

Gammarus sp. and Asellus sp. showed an increase in 1975 abundance over corresponding 1974 values ($p < 0.05$) (Figures 5 and 6). A decrease in Hydracarina abundance was detected from 1974 to 1975 ($p < 0.05$) while remaining taxa sustained their respective 1974 populations with no detectable increase in 1975 standing crop.

Olson (1974, 1975) reported maximum Asellus sp. and Physa sp. densities of $14/m^2$ and $4/m^2$ respectively in 1973. This study found higher densities in 1974 and 1975. Asellus sp. grew to a maximum of $60/m^2$ in 1974 while it increased to $143/m^2$ in 1975. Physa sp. similarly increased from $17/m^2$ in 1973 to a maximum of $67/m^2$ in 1974 and $183/m^2$ in 1975.

Gammarus sp. had greater standing crop in 1975 than recorded in 1973 (Olson, 1974, 1975) while 1973 and 1974 densities were similar. The Oligochaeta and Hydracarina decreased in 1974 and 1975 from substantially higher 1973 densities. The Chironomidae and Ephemeroptera did not increase since the first year of operation. On two occasions Ostracoda (Candona sp.) were collected, a group not previously encountered in the Hester-Dendy samples.

The Tubificidae and Naididae of the Oligochaeta were equally represented in the Hester-Dendy collections (Table 8). Limnodrilus sp. and Tubifex sp. comprised the mature Tubificidae as did Nais sp., Paranais sp., and Stylaria sp. the Naididae. Stylaria sp., the most abundant genera, reached densities of $23/m^2$ in July 1975. Occurrences of most genera were rare and numerically low.

The Chironomids Parachironomus sp. and Conchapelopeia sp. contributed major portions to Chironomidae abundance (Table 9). On occasion, Chironomus sp., Cryptochironomus sp., and Polypedilum sp. gained in

Table 7. Monthly Mean Number/$m^2$ of Major Taxonomic Groups in 1974 and 1975 Hester-Dendy Samples from the Ludington Reservoir.

| Taxon | 1974 | | | 1975 | | |
|---|---|---|---|---|---|---|
| | 6/17 | 7/16 | 9/9 | 6/16 | 7.14 | 8.11 |
| Oligochaeta | .7 | 7.0 | 0 | 6.3 | 29.4 | 0 |
| Chironomidae | 18.8 | 11.0 | 1.8 | 6.1 | 35.2 | 20.6 |
| Hydracarina | .2 | 76.6 | 0 | .5 | .3 | 0 |
| Amphipoda | 13.1 | 14.0 | 28.3 | 61.1 | 78.8 | 143.5 |
| Isopoda | 2.5 | 41.7 | 60.6 | 133.6 | 279.7 | 401.0 |
| Ostracoda | 0 | .3 | .7 | 0 | 0 | 0 |
| Gastropoda | 2.2 | 49.7 | 67.0 | 9.8 | 182.8 | 86.2 |
| Ephemeroptera | .8 | .8 | 3.7 | 0 | 0 | 0 |

Figure 5. Seasonal Abundance of *Gammarus* sp. (Amphipoda) in the 1974 and 1975 Hester-Dendy Samples.

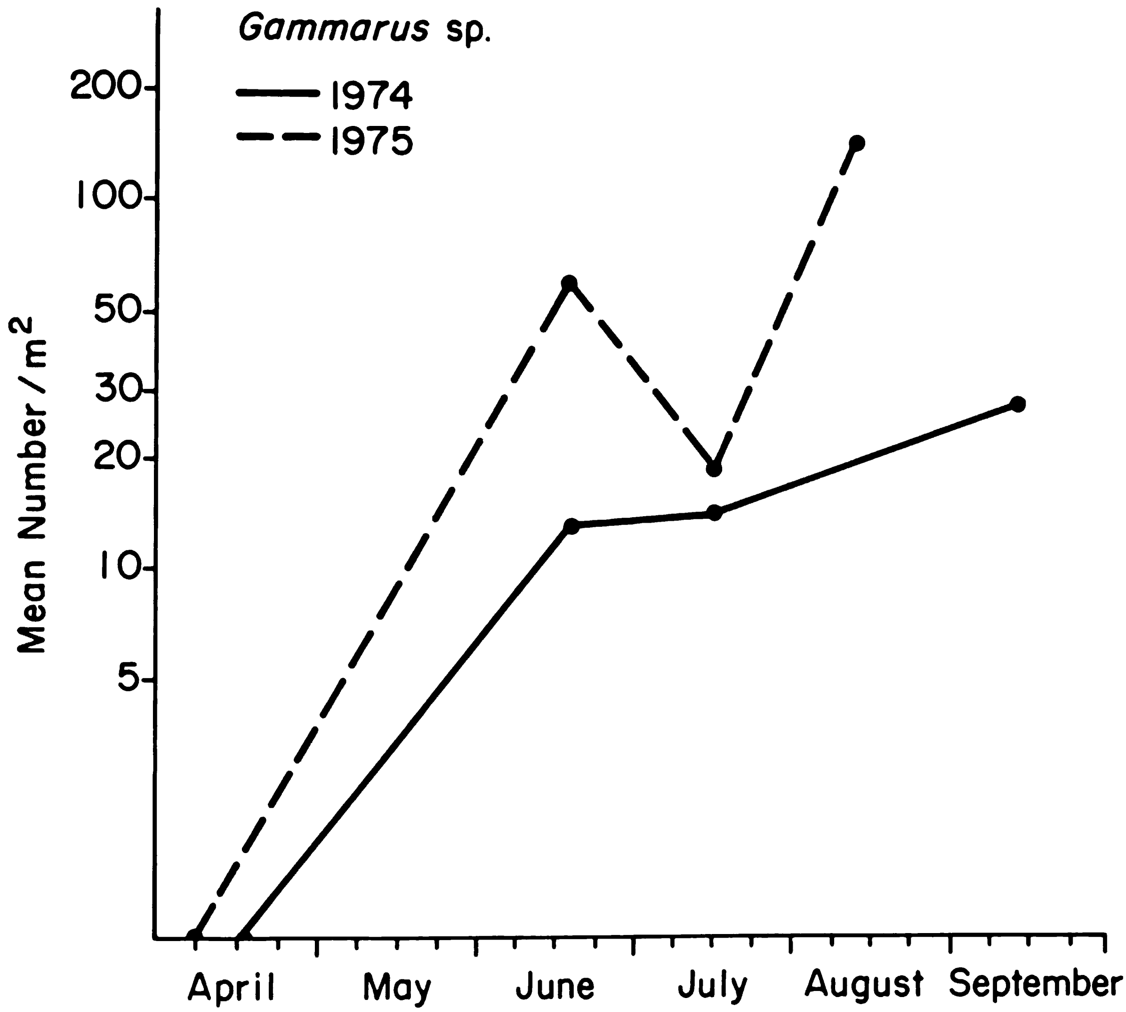
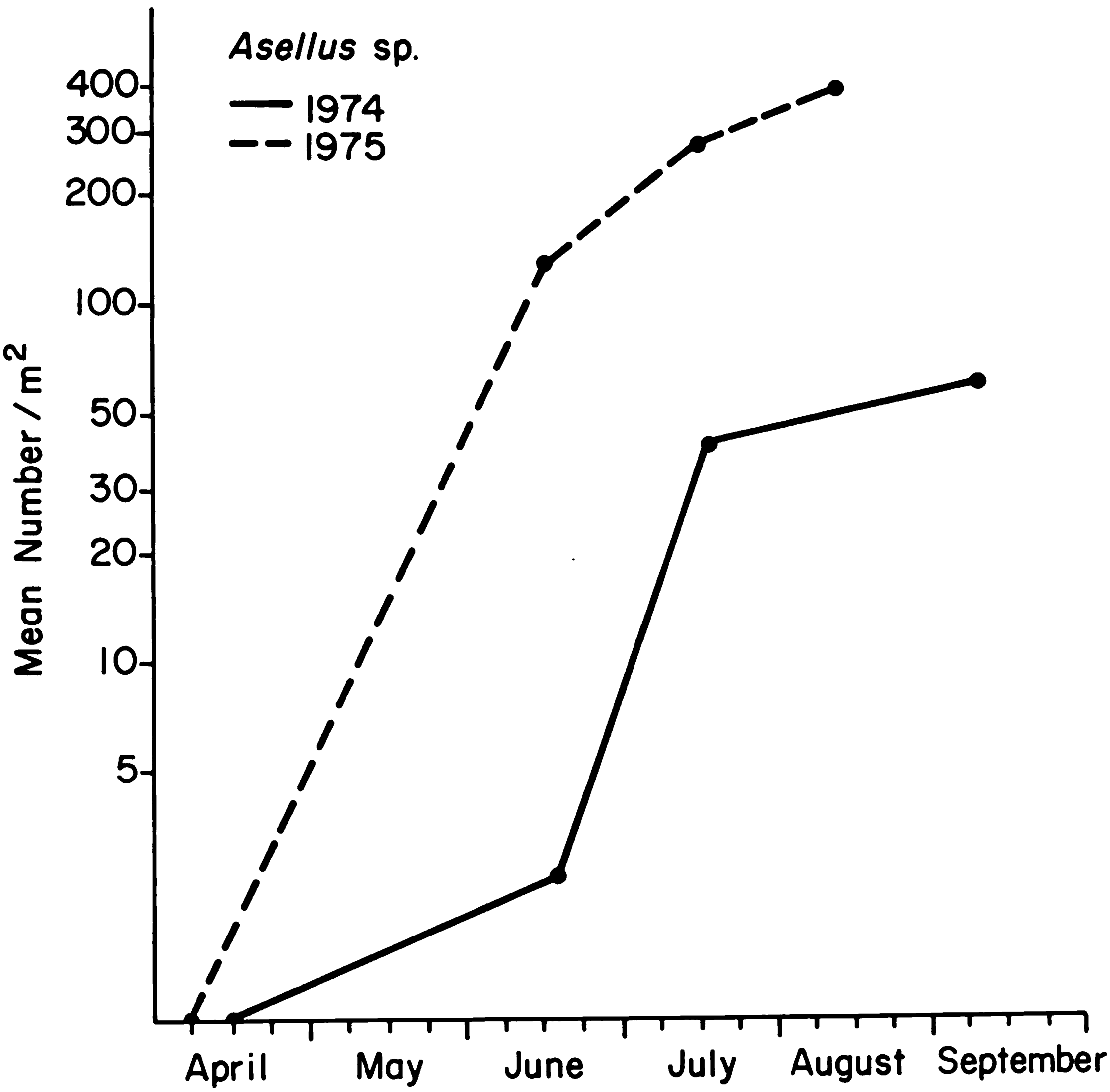

Gammarus sp.
1974
1975
200
100
50
30
20
10
5
Mean Number / m2
April
May
June
July
August
September

Figure 6. Seasonal Abundance of *Asellus* sp. (Isopoda) in the 1974 and 1975 Hester-Dendy Samples.



Asellus sp.
1974
1975
400
300
200
100
50
30
20
10
5
Mean Number / m2
April
May
June
July
August
September

Table 8. Monthly Mean Number/$m^2$ of Oligochaeta in 1974 and 1975 Hester-Dendy Samples from the Ludington Reservoir.

| Species | 1974 | | | 1975 | | |
|---|---|---|---|---|---|---|
| | 6/17 | 7/16 | 9/9 | 6/16 | 7/14 | 8/11 |
| Tubificidae | | | | | | |
| *Limnodrilus* sp. | 0 | 1.5 | 0 | 1.0 | .3 | 0 |
| Imm. Without Hair Setae | 0 | 2.5 | 0 | 4.3 | .9 | 0 |
| *Tubifex* sp. | .3 | 0 | 0 | 0 | 0 | 0 |
| Imm. With Hair Setae | .3 | 1.5 | 0 | .7 | 1.5 | 0 |
| Naididae | | | | | | |
| *Nais* sp. | 0 | .7 | 0 | 3.0 | 3.5 | 0 |
| *Paranais* | 0 | .7 | 0 | 0 | 0 | 0 |
| *Stylaria* sp. | 0 | .2 | 0 | 0 | 23.2 | 0 |

Table 9. Monthly Mean Number/$m^2$ of Chironomidae in 1974 and 1975 Hester-Dendy Samples from the Ludington Reservoir.

| Species | 1974 | | | 1975 | | |
|---|---|---|---|---|---|---|
| | 6/17 | 7/16 | 9/9 | 6/16 | 7/14 | 8/11 |
| Chironomidae | | | | | | |
| *Chironomus* sp. | 0 | .2 | 0 | 0 | 2.6 | 1.0 |
| *Cryptochironomus* sp. | 0 | .2 | 0 | 0 | 3.3 | 0 |
| *Glyptotendipes* sp. | 0 | .2 | .3 | 0 | .2 | 0 |
| *Parachironomus* sp. | 8.3 | .8 | 8.3 | 4.5 | 0 | 2.8 |
| *Polypedilum* sp. | 3.5 | 0 | 0 | 0 | 4.8 | 0 |
| *Tanytarsus* sp. | 0 | 0 | 0 | 0 | 0 | .3 |
| *Conchapelopia* sp. | 6.7 | 3.2 | .3 | 1.6 | 24.3 | 15.8 |
| *Cricotopus* sp. | .3 | 0 | 0 | 0 | 0 | 0 |
| *Heterotrissocladius* sp. | 0 | 0 | 0 | 0 | 0 | .5 |
| *Psectrocladius* sp. | 0 | .2 | .3 | 0 | 0 | 0 |

importance while the remaining genera were rarely encountered.

Hygrobates sp., Mideopsis sp. and Lebertia sp. comprised the Hydracarina genera sampled (Table 10). These genera, seldom found in 1975, suggested a reduction in numbers from 1973 and 1974 (Olson, 1974, 1975).

Table 10. Monthly Mean Number/$m^2$ of Taxa in 1974 and 1975 Hester-Dendy Samples from the Ludington Reservoir.

| Species | 1974 | | | 1975 | | |
|---|---|---|---|---|---|---|
| | 6/17 | 7/16 | 9/9 | 6/16 | 7/14 | 8/11 |
| Hydracarina | | | | | | |
| _Hygrobates_ sp. | 0 | 54.7 | 0 | .3 | 0 | 0 |
| _Lebertia_ sp. | .2 | 4.8 | 0 | .2 | .3 | 0 |
| _Mideopsis_ sp. | 0 | 17.1 | 0 | 0 | 0 | 0 |
| Amphipoda | | | | | | |
| _Gammarus_ sp. | 13.1 | 14.0 | 28.3 | 61.1 | 18.7 | 143.5 |
| Isopoda | | | | | | |
| _Asellus_ sp. | 2.5 | 41.7 | 60.6 | 133.6 | 279.7 | 401.0 |
| Ostracoda | | | | | | |
| _Candona_ sp. | 0 | .3 | .7 | 0 | 0 | 0 |
| Gastropoda | | | | | | |
| _Physa_ sp. | 2.2 | 49.7 | 67.0 | 9.8 | 182.8 | 86.2 |
| Ephemeroptera | | | | | | |
| _Stenonema_ sp. | .8 | .8 | 3.7 | 0 | 0 | 0 |

# SUMMARY AND CONCLUSIONS

The continued colonization of the Ludington Pumped Storage Reservoir by benthic macroinvertebrates was monitored during 1974 and 1975. Data was furnished monthly via quadruplicate ponar dredge samples taken from April to October while Hester-Dendy samples augmented the dredge information during the summer months. Combined information yielded significant ($p < 0.05$) increases in Oligochaeta, Chironomidae, Amphipoda and Isopoda abundance during the present two year study. Hydracarina appeared to decrease in 1975. Since filling in 1973 the densities of Oligochaeta, Chironomidae, Amphipoda, Isopoda and Gastropoda have significantly increased.

The Oligochaeta revealed a generic composition similar to that reported by Olson (1974, 1975) except for the decline of *Peloscolex* sp. and the recent introduction of *Potamothrix* sp. in the present work.

Chironomidae drastically changed in generic composition as *Chironomus* sp. dominated the collections in late 1974 and all of 1975. A higher standing crop in the south end of the reservoir was assumed to be in response to favorable conditions and a generous food supply.

Generally, the Ludington Reservoir had greater benthic abundance than Lake Michigan. The differences in current and substrate likely favored a higher benthic standing crop within the reservoir. Indicator organisms and direct evidence of allochthanous inputs indicated organic enrichment of the Ludington Reservoir since filling in 1973. This enrichment will continue in the future.

Further studies are needed to quantitatively determine the extent of allochthonous organic loading. Also, water current information coupled with sedimentation studies would be of value in the interpretation of benthic distribution patterns.

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Appendix. Records of numbers per $m^2$ of major invertebrate groups taken with each ponar dredge and Hester-Dendy sample in the Ludington Reservoir during 1974 and 1975.

RESERVOIR PONAR DREDGE SAMPLES 4/16/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 227 | 340 | 0 | 0 | 0 | |
| | 277 | 302 | 0 | 0 | 0 | |
| 1 | 510 | 57 | 0 | 19 | 0 | |
| | 1,739 | 265 | 19 | 19 | 0 | |
| | 3,799 | 378 | 0 | 0 | 0 | |
| | 4,933 | 473 | 0 | 57 | 0 | |
| 4 | 6,539 | 662 | 0 | 38 | 0 | |
| | 4,007 | 189 | 0 | 38 | 0 | |
| | 3,137 | 586 | 0 | 95 | 0 | |
| | 661 | 246 | 0 | 57 | 0 | |
| 6 | 6,974 | 756 | 0 | 57 | 0 | |
| | 605 | 284 | 0 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 5/23/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 0 | 76 | 0 | 0 | 0 | |
| | 0 | 151 | 19 | 0 | 0 | Ost. 19 |
| 1 | 76 | 95 | 19 | 19 | 0 | Ost. 57 |
| | 19 | 189 | 19 | 38 | 0 | |
| | 0 | 57 | 0 | 38 | 0 | |
| 4 | 19 | 246 | 0 | 0 | 0 | Ost. 38 |
| | 0 | 19 | 0 | 38 | 0 | |
| | 0 | 0 | 0 | 0 | 0 | |
| | 0 | 38 | 0 | 0 | 0 | |
| | 1,304 | 397 | 0 | 0 | 0 | |
| 6 | 1,907 | 397 | 0 | 0 | 0 | |
| | 0 | 170 | 0 | 0 | 0 | |

Ost. = Ostracoda. Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 6/26/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 265 | 1,229 | 0 | 0 | 0 | |
| | 113 | 510 | 0 | 0 | 0 | |
| 1 | 567 | 1,380 | 0 | 0 | 0 | |
| | 1,115 | 1,077 | 0 | 0 | 0 | Ost. 95 |
| | 265 | 378 | 19 | 0 | 0 | |
| | 491 | 1,021 | 38 | 0 | 0 | |
| 4 | 359 | 567 | 0 | 19 | 0 | |
| | 1,664 | 1,928 | 19 | 0 | 0 | |
| | 1,512 | 3,364 | 0 | 0 | 0 | |
| | 3,137 | 2,816 | 38 | 0 | 0 | |
| 6 | 265 | 662 | 0 | 0 | 0 | |
| | 3,780 | 2,930 | 0 | 0 | 0 | |

Ost. = Ostracoda. Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 8/5/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 1,360 | 208 | 19 | 0 | 19 | Iso. 19 |
| 1 | 794 | 151 | 0 | 19 | 0 | |
| | 2,665 | 132 | 0 | 0 | 0 | |
| | 246 | 57 | 0 | 19 | 0 | |
| | 1,040 | 170 | 19 | 0 | 19 | |
| 4 | 926 | 151 | 0 | 0 | 0 | |
| | 1,266 | 132 | 38 | 0 | 76 | |
| | 133 | 76 | 0 | 76 | 0 | |
| | 57 | 38 | 19 | 0 | 0 | |
| 6 | 662 | 57 | 0 | 0 | 0 | |
| | 832 | 0 | 0 | 38 | 0 | |
| | 95 | 38 | 57 | 0 | 0 | |

Iso. = Isopoda. Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 10/1/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| 1 | 170 | 2,835 | 0 | 0 | 0 | |
| | 4,725 | 2,287 | 19 | 19 | 0 | |
| | 2,944 | 1,058 | 0 | 0 | 0 | |
| | 5,197 | 2,155 | 0 | 0 | 0 | |
| 4 | 1,984 | 0 | 0 | 19 | 0 | |
| | 5,670 | 265 | 19 | 0 | 0 | |
| | 10,395 | 189 | 38 | 0 | 0 | |
| | 23,247 | 0 | 19 | 19 | 0 | Iso. 19 |
| 6 | 3,780 | 208 | 19 | 0 | 0 | Iso. 19 |
| | 7,560 | 95 | 19 | 19 | 0 | |
| | 4,252 | 510 | 0 | 0 | 0 | |
| | 8,505 | 0 | 0 | 0 | 0 | |

Iso. = Isopoda. Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 11/1/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 2,003 | 3,081 | 0 | 19 | 19 | |
| 1 | 2,646 | 1,663 | 0 | 38 | 0 | |
| | 1,777 | 2,003 | 0 | 0 | 0 | |
| | 1,588 | 2,533 | 0 | 0 | 0 | |
| | 19 | 813 | 0 | 0 | 132 | |
| 4 | 491 | 567 | 38 | 0 | 38 | |
| | 208 | 851 | 19 | 0 | 0 | |
| | 11,340 | 605 | 38 | 57 | 38 | |
| | 19 | 416 | 0 | 0 | 0 | |
| 6 | 435 | 151 | 113 | 19 | 19 | |
| | 2,249 | 567 | 0 | 0 | 19 | |
| | 1,921 | 529 | 0 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 4/24/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 4,875 | 2,608 | 0 | 0 | 0 | |
| 1 | 7,030 | 3,515 | 0 | 0 | 0 | |
| | 7,940 | 1,474 | 0 | 0 | 0 | |
| | 4,082 | 2,948 | 0 | 0 | 0 | |
| | 3,742 | 227 | 0 | 0 | 0 | |
| 4 | 9,412 | 794 | 0 | 0 | 0 | |
| | 11,113 | 340 | 0 | 0 | 0 | |
| | 27,556 | 2,003 | 0 | 0 | 0 | |
| | 12,360 | 454 | 0 | 0 | 0 | |
| 6 | 12,927 | 2,835 | 0 | 0 | 0 | |
| | 8,732 | 1,361 | 227 | 0 | 0 | |
| | 11,680 | 1,701 | 0 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 5/29/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 283 | 302 | 0 | 0 | 0 | |
| | 0 | 3,742 | 0 | 0 | 0 | |
| 1 | 5,670 | 1,134 | 0 | 0 | 0 | |
| | 7,031 | 1,814 | 0 | 0 | 0 | |
| | 680 | 0 | 0 | 0 | 0 | |
| | 907 | 567 | 0 | 0 | 0 | |
| 4 | 6,464 | 0 | 0 | 0 | 0 | |
| | 2,381 | 1,361 | 0 | 0 | 0 | |
| | — | — | — | — | — | |
| | 11,888 | 567 | 0 | 0 | 0 | |
| 6 | 18,598 | 340 | 113 | 0 | 0 | |
| | 888 | 265 | 0 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 7/7/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| 1 | 12,814 | 4,763 | 0 | 0 | 0 | |
| | 5,216 | 1,588 | 0 | 0 | 0 | |
| | 7,377 | 113 | 0 | 0 | 0 | |
| | 8,505 | 340 | 0 | 0 | 0 | |
| 4 | 1,361 | 454 | 0 | 0 | 0 | |
| | 1,134 | 0 | 0 | 0 | 0 | |
| | 4,536 | 113 | 0 | 0 | 0 | |
| | 4,195 | 340 | 0 | 0 | 0 | |
| 6 | 10,205 | 0 | 0 | 0 | 0 | |
| | 15,536 | 907 | 0 | 0 | 0 | |
| | 6,464 | 227 | 0 | 0 | 0 | |
| | 19 | 227 | 113 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 8/4/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| | 5,216 | 2,608 | 0 | 0 | 0 | |
| 1 | 5,330 | 1,701 | 0 | 0 | 0 | |
| | 6,010 | 2,495 | 0 | 0 | 0 | |
| | 12,814 | 2,948 | 0 | 0 | 0 | |
| | 0 | 907 | 0 | 0 | 0 | |
| 4 | 0 | 0 | 0 | 0 | 0 | |
| | 1,361 | 680 | 0 | 0 | 0 | |
| | 0 | 0 | 0 | 0 | 0 | |
| | 0 | 0 | 0 | 0 | 0 | |
| 6 | 12,473 | 0 | 0 | 0 | 0 | |
| | 2,267 | 113 | 0 | 0 | 0 | |
| | 9,411 | 340 | 0 | 0 | 0 | |

Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 9/16/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| 1 | 6,804 | 340 | 0 | 0 | 0 | |
| | 5,624 | 340 | 0 | 0 | 0 | |
| | 7,485 | 680 | 0 | 0 | 0 | |
| | 3,742 | 2,948 | 0 | 0 | 0 | |
| 4 | 680 | 794 | 0 | 0 | 0 | |
| | 0 | 227 | 227 | 113 | 0 | |
| | 3,175 | 1,361 | 113 | 0 | 113 | Pel. 227 |
| | 1,021 | 340 | 0 | 0 | 0 | |
| 6 | 9,298 | 1,247 | 0 | 0 | 454 | Iso. 113 |
| | 16,443 | 1,247 | 0 | 0 | 0 | |
| | 8,278 | 1,701 | 0 | 0 | 113 | |
| | 9,184 | 680 | 0 | 0 | 227 | Pel. 113 |

Pel. = Pelecypoda;  Iso. = Isopoda.  Units are numbers/meter$^2$.

RESERVOIR PONAR DREDGE SAMPLES 10/14/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | OTHER |
|---|---|---|---|---|---|---|
| 1 | 5,103 | 680 | 0 | 0 | 0 | |
| | 7,937 | 1,021 | 0 | 0 | 0 | |
| | 12,247 | 794 | 0 | 0 | 0 | |
| | 4,763 | 567 | 0 | 0 | 0 | |
| 4 | 113 | 0 | 113 | 0 | 0 | |
| | 113 | 113 | 227 | 0 | 0 | |
| | 113 | 0 | 0 | 0 | 0 | |
| | 0 | 0 | 38 | 0 | 0 | |
| 6 | 2,495 | 0 | 0 | 0 | 0 | |
| | 2,155 | 113 | 0 | 0 | 0 | |
| | 3,175 | 113 | 0 | 0 | 0 | |
| | 16,330 | 794 | 0 | 0 | 227 | |

Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 6/17/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 8 | 40 | 0 | 0 | 0 | |
| 2 | 0 | 37 | 39 | 1 | 2 | 4 | Eph. 2 |
| 3 | 0 | 29 | 0 | 1 | 3 | 4 | |
| 4 | 4 | 16 | 0 | 0 | 1 | 3 | Eph. 2 |
| 5 | 0 | 7 | 0 | 2 | 7 | 3 | |
| 6 | 0 | 16 | 0 | 0 | 0 | 3 | Eph. 2 |

Eph. = Ephemeroptera. Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 7/16/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 9 | 22 | 201 | 108 | 0 | Eph. 3 |
| 2 | 20 | 1 | 37 | 184 | 107 | 15 | Ost. 1 |
| 3 | 21 | 38 | 18 | 0 | 36 | 123 | Ost. 1 |
| 4 | 0 | 0 | 2 | 0 | 15 | 15 | Eph. 1 |
| 5 | 0 | 18 | 1 | 0 | 30 | 97 | Eph. 1 |
| 6 | 0 | 0 | 4 | 76 | 2 | 0 | |

Eph. = Ephemeroptera; Ost. = Ostracoda. Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 9/9/74

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 22 | 1 | 0 | 56 | 50 | Eph. 1 |
| 2 | 0 | 6 | 13 | 0 | 145 | 43 | Eph. 6 |
| 3 | 0 | 0 | 71 | 0 | 0 | 89 | Eph. 4<br>Ost. 2 |
| 4 | — | — | — | — | — | — | |
| 5 | — | — | — | — | — | — | |
| 6 | — | — | — | — | — | — | |

Eph. = Ephemeroptera; Ost. = Ostracoda. Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 6/16/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 18 | 0 | 0 | 0 | |
| 2 | 18 | 6 | 30 | 0 | 6 | 65 | |
| 3 | 0 | 6 | 134 | 0 | 20 | 211 | |
| 4 | 0 | 4 | 47 | 0 | 16 | 229 | |
| 5 | 0 | 9 | 138 | 2 | 10 | 150 | |
| 6 | 0 | 11 | 0 | 1 | 7 | 147 | |

Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 7/14/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 21 | 21 | 4 | 0 | 295 | 13 | |
| 2 | 0 | 28 | 11 | 0 | 259 | 486 | |
| 3 | 33 | 29 | 19 | 0 | 7 | 242 | |
| 4 | 43 | 31 | 14 | 2 | 46 | 360 | |
| 5 | 64 | 30 | 0 | 0 | 297 | 323 | |
| 6 | 18 | 44 | 64 | 0 | 192 | 254 | |

Units are numbers/meter$^2$.

RESERVOIR HESTER-DENDY SAMPLES 8/11/75

| STATIONS | OLIGOCHAETA | CHIRONOMIDAE | AMPHIPODA | HYDRACARINA | GASTROPODA | ISOPODA | OTHER |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 6 | 26 | 0 | 111 | 27 | |
| 2 | 0 | 78 | 119 | 0 | 20 | 490 | |
| 3 | 0 | 13 | 296 | 0 | 94 | 632 | |
| 4 | 0 | 3 | 133 | 0 | 120 | 456 | |
| 5 | — | — | — | — | — | — | |
| 6 | — | — | — | — | — | — | |

Units are numbers/meter$^2$.