Hydrobiologia vol. 54, 2, pag. 169-176, 1977

DISTRIBUTION OF BENTHIC MACROINVERTEBRATES IN AN ARTIFICIALLY DESTRATIFIED RESERVOIR[1]

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[1] Research supported with funds from the Oklahoma Water Resources Research Institute and the Bureau of Reclamation.

Received July 3, 1976

Keywords: benthic macroinvertebrates, species diversity, artificial destratification

Abstract

A total of 76 taxa of benthic macroinvertebrates as collected from Ham's Lake, Oklahoma, during 1974 and 1975. The composition and density of the benthic assemblage was similar to that of other Oklahoma reservoirs. The number of species and density of macroinvertebrates decreased from March to the end of July, 1975. Species diversity and biomass did not change significantly with time. Number of species and species diversity decreased with depth on all sampling periods. The most pronounced changes occurred between 4 and 5 m during periods of thermal stratification and hypolimnion anoxia. Artificial destratification removed the thermocline from Ham's Lake within 2 wk. More gradually, the deep waters were reoxygenated. Destratification did not substantially alter the depth distribution of benthic macroinvertebrates until oxygen level of the deep water was increased.

Introduction

Benthic macroinvertebrates are not uniformly distributed on the bottom of lakes and ponds (Ransom, 1969; Saether, 1970; Inland Fisheries Branch, 1970; Fast, 1971; McLachlan & McLachlan, 1971). Thermochemical stratification may be the most important factor affecting the vertical distribution of the benthos (Eggleton, 1931). During periods of stratification in the hypolimnion, the profundal zone typically contains a small number of species (McLachlan and McLachlan, 1971). Destratification and hypolimnetic aeration may result in changes in the density and distribution of benthic macroinvertebrates (Toetz, Wilhm & Summerfelt, 1972). Destratification of a eutrophic lake enabled large numbers of chironomids and oligochaetes to reinvade the profundal zone (Inland Fisheries Branch, 1970; Fast, 1973). Hypolimnetic aeration of another eutrophic lake, in which thermal stratification was maintained, extended the distribution of populations of benthic macroinvertebrates into deeper water (Fast, 1971). In contrast, destratification of an oligotrophic lake (Fast, 1971) and a montane mesotrophic lake (Lackey, 1973) had little effect on the distribution of the benthos, although a decrease in the standing crops of chironomids was reported for both lakes. Thus, conflicting data exists concerning the effects of destratification on the distribution of populations of benthic macroinvertebrates. The primary objectives of the present study are to observe the (1) depth variation of density, number of species, biomass, and species diversity of the benthic macroinvertebrates in Ham's Lake; (2) influence of dissolved oxygen, water temperature, conductivity, and pH of the sediments on the distribution of the assemblage; and (3) effect of destratification on the distribution of the benthos.

Study Area

Ham's Lake is located in Payne County, Oklahoma, about 8 km west of Stillwater (Fig. 1). The lake was built in 1965 by the Soil Conservation Service as a flood detention reservoir. The surface area is 40 ha and the volume is 115 ha-m at principle spillway level (Steichen, 1974). The deepest part of the lake is 9.5 m, the length of the central

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pool is about 1.3 km, and the drainage area is 1470 km^2.

During the summer, Ham's Lake stratifies thermally and chemically. The thermocline forms at 4 m and dissolved oxygen is depleted below that (Steichen, 1974). In 1973, the lake was artifically destratified by pumping surface water to the bottom (Quintero & Garton, 1973). Within 2 wk the lake was thermally destratified, but destratification of dissolved oxygen took longer. This same destratification technique was used in the present study.

Three transects were established for sampling benthic macroinvertebrates. Transect 3 extended from the northwest part of the lake near the shore to the central pool, while 1 and 2 were in the southeast and southwest areas, respectively (Fig. 1).

Materials and Methods

Preliminary Study.

Samples were taken after pumping began on 13 May 1974 at depths of 1, 3, 5 and 8 m from each transect on 13 July 1974. Time restraints necessitated reducing the collections of 30 July and 22 August 1974, and the 3 and 5 m depths were combined into a single collecting depth of 4.5 m. Three Ekman grabs were taken at each depth, washed on a U.S. standard # 30 soil sieve, and preserved in 8% formalin. Species diversity was determined by the formula (Shannon & Weaver, 1963):

$$\bar{d} = -\sum_{i=1}^{s} (n_i/n) \log_2 (n_i/n)$$

where n_i = number of individuals of each taxon, n = total number of individuals, and s = total of species. Shannon's formula was first used as a measure of species diversity by Pattern (1962), and the advantages of this equation are described by Wilhm & Dorris (1968).

Main Study.

The data collected in summer, 1974, revealed that variation among depths was considerable greater than variation among stations and that considerable variation existed among replicate samples. On 1 March, 21 May, 14 June, 10 July, and 31 July 1975, four samples were taken from each of eight depths at Transect 3. The depths were at 1 m intervals from 1 to 8 m. The latter two dates were after pumping operations began on 19 June. Samples were analyzed as described for the priliminary study. Three additional samples were taken from each of the eight depths every sampling period for determining oven-dry weight of macroinvertebrates (Weber, 1973).

Three measurements each of temperature, dissolved oxygen, and conductivity were made of the water just above the mud-water interface at each depth. The bottom sediments at each depth were analyzed for pH. Temperature and dissolved oxygen were measured with an air calibrated Yellow Springs Instrument (YSI) model 54 oxygen meter. Specific conductance was measured with a YSI model 33 salinity-conductivity-temperature meter and pH with an Orion model 407 specific ion meter, respectively.

Results

Preliminary Study.

A total of 67 taxa of benthic macroinvertebrates was collected in Ham's Lake during the study (Table 1). The number of species collected in 1974 by transect and depth

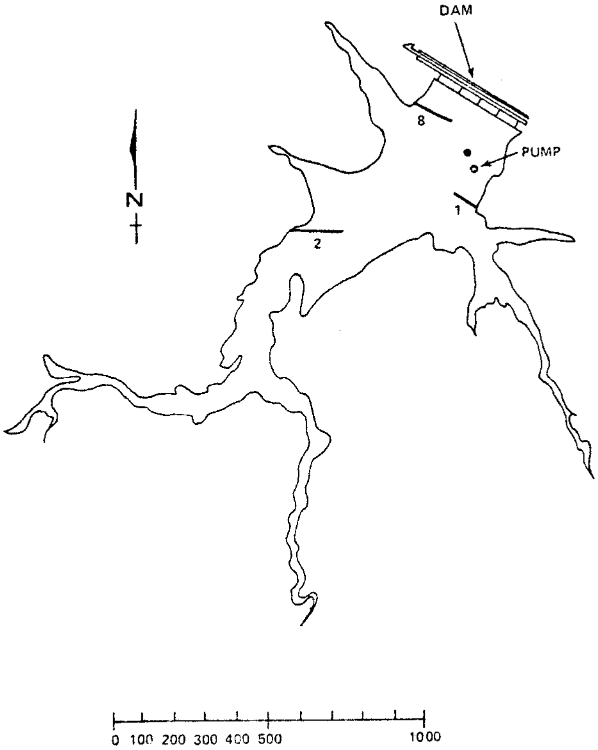

Fig. 1. Map of Ham's Lake showing location of pump and sampling stations.

Table 1. Benthic Macroinvertebrates collected in Ham's Lake from July, 1974 to July, 1975.

- Coelenterate
  - Hydrozoa
    - *Hydra* sp.
- Platyhelminthes
  - Turbellaria
    - *Dugesia* sp.
- Nematoda
  - Unidentifiable species
- Annelida
  - Oligochaeta
    - *Chaetogaster* sp.
    - *Dero digitata* (Muller)
    - *Nais* sp.
    - *Stylaria lacustris* (Linn.)
    - *Aulodrilus pigueti* Kowalewski
    - *Ilyodrilus* sp.
    - *Limnodrilus hoffmeisteri* Clap.
    - *L. cervix* Brinkhurst
    - *L. claparedianus* Ratzel
    - *L. udekemianus* clap.
    - *Tubifex tubifex* (O.F.M.)
    - Unidentifiable tubificid w/capilliform chaetae
    - Unidentifiable tubificid w/out capilliform chaetae
- Anthropoda
  - Arachnida
    - Hydracarina
      - Unidentifiable species
  - Crustaceae
    - Unidentifiable species
    - *Hyalella azteca* (Saussure)
  - Insecta
    - Ephemeroptera
      - *Hexagenia limbata* (Serville)
      - *Caenis* sp.
      - *Cloeon* sp.
      - *Centroptilum* sp.
      - Unidentifiable Baetidae
    - Odonata
      - *Gomphus* sp.
      - *Epicordulia* sp.
      - *Macromia* sp.
      - *Plathemis* sp.
      - *Somatochlora*
      - *Sympetrum* sp.
      - *Ischnura* sp.
      - Unidentifiable Coenagrionidae
- Arthropoda
  - Megaloptera
    - *Sialis* sp.
  - Trichoptera
    - Unidentifiable Leptoceridae
    - *Oecetis* sp.
    - *Polycentropus* sp.
    - *Molanna* sp.
  - Coleoptera
    - *Berosus* sp.
    - *Haliplus* sp.
  - Diptera
    - Unidentifiable Ceratopogonidae
    - *Chaoborus punctipennis* (Say)
    - *Ablabesmyia* sp.
    - *Anatopynia* sp.

Table 1 (continued)

- Arthropoda
  - Diptera
    - *Coelotanypus* sp.
    - *Pentaneura* sp.
    - *Procladius* sp.
    - *Tanypus* sp.
    - Unidentifiable Pentaneurini
    - *Chironomus* sp.
    - *Cryptochironomus abortivus* (Malloch)
    - *Cryptochironomus* sp.
    - *Dicrotendipes* sp.
    - *Endochironomus* sp.
    - *Glyptotendipes* sp.
    - *Goeldichironomus* sp.
    - *Harnischia* sp.
    - *Lauterborniella* sp.
    - *Parachironomus* sp.
    - *Paralauterborniella* sp.
    - *Phaenopsectra* sp.
    - *Polypedilum* sp.
    - *Pseudochironomus* sp.
    - *Stenochironomus* sp.
    - *Stictochironomus* sp.
    - *Tribelos* sp.
    - Chironomini sp. A
    - Chironomini sp. B
    - Chironomini sp. C
    - Chironomini sp. F
    - *Micropsectra* sp.
    - *Rheotanytarsus* sp.
    - *Tanytarsus* sp.
    - *Cricotopus* sp.
    - *Orthocladius* sp.
    - *Psectrocladius* sp.
    - Chironomid pupae
- Mollusca
  - Pelecypoda
    - *Pisidium* sp.
  - Gastropoda
    - *Gyralus* sp.
    - *Physa* sp.

varied from 2 to 17 (Table 2). One meter depths generally contained more species ($\bar{x} = 8.9$) than the middle or deep water stations ($\bar{x} = 5.2$ and 3.5, respectively). Ten species were found only at 1 m, the only three odonates taken during 1974, *Macromia* sp., *Epicordulia* sp., and *Somatochlora* sp., and seven chironomids of the tribe Chironomini. Six taxa were found only at the shallow and middle depths including all of the mayfly nymphs, Pentaneurini, and *Harnischia* sp. Only four taxa, *Chaoborus punctipennis, Chironomus* sp., *Coelotanypus* sp., and *Tanypus* sp., were found at all depths on all three sampling dates. A tendency existed for the number of species collected to increase slightly during the summer. Variation among stations existed, but was considerably less than variation among depths.

Table 2. Number of taxa(s), numbers/m^2 (n), and pooled species diversity ($\bar{d}$) from three Ekman grabs of benthic macroinvertebrates by transect and depth during summer, 1974, in Ham's Lake.

Station	Depth (m) s	13 July			30 July			22 August		
		s	n	$\bar{d}$	s	n	$\bar{d}$	s	nd	$\bar{d}$
1	1	12	931	2.2	12	832	2.8	16	2810	2.9
	3	8	931	1.8	–	–	–	–	–	–
	5*	10	501	2.7	6	644	1.9	9	903	2.5
	8	8	1348	2.3	6	1677	0.8	7	4648	0.5
2	1	9	614	2.2	15	1532	2.8	17	716	3.6
	3	9	615	2.8	–	–	–	–	–	–
	5*	9	759	2.7	7	816	2.0	10	773	2.6
	8	8	445	2.6	2	129	1.0	5	1047	1.6
3	1	13	1032	3.2	17	3341	2.3	16	1792	3.1
	3	9	659	1.8	–	–	–	–	–	–
	5*	7	315	2.6	3	114	1.0	10	543	2.5
	8	4	114	1.7	3	773	0.3	4	961	0.8

Depth = 4.5 m on 30 July and 22 August.
–Samples not taken.

The density of the benthic macroinvertebrate assemblage ranged from 114 to 4686 organisms/m^2 (table 2). The fauna of the shallow depths was dominated by the chironomids *Tanytarsus* sp. and *Procladius* sp. *Tanypus* sp. and *Chironomus* sp. were also found in considerable numbers at 1 m in August. The middle depths were dominated by *Procladius*, *Chironomus*, and *Tanypus*, but all three were less abundant than in the shallow water. *Chironomus* sp., *Tanypus* sp., and *Chaoborus punctipennis* were abundant on one more sampling dates at 8 m. Variation in density among transects was not consistent. Density increased significantly ($P < .001$) with time, primarily due to a large increase in the *Chaoborus* population.

Species diversity ($\bar{d}$) of benthic macroinvertebrates ranged from 0.3 to 3.6 (Table 2). Diversity varied little among stations and was nearly uniform at all depths on 13 July. On 30 July and 22 August, $\bar{d}$ decreased consistently with depth at all stations. The low values at 4.5 and 8 m were primarily the result of a decrease in the number of species and an increase in the *Chaoborus* population.

Main Study. Temperature, dissolved oxygen (DO), and conductivity of the bottom water and pH of the sediments were relatively uniform over depth at Station 3 on 1 March 1975 (Table 3). The level of DO decreased considerably at all depths between 1 March and 21 May. On 21 May an abrupt decrease in DO occurred between 3 and 4 m, while conductivity decreased abruptly between 4 and 5 m. No consistent pattern was observed for pH of the sediments. On 14 June, just prior to the beginning of pumping operations, the deep water was almost devoid of DO and a considerable decrease in DO and temperature occurred between 5 and 6 m. Conductivity decreased slightly with depth. On 10 July, about 3 weeks after pumping began, the water temperature was relatively uniform at all depths. The sharpest decrease in DO on this date occurred between 1 and 2 m. Between 14 June and 10 July, oxygen decreased in the shallow waters and increased in the bottom waters as a result of pumping. The decrease in conductivity with depth that was observed on 21 May and 14 June was not apparent on 10 July. On 31 July DO as well as temperature, was relatively uniform at all depths and values below 4 m were similar to those measured on 10 July. A dense growth of macrophytes at 1 and 2 m on 31 July prevented collecting of benthic macroinvertebrates and thus measurements of temperature and oxygen were not taken on this date.

Numbers of species tended to decrease with depth in 1975 as in 1974 (Table 4). Eighteen species were taken only

Table 3. Physicochemical conditions* of three samples of the bottom water (pH is of the bottom sediments) over depth at Transect 3 during 1975 in Ham's Lake.

Date	Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/1)	Conductivity (umhos)	pH
1 March	1	5.7	12.3	203	7.8
	2	5.5	11.8	205	7.5
	3	5.0	11.7	203	7.9
	4	5.4	11.3	201	7.3
	5	5.0	13.1	205	7.4
	6	5.0	9.5	202	7.3
	7	5.1	11.9	208	7.2
	8	5.2	12.5	290	8.0
21 May	1	17.8	7.8	322	6.8
	2	17.5	7.3	318	7.3
	3	17.5	8.0	320	7.3
	4	17.8	3.7	303	7.8
	5	20.4	3.1	215	7.7
	6	20.4	3.3	207	8.0
	7	20.7	3.2	188	7.1
	8	16.2	2.5	216	5.9
14 June	1	23.0	7.7	335	6.9
	2	22.5	7.3	330	7.4
	3	22.5	7.0	330	7.6
	4	22.5	6.1	345	7.8
	5	22.5	6.2	340	7.1
	6	19.0	0.2	337	6.8
	7	18.0	0.1	303	7.1
	8	18.0	0.1	305	6.9
10 July	1	30.0	6.4	396	6.9
	2	29.0	3.9	410	*
	3	29.0	3.4	432	*
	4	28.5	2.6	419	*
	5	28.5	2.6	419	*
	6	28.5	2.8	420	*
	7	28.5	2.5	420	*
	8	28.0	1.7	447	*
31 July	1	*	*	*	*
	2	*	*	*	*
	3	28.2	2.4	*	6.3
	4	28.0	2.5	*	7.5
	5	28.0	2.9	*	7.0
	6	28.0	2.6	*	6.9
	7	28.0	1.3	*	6.5
	*	28.0	2.3	*	7.5

*Values not measured.
Vertical line designates beginning of pumping (i.e. 19 June 1975).

from the 1 and 2 m samples. Number of species decreased by nine between 1 and 2 m and between 2 and 3 m on 1 March. Although considerable variation in the number of species existed between 1 and 2 m on the following dates, less variation existed between 2 and 3 m. A decrease in number of species occurred between 4 and 5 m on 14 June and 10 July. Samples from 5 to 8 m on both of these dates had fewer species than existed in the profundal zone

Table 4. Number of taxa(s), numbers/m² (n), and pooled species diversity (d) from four Ekman grabs of benthic macroinvertebrates by depth at Transect 3 during 1975 in Ham's Lake.

Depth (m)	1 March			21 May			14 June			10 July			31 July		
	s	n	$\bar{d}$	s	n	$\bar{d}$	s	n	$\bar{d}$	s	n	$\bar{d}$	s	n	$\bar{d}$
1	29	16639	3.3	30	9240	3.0	25	6038	2.9	20	1079	3.3		*	
2	20	3058	2.9	7	1259	2.0	13	605	3.0	13	2465	2.6	14	959	2.8
3	11	1357	2.6	11	2229	2.6	11	1141	2.9	15	1901	3.1	17	2382	2.3
4	5	144	2.0	10	814	2.7	11	453	3.2	11	506	3.0	10	400	2.7
5	9	1013	1.9	9	647	2.2	5	119	2.2	4	194	2.0	8	75	1.4
6	12	2908	1.6	8	496	2.8	4	635	0.5	5	205	1.5	10	593	2.6
7	7	3197	1.5	9	444	2.4	4	851	0.6	6	335	1.5	5	495	1.4
8	9	5878	1.5	7	529	2.2	5	711	0.6	4	506	0.8	8	603	2.1

*Samples not taken.
Vertical line designates beginning of pumping (i.e., 19 June 1975).

in March and May. By 31 July, the total number of species found in the profundal zone increased from the previous sample.

Mean benthic macroinvertebrates density ranged from 75 to 16,639 organisms/m² (Table 4). Density decreased significantly ($P < 0.001$) with time. On 1 March, the shallow water samples were dominated by *Dero digitata, Aulodrilis pigueti, ceratopogonids,* and *Ilyodrilus* sp. Large numbers of *Dicrotendipes* sp., *Procladius* sp., *Tanytarsus* sp., *Hyalella azteca,* and *Hexagenia limbata* were also found. Most of these taxa were found in reduced numbers in the mid-depths. The higher density at the 5 to 8 m depths was primarily due to the presence of one species, *Chaoborus punctipennis.* On 21 May, the benthic assemblage was essentially the same in composition and distribution as on 1 March, but in reduced numbers. A 98% reduction occurred in the density of *Chaoborus* in the profundal zone. *Aulodrilus pigueti* and *Dictotendipes* were also found in greatly reduced numbers. Density decreased by 14 June at the 1 to 5 m depths. *Chaoborus,* although considerably reduced from March levels, accounted for over 90% of the benthic invertebrates below 4 m. On 10 July, the average density of *Hyalella* and *Chaoborus* was reduced to 25% of its spring level of 400 organisms/m². *Stylaria lacustris,* which had been found in excess of 1000 organisms/m² at the 1 m depths in the spring and early summer, was not taken in July. On 31 July, the profundal zone supported a larger density, while shallower water populations continued to decrease.

The oven-dry weight of benthic macroinvertebrates ranged from 0.01 to 5.83 g/m² (Table 5). The greatest values were generally found at 1 and 2 m and except for the March sample, biomass generally decreased with depth. The decrease was pronounced from 1 to 3 m and slightly below that. Variation of biomass over time was not significant.

Species diversity ($\bar{d}$) ranged from 0.5 to 3.3 (Table 4). Diversity decreased significantly with depth on 1 March, 14 June, and 10 July ($P < .001, .005, .002$, respectively), but was not significantly correlated with depth on 21 May and

Table 5. Mean oven-dry weight (g/m²)* of three Ekman grabs benthic macro-invertebrates by depth at Transect 3 during 1975 in Ham's Lake.

Depth (m)	1 March	21 May	14 June	10 July	31 July
1	2.23	1.14	1.69	5.83	*
2	0.78	1.21	0.41	0.93	0.20
3	0.73	0.67	0.67	0.82	0.35
4	0.09	0.27	0.06	0.30	0.24
5	0.09	0.21	0.02	0.11	0.01
6	0.37	0.06	0.08	0.27	0.40
7	1.22	0.11	0.18	0.09	0.19
8	0.59	0.27	0.16	0.12	0.10

*Sample not taken.
Vertical line designates beginning of pumping (i.e., 19 June, 1975).

31 July. On 1 March, $\bar{d}$ decreased uniformly with depth, while values decreased abruptly between 5 and 6 m on 14 June and between 4 and 5 m on 10 July. Diversity values of the 1 to 5 m depths varied little seasonally.

Discussion

The 67 species of benthic macroinvertebrates collected from Ham's Lake in 1974 and 1975 is within the range of that reported for other reservoirs in Oklahoma. Craven (1968) collected only 29 species in Boomer Lake, a 102 ha impoundment in Stillwater, Oklahoma, but did not identify chironomids. Ransom (1969) collected only 25 species from Keystone Reservoir, a 10,000 ha impoundment of the Arkansas River. More species (95 and 87, respectively) were found in Arbuckle Reservoir (Wilhm, 1976) and Lake Texoma (Sublette, 1957) possible due to the larger size of the impoundments and drainage basins.

The insect fauna of the various Oklahoma reservoirs was similar to that found in Ham's Lake; however, variation exists in the oligochaete populations. Craven (1968) found *Branchiura sowerbyi* to be the only abundant worm in Boomer Lake. In Keystone Reservoir, the oligochaete fauna consisted of *Dero* sp. and *Limnodrilus hoffmeistrei* (Ransom, 1969). *Stylaria lacustris, Dero digitata,* and *Aulodrilus pigueti* dominated the oligochaete fauna of Ham's Lake.

The density and number of species of benthic macroinvertebrates in Ham's Lake decreased during the summer. Similarly, Sublette (1957) noted that most macroinvertebrate populations were at peak abundance in late winter to early spring. Similar trends were reported in both Arbuckles (Wilhm, 1976) and Keystone (Ransom, 1969) Reservoirs.

Species composition and diversity varied with depth. The shallow water sediments of Ham's Lake contained several abundant and many rare species of benthic macroinvertebrates resulting in high values of diversity. The middle depths were the least densely populated area of the lake. Fewer species were found in these middle depths than in the shallower water causing the diversity values to be somewhat lower. The benthic assemblage in the profundal zone contained one or two abundant and few rare taxa resulting in low values of species diversity. Variation in composition of benthic macroinvertebrates and diversity ($\bar{d}$) with depth in the Ham's Lake is comparable to findings in other lakes. Diversity decreased with depth in Keystone Reservoir (Ransom, 1969). Chironomids and oligochaetes of El Capitan Reservoir decreased in abundance with depth throughout the year and were more concentrated in the littoral zone during summer stratification (Inland Fisheries Branch, 1970, Fast, 1973). *Hexagenia* spp. and Tendipedidae (= Chironomidae) were concentrated in shallow water in Boomer Lake and *Chaoborus* mainly in the profundal zone as was found in the present study (Craven, 1968). Concentration zones for the benthos in several Michigan lakes were variable, although the profundal depths rarely supported a large density during severe stratification (Eggleton, 1931).

The abundance and depth distribution of many species of benthic macroinvertebrates increased after lake destratification (Wirth *et al.*, 1970; Inland Fisheries Branch, 1970; Fast, 1973). Hypolimnetic aeration (Fast, 1971) of a Michigan lake enabled the zoobenthos to recolonize the profundal muds in great quantity even though the thermocline remained intact. In Ham's Lake, oxygen concentration below 5 m dropped from 3.0 mg/l on 21 May to 0.1 mg/l on 14 June. The number of species collected from this zone decreased during this period from 13 to five, while species diversity ($\bar{d}$) decreased from 2.5 to 0.6. The hypolimnion again contained oxygen, 2.3 mg/l, on 10 July and the number of species increased to 11, resulting in higher diversity values. On 31 July, the lake was thermally and chemically destratified. Most species of benthic macroinvertebrates which had been collected in the profundal waters in the May sample, were again found in deep water, some abundantly. This increase in species was also reflected in larger species diversity values, which suggest healthier environmental conditions (Wilhm & Dorris, 1968).

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