# A COMPARISON OF BENTHIC OLIGOCHAETE POPULATIONS IN ACID AND NEUTRAL LENTIC ENVIRONMENTS IN SOUTHEASTERN OHIO[1]

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Acid mine-drainage is a serious pollution problem associated with coal-mining operations. The influence of acid mine-drainage on benthic oligochaetes was assessed by comparing an oligochaete population in an acid-polluted impoundment (Lake Hope, Vinton County, Ohio) with a population from a non-polluted impoundment (Dow Lake, Athens County, Ohio). At monthly intervals during the Summer of 1971, faunal, water, and sedimentary samples were collected from a comparable cove in each lake. The H' species diversity of the benthic oligochaetes in samples from Lake Hope was found to be significantly lower than in those from Dow Lake, although the abundance of individuals in the two sampling areas was similar. Results of a similarity analysis based on shared species diversity indicated that $S_{H'}$ values were nearly as great among Lake Hope samples as among Dow Lake samples, but that both differed significantly from values between samples from the two lakes. Changes in water quality associated with acid mine-pollution, then, are reflected in altered values of intergrative biological parameters associated with community structure such as H' species diversity and $S_{H'}$ index of similarity.

Acid mine-drainage is a condition commonly associated with the mining of bituminous coal and forms when water percolates through pyritic debris, which becomes exposed to the atmosphere following surface or underground mining operations (Porges *et al.*, 1968). Water polluted by acid mind-drainage generally has an extremely low pH, large net acidity, and high iron and sulfate content, with considerable amounts of aluminum, manganese, calcium, and magnesium present (Hill, 1968). Aquatic organisms and the aesthetic value of lakes and streams are often negatively affected by acid mine-drainage.

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Lake Hope (N39°20′, W82°21′) is a major recreational center in Southeastern Ohio. This impoundment, formed by the damming of Sandy Run in 1939, is heavily polluted with acid mine-drainage. Harris (1973) reports that the pH of Lake Hope water has ranged between 3.0 and 7.8 with a median pH value of 4.5, and that acidity averaged 35 ppm. This acid, carried into the lake from the yet unreclaimed watershed of Sandy Run, tends to inhibit biological activity within Lake Hope (Koehrsen, 1969). The abundance of benthic organisms, in Lake Hope is less than that found in unpolluted lakes of the same geographical region (Harris, 1973).

Lake Hope is similar in many respects to Dow Lake (N39°20′, W82°02′; figure 1). Dow Lake, impounded by damming Strouds Run in 1960, is also used for recreational purposes. Lake Hope (120 surface acres) is nearly as large as Dow Lake (153 surface acres) and both share the elongate shape and branching coves characteristic of dammed stream valleys. However, there is no indication of any significant pollution from acid mine-drainage at Dow Lake, making it an excellent natural control for this study.

The purpose of this study is to assess the influence of acid mine-drainage on benthic oligochaetes by comparing the abundance and species diversity of the oligochaete populations found in Lake Hope and Dow Lake. Some insight into the typical condition of life in the benthos of a lake polluted by acid mine-drainage may also be gained from these comparisons. Furthermore, information obtained from this study may be used as a baseline to measure the success of any future acid mine-drainage abatement program carried out in the watershed of Sandy Run.

## MATERIALS AND METHODS

Field work for this study was carried out at

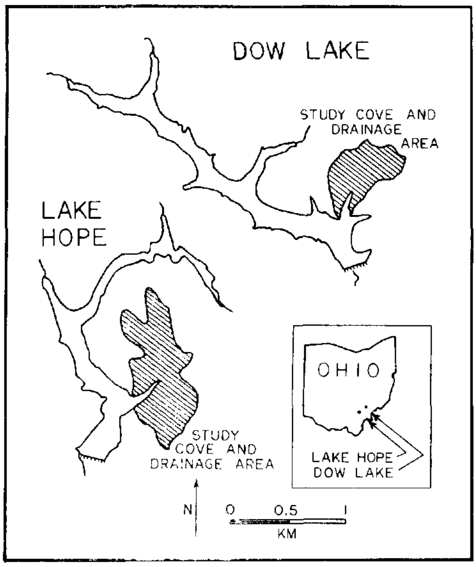


FIGURE 1. Sketch maps of Dow Lake and Lake Hope showing the drainage area surrounding the study cove at each lake. The insert indicates the approximate locations of Lake Hope and Dow Lake in Ohio.

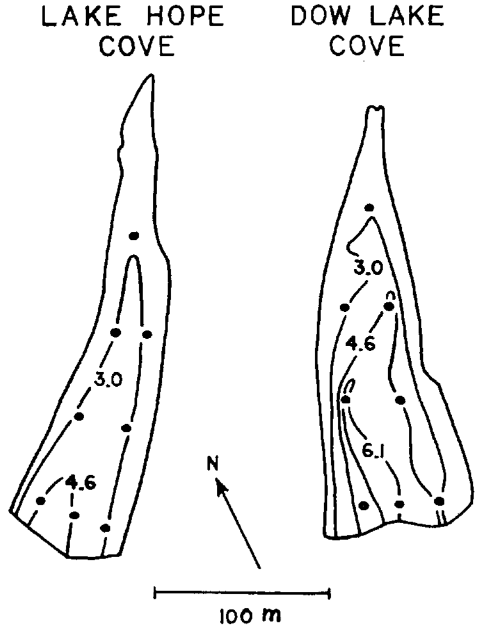


FIGURE 2. Maps of the Lake Hope and Dow Lake study coves with contour lines in meters and with points indicating the locations of sampling stations.

Lake Hope in Zaleski State Forest, Vinton County, Ohio, and at Dow Lake in Strouds Run State Forest, Athens County, Ohio, during the summer of 1971. Within each lake, a single cove was studied. Both coves were selected on the basis of having similar surface areas (Lake Hope cove=1.1 ha, Dow Lake cove=1.3 ha), depths, drainage areas, and lake locations (figures 1 and 2). The two coves were sampled on three dates at alternate two week intervals and, within each cove, samples were collected at eight evenly distributed stations (figure 2) per sampling date, using SCUBA.

At each station water samples were collected at the water-mud interface and from the water column 0.5 m above the bottom by triggering a horizontally held Van Dorn bottle. An additional water sample from the water-mud interface was collected using a 50 ml syringe. Substratum samples were collected from the upper 8 cm of lake-bottom sediment by means of a hand-operated piston-corer of 3.4 cm inside diameter. Two cores were utilized to gather data on abundance and diversity of oligochaetes while a third core, taken on only the first and last sampling dates, was used for sedimentary analysis. The sampling sequence at each station proceeded from top to bottom in order to keep disturbance of the water column to a minimum.

Dissolved oxygen of each water sample collected in the Van Dorn bottle was read immediately by an assistant aboard a rowboat by inserting the probe of a YSI Model 51A Oxygen Meter midway into the water sample.

Each water sample collected 0.5 m from the bottom was stored in a BOD bottle and was tested the same day in the laboratory for pH, sulfate, total alkalinity, and iron. Water from the interface syringe sample was carefully placed in 50 ml bottles and used for pH and iron determinations. Sulfate, total alkalinity, and iron were determined by test kit (Hach Chemical Co., Ames, Iowa) and pH was read with a Beckman Zeromatic SS-3 pH Meter. Sediment samples, obtained for grain-size analysis, were stored in plastic bags and were later analyzed from 2.38 mm to $6.25 \times 10^{-2}$ mm by dry sieving and from $6.25 \times 10^{-2}$ mm to $3.9 \times 10^{-3}$ mm by the wet sieving method of Folk (1968).

Core samples to be examined for oligochaetes were sectioned into 2-cm lengths and placed into separate jars. In the laboratory, oligochaetes were removed by applying weak jets of water to each 2 cm core subdivision, which was then decanted several times into a sieve with 125 $\mu$m openings. Most oligochaetes could then be located on the sieve under a dissecting microscope. The coarser grained residue in the petri dish was similarly checked for oligochaetes. Specimens were fixed with 10% formalin and then transferred to 70% alcohol. Identifications were made at 430×, using Brinkhurst's keys, both for the Naididae (Brinkhurst, 1964) and for the Tubificidae Brinkhurst, 1965).

RESULTS

During sampling operations, casual observations of the aquatic life in both study coves were made by SCUBA. In the Dow Lake cove, many small fish were observed swimming between long strands of water milfoil. This vegetation, usually found in water less than 3 m deep, became more abundant as the summer progressed. However, the cove at Lake Hope was virtually devoid of the abundant fish population and of the heavy vegetative growth at Dow Lake. Small clumps of rooted vegetation were observed in the shallow water of Lake Hope during the spring, but these disappeared by early summer. A group of water lillies, at the mouth of a stream running into the cove, was the only vegetation found within the Lake Hope cove throughout the summer. A small water snake was observed near the water surface, but no fish were ever seen. The bottom of the Lake Hope cove appeared granular due to a thin surface layer of pale, aggregated sediment which may have been fecal material produced by oligochaetes and other benthic organisms (Rhoads and Young, 1970). Visibility in the Lake Hope cove was no greater than 1.5 m, while visibility in the Dow Lake cove was about 3 m.

The number of oligochaetes collected during each sampling of the Lake Hope and Dow Lake study coves and their species diversities are shown in table 1. Although the number of oligochaetes collected from Dow Lake was somewhat greater than from Lake Hope, no significant difference between total oligochaete numbers in coves of the two lakes were found using the Mann-Whitney U test (Woolf, 1968). In both lakes oligochaete numbers varied from month to month. In July more oligochaetes were collected from the Lake Hope cove than from the Dow Lake cove. The numerical abundance of oligochaetes in samples from both lakes ranged from 0 to 13,800 individuals/m$^2$ ($\bar{X}=2{,}523$; SD$=\pm 3,\ 694$; n$=96$). The dominant species in both coves was *Limnodrilus hoffmeisteri*, which was 75.3% of the population at Lake Hope, but only 47.6% at Dow Lake. Three species of oligochaetes were common to samples from both lakes, whereas two species, including the abundant *Dero digitata*, were found only in those from Dow Lake and one species was found only in those from Lake Hope. Species diversity, determined by the information index, H' (Lloyd *et al.*, 1968), was significantly higher (.10>P) in the Dow Lake cove than in the Lake Hope cove. Using the $S_{H'}$ measure of faunal similarity based on shared species diversity (Hummon, 1974), it was found that oligochaetes from among Dow Lake samples taken on different dates shared 37.0±6.5% of their species diversity

TABLE 1

*Oligochaetes collected from the Dow Lake and Lake Hope study coves during July, August, and September, 1971 and their H' species diversity in bits*

| | July (n=16) | August (n=16) | September (n=16) | Summer Aggregate (n=48) |
|---|---|---|---|---|
| LAKE HOPE | | | | |
| *Limnodrilus hoffmeisteri* Claparède | 21 | 12 | 25 | 58 |
| *Ilyodrilus templetoni* (Southern) | 3 | 0 | 1 | 4 |
| *Aulodrilus piqueti* Kowalewski | 0 | 3 | 11 | 14 |
| *Pristina longiseta leidyi* Smith | 0 | 0 | 1 | 1 |
| Total Oligochaeta | 24 | 15 | 38 | 77 |
| Species Diversity | 0.5436 | 0.7219 | 1.1913 | 1.0581 |
| DOW LAKE | | | | |
| *Limnodrilus hoffmeisteri* Claparède | 5 | 36 | 27 | 68 |
| *Ilyodrilus templetoni* (Southern) | 1 | 4 | 35 | 40 |
| *Aulodrilus piqueti* Kowalewski | 0 | 0 | 7 | 7 |
| *Dero digitata* Müller | 5 | 10 | 11 | 26 |
| *Aulodrilus limnobius* Bretscher | 0 | 1 | 1 | 2 |
| Total Oligochaeta | 11 | 51 | 81 | 143 |
| Species Diversity | 1.3485 | 1.2148 | 1.8261 | 1.7704 |

and that oligochaetes from among Lake Hope samples shared $21.3 \pm 15.7\%$ of their species diversity. But oligochaetes taken from Dow Lake on different dates shared only $12.4 \pm 3.6\%$ of their species diversity with those from Lake Hope. Analysis of variance indicates that there is no difference between $S_{H'}$ values from among Dow Lake samples and those from among Lake Hope samples. But these $S_{H'}$ values are significantly different ($.10 > P$) from $S_{H'}$ values of species diversity shared between samples taken from Dow Lake and those taken from Lake Hope.

The density-free dispersion index of Green (1966) indicated that oligochaetes in each cove had a moderately aggregated dispersion at the beginning of summer, but steadily approached randomness as the summer progressed. A chi square test with Yates' correction for continuity (Woolf, 1968) showed that, in both lakes, *Limnodrilus hoffmeisteri* was virtually the only species which burrowed below 2 cm in the sediment ($P > .001$ with $df = 1$). Of the total summer occurrence of *L. hoffmeisteri*, 33.6% at Dow Lake and 27.3% at Lake Hope were found below 2 cm, while 9.8% at Dow Lake and 1.3% at Lake Hope were found below 4 cm. No oligochaetes were collected below 6 cm in the sediment.

The results of chemical analyses of water samples collected from both study coves are shown in figure 3. Levels of pH and total alkalinity were substantially lower, and sulfate higher, in Lake Hope than in Dow Lake samples. Levels of soluble iron and oxygen were variable and overlapping in the two areas. Sediment at Lake Hope was finer than that at Dow Lake. The arithmetic mean ($\bar{X}$) of mean grain size (Folk, 1968) values was $2.5 \times 10^{-2}$ mm (medium silt) at Dow Lake compared to $1.2 \times 10^{-2}$ mm (fine silt) at Lake Hope. Sediments of the Lake Hope cove were somewhat better sorted than those of the Dow Lake cove.

## DISCUSSION

Lake Hope, polluted by acid mine-drainage, was found to be chemically different from the unpolluted control, Dow Lake. Chemical differences in both lakes are accounted for either directly or indirectly by the influence of acid mine-drainage. The steady increase in oxygen found in the water column at Dow Lake coincided with the continuous summer growth of vegetation. A similar increase in dissolved oxygen was not found in Lake Hope partly due to the virtual absence of vegetation in the study cove. Soluble iron, which in high concentrations may indicate acid mine-drainage (Hill, 1968), reached fairly high, variable levels at the water-mud interface at Lake Hope. In Lake Hope, the low pH and high sulfate were a direct result of acid mine-drainage and the low alkalinity may have been related to the loss of buffering agents to acid water (Porges *et al.*, 1966).

The severe reduction of both vegetation and fishes in Lake Hope suggests that acid mine-drainage is detrimental to these organisms. In addition, acid mine-water in Lake Hope was found by Horvath (1972) to affect both abundance and diversity of planktonic rotifers. However, evidence presented in this study indicates that abundance of benthic oligochaetes is not significantly affected by acid mine-drainage. The numerical abundance of oligochaetes in Lake Hope and Dow Lake agrees favorably with comparable data (Eggleton 1931) in which oligochaetes from an unpolluted natural lake ranged from 150 to 16,000 individuals/m$^2$ ($\bar{X} = 3{,}600$; $SD = 5{,}800$; $n = 10$), using collections from June to October at 3–8 m depth. These data indicate that the abundances of oligochaetes in Dow Lake and Lake Hope may be typical of those found in unpolluted lakes.

The effects of acid mine-drainage are more pronounced on species diversity than on abundance of benthic oligochaetes. $H'$ species diversity values at Dow Lake were significantly higher than those in Lake Hope, and $S_{H'}$ values of faunal similarity among Dow Lake and among Lake Hope samples, based on shared species diversity, differed significantly from values between Dow Lake and Lake Hope samples. The lower $H'$ species diversity in Lake Hope samples occurred in part because of the few species present, with three-quarters of oligochaetes comprised of *Limnodrilus hoffmeisteri* Samples from Dow Lake showed more species and a

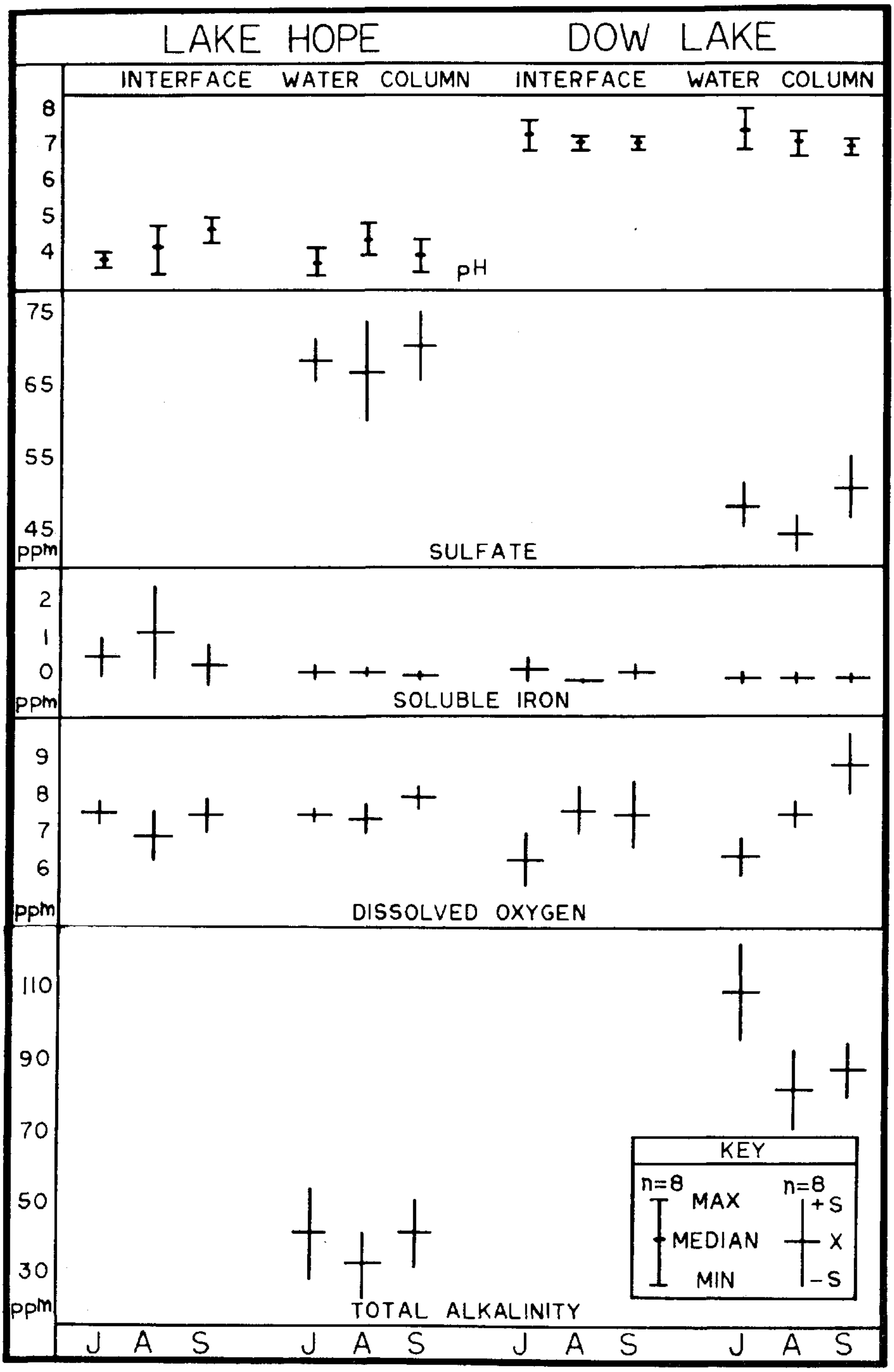


FIGURE 3. Values of sulfate, soluble iron, dissolved oxygen, and total alkalinity, in parts per million and pH in pH units for water samples collected at the eight sampling stations from the water-mud interface and water column (0.5 m from the bottom) during July (J), August (A), and September (S) 1971, within the Dow Lake and Lake Hope study coves.

more even distribution among species. Shared species diversity was nearly as similar among Lake Hope samples as among Dow Lake samples, but was clearly different between samples from the two lakes.

It was suggested by Wilhm and Dorris (1968) that differences in water quality could be determined by integrative biological parameters of community structure such as species diversity as by physical or chemical analyses. They further held that communities occurring in zones of decreased water quality would tend to exhibit decreased species diversity, due to reduced species number and more uneven distribution of individuals among species. They gave examples associated with several sources of pollution. Dills and Rogers (1974) have examined the effect of mine-acid effluents on aquatic insects in lotic environments and have proven that species diversity is reduced in the presence of acid mine-drainage. Our data suggest that the same thing is true with respect to the benthic oligochaete subcommunity in lentic environments. We have also shown that, though densities may not differ between lake sediments free of and those subjected to mine acids, indices of faunal similarity are reduced between lake sediments free of and those subjected to mine acids.

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