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Benthic Invertebrates in Lake Ashtabula Reservoir, North Dakota

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ABSTRACT: The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded at a single station located 3.2 km N of the dam. The average standing crops of benthic invertebrates in the sampling station collected during April, June and August 1967 were 6.4, 8.2 and 7.1 g m⁻², respectively, and 1831, 2622 and 1295 individuals m⁻². Organisms in the 0-3 m depth zone accounted for 28% by number and 53% by weight of all organisms present in the study area from April to August; 56% by number and 37% by weight were in the 3-8 m depth zone; and 16% by number and 9% by weight were in the 8-12 m depth zone. The quantity and kinds of its benthic invertebrates indicate Lake Ashtabula is eutrophic when compared with data available from other lakes that are also unstratified during open-water periods.

INTRODUCTION

The kinds and amounts of benthic invertebrates in Lake Ashtabula, a 20-year-old eutrophic reservoir in southeastern North Dakota, were recorded as part of a continuing study designed to characterize the reservoir in terms of its water chemistry and primary productivity.

Lake Ashtabula is to receive waters in the late 1970's from the Garrison Diversion Project, which will provide irrigation water from the Garrison Reservoir to eastern and central North Dakota. As these waters pass through North Dakota farmland and highly saline Devils Lake, they are expected to increase in total dissolved solids which could modify environmental conditions in Lake Ashtabula. Because studies of benthic invertebrates have been useful elsewhere in determining effects of various environmental changes occurring in lakes and streams (*e.g.*, Brinkhurst [1969], Carr and Hiltunen [1965] and others on changing kinds and numbers of benthic invertebrates in Lake Erie associated with organic pollution; Cowell and Hudson [1967] on the effects of variations in morphometry and water level fluctuations on benthic invertebrates in reservoirs on the Missouri River; and Mills, Starrett and Bellrose [1966], who reviewed changes in benthic invertebrates in the Illinois River as affected by activities of man), it is hoped that we will be able to assess any changes in the biota caused by receipt of diversion waters from data collected from Lake Ashtabula. Since there have been no detailed studies of benthic invertebrates from North Dakota reservoirs, it is hoped that information presented here will contribute to the limnology of the Upper Great Plains and, on a broader scope, to knowledge of benthic invertebrates in reservoirs which do not stratify during open-water periods and which do not experience large and rapid changes of water levels.

The lake's limnology, primary productivity and zooplankton standing crops were studied by Peterka and Reid (1968) and Peterka and

Knutson (1970). Lake Ashtabula has a surface area at normal pool of 2197.5 ha, a length of 43.5 km, a maximum width of 0.97 km, a mean depth of 4.0 m, a maximum depth slightly over 15 m and drains an area of 10,717.5 km² (Peterka and Reid, 1968). The water exchange ratio (volume of water entering the reservoir divided by the volume of the reservoir at normal pool) from March to November 1965, 1966 and 1967 averaged 2.1. Except for periods of a few days when stratification occurred, water temperatures were uniform from top to bottom during ice-free periods. Lake Ashtabula is highly productive with average annual gross primary productivity rates of 4.1 and 6.8 g O₂ m⁻² day⁻¹ for 1967 and 1968, respectively. Heavy blooms of *Aphanizomenon holsaticum* occurred, comprising about 90% of the total algal bloom in numbers and volume during summer and autumn of 1967 and 1968 (Peterka and Knutson, 1970). *Daphnia* comprised 84% of total zooplankton dry weight standing crop in 1967 and 81% in 1968; copepods 14% in 1967 and 17% in 1968. The average dry weight daily standing crop of *Daphnia pulex* was 1110 in 1967 and 2851 mg m⁻² in 1968; of *Daphnia galeata mendotae*, it was 294 in 1967 and 7.2 mg m⁻² in 1968.

METHODS

A 15.2-cm-sq Ekman dredge (232 cm²) was used to sample transects of the reservoir bottom for benthic invertebrates in the spring and summer of 1967. Dredge hauls were taken in three depth zones: the littoral zone (0-3 m), the old river floodplain (3-8 m), and the old river channel (8-12 m).

All sampling was done at a station, which will be referred to as the study area, located 3.2 km (2 miles) N of the dam (Fig. 1). On 26 April 1967, 12 Ekman dredge hauls were made in the 0-3, and six hauls each in the 3-8 and 8-12 m depth zones. From 6-12 June 1967, 60 dredge hauls were made in the 0-3, 64 hauls in the 3-8, and 32 hauls in the 8-12 m depth zones. From 22-30 August 1967, 60 dredge hauls were made in the 0-3, 52 hauls in the 3-8, and 20 hauls in the 8-12 m depth zones. Within each depth zone, sampling was accomplished by anchoring the boat, taking four dredge hauls, and then permitting the boat to drift before taking another series of four hauls. Bottom samples from each four dredge hauls were combined and washed through a sieve with a mesh size of 0.5 mm. Retained organisms were preserved in 5-10% formalin and later counted and weighed to the nearest 0.001 g after being centrifuged in wire-mesh cones to remove surface moisture. Many organisms not easily visible, such as nematodes, Naididae and early stages of organisms retained, were undoubtedly lost during sieving; those retained were not counted.

Results are expressed as numbers and wet weights per m². Before weighing, caddis fly larvae were removed from their cases. Only living molluscs with their shells were counted and weighed. A weighted standing crop value for the entire study area accounts for the contributions made by each of the depth zones, which were 15% by the

littoral zone, 70% by the old river floodplain and 15% by the old river channel. Standard errors of the weighted mean wet weights of organisms in the study area for July and August were computed after the methods of Snedecor and Cochran (1967) for randomly stratified samples.

Invertebrates located on submergent vegetation were not included in samples taken in the littoral zone. A rough estimate of organisms present in and on rooted vegetation, however, was obtained from seven samples made on 27 June and 14-15 July 1967, using a 0.1 m² sampler constructed of a cylindrical net bag 3 m long with a mesh size of 0.4 mm, attached to a heavy cutting rim. This sampler was dropped over the vegetation and forced to the lake bottom. Plants within the bag were then uprooted by hand and the entire contents brought to the surface where the organisms were separated and preserved as described for Ekman dredge samples. Plants were dried to a constant weight at 100 C. The data from the plant samples are treated in a separate section from samples collected with the Ekman dredge.

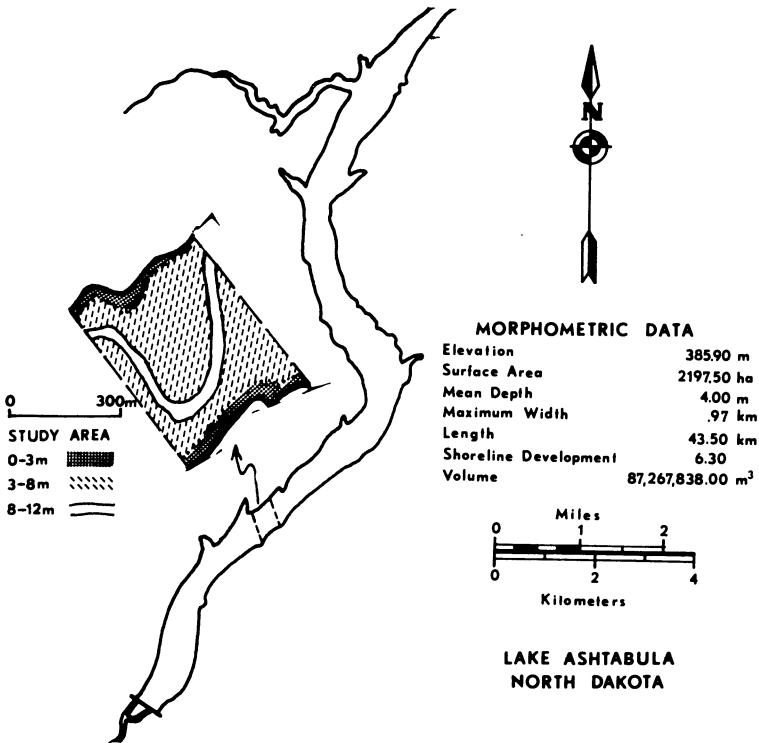


Fig. 1.—Map of Lake Ashtabula, North Dakota, showing the location of the sampling station

RESULTS

Mollusca.—About 46% of the average biomass of all invertebrates collected from the study area from 26 April to 30 August 1967 was comprised of gastropods belonging to the genera *Valvata*, *Physa*, *Helisoma* and *Amnicola*. *Amnicola* accounted for about 56% and *Helisoma* and *Valvata* each accounted for 20% of the total biomass of gastropods. Pelecypoda, about 8% of the total average biomass of the study area, were mostly *Pisidium* and a few *Musculium*.

The 0-3 m depth zone contained most of the molluscs (Fig. 2). There were no members of *Musculium*, *Helisoma* or *Amnicola* collected in the 8-12 m zone and only occasional *Valvata* and *Physa*. In the 3-8 m zone, no *Musculium* were collected, and *Physa* and *Helisoma* never exceeded more than 10 individuals m^{-2} .

The average standing crop of molluscs from April to August 1967 in the study area was 306 individuals weighing $3.93 g m^{-2}$. Of these, 212 were gastropods weighing $3.38 g m^{-2}$. The maximum biomass of gastropods was reached in August; pelecypods reached their maximum biomass in June (Fig. 3).

Diptera.—About 34% of the total biomass of the study area was comprised of dipterans which included 79% chironomids, 20% ceratopogonids and 1% culicids (mostly *Chaoborus*).

Biomass of dipterans in the 3-8 m depth zone was about three

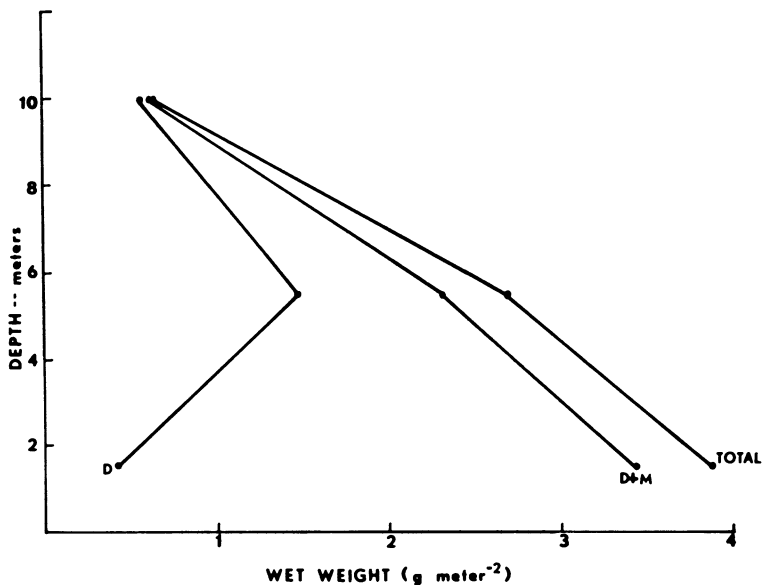


Fig. 2.—Distribution with depth of the mean wet weights of dipterans (D), molluscs (M) and of the total benthic invertebrates from April to August 1967, Lake Ashtabula, North Dakota.

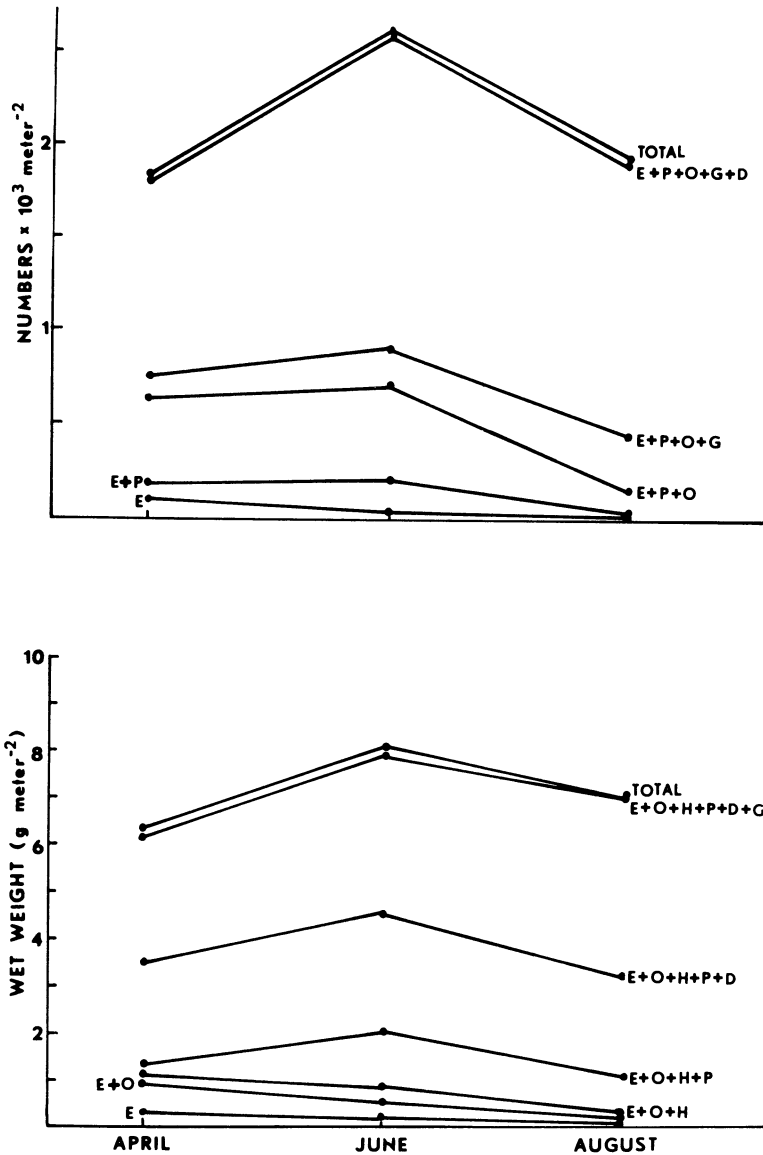


Fig. 3.—Seasonal changes of biomass of ephemeropterans (E), oligochaetes (O), hirudinea (H), pelecypods (P), dipterans (D), gastropods (G) and of the total benthic invertebrates during April, June, August 1967 in Lake Ashtabula. Seasonal changes in numbers of ephemeropterans (E), pelecypods (P), oligochaetes (O), gastropods (G), dipterans (D) and of the total bottom fauna during April, June, August 1967 in Lake Ashtabula, North Dakota

times higher than in the 0-3 m zone and about two times higher than in the 8-12 m zone (Fig. 2). The maximum density of large chironomids, consisting of members of the genus *Cryptochironomus* and the species *Chironomus plumosus*, occurred in August 1967 when there were 103 and 105 individuals weighing 1.58 and 2.94 g m⁻², respectively, in the 0-3 and 8-12 m depth zones, and only 27 individuals weighing 0.48 g m⁻² in the 3-8 m depth zone. Of the small chironomids, the genera *Procladius*, *Cryptochironomus* and *Tanytarsus* occurred most frequently; *Anatopynia*, *Einfeldia*, *Polypedilum* and *Cricotopus* were also present. The maximum density occurred in the 0-3 m depth zone in August 1967 when there were 3592 individuals weighing 3.65 g m⁻², in the 3-8 m depth zone in June 1967 when there were 1290 individuals weighing 1.34 g m⁻², and in the 8-12 m depth zone in April 1967 when there were 1765 individuals weighing 2.83 g m⁻².

The average standing crop of dipterans from April to August 1967 in the study area was 1391 individuals weighing 2.47 g m⁻², of which 1093 were chironomids weighing 1.94 g m⁻². The biomass of dipterans increased from 2.16 g m⁻² in April to 2.69 g m⁻² in August 1967, while numbers were highest in June (Fig. 3). Most of the increase in biomass from April to August was the result of the increase in chironomid standing crop from 1.66 in April to 1.86 and 2.31 g m⁻², during June and August 1967.

Annelida.—About 9% of the total biomass of the study area was comprised of annelids of which Hirudinea contributed 40% and oligochaetes (Tubificidae) contributed 60%. The average standing crop of annelids from April to August 1967 in the study area was 358 individuals weighing 0.66 g m⁻², of which four were Hirudinea weighing 0.26 g m⁻². The biomass of annelids decreased from 0.93 in April, to 0.73 in June, to 0.32 g m⁻² in August, largely a reflection of an April to August decrease in tubificids (Fig. 3).

Ephemeroptera.—About 2% of the total biomass of the study area was contributed by ephemeropterans, which were mostly found in the 0-3 m depth zone. *Caenis* accounted for 69% of the total biomass of ephemeropterans; the remaining 31% were mostly *Hexagenia*.

The average standing crop of ephemeropterans from April to August 1967 in the study area was 43 individuals weighing 0.14 g m⁻², of which 42 were *Caenis* weighing 0.10 g m⁻² and one was *Hexagenia* weighing 0.04 g m⁻².

The standing crop in the study area decreased from 102 individuals weighing 0.23 g m⁻² in April to 28 individuals weighing 0.17 g m⁻² in June to one individual weighing 0.02 g m⁻² in August.

Others.—About 2% of the total biomass of the study area was contributed by trichopterans (mostly *Oecetis*), amphipods (mostly *Hyalolela*), haliplids, and zygopterans, all of which occurred largely in the 0-3 m depth zone. Trichopterans accounted for 59%, amphipods 35% and zygopterans and haliplids each 3% of the average biomass of 0.16 g m⁻² present in the study area from April to August 1967.

Plant and fauna samples.—Most of the submerged macrophytes in

the reservoir were *Potamogeton* species. These occurred in a band approximately 10 to 20 m wide throughout the length of the reservoir in water 0.6 to 2.5 m deep. *Potamogeton pectinatus* was the dominant species in the study area with some *P. perfoliatus*. The dry weight of plants collected on 27 June and 14-16 July 1967 was 139 g m⁻² (range 100-183) near the shore in water 1.2 to 1.5 m deep, 244 g m⁻² (range 199-286) in the center of the plant band in water 1.5 m deep, and 244 g m⁻² (range 197-308) near the open-water edge of the plant band in water 2.0 m deep. The corresponding wet weights of invertebrates in the plant samples were 25.4 g m⁻² (range 21.4-29.5), 40.6 g m⁻² (range 19.0-62.1) and 30.4 g m⁻² (range 13.8-47.5). The average standing crop of invertebrates in the plant zone from 27 June to 15 July 1967 of about 32 g m⁻² was about three times the standing crop of 10 g m⁻² (range 7.25 to 12.89 g m⁻²) of two samples of benthic invertebrates collected at a depth of 1.5 m with the Ekman dredge on 15 July.

Gastropods (mostly *Amnicola*) accounted for 88% of the biomass and 64% of the individuals in the plant zone. Ephemeropterans, *Piscidium*, chironomids and Hirudinea each accounted for 2% of the total biomass. Tubificids accounted for 15%, chironomids 12% and *Hyallela* 3% of the total individuals.

DISCUSSION

The standing crop of benthic invertebrates in the study area during April, June and August was 6.4, 8.2 (± 2.5 , SE of the mean with 39 samples) and 7.1 (± 8.0 , SE of the mean with 33 samples) g m⁻², respectively, and 1831, 2622 and 1925 individuals m⁻² (Table 1). The average standing crop for all organisms for the study area from April to August 1967 was 2126 individuals weighing 7.2 g m⁻². Organisms in the 0-3 m depth zone accounted for 28% by number and 53% by weight of all organisms present in the study area from April to August; 56% by number and 37% by weight were in the 3-8 m depth zone; and 16% by number and 9% by weight were in the 8-12 m depth zone.

The quantity and kinds of benthic invertebrates in Lake Ashtabula indicate that it is eutrophic when compared with data available from other lakes that are also unstratified during open-water periods. The standing crop of benthic invertebrates reached 7 g m⁻² in reservoirs of the Missouri River (Cowell and Hudson, 1967) which is lower than the maximum of 8.2 g m⁻² recorded for the study area in Lake Ashtabula. The maximum standing crop recorded from Lake Ashtabula was in June at a depth of 2 m when there were 8202 individuals m⁻² weighing 27.5 g m⁻². Webb (1965), using a wire screen having openings of 0.59 mm, reported the mean wet weight of benthic invertebrates in Cedar Lake, Saskatchewan, a natural lake, was 17.6 g m⁻² from June to August 1962, which is high when compared with an average of 7.6 g m⁻² during June and August 1967 in Lake Ashtabula. Cedar Lake, reported by Webb to be eutrophic, received large amounts of suspended materials from several large rivers which enter it.

The average per cent composition weighted by contributions made

by each depth zone during June to August 1967 of chironomids, gastropods, oligochaetes, ephemeropterans and fingernail clams (*Sphaeriidae*) for the study area in Lake Ashtabula was 51, 10, 17, 2 and 4%, respectively, and, except for ephemeropterans, was similar to the average per cent composition of 40, 15, 14, 13 and 4%, respectively, for collections made in the S basin of Lake Winnipeg during March 1962 to September 1969 (Crowe, 1970). Mean benthic standing crop during June, July and August 1967 was 7.2 g m⁻² in Lake Ashtabula and was 6.6 g m⁻² in Lake Winnipeg (Crowe, 1970). The kinds and amounts of benthic invertebrates were very similar in the two lakes. Crowe (1970) reports data collected from 1962 to 1969 represent an increase in standing crop, from 4.4 to 6.6 g m⁻², and a decrease in per cent composition of ephemeropterans, from 40 to 13%, and an increase in chironomids, from 6 to 40%, when compared with data collected from Lake Winnipeg in 1930. She also reported that amphipods contributed from 44 to 83% of the numbers of benthic invertebrates in 1930 and, apparently, less than 4% in 1962-1969. Crowe attributes pollution as a major factor reducing amphipod and mayfly populations in the S basin of Lake Winnipeg.

According to Carr and Hiltunen (1965), increases in numbers from 1930 to 1961 of oligochaetes, chironomids, gastropods and sphaeriids and decreases in *Hexagenia* in the open lake area of western Lake Erie were indicative of increases in the enrichment of bottom sediments. Damach (1969) and Brinkhurst (1969) have also attributed the

TABLE 1.—Standing crops of all benthic invertebrates in numbers and wet weight, in g m⁻², collected at 0-3, 3-8 and 8-12 m depth zones during April, June and August 1967, Lake Ashtabula, North Dakota. Numbers in parentheses are adjusted to the per cent of lake bottom of the study area occupied by each depth zone

Depth zone (m)	Numbers			
	April	June	August	Total
0- 3	2686 (403)	3305 (496)	6117 (918)	12,108 (1816)
3- 8	1184 (829)	2674 (1872)	1244 (871)	5102 (3571)
8-12	3993 (599)	1698 (255)	915 (137)	6606 (991)
Total	7863 (1831)	7677 (2622)	8276 (1925)	23,816 (6378)
		Weight		
0- 3	23.7 (3.6)	23.6 (3.5)	29.7 (4.5)	77.0 (11.6)
3- 8	2.7 (1.9)	5.9 (4.2)	2.8 (1.9)	11.4 (8.0)
8-12	6.2 (0.9)	3.1 (0.5)	4.2 (0.6)	13.5 (2.0)
Total	32.6 (6.4)	32.6 (8.2)	36.7 (7.1)	101.9 (21.6)

decline of *Hexagenia* in western Lake Erie to increases in organic matter there. The average number of oligochaetes in the open lake area of western Lake Erie collected from depths ranging from 8-10 m during 31 May to 16 June 1961, as computed from Table 2 of Carr and Hiltunen (1965), was 1133 individuals m^{-2} ; for sphaeriids was 891; for chironomids, 337; for gastropods, 261, and for *Hexagenia*, 1.2. The average number of oligochaetes from depths of 3 to 8 m during June 1967 in Lake Ashtabula was 633 individuals m^{-2} ; for sphaeriids was 108; for chironomids was 1306; for gastropods was 78 and for *Hexagenia* was 2.7. Chironomids in Lake Ashtabula were the only group that greatly exceeded the numbers in western Lake Erie; *Hexagenia* apparently was more abundant in Lake Ashtabula than in western Lake Erie but was still low in comparison to 394 *Hexagenia* m^{-2} reported in western Lake Erie in 1930.

Apparently, numbers of oligochaetes relative to chironomids increase in lakes as organic enrichment increases, since the organic matter supports the bacteria which are fed upon by the tubificids (oligochaetes) (Brinkhurst, 1969). Judging from the relative numbers of chironomids to oligochaetes in its benthic fauna, Lake Ashtabula is not as organically polluted as western Lake Erie, since chironomids in Lake Ashtabula comprised 56% and oligochaetes 22% of the total number of organisms in the profundal zone whereas chironomids in Lake Erie in 1958 comprised 27% and oligochaetes 60%, a radical shift from 1929-1930 when chironomids comprised 10% and oligochaetes 1% of the total number of organisms in the profundal zone of western Lake Erie (Beeton, 1961).

Lake Ashtabula differs radically in relative numbers of chironomids and oligochaetes from Lake Francis Case, a reservoir on the Missouri River, South Dakota, where chironomids comprised 93% and oligochaetes 6% of the total number of organisms in the profundal zone in 1966 (Cowell and Hudson, 1967). Perhaps some of the explanation for these differences in the two reservoirs lies in the difference in water exchange rates during open-water periods of 4 months for Lake Ashtabula and 3 months for Lake Francis Case (Cowell and Hudson, 1967). The high primary production of phytoplankton coupled with slow exchange rates may permit more accumulation of organic matter in Lake Ashtabula, which may offer better food resources for oligochaetes than Lake Francis Case.

Tanytarsus from various dates collected from Lake Ashtabula comprised 2, 8, 14 and 20% of the total number of chironomids at depths of 9, 5, 4 and 2 m, respectively, and was not present below 10 m. Apparently oxygen was a limiting factor below 10 m, due to high oxygen demand of the reservoir bottom when lake stratification occurred for only an occasional few days during open-water periods and when, during winter, stratification created a rapid oxygen depletion near the bottom. *Tanytarsus* has been reported as characteristic of the profundal waters of more oligotrophic lakes (Brundin, 1958) and was also found in the northern and eastern sections of Lake Erie, where

more oligotrophic conditions were present than in its eutrophic western section (Brinkhurst, 1969). The higher occurrence of *Tanytarsus* in shallow depths in Lake Ashtabula may be associated with the continual presence of oxygen in the upper layers of water. *Tanytarsus* may be a good indicator of changing conditions in the reservoir related to organic accumulations and associated oxygen depletion. Chironomids belonging to the genera, *Chironomus*, especially *C. plumosus*, *Procladius*, and *Cryptochironomus*, in relatively high abundance in Lake Ashtabula, have been listed as tolerant genera to eutrophic conditions in the St. Lawrence Great Lakes (Brinkhurst *et al.*, 1968) and were considered to be good indicators of eutrophic conditions in Lake Ashtabula.

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