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ACTON LAKE: BIOLOGY OF ITS BENTHOS AND NOTES ON ITS PHYSICAL LIMNOLOGY 1959-1970¹

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ABSTRACT

Acton Lake is a 253-hectare impoundment located in a heavily used state park in southwestern Ohio. The length from inflow stream to spillway is 4.3 km, the total shoreline length is 13.9 km, the mean depth is 4.3 m and the maximum depth is 10.4 m. Sediment accumulation averaging 0.023 m annually provide a possible useful life of the lake for recreation of about 140 years. The lake stratifies chemically and thermally in the summer. Oxygen depletion occurs at the lower depths in the summer.

Chironomids are the most numerous component of the macrobenthic fauna of the whole lake and chaoborids are quite abundant in deeper waters. The wet-weight benthic biomass is greatest in late winter before spring emergence. Funnel trapping has yielded a total of 1400 organisms per square meter for the emergence season from early spring to late fall. Annelids and pelecypods appear to have been increasing in numbers in recent years.

INTRODUCTION

Acton Lake is a 253-hectare impoundment about 64 kilometers northwest of Cincinnati in Hueston Woods State Park in northwestern Butler County and southwestern Preble County. Impoundment was begun in 1957, and limnological investigation has been continuous since 1959. During the period since impoundment, the lake and surrounding state park has had heavy recreational use. Mr. Maynard Dils, Hueston Woods Park Manager in 1970, supplied information on park use between 1964 and 1970 which is summarized in Table 1. The lake is drawn down approximately 2 meters each winter to prevent ice damage to the docks.

Acton Lake is located at the confluence of two branches of Four Mile Creek, with the impounded area extending 4.3 km northward from the spillway. Some of the original physical characteristics as compiled by Winner *et al.* (1962) are given in Table 2. The deepest portion of the lake, located near the dam, is 10.4 m deep. The watershed is composed of an area of 270 sq. km, which is largely

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TABLE 1
Hueston Woods State Park Attendance Figures

Fiscal Year Ending	Cabins and Lodge	Campers	Swimmers	Fishermen	Other Visitors	Total
6/30/64	20392	94045	277278	24780	401561	818056
6/30/65	20086	111929	299218	31704	577896	1038683
6/30/66	22128	160025	316051	41592	774012	1313808
6/30/67	33457	195402	401988	13043	944483	1589374
6/30/68	79004	225410	403621	15016	1313043	2036094
6/30/69	75303	232129	589508	16293	1285306	2198539
6/30/70	91383	177336	693272	28128	1126385	2116504

agricultural and pastoral. Most of the immediate shoreline within the park is timbered.

Several investigations have been made at Acton Lake since impoundment. These include those on physical and chemical characteristics by Winner *et al.* (1962); those on plankton studies by Fisher (1960), Haney (1963), McMahon (1965), and Winner and Haney (1967); and those on food habits of the bluegill by Doxtater (1962). The present investigation provides more recent data on physical and chemical characteristics, with which the earlier information (Winner, *et al.* 1962) are compared, and also includes sediment-deposition measurements. Benthos standing crops were measured between 1964 and 1970, and funnel-trapped insect emergence was recorded during 1964. These data, together with some sampling done in intervening years, make possible recognition of some general trends. Shoreline counts of pelecypods during fall drawdowns of 1967 and 1970 are also compared.

TABLE 2
Physical Characteristics of Acton Lake
(drawn from Winner *et al.*, 1962)

Shoreline	8.7 miles	(13.9 km)
Length inflow to dam	2.7 miles	(4.3 km)
Mean width	.4 miles	(.64 km)
Surface area	625 acres	(253 ha)
Mean depth	12.8 feet	(3.9 m)
Area within 10-foot contour	382 acres	(155 ha)
Area within 20-foot contour	135 acres	(55 ha)
Area within 30-foot contour	20 acres	(8 ha)
Estimated volume	8000 acre feet	
Percent of volume 0-10 feet	62%	
Percent of volume 10-20 feet	29%	
Percent of volume below 20 feet	9%	

COLLECTING SITES, METHODS, AND MATERIALS

Collecting sites include those utilized by Winner (1962) and two new additional locations, one in shallow water to sample littoral fauna and one in deep water. These are indicated in Figure 1.

Station 1 is located in an area less than three meters deep in the north end of the lake. Station 2 occurs offshore from Hueston Woods Lodge where the water is approximately six meters deep. Station 3 lies about midway between the Lodge and the spillway, near the east shoreline and over a rubble-type bottom, and has a depth of six meters. Station 4 is near the spillway and is over nine meters deep. Station 5 is on the west side of the lake in an area about one meter deep.

Water samples were collected by Kemmerer sampler, with temperatures

recorded by thrusting a thermometer into the top of the sample as soon as it reached the boat. Dissolved oxygen was measured using pillows of Hach chemicals for the Alsterberg modification of the Winkler technique and titrating with phenylarsene oxide using a 25-ml automatic burette. Methyl-orange alkalinity and phenolphthalein alkalinity were measured using the methods of Welch (1948). All physical and chemical data were collected at deep-water Station 4.

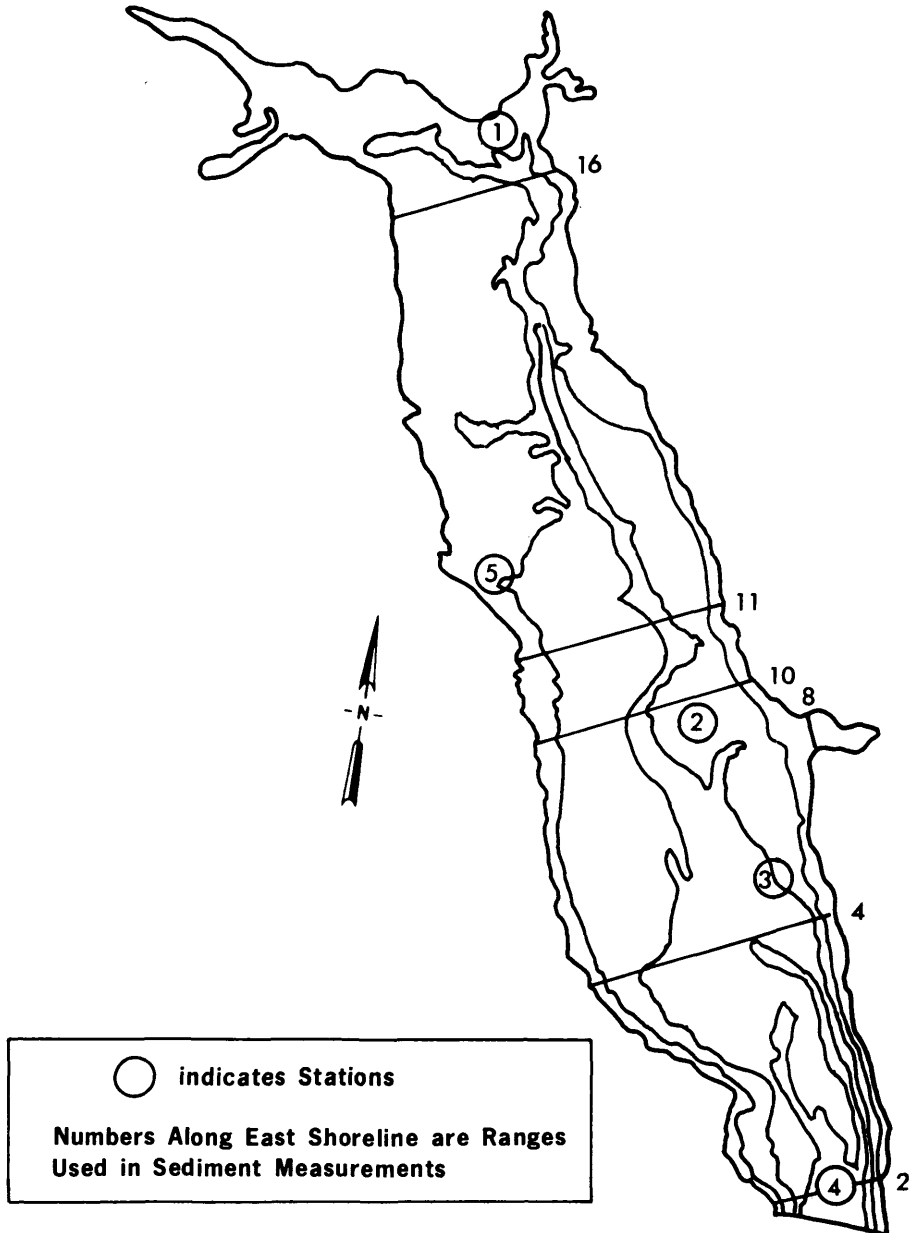


FIGURE 1. Acton Lake, Hueston Woods State Park. Ranges shown by lines and stations shown by circled numbers. Contour interval of contour lines showing bottom topography of lake is 10 feet.

Sediment deposition was measured by members of the Ohio Division of Water in 1961. These data were made available by the Division of Water through the cooperation of Mr. C. L. Hahn (personal communication, 1964) and compared with data collected in 1970 using techniques outlined by Hahn (1955). The ranges, or transects across the lake along which sedimentation was measured, were originally surveyed by the Division of Water in 1961. These same ranges were used in the 1970 study and are indicated in Figure 1. To obtain sediment thicknesses, a calibrated aluminum pipe 12 mm in diameter was lowered to the bottom of the lake and thrust downward through the sediment to the solid substrate below. Sediment depths were measured at six-meter intervals along the selected ranges. Water transparency was measured using a Secchi disc.

Benthos samples were obtained at all stations using a 15-cm Ekman grab sampler, with five grabs at each site pooled to constitute one sample. Samples were washed through screens of 6 meshes per cm and 14 meshes per cm and returned to the laboratory for immediate sorting, counting, and weighing. All macrobenthos clearly visible to the naked eye was included in the sample.

Emergence traps were placed at all stations between late March and November in 1964. The funnel traps were composed of 0.6-mm stainless steel mesh. The open end of the funnel was one-fourth square meter in area, and the narrow end was fitted with a one-quart Mason jar, a modification of the designs of Mundie (1956) and of Borutzky (1955). The traps were suspended from floats consisting of pieces of lumber approximately two meters long fitted with styrofoam floats on the ends, and anchored into position by two concrete-filled number-10 cans. The traps were placed so that they either rested on the bottom or just above the bottom. Traps were serviced on a semi-weekly basis between lake March and November of 1964. The trap at Station 4 disappeared in late August of that year and was not available after that time. Jars were exchanged at each servicing, and insects were killed with chloroform and removed in the laboratory. The pelecypod counts were made during the November drawdown periods of 1967 and 1970. Visual observations and counts were made on newly exposed areas of lake bottom along the shoreline, as indicated in Figure 6.

RESULTS

The measurements of sediment depths in 1961 and 1971 reveal an average annual increment of 0.023 m during the period of 1957 to 1970. Table 3 shows the variation in sediment accumulation from range 2 near the spillway to range 16 near the inflow streams (for location of ranges, or sampling belts in the lake, see fig. 1). The thick accumulation of sediment in the upper areas of the lake, which is shown by an average depth of 0.46 m of sediment at range 16 in shallow water, indicates that some dredging will be needed to maintain present recreational use (particularly sailing) in this area. Average annual increments in sediments for the 1957-1961 period and for the 1962-1970 period are shown in Table 4. Using an estimated volume of 8000 acre-feet for the lake as a whole, it may be estimated, based on the following relationship, that the lake was 8.0% filled in 1970.

$$\frac{1.02 \text{ feet of sediment} \times 625 \text{ acres}}{8000 \text{ acre-feet of capacity}}$$

$$= 8.0\%$$

If the useful life of a reservoir is considered to be the time required for 80% of the original capacity to be filled with sediment, the useful life of Acton Lake will probably be in the neighborhood of 140 years.

Water temperatures recorded by Winner *et al.* (1962) in the summers of 1959 and 1960 near Station 4 were generally lower than those obtained in 1964 and in 1970 in the same vicinity. Winner *et al.* (1962) recorded surface temperature of over 26°C in June, July, and August of 1959, and in July and August of 1960.

TABLE 3
Sediment Deposition in Acton Lake

Range	Maximum Water Depth Meters	Maximum Sediment Depth Meters	Number of Samples	Average Measured Sediment Depth Meters 1970	Average Measured Sediment Depth Meters 1961
2	10.7	.55	51	.17	.07
4	9.8	.61	110	.27	.08
8	1.8	.64	14	.32	.12
10	7.7	1.16	110	.34	.14
11	6.9	1.13	89	.32	.10
16	2.2	.95	62	.46	.21

TABLE 4
Summary of Sediment Deposition in Acton Lake

Average Depth of Sediment 1961	.12 meters
Average Depth of Sediment 1970	.31 meters
Annual Increment 1957-1961	.023 meters
Annual Increment 1962-1970	.022 meters
Average Annual Increment 1957-1970	.023 meters
Total Loss of Capacity 1957-1970	643 acre-feet
Loss as percentage of total	8.0%
Annual loss through sediment	46.3 acre-feet
Life Expectancy based on loss of 80% of Capacity	138 years

A maximum surface temperature of 31°C was recorded at this station in late July of 1964. During 1970, a maximum temperature of 27°C was recorded at the surface during late August. Maximum bottom temperature recorded by Winner *et al.* (1962) was 18°C in 1959. Maximal bottom temperature in 1964 was 17°C and in August of 1970 was 20°C. Several temperature profiles from 1970 are given in Figure 2. It is clear that stratification occurs during the summer months and that in 1970 it was broken by early October.

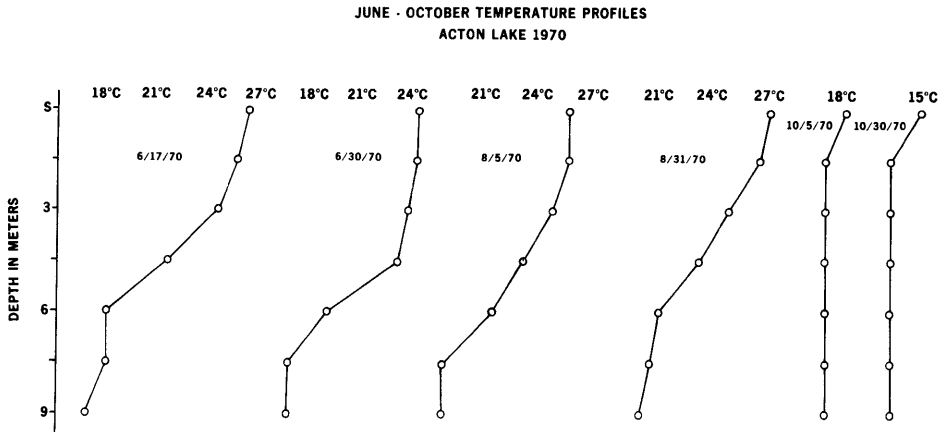


FIGURE 2. Temperature profiles of Acton Lake from June to October, 1970.

Winner *et al.* (1962) recorded a transparency range, using a Secchi disc, of 37 cm to 165 cm in 1959 and 1960. 1970 readings ranged from 32 cm to 81 cm and are given in Table 5. In no case did 1970 transparency values approach the maximum of 165 cm recorded by Winner *et al.* (1962).

TABLE 5
Secchi Disc Readings in cm in Acton Lake, 1970

6/16	6/17	6/24	7/9	7/17	7/22	7/21	8/19	8/31	10/12
46	50	70	81	64	66	76	32	55	54

Oxygen depletion in the hypolimnion occurred in early June in 1959 and 1960 (Winner *et al.*, 1962). The 1970 oxygen data show that, though the upper three meters contained large amounts of oxygen throughout the summer period, there was a complete absence of oxygen in the deeper waters during July and August (Table 6). The high amounts of oxygen in the surface waters in mid-June and late August were probably due to high photosynthetic activity of phytoplankton at these times. Relatively low Secchi-disc readings at these times may well indicate a double phytoplankton bloom in 1970.

TABLE 6
Dissolved Oxygen at Station 4 Acton Lake, 1970

Depth in Meters	Expressed in ppm O ₂						
	6/17	6/30	7/17	8/5	8/31	10/5	10/30
S	10.5	4.9	5.0	9.8	12.8	4.9	7.5
1.5	5.5	8.1	9.5	8.9	12.4	4.0	7.6
3	3.0	6.8	4.6	8.7	6.1	5.2	6.8
4.5	0.4	7.2	1.3	0.9	0.2	5.3	6.5
6	0.4	0.7	0.0	0.2	0.0	4.4	6.6
7.5	0.3	0.2	0.0	0.0	0.0	3.2	6.6
9	0.1	0.2	0.0	0.0	0.0	3.2	5.5

Total alkalinity, which includes both phenolphthalein alkalinity and methyl-orange alkalinity, was significantly higher at depths below five meters during stratification. Table 7 shows the absence of phenolphthalein alkalinity after overturn and a relatively uniform distribution of methyl-orange alkalinity. Using the concept of Welch (1948), the epilimnion is interpreted to consist chiefly of bicarbonates, as indicated by the lack of phenolphthalein alkalinity after overturn.

TABLE 7
Alkalinity Station 4 Acton Lake, 1970

Depth in Meters	6/17		8/5		8/31		10/5		10/30	
	P. Alk.	M.O. Alk.	P. Alk.	M.O. Alk.	P. Alk.	M.O. Alk.	P. Alk.	M.O. Alk.	P. Alk.	M.O. Alk.
S	9	110	5	112	17	112	0	105	0	104
1.5	6	110	10	116	20	100	0	110	0	118
3	0	124	8	110	6	104	0	105	0	135
4.5	0	120	0	130	0	120	0	108	0	135
6	0	169	0	168	0	190	0	106	0	130
7.5	0	170	0	229	0	176	0	90	0	142
9	0	182	0	200	0	241	0	100	0	142

P. Alk.=Phenolphthalein alkalinity, M.O. Alk.=Methyl Orange alkalinity, Total Alkalinity=M.O. Alk+P. Alk.

Benthos sampling was done all years at all stations between 1964 and 1971 except 1968. The March 1964 data reveal a wet-weight invertebrate biomass of 15.5 gm per square meter. At this time of year, more than at any other, the biological energy of the lake is in the form of macroinvertebrate benthos. Mid-June and early September figures for wet-weights drop to 1.97 gm per square meter and 1.47 gm per square meter, respectively.

Values for standing crop expressed as organisms per square meter are given in Figures 3 and 4. Figure 4 suggests that chaoborids make up a major share of the benthic fauna at Stations 3 and 4 during most of the year. At Station 2, chaoborids make up the major share during later summer, though chironomids also comprise a

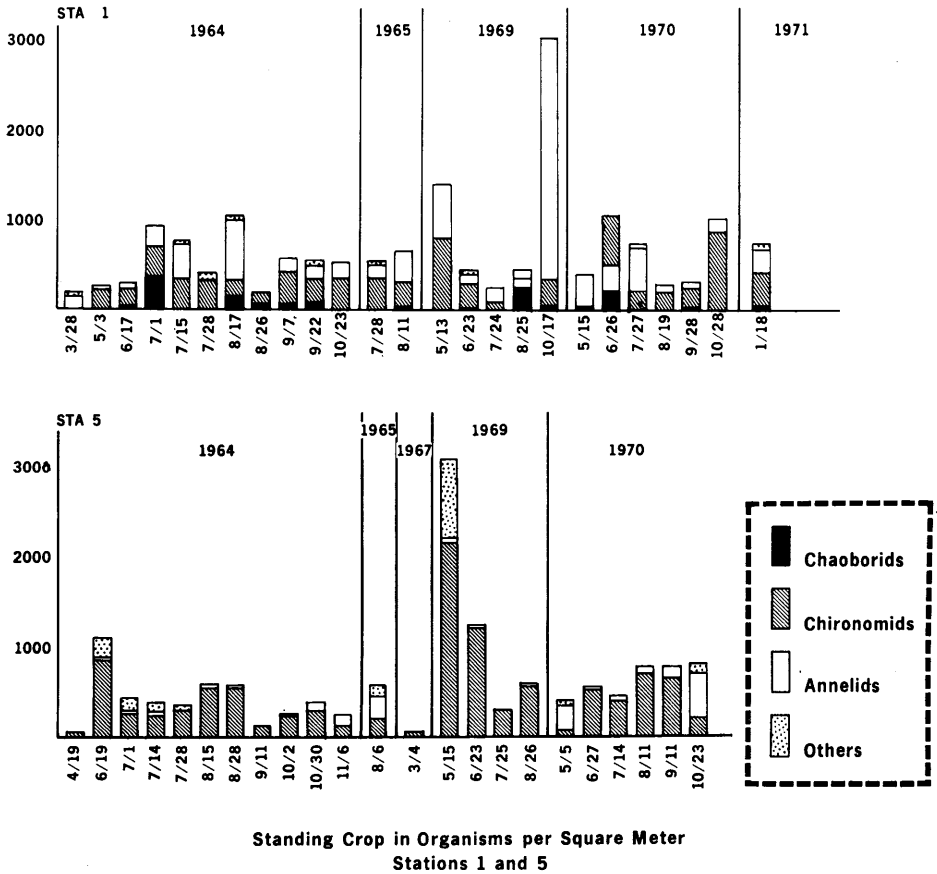


FIGURE 3. Standing crop of benthos in Acton Lake at Station 1 (approximately three meters deep) and Station 5 (approximately one meter deep). Data given in organisms per square meter.

significant part of the fauna. Chironomids predominate at Stations 1 and 5, which occur in more shallow water than the other stations, as shown in Figure 3. Ceratopogonids, ephemerids, and trichopterans make up the category of "other" at these two stations (fig. 3).

Annelids, largely *Limnodrilus hoffmeisteri* Clap., were a part of most collections in all years at all stations except at Station 5. An examination of the 1969 standing crop suggests that annelids have increased since the time of the 1964 sampling. In 1969 they made up 40 percent of the organisms in the standing crop at Stations

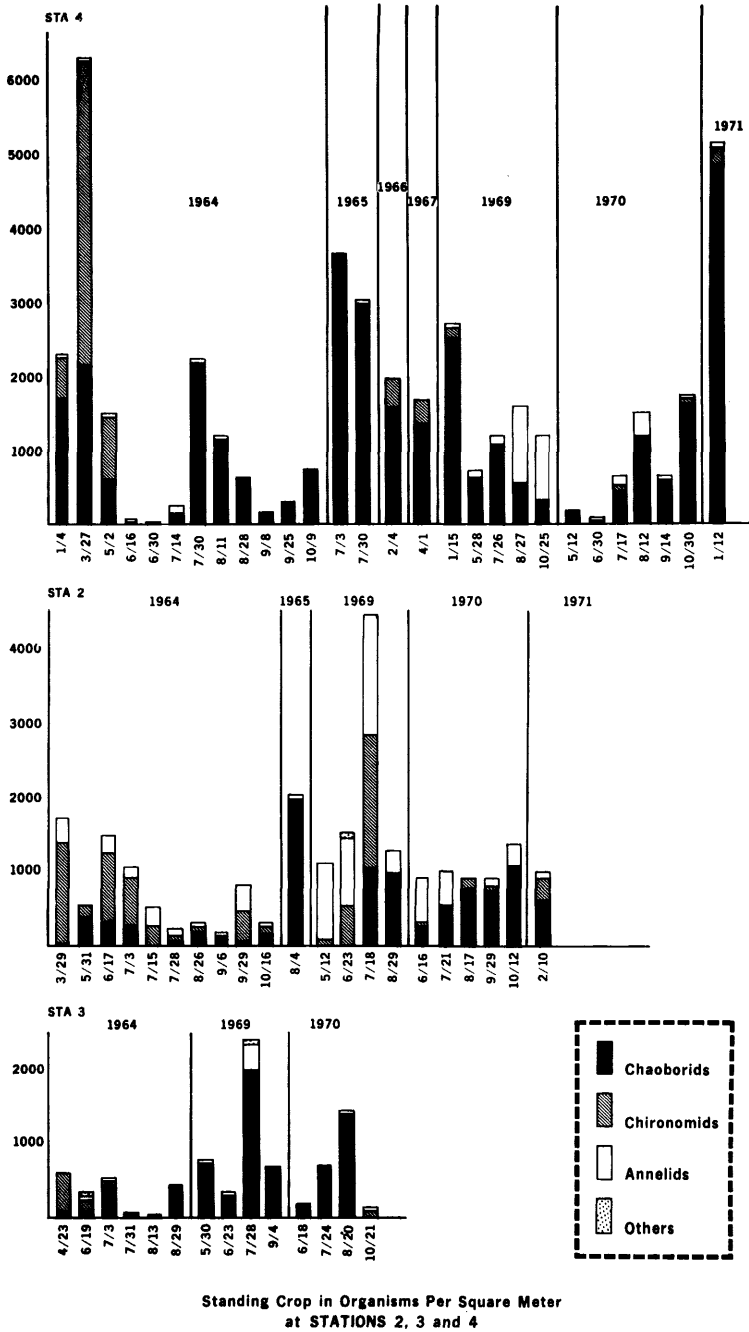


FIGURE 4. Standing crop of benthos in Acton Lake at Station 2 (approximately six meters deep), Station 3 (approximately six meters deep), and Station 4 (over nine meters deep). Data given in organisms per square meter.

1, 2, 3, and 4, as compared with only 13 percent at the same stations in 1964. In 1970, annelids made up 24 percent of the standing crop. Continued investigation will determine whether annelids will continue to constitute an increasing or decreasing percentage of the benthic fauna.

A total of 3,691 insects was removed from all the emergence traps at all stations, including the one at Station 3, which disappeared in late August of 1964. Of these, over 78 percent were of the tribe Chironomini and 12 percent were of the tribe Tanytarsini; thus, over 90 percent were of the family Tanypodinae. Orthocladinae accounted for 5 percent of the total. Considered together, Chironomids made up over 96 percent of the total trapped emerging insects. The family Chaoboridae produced over 2 percent and the Heleidae 0.3 percent of the total catch. Dipterans thus represented nearly 99 percent of the trapped emerging insects.

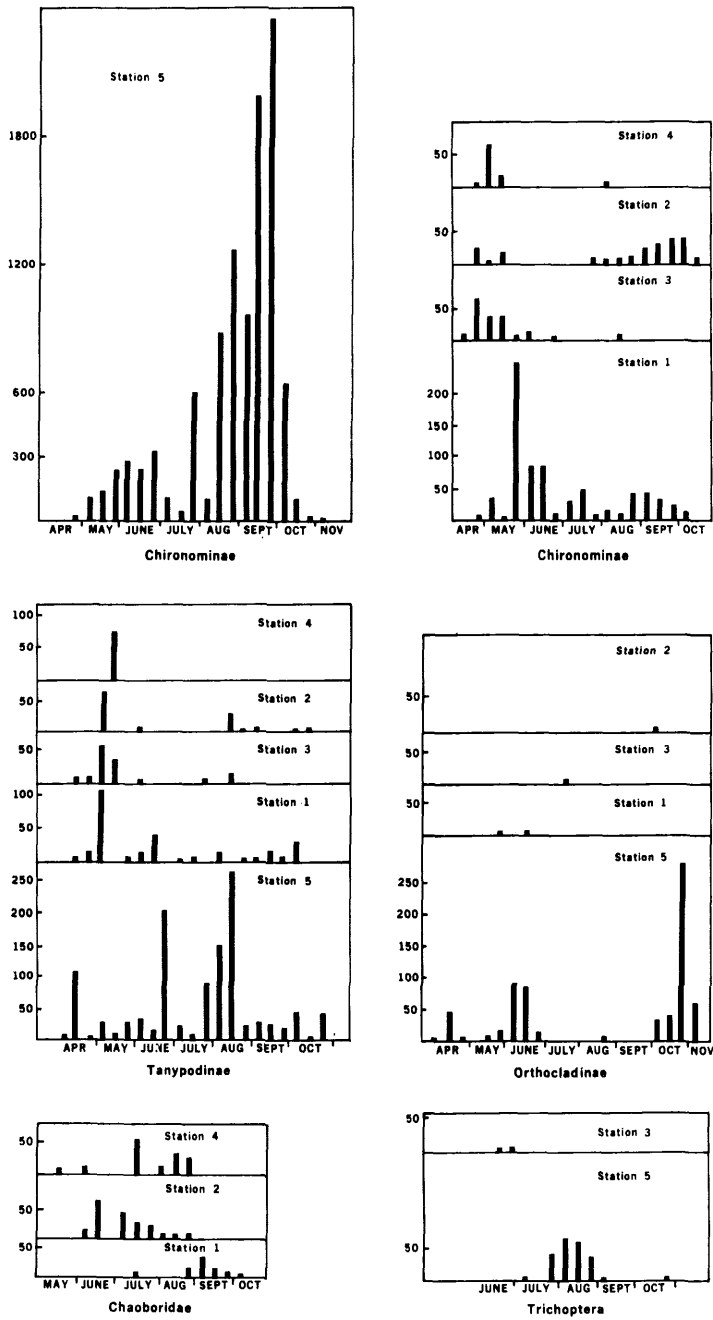
Trichopterans and ephemeropterans constituted the remainder of the trapped insects. Chironomids were the most frequent insects trapped at all stations except for Station 4, where chaoborids were more numerous. Insects obtained from deeper water showed an earlier emergence pattern than did those at shallower stations. From June throughout the rest of the year, Station 5 far exceeded all others in numbers of trapped insects. The small number of Helidae is not surprising, in light of the apparent avoidance of funnel traps by members of this family (Guyer, 1955). Figure 5 indicates emergence patterns of the predominant taxa over the period of April to November, 1964.

Only one species of pelecypod, *Anodonta grandis* (Say), was identified from Acton Lake. This species apparently makes up most, if not all, the pelecypod fauna here. *Anodonta grandis* (Say) has been collected by students and staff at Miami University in the watershed supplying the lake for many years. Occasional specimens were observed in the lake, either as valve fragments or as living animals, during the first few years of impoundment. In November, during the drawdown period, a considerable portion of the shoreline was examined for clams, the actual distribution of individual living animals being mapped, as shown in Figure 6. A similar reconnaissance was made during the 1970 drawdown and is also shown in Figure 6. The 1970 survey appears to reveal about 30 times as many living clams for about the same amount of shoreline as were observed in 1967. The distribution of clams over the whole bottom is not known. Only one living pelecypod (also *Anodonta grandis*) has been taken in regular Ekman grab sampling over the fourteen-year period during which sampling has been done. This was at Station 3 at a depth of six meters.

DISCUSSION

The mean masses per benthic organism were 0.015 gm, 0.002 gm, and 0.007 gm for March, June, and September 1964 standing crops, respectively. Neess and Dugdale (1959) utilize this kind of information, together with the number of organisms per unit area, to produce a productivity curve for *Tanytarsus jucundus* (Walker). Their curve is based on a cohort in which individuals grew at approximately the same rate and emerged together. Because the Acton Lake samples contain several cohorts, the Neess-Dugdale method does not apply completely. The smaller individual biomass of organisms in June compared to in March indicates either that the large insects had emerged, leaving the smaller ones to emerge later, or that the larvae were from second-generation individuals for the season and are thus small. Both explanations probably apply. Large midges such as *Chironomus staegeri* (Lundbeck) and *Chironomus crassicaudatus* (Malloch) were common in trapped material between April and mid-June. This suggests that the number of large insects left in the benthic region had decreased.

An estimate of the total number of insects emerging per square meter in the whole lake can be made from the data obtained. Based on the assumption that



INSECT EMERGENCE IN ORGANISMS PER SQUARE METER ACTON LAKE, 1964

FIGURE 5. Numbers of insects emerging in Acton Lake during 1964.

the mean numbers of insects emerging from Stations 1 and 5 are representative of that portion of the lake less than three meters deep, the numbers from Station 2 are representative of the area between three and six meters deep, and the numbers from Station 4 are representative of the region more than six meters deep, as seems reasonable from this study, numbers which must then be weighted according to the relative extents of each of these depth zones in the lake, an average emergence of about 1400 organisms per square meter for the year 1964 is reached for the

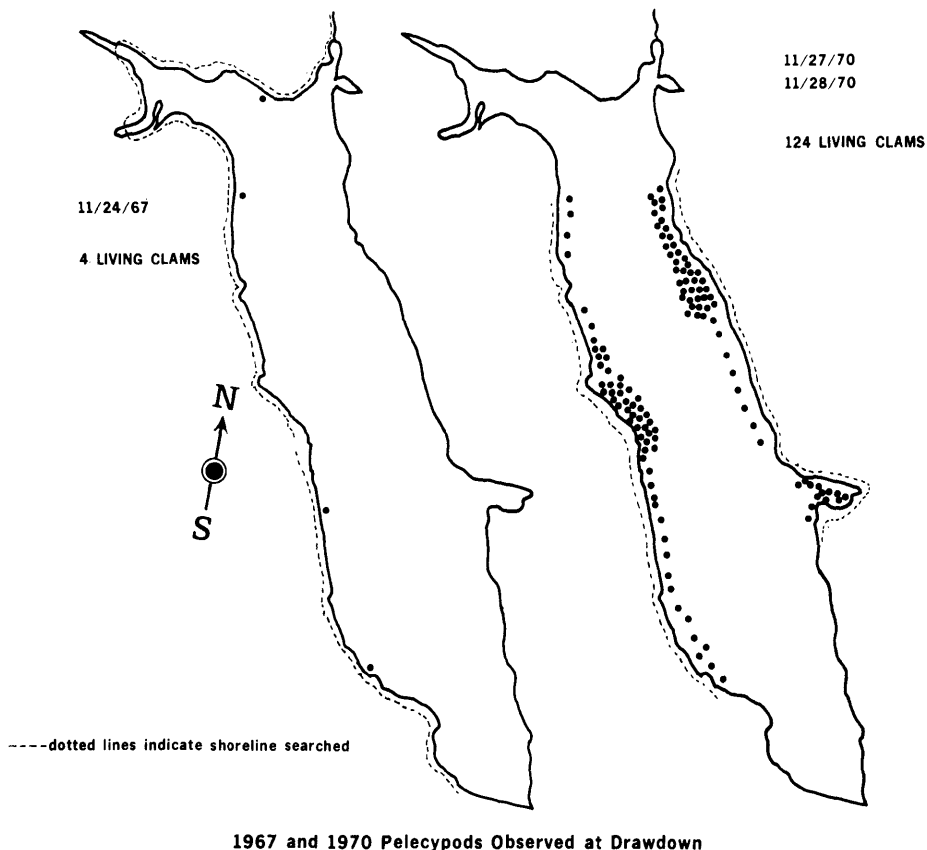


FIGURE 6. Actual mapping of distribution of living clams observed during drawdowns of Acton Lake in 1967 and in 1970.

lake as a whole. A more meaningful value would be that for the part of the year between April and mid-June, for which a value of 325 insects per square meter is reached. This value is probably more accurate than are values which could be derived from data obtained later in the season because: (1) there is less fungal decomposition in the collecting bottles than later, (2) there is less likelihood of mixing two generations at this time, and (3) the traps have not yet collected any epifauna so as to serve as breeding chambers.

The 325 emerged insects represent 28 percent of the March standing crop obtained by dredge sampling. It is probable that somewhere between 30 percent and 50 percent of the March standing crop must have emerged by June. The remainder has either (1) remained to become part of the June standing crop, (2) become limnetic, (3) died and become reduced by benthic bacteria, or (4)

become prey of secondary consumers and thus been raised to a higher trophic level. Doxtater (1962) has stated that chironomids were in 76 percent of the stomachs of the blue gill *Lepomis macrochirus* Rafinesque from Acton Lake that he examined. He found chironomids in 67 percent of the 25-mm specimens and in all of the 50-mm, 75-mm, and 100-mm fish, and in lesser amounts in large fishes. He did not find *Chaoborus* in Acton Lake bluegills. Predation by fishes and emergence together probably account for most of the decrease in benthic biomass between March and June. Neess and Dugdale (1959), using the data of Anderson and Hooper (1956), estimate that no more than 18.2 percent of the energy of the cohort of *Tanytarsus jucundus* in a Michigan lake left the lacustrine ecosystem. Our emergence information indicates that considerably more than that left the ecosystem at Acton Lake in the period from March to November of 1964.

Thus far physical and benthic changes are relatively slight when compared to the increase in park and lake usage between 1964 and 1970. As long as heavy lake use continues, transparency will probably continue to decrease. In addition, the great number of overnight visitors in recent years puts considerably more waste through the park's waste-treatment plants and into the lake. Continued study is planned to determine the effects of this long-range enrichment on Acton Lake benthos and physical limnology.

SUMMARY

1. Usage of Acton Lake and the surrounding Hueston Woods State Park has increased in all categories between 1963 and 1970. Overall usage has increased more than 250 percent, but benthic and physical changes seem relatively slight.

2. Sediment has been accumulating on the lake bottom at the rate of 0.023 m annually, which suggests that, if the rate of sedimentation is not changed, the lake will have a useful life of about 140 years. Shallow areas of the lake already require dredging every few years to maintain present recreational use.

3. The lake stratifies thermally in the summer period and typically turns over in early October.

4. The lake is quite turbid, with Secchi-disc readings now usually being less than one meter and never exceeding two meters.

5. Complete oxygen depletion occurs during July, August, and September at depths below six meters.

6. Total alkalinity is significantly higher during mid-summer in the zone below six meters.

7. Chironomids make up the dominant benthic fauna of the shallower water throughout the year, and of the deeper waters during the winter and spring. Chaoborids are found in sediments from the deeper waters throughout the year, and are the only macrobenthic fauna under the hypolimnion during summer stagnation. Annelids appear to be increasing in numbers in the benthos.

8. Wet-weight biomass is greatest in late winter. A maximum of 15.5 gm per square meter was recorded in March, 1964.

9. Funnel trapping has yielded an average of 1400 emerging insects per square meter per season for Acton Lake.

10. A decrease in benthic biomass between March and June is probably accounted for chiefly by a combination of predation and date of emergence.

11. Pelecypod population, as measured by actual counts during drawdown, has increased 30 fold between 1967 and 1970. The only species recognized in the lake is *Anodonta grandis*.

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