DISTRIBUTION OF BENTHIC MACROINVERTEBRATES IN AN ARTIFICIALLY DESTRATIFIED RESERVOIR

By

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RESERVOIR

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CHAPTER I

INTRODUCTION

Benthic macroinvertebrates are not uniformly distributed on the bottom of lakes and ponds. Variation with depth of species composition (Baker 1918, Saether 1970), density (Muttkowski 1918, Juday 1922, Inland Fisheries Branch 1970), species diversity (Ransom 1969), and biomass (McLachlan and McLachlan 1971, Fast 1971) has been reported. The presence of many organisms within a limited depth range has been referred to as a concentration zone (Eggleton 1931). Concentration zones, based both on density of individuals and biomass, varied with depth seasonally within lakes (Eggleton 1931, McLachlan and McLachlan 1971) and varied among nearby lakes sampled concomitantly (Eggleton 1935). Large concentrations of organisms, usually of only a few species, are often reported from deep profundal basins (Juday 1922). High diversity values have been reported from littoral collections (Ransom 1969). Collections made near the edge of exposed shorelines have yielded fewer species and individuals than in somewhat deeper water (Baker 1918, McLachlan and McLachlan 1971).

Seasonal changes in the depth distribution of benthic macroinvertebrates are often pronounced. The concentration zones may shift from near the shoreline in summer to the deep profundal during the winter (Eggleton 1931, McLachlan and McLachlan 1971). These shifts represent periodic migrations of some populations, changes in the relative abundances of taxa, and the colonization of the bottom by some species during part of the year (Eggleton 1931). Seasonal changes in the depth distribution of the benthos are most evident in the profundal zone. During periods of hypolimnion stagnation only a limited number of taxa inhabit the deep strata, while during turnover periods the composition of the profundal zone may be similar to the littoral zone (McLachlan and McLachlan 1971).

Eggleton (1931) separated the factors which influence the depth distribution of benthic macroinvertebrates into bottom characteristics, physiochemical factors, and biological factors. Bottom characteristics refer essentially to the nature and composition of materials which afford support, protection, and often a food source for the benthos. Distinct benthic assemblages have been associated with various bottom types (Baker 1918). Thermochemical stratification is the most important factor affecting the vertical distribution of the benthos (Eggleton 1931). Anoxic conditions of the profundal zone during periods of stratification are primarily responsible for the decrease in kinds and abundance of organisms (McLachlan and McLachlan 1971). In shallower areas of artifically constructed impoundments, reduced populations of benthic macroinvertebrates have been attributed to wave and current activities (Cowell and Hudson 1967) and high siltation rates (McLachlan and McLachlan 1971). Conductivity, pH of the water (Topping 1971), pH of the sediments, and Secchi disc visibility (Hilsenhoff and Narf 1968) have also been correlated with the presence or absence and abundance of populations of benthic macroinvertebrates.

Destratification and hypolimnion aeration may result in changes in the density and distribution of benthic macroinvertebrates (Toetz, Wilhm, and 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). 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.

Few principles exist for the depth distribution of benthic macroinvertebrates. In previous studies distribution was represented by only one or two parameters, usually number of species or density. The relationships among these variables has received little attention and, therefore, comparing results among studies is difficult. The factors regulating the distribution of the benthos are also little understood. The primary objectives of the present study were to (1) determine the variation with depth of density, number of species, biomass, and species diversity of the benthic macroinvertebrates in Ham's Lake; (2) determine the influence of dissolved oxygen, water temperature, conductivity, and pH of the sediments on the distribution of the benthic macroinvertebrate assemblage; and (3) determine the effect of destratification on the distribution of the benthos.

CHAPTER II

STUDY AREA

Ham's Lake is located in Payne County, Oklahoma, about 8 km west of Stillwater (Figure 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 and the length of the central pool is about 1.3 km. 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 and 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 stations were established for sampling benthic macroinvertebrates. Station 8 is a transect extending from the northwest part of the lake near the shore to the central pool, while Station 1 and 2 are transects in the southeast and southwest areas, respectively (Figure 1). The station numbers correspond to those used in concomitant studies in the lake.

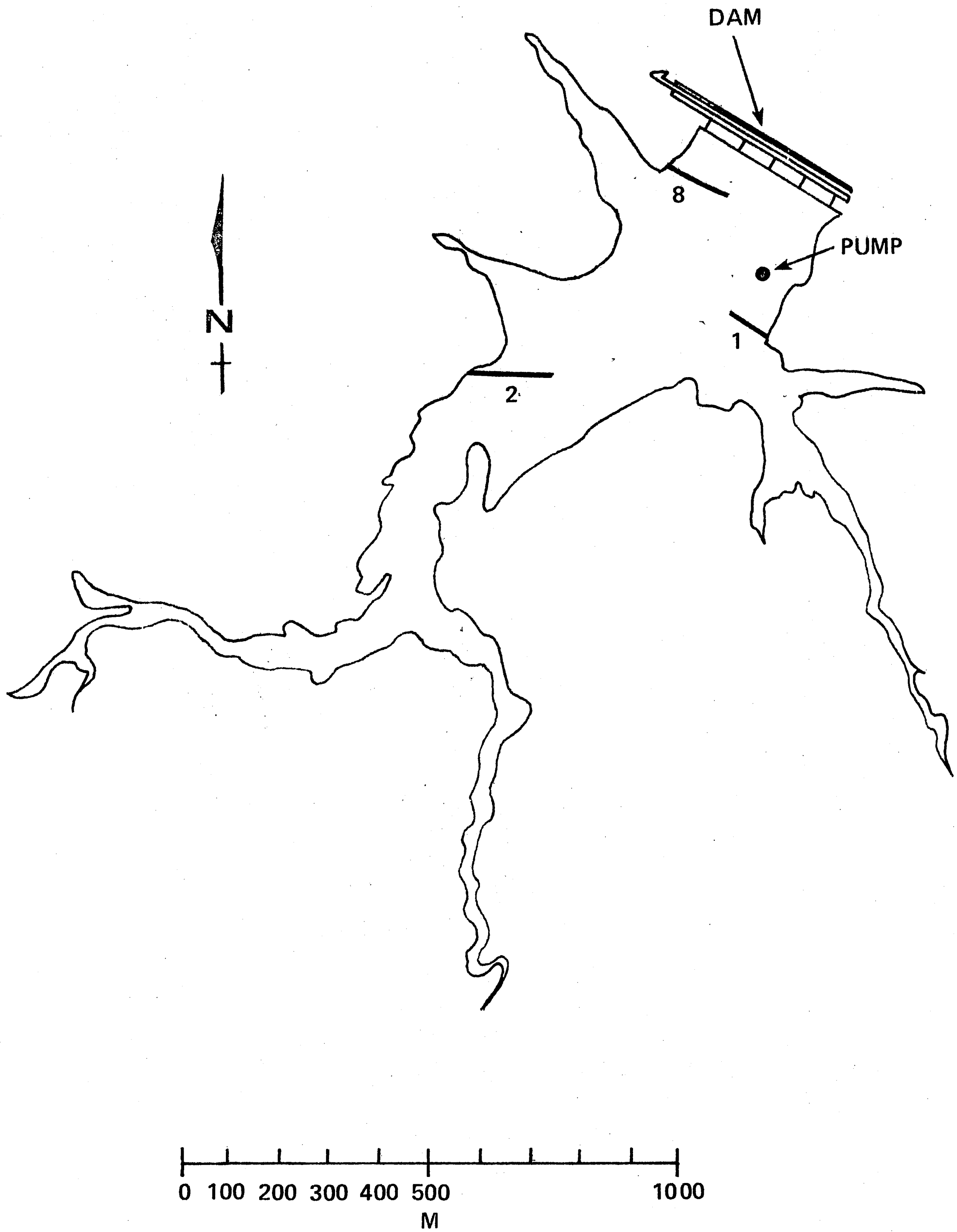

Figure 1. Ham's Lake showing sampling stations

CHAPTER III

MATERIALS AND METHODS

Preliminary Study

Depth distribution of benthic macroinvertebrates was studied at the three stations over three time periods in the summer, 1974. Samples were taken after pumping began on 13 May 1974. Three samples each were taken with an Ekman grab sampler at depths of 1, 3, 5, and 8 m from each station on 13 Jul 1974. Samples were washed in a U.S. standard #30 soil sieve and preserved in 8% formalin. The time required to sort and identify organisms necessitated reducing the number of samples during the subsequent sampling periods. Since considerable variation existed among replicate samples, replication was not decreased. The number of stations sampled was not reduced since this was a preliminary study of the lake. Thus, during the collections of 30 Jul and 22 Aug 1974, the 3 and 5 m depths were combined into a single collecting depth of 4.5 m. Identification was to species when possible; otherwise, identification was to the lowest practical taxon. Nomenclature followed Pennak (1953), Brinkhurst and Jamison (1973), and Mason (1973). Identification was aided by keys and descriptions in Usinger (1971), Beck (1968), Beck and Beck (1966), Brinkhurst (1964, 1965), and Brinkhurst and Cook (1966). Species diversity was determined by the formula (Shannon and Weaver 1963):

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

and by Hurlbert's (1971) formula for the probability of interspecific encounter (PIE):

$$PIE = n/(n-1) \sum_{i=1}^{s} (n_i/n) ([n-n_i]/[n-1])$$

where: n_i = number of individuals of the taxon

n = total number of individuals, and

s = total number of species.

Shannon's formula was first adopted as a measure of community diversity by Patten (1962). The PIE formula was modified from Simpson's (1949) formula for the measure of concentration. Both measures are unbiased estimators which level off as sample size increases (Wilhm and Dorris 1968, Hurlbert 1971). Wilhm found that multiple Ekman grab samples were almost always required to reach an asymptotic level of $\bar{d}$. Thus, a single diversity estimate was made from pooled replicate samples.

Main Study

The data collected in summer, 1974, revealed that variation among depths was considerably greater than variation among stations and that considerable variation existed among replicate samples. In 1975, four samples were taken from each of eight depths at Station 8. The depths were at 1 m intervals from 1 to 8 m and the samples were taken on 1 Mar, 21 May, 14 Jun, 10 Jul, and 31 Jul. The latter two samples were taken after pumping operations began on 19 Jun. Samples were sorted and identified as described for the preliminary study. Three additional samples were taken from each of the eight depths every sampling period. Oven-dry weight of the organisms from these samples was determined by gravimetric analysis (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 and pH were measured with a YSI model 33 salinity-conductivity-temperature meter and an Orion model 407 specific ion meter, respectively.

This study was designed to be analyzed as a factorial arrangement of treatments; the treatments being depths, sampling periods, and during the preliminary study, stations. Treatments were judged to be significantly different when the OSL ≤ 0.01. Correlations among physicochemical parameters and characteristics of the benthic assemblage were observed with the aid of product-moment correlation coefficients and canonical correlation analysis. Data from the main study were tested against the following models:

$$\text{Index} = B_0 + B_1 D + B_2 D^2 + B_3 D^3 \quad (1)$$

$$\text{Log Index} = B_0 + B_1 D + B_2 D^2 + B_3 D^3 \quad (2)$$

$$\text{Index} = B_0 + B_1 \text{DissO}_2 + B_2 \text{Temp} + B_3 \text{Cond} + B_4 \text{pH} + B_5 D \quad (3)$$

where: B_i's were least square fit coefficients

D = depth

DissO_2, Temp, Cond, and pH were physicochemical data and,

Index = Biomass, Number of species, or density.

Models (1) and (2) test whether knowledge of depth, as simple linear, quadratic, or cubic functions, were valuable as predictors of the density, biomass, or number of species of the benthic assemblage. Model (3) was used to determine whether knowledge of the physicochemical conditions of the water and substrate could be used to predict the density, biomass, or number of species of the benthos.

CHAPTER IV

RESULTS

Preliminary Study

Of the 67 species of benthic macroinvertebrates collected in Ham's Lake during the study (Table 1), 45 were taken during 1974. During summer, 1974, only four taxa, *Chaoborus punctipennis*, *Chironomus* sp., and *Tanypus* sp., were found at all depths on all three sampling dates. 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 additional taxa were found only at the shallow and middle depths including all of the mayfly nymphs, chironomids of the tribe Pentaneurini, and *Harnischia* sp.

The number of species collected in 1974 by station and depth varied from 2 to 17 (Table 2). One meter samples generally contained more species ($\bar{x}$ = 8.9) than the middle or deep water stations ($\bar{x}$ = 5.2 and 3.5, respectively). 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.

The density of the benthic macroinvertebrate assemblage ranged from 114 to 4686 organisms/m^2 (Table 3). A consistant variation in density among stations was not observed. Density increased signifi-

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

Coelenterata
    Hydrozoa
        Hydra sp.

Platyhelminthes
    Turbellaria
        Dugesia sp.

Nematoda
        Undidentifiable species

Annelida
    Oligochaeta
        Chaetogaster sp.
        Dero digitata (Müller)
        Nais sp.
        Stylaria lacustris (Linn.)
        Aulodrilus pigueti Kowalewski
        Ilyodrilus sp.
        Limnodrilus hoffmeisteri Clap.
        L. cervix Brinkhurst
        L. claparedianus Ratzel
        L. undekemianus Clap.
        Tubifex tubifex (Müller)
        Unidentifiable tubificid w/capilliform chaetae
        Unidentifiable tubificid w/out capilliform chaetae

Arthropoda
    Arachnida
        Hydracarina spp.
    Crustacea
        Unidentifiable Astacidae
        Hyalella azteca (Saussure)
    Insecta
      Ephemeroptera
        Hexagenia limbata (Serville)
        Caenis sp.
        Cloeon sp.
        Centroptitum sp.
        Unidentifiable Baetidae
      Odonata
        Gomphus sp.
        Epicordulia sp.
        Macromia sp.
        Plathemis sp.
        Somatochlora sp.
        Sympetrum sp.
        Ischnura sp.

Table 1. (Continued)

Arthropoda (continued)
        unidentifiable Coenagrionidae
    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.
        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.

Table 1. (Continued)

Arthropoda (continued)
Chironomid pupae
Mollusca
Pelecypoda
Pisidium sp.
Gastropoda
Gyralus sp.
Physa sp.

Table 2. Number of species* of benthic macroinvertebrates by station and depth during summer, 1974, in Ham's Lake.

Station	Depth (m)	13 Jul	30 Jul	22 Aug
8	1	13	17	16
	3	9	–	–
	5**	7	3	10
	8	4	3	4
1	1	12	12	16
	3	8	–	–
	5**	10	6	9
	8	8	6	7
2	1	9	15	17
	3	9	–	–
	5**	9	7	10
	8	8	2	5

*Values are number of species in three Ekman grab samples.

**Depth = 4.5 m on 30 Jul and 22 Aug.

– = Sample not taken.

Table 3. Density (individuals/m^2)* of benthic macroinvertebrates by station and depth during summer, 1974, in Ham's Lake.

Station	Depth (m)	13 Jul	30 Jul	22 Aug
8	1	1032	3341	1792
	3	659	-	-
	5**	315	114	543
	8	114	773	961
1	1	931	832	2810
	3	931	-	-
	5**	501	644	903
	8	1348	1677	4648
2	1	614	1532	716
	3	615	-	-
	5**	759	816	773
	8	445	129	1047

*Values are mean densities of three Ekman grab samples.

**Depth = 4.5 m on 30 Jul and 22 Aug.

- = Samples not taken.

cantly (OSL < .001) with time, primarily due to a large increase in the Chaoborus population. The fauna of the shallow depths was dominated by the chironomids Tanytarsus sp. and Procladius sp. (Tables 12-14). In August, Tanypus sp. and Chironomus sp. were also found in considerable numbers at 1 m. The middle depths were again dominated by Procladius, Chironomus, and Tanypus, but all three were less abundant than in the shallow water. No one taxon was consistantly found in large numbers at 8 m. Chironomus and Tanypus were abundant in mid-July, especially at Station 1. During the latter two sampling periods, these two decreased in abundance in deep water and large numbers of Chaoborus were collected.

Species diversity ($\bar{d}$) of benthic macroinvertebrates ranged from 0.3 to 3.6 (Table 4). Probability of interspecific encounter (PIE) ranged from .07 to .89 (Table 5) and was highly correlated with the $\bar{d}$ values. Diversity varied little among stations and was nearly uniform at all depths on 13 Jul. On 30 Jul and 22 Aug, $\bar{d}$ and PIE decreased consistantly 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.

Data from the preliminary study indicated that variation among depths and over time of the species composition and diversity of the benthic macroinvertebrate assemblage was greater than variation among stations. Thus, in the more intensive sampling program conducted in 1975, physicochemical measurements and invertebrate samples were collected from 1 m intervals along the transect at Station 8. Sampling was conducted during periods of natural destratification (spring), stratification (early summer), and artificial destratification (late

Table 4. Species diversity ($\bar{d}$)* of populations of benthic macroinvertebrates by station and depth during summer, 1974, in Ham's Lake.

Station	Depth (m)	13 Jul	30 Jul	22 Aug
8	1	3.2	2.3	3.1
	3	1.8	-	-
	5**	2.6	1.0	2.5
	8	1.7	0.3	0.8
1	1	2.2	2.8	2.9
	3	1.8	-	-
	5**	2.7	1.9	2.5
	8	2.3	0.8	0.5
2	1	2.2	2.8	3.6
	3	2.8	-	-
	5**	2.7	2.0	2.6
	8	2.6	1.0	1.6

*Values are total diversity of three pooled samples.

**Depth = 4.5 m on 30 Jul and 22 Aug.

- = Samples not taken.

Table 5. Probability of interspecific encounter (PIE)* of benthic macroinvertebrates by station and depth during summer, 1974, in Ham's Lake.

Station	Depth (m)	13 Jul	30 Jul	22 Aug
8	1	.79	.70	.83
	3	.52	–	–
	5**	.83	.07	.77
	8	.73	.07	.27
1	1	.62	.80	.82
	3	.56	–	–
	5**	.80	.69	.78
	8	.75	.28	.11
2	1	.76	.80	.89
	3	.83	–	–
	5**	.81	.64	.77
	8	.81	.50	.55

*Values are total probability based on three pooled samples.

**Depth = 4.5 m on 30 Jul and 22 Aug.

– = Sample not taken.

summer) to determine the immediate influence of artificial destratification on the depth distribution of the benthos.

Main Study

Temperature, dissolved oxygen, and conductivity of the bottom water and pH of the sediments in Ham's Lake were relatively uniform over depth at Station 8 on 1 Mar 1975 (Table 6). The level of dissolved oxygen decreased considerably at all depths between 1 Mar and 21 May. On 21 May an abrupt decrease in dissolved oxygen 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 Jun, just prior to the beginning of pumping operations, the deep water was almost devoid of oxygen and a considerable decrease in oxygen and temperature occurred between 5 and 6 m. Conductivity decreased slightly with depth. On 10 Jul, about 3 weeks after pumping began, the water temperature was relatively uniform at all depths. The sharpest decrease in dissolved oxygen on this date occurred between 1 and 2 m. Between 14 Jun and 10 Jul, oxygen decreased in the shallow waters and increased in the bottom waters possibly as a result of pumping. The decrease in conductivity with depth that was observed on 21 May and 14 Jun was not apparent on 10 Jul. Because of a malfunction in the meter pH was not measured on this date. On 31 Jul dissolved oxygen as well as temperature was relatively uniform at all depths and values were similar to those measured on 10 Jul. A dense growth of macrophytes at 1 and 2 m on 31 Jul prevented collecting of benthic macroinvertebrates and thus measurements of temperature and oxygen were not taken on this date. Malfunction of the conductivity meter prevented measurements of

Table 6. Physicochemical conditions* of the bottom water (pH is of the bottom sediments) over depth at Station 8 during 1975 in Ham's Lake.

Date	Water Depth (m)	Temperature (°C)	Oxygen (mg/l)	Conductivity (umhos)	pH
1 Mar	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	209	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 Jun	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 Jul	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 Jul	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 are means of three measurements

**Values not measured

this parameter on 31 Jul.

Fifty-seven taxa of benthic macroinvertebrates were collected from Ham's Lake in 1975. The species collected differed only slightly from those collected in 1974. A few additional species were found because of the increased sampling effort. Chironomus sp. and Tanypus sp., which were found infrequently in 1975, were abundant in Ham's Lake the previous year. The reverse trend was observed for Dero digitata. One specimen was found in the 1974 samples while Dero was the most abundant organism in 1975.

Chaoborus punctipennis, Coelotanypus sp., and Dero digitata were collected during each sampling period (Tables 15-19). Eighteen taxa were taken only from the 1 and 2 m samples, all but Gyralus sp. and Hyalella azteca were rare. Most species of benthic organisms found below 2 m were also taken from the shallow water. The exceptions to this were Pisidium sp., Lauterborniella sp. and an unidentified chironomid, Chironomini F. Pisidium was found from 3 to 6 m and the two chironomids were found at 6 and 8 m, respectively.

Numbers of species tended to decrease with depth as in 1974 (Table 7). A marked decrease occurred between 1 and 2 m. Significant changes generally were not observed between the 2 to 8 m depths in the March and the May samples. However, a pronounced decrease in number of species occurred between 4 and 5 m on 14 Jun and 10 Jul. Samples from 5 to 8 m on both of these dates had considerably fewer species than existed in the profundal zone in March and May. By 31 Jul, the total number of species found in the profundal zone increased from the previous sample.

Mean benthic macroinvertebrate density ranged from 75 to 16,639

Table 7. Numbers of species* of benthic macroinvertebrates by depth at Station 8 during 1975 in Ham's Lake.

Depth (m)	1 Mar	21 May	14 Jun	10 Jul	31 Jul
1	29	30	25	20	-
2	20	7	13	13	14
3	11	11	11	15	17
4	5	10	11	11	10
5	9	9	5	4	3
6	12	8	4	5	10
7	7	9	4	6	5
8	9	7	5	4	8

*Values are numbers of species in four Ekman grab samples.

- = Samples not taken.

Vertical line designates beginning of pumping (i.e., 19 Jun 1975).

organisms/m^2 (Table 8). Density decreased significantly (OSL < 0.001) with time. On 1 Mar, the shallow water samples were dominated by *Dero digitata*, *Aulodrilus 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 and only three were found at 8 m. The large 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 Mar, 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 was even smaller on 14 Jun. Most populations continued to decline in abundance, only *Chaoborus* and *Hyalella* increased substantially. *Chaoborus*, although considerably reduced from March levels, accounted for over 90% of the benthic invertebrates below 4 m. On 10 Jul, the average density of *Hyalella* and *Chaoborus* was reduced to 25% of its spring level of 400 organisms/m^2. *Stylaria lacustris*, which had been found in excess of 1000 organisms/m^2 at the 1 m depths in the spring and early summer, was not taken in Jul. On 31 Jul, 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/m^2 (Table 9). The greatest values were generally found at 1 and 2 m and except for the Mar sample, biomass generally decreased with depth. The decrease was pronounced from 1 to 3 m and slight below that. Variation of biomass over time was not significant.

Table 8. Density (individuals/m^2)* of benthic macroinvertebrates by depth at Station 8 during 1975 in Ham's Lake.

Depth (m)	1 Mar	21 May	14 Jun	10 Jul	31 Jul
1	16639	9240	6038	1079	-
2	3058	1259	605	2465	959
3	1357	2229	1141	1901	2382
4	144	814	453	506	400
5	1013	647	119	194	75
6	2908	496	635	205	593
7	3197	444	851	335	495
8	5878	529	711	506	603

*Values are mean densities of four Ekman grab samples.

- = Samples not taken.

Vertical line designates beginning of pumping (i.e., 19 Jun 1975).

Table 9. Oven-dry weight (g/m^2)* of benthic macroinvertebrates by depth at Station 8 during 1975 in Ham's Lake.

Depth (m)	1 Mar	21 May	14 Jun	10 Jul	31 Jul
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

*Values are mean estimates based on three Ekman grab samples.

- = Sample not taken.

Vertical line designates beginning of pumping (i.e., 19 Jun 1975).

Species diversity ($\bar{d}$) ranged from 0.5 to 3.3 (Table 10). Diversity decreased significantly with depth on 1 Mar, 14 Jun, and 10 Jul (OSL < .001, .005, .002, respectively), but was not significantly correlated with depth on 21 May and 31 Jul. On 1 Mar, $\bar{d}$ decreased uniformly with depth, while values decreased abruptly between 5 and 6 m on 14 Jun and between 4 and 5 m on 10 Jul. Diversity values of the 1 to 5 m depths varied little seasonally. The depths below 5 m varied from 0.6 to 2.8 ($\bar{x}$ = 1.6) and varied considerably with time. Probability of interspecific encounter (PIE) values ranged from .16 to .89 (Table 11) and, as in the preliminary study, were highly correlated with $\bar{d}$ (OSL < .001). Observed trends in depth and seasonal variation were similar to those described using $\bar{d}$.

The proposed models for the analysis of the variation on species composition and density with depth (models 1 and 2) were not satisfactory in mathematically describing the distribution of the benthic macroinvertebrates. A polynomial function of greater than third degree was always necessary to account for a significant part of the depth variation of density biomass, and number of species. Physicochemical data, expressed as linear functions (model 3), did not contribute significantly to an understanding of the depth distribution of the benthos.

Table 10. Species diversity ($\bar{d}$)* of populations of benthic macroinvertebrates by depth at Station 8 during 1975 in Ham's Lake.

Depth (m)	1 Mar	21 May	14 Jun	10 Jul	31 Jul
1	3.3	3.0	2.9	3.3	-
2	2.9	2.0	3.0	2.6	2.8
3	2.6	2.6	2.9	3.1	2.3
4	2.0	2.7	3.2	3.0	2.7
5	1.9	2.2	2.2	2.0	1.4
6	1.6	2.8	0.5	1.5	2.6
7	1.5	2.4	0.6	1.5	1.4
8	1.5	2.2	0.6	0.8	2.1

*Values are total diversity of four pooled samples.

- = Samples not taken.

Vertical line designates beginning of pumping (i.e., 19 Jun 1975).

Table 11. Probability of interspecific encounter (PIE)* of benthic macroinvertebrates by depth at Station 8 during 1975 in Ham's Lake.

Depth (m)	1 Mar	21 May	14 Jun	10 Jul	31 Jul
1	.84	.80	.78	.85	-
2	.83	.67	.84	.77	.78
3	.79	.79	.84	.82	.62
4	.74	.82	.89	.83	.78
5	.64	.71	.81	.72	.63
6	.51	.85	.16	.51	.80
7	.52	.76	.17	.51	.49
8	.48	.72	.17	.30	.72

*Values are total probability based on four pooled samples.

- = Samples not taken.

Vertical line designates beginning of pumping (i.e., 19 Jun 1975).

CHAPTER V

DISCUSSION

Benthic Macroinvertebrate Assemblage

Sixty-seven species of benthic macroinvertebrates were collected from Ham's Lake in 1974 and 1975. This is within the range of that reported for other reservoirs in Oklahoma. Craven (1968) found 29 species, exclusive of chironomids, from Boomer Lake, a 102 ha impoundment in Stillwater, Oklahoma. More species (95 and 87, respectively) were found in Arbuckle Reservoir (Wilhm 1976) and Lake Texoma (Sublette 1957) possibly due partly to the larger size of the impoundments and drainage basins. Ransom (1969) collected only 25 species from Keystone Reservoir, a 10,000 ha impoundment of the Arkansas River, thus, the relationship of number of species and impoundment size may not hold.

Chaoborus punctipennis, *Dero digitata*, *Procladius* sp., and unidentified ceratopogonids were among the most common taxa collected in Ham's Lake. *Dicrotendipes* sp., *Hyalella azteca*, *Hexagenia limbata*, *Stylaria lacustris* and *Aulodrilus pigueti* were abundant at times in shallow water. The insect fauna of the various Oklahoma reservoirs was similar to that found in Ham's Lake. The more restricted oligochaetes, however, were different at each location. 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 hoffmeisteri (Ransom 1969). A more varied fauna was reported from Arbuckle Lake (Wilhm 1976) where 19 species of annelids, dominated by Stylaria lacustris, Dero digitata, and Aulodrilus pigueti, were found.

The density and number of species of benthic macroinvertebrates in Ham's Lake decreased during the summer. Over 4200 organisms/m^2 representing 34 taxa were taken in Mar, while the density was reduced to 787 organisms/m^2 and the number of species to 32 by 31 Jul. 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.

Depth Distribution of the Benthos

The shallow water sediments of Ham's Lake contained several abundant and many rare species of benthic macroinvertebrates. This generally produced high values of diversity. Several of the shallow water taxa were large, heavy-bodied taxa (e.g., astacids, odonates, sialids, and ephemerids); thus, the biomass was often high. Density and number of species steadily decreased throughout the spring and summer. Biomass and diversity values, however, showed no seasonal fluctuations.

The 4 to 5 m 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. Biomass was less in the middle depths as most of the larger organisms were rare or absent below 3 m. As in the shallow water, there were no consistant seasonal trends in diversity or biomass, and the number of species and density decreased with time.

The benthic assemblage in the profundal zone contained one or two abundant and few rare taxa resulting in low values of species diversity. Although density often was extremely large in this zone, the dominant organism, Chaoborus, is small (Ransom 1969) and the total biomass was generally small. Between Mar and May, density and biomass of the benthos of the profundal zone decreased sharply due to an emergence of Chaoborus, while diversity and the number of species were similar. Decreased species richness during the Jun and mid-Jul samples produced low diversity values. By 31 Jul, both number of species and diversity increased to the May levels.

Variation in species diversity ($\bar{d}$) and composition of benthic macroinvertebrates 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). In Boomer Lake, the density distribution of macroinvertebrates was bimodal (Craven 1968). Hexagenia spp. and Tendipedidae (=Chironomidae) were concentrated in shallow water and Chaoborus mainly in the profundal zone as was found in the present study. 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). Baker (1918) found the number of species of benthic macroinvertebrates to increase with depth for the first 1 to 1.5 m then decrease in Oneida Lake. Many species were confined to narrow depth ranges, mostly in comparatively shallow water. The most pronounced decrease in species occurred from 2.5 to 5 m. The benthic biomass of Lake Kariba was negatively correlated with depth in protected bays (McLachlan and McLachlan 1971). Most of the heavier benthic invertebrates and, thus, the concentration of biomass of Hemlock Lake, Michigan, were confined to the upper 4 m depths (Fast 1971).

Effects of Physicochemical Conditions

Oxygen depletion in the hypolimnion greatly affected the species richness of the benthic macroinvertebrates in the profundal zone. Oxygen concentration below 5 m dropped from 3.0 mg/l on 21 May to 0.1 mg/l on 14 Jun. The number of species collected from this zone decreased during this period from 13 to five. Species diversity ($\bar{d}$) showed a similar trend and decreased from 2.5 to 0.6. The hypolimnion again contained oxygen, 2.3 mg/l, on 10 Jul and the number of species increased to 11. This increased species richness was also reflected in higher diversity values. Most of the species collected in the profundal zone in May were again found in Jul. *Sialis* sp., which had been previously collected only rarely below 5 m was abundant on 31 Jul. Oxygen concentration was not correlated with density or biomass of the profundal benthos, or with composition or distribution of the littoral-sublittoral assemblage. Conductivity and pH of the substrate had little observable effect on the depth distribution of the benthos. pH was significantly (OSL $<$ .001) negatively related to the biomass distribution in May, but at no other time.

Except possibly in deep lakes, depth acts as a limiting factor in the distribution of benthic macroinvertebrates only in combination with other environmental factors (Cowell and Hudson 1967). During summer, thermal stratification and chemical stagnation are two of the most powerful set of factors influencing the depth distribution of the benthic fauna of several Michigan lakes (Eggleton 1931). Anoxia in the hypolimnion was given as the prime factor for the elimination of species (Cowell and Hudson 1967, LaRow 1970) and reduction in biomass (McLachlan and McLachlan 1971) and density (Eggleton 1931, Inland Fisheries Branch 1970) of benthic macroinvertebrates in the profundal zone. Hilsenhoff and Narf (1968) found the presence of two species of chironomids to be positively correlated to the pH of the substrate of various Wisconsin lakes. Topping (1971) discerned a positive correlation between the abundance of _Chironomus tentans_ and conductivity.

Effects of Artificial Destratification

Collections of benthic macroinvertebrates in Ham's Lake of 10 Jul were made 21 days after artificial destratification operations began. The lake was thermally destratified but the hypolimnion still contained oxygen. The composition of benthic assemblage of the profundal zone changed little from the sample of 14 Jun, although species diversity and PIE both increased, primarily because of a reduction in the abundance in the dominant species, _Chaoborus_. For this same reason, total density and biomass of the profundal zone was reduced. On 31 Jul, 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 are suggestive of healthier environmental conditions (Wilhm and Dorris 1968).

Eggleton (1935) suggested that the benthic assemblage undergoes four major distributional changes corresponding to the "limnological seasons": vernal overturn, summer stagnation, autumnal overturn, and winter stagnation. Within each season, the distribution of the benthos changes only slightly. In tropical Lake Kariba, only two distinct distributional patterns, corresponding to summer stagnation and winter overturn, were found (McLachlan and McLachlan 1971). The benthic assemblage was found to change little within the period of summer stagnation. The composition and distribution of the Ham's Lake benthos probably would have remained much like it was on 14 Jun until the autumnal turnover if destratification had not been induced artificially.

Artificial destratification of eutrophic lakes has generally been beneficial (American Water Works Association 1971, Fast 1971, 1973). 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). Hypolimnion aeration (Fast 1971) of a Michigan lake enabled the zoobenthos to recolonize the profundal muds in great quantity even though the thermocline remained intact. Thus, it seems that anoxic conditions may limit profundal zone colonization by benthic macroinvertebrates. The increased heat budget of an artificially destratified reservoir (Fast 1968) has been suggested as a factor in the reduction in the standing crop of individuals and biomass of benthic species in an oligotrophic lake (Fast 1971) and a montane mesotrophic reservoir (Lackey 1973). In eutrophic lakes (Wirth et al. 1970, Inland Fisheries Branch 1970, Fast 1973) and a warm water mesotrophic lake (present study) the increased heat budget may not play as important role as in coldwater mesotrophic and oligotrophic lakes. However, destratification may reverse the normal aging process of a lake (Quintero and Garton 1973) and as the lake becomes more oligotrophic, thermal stress may hinder the development of the macroinvertebrate assemblage.

CHAPTER VI

SUMMARY

1. Benthic macroinvertebrates were collected from three depths at each of three stations in Ham's Lake, Oklahoma, during summer, 1974, and eight depths at one station during spring and summer, 1975. The composition and diversity of the benthic assemblage was analyzed for variation in distribution with time and depth. The effects of artificial destratification on the benthic assemblage were also observed.
2. A total of 76 species of benthic macroinvertebrates was collected during the study. 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 Mar to the end of Jul, 1975. Species diversity, probability of interspecific encounter, and biomass did not change significantly with time.
3. Number of species, species diversity, and probability of interspecific encounter 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. Density and biomass of the assemblage decreased with depth, but the decrease could not be directly related to the physicochemical conditions of the lake.

4. 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. Destratification and aeration enabled species of chironomids and *Sialis* to recolonize the profundal zone, thus increasing the number of species, density, and species diversity of the profundal benthos.
5. Increased species diversity ($\bar{d}$) has been associated with healthier environments. It was concluded that artificial destratification increased the quality of the profundal zone of Ham's Lake.

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APPENDIX

Table 12. Density (individuals/m^2) of benthic macroinvertebrates by station and depth in Ham's Lake on 13 July 1974.

	Station 8				Station 1				Station 2			
Depth (m):	1	3	5	8	1	3	5	8	1	3	5	8
<u>Dero</u> sp.		14										14
<u>Aulodrilus pigueti</u>											100	29
<u>Limnodrilus clap</u>.		29					29					14
Tubif. w/cap. ch.									14*			
Tubif. w/out cap. ch.	14*	29*			14*	14*	14*		43*			14*
<u>Hyalella azteca</u>	14											
<u>Hexagenia limbata</u>	72	14	57		43	86			14	172	29	
<u>Caenis</u> sp.					29							
<u>Cloeon</u> sp.					14							
<u>Sialis</u> sp.	72				14	14	29	14	14	57		
Leptoceridae			14	14								
Ceratopogonidae								43	14		258	
<u>Chaoborus punctipen</u>.							43	186	14			29
<u>Coelotanypus</u> sp.			43	14	14	57	43	29	29	14	57	72
<u>Procladius</u> sp.	258	416	86	29	560	602	158	158	229	100	43	86
<u>Tanypus</u> sp.	143			14	100	29	129	416		29	14	29
Pentaneurini	72	43	29				14			129	115	
<u>Chironomus</u> sp.	29	14	43	57	43	86	14	473		57	129	115
<u>Cryptochironomus</u> sp.	14							29			14	
<u>Glyptotendipes</u> sp.	14											
<u>Paralauterborn</u>. sp.	86								43			
<u>Phaenopsectra</u> sp.					29							
<u>Polypedilum</u> sp.	43	14			14	14	14			43		
<u>Stictochironomus</u> sp.	43											
<u>Tribelos</u> sp.					14							
<u>Tanytarsus</u> sp.	158	72	43		43	29	14		186	14		
<u>Cricotopus</u> sp.									14			
Chironomid pupae								14*		14*		43*

*These values included in density totals but not used in determining total number of species or species diversity since they are unidentifiable immature forms and probably do not represent different species.

Table 13. Density (individuals/m^2) of benthic macroinvertebrates by station and depth in Ham's Lake on 30 July 1974.

	Station 8			Station 1			Station 2		
Depth (m):	1	4.5	8	1	4.5	8	1	4.5	8
Aulodrilus pigueti								14	
Limnodrilus udekemianus							14		
Tubif. w/cap. ch.					14*		14*		
Hyalella azteca							14		
Hexagenia limbata	215						244		
Caenis sp.	14						14		
Baetidae				14					
Epicordulia sp.				86					
Sialis sp.				100		14	72		
Leptoceridae	14								
Chaoborus punctipen.	29	86	731	29	43	1406			57
Coelotanypus sp.			14	14	14	14	43	100	
Procladius sp.	1492	14		316	301		387	459	
Tanypus sp.	230		14	29	100		43	100	
Pentaneurini	43						72	29	
Chironomus sp.	158	14		129	158	215		100	72
Cryptochironomus sp.							14		
Dicrotendipes sp.	14			29					
Glyptotendipes sp.						14			
Goeldichironomus sp.	14						29		
Paralauterborn. sp.	14								
Phaenopsectra sp.				29			57		
Polypedilum sp.	29			43			14		
Pseudochironomus sp.	14								
Stictochironomus sp.							14		
Chironomini sp. A	14								
Chironomini sp. B	14								
Chironomini sp. C	14			14					
Tanytarsus sp.	976				14	14	473	14	
Chironomid pupae	43*		14*				14*		

*See footnote on Table 12.

Table 14. Density (individuals/m^2) of benthic macroinvertebrates by station and depth in Ham's Lake on 22 August 1974.

	Station 8			Station 1			Station 2		
Depth (m):	1	4.5	8	1	4.5	8	1	4.5	8
Nais variabilis	57	57			14		14		
Aulodrilus pigueti		29						72	
Limnodrilus cervix					29	14			
Tubif. w/out cap. ch.	43*				29*	14*			
Astacidae							14		
Hyalella azteca							14		
Hexagenia limbata	72			29			57	14	
Caenis sp.								14	
Epicordulia sp.							14		
Macromia sp.							29		
Somatochora sp.				57					
Sialis sp.	43	14		14			29		
Leptoceridae	14						14		
Polycentropus sp.		14							
Ceratopogonidae	29			86	43	29		14	
Chaoborus punctipen.	14	172	818		43	4362	72	29	674
Anatopynia sp.	14								
Coelotanypus sp.		14		43		43	14	129	86
Pentaneura sp.				14					
Procladius sp.	473	186	14	602	215	43	72	143	57
Tanypus sp.	115		43	789	172	43		14	72
Pentaneurini				43	43				
Chironomus sp.	100	14	86	502	301	100		301	158
Cryptochir. abortivus				14					
C. sp.	43			29			43		
Dicrotendipes sp.	29						72		
Harnischia sp.	86	14		316			14		
Paralauterborn. sp.				29					
Polypedilum sp.				100	14		29		
Pseudochironomus sp.	29								
Tanytarsus sp.	502	29		57			186	43	
Orthocladius sp.	115						29		
Chironomid pupae	14*			86*					14*

*See footnote on Table 12.

Table 15. Density (individuals/m^2) of benthic macroinvertebrates by depth in Ham's Lake on 1 March 1975.

	Depth (m)							
Taxa	1	2	3	4	5	6	7	8
Hydra sp.		22						
Dero digitata	4575	506	172		11	108	64	215
Nais sp.	32							
Stylaria lacustris	247	22						
Aulodrilus pigueti	3337				86	161	11	11
Ilyodrilus sp.	1388	11	22					
Limnodrilus cervix.			11					
L. claparedianus	97							
Tubif. w/cap. ch.	118*							
Tubif. w/out cap. ch.	43*	97*	54*	11*				22*
Hydracarina	32	11		11				
Hyalella azteca	527	11						
Hexagenia limbata	22	484	64	64		11		11
Caenis sp.	151	11						
Gomphus sp.		11						
Plathemis sp.	32							
Ischnura sp.	43	43						
Sialis sp.	54	11			11	22		
Oecetis sp.	140	11				11		
Berosus sp.	32							
Ceratopogonidae	2400	355	161					
Chaoborus punctipen.	118	258	355	22	560	1991	2120	4101
Coelotanypus sp.	118	118	11		108	377	549	646
Procladius sp.	312	947	420	22	204	183	334	721
Chironomus sp.	22	22			11	11	22	97
Cryptochironomus sp.		32	22		11	11	97	32
Dicrotendipes sp.	1108							
Paralauterborn. sp.	312							
Polypedilum sp.	97							
Tribelos sp.	54					11		
Micropsectra sp.	108		11			11		
Tanytarsus sp.	883	64	54	14				
Psectrocladius sp.	11				11			22
Pisidium sp.		11						
Gyralus sp.	204							
Physa sp.	22							

*See footnote on Table 12.

Table 16. Density (individuals/m^2) of benthic macroinvertebrates by depth in Ham's Lake on 21 May 1975.

	Depth (m)							
Taxa	1	2	3	4	5	6	7	8
Dugesia sp.	118							
Chaetogaster sp.	125							
Dero digitata	3530	646	700	108	301	108	54	237
Stylaria lacustris	1259					32		
Aulodrilus pigueti	86							
Ilyodrilus sp.	624							
Limnodrilus cervix	43		108	151				
L. claparedianus				11				
Tubif. w/out cap. ch.	32*		172*		11*		11*	
Astacidae	11							
Hyalella azteca	125							
Hexagenia limbata	237	172	441	231	161	86		
Caenis sp.	97							
Centroptilum sp.	11							
Gomphus sp.	11							
Sympetrum sp.	11							
Ischnura sp.	11							
Sialis sp.	22	43	172		11			
Oecetis sp.	11							
Ceratopogonidae	1216	64	377	151	54	75	54	108
Chaoborus punctipen.	11			11			65	86
Ablabesmia sp.	11							
Coelotanypus sp.	32		43	32	11	54	194	43
Procladius sp.	850	258	172	97	65	75	11	22
Chironomus sp.								11
Dicrotendipes sp.	22						11	22
Endochironomus sp.	11							
Harnischia sp.			11	11		22	11	
Lauterborniella sp.					11			
Paralauterborn. sp.	140				11			
Polypedilum sp.	22							
Pseudochironomus sp.							11	
Micropsectra sp.	54		11					
Tanytarsus sp.	474	54	11			22	22	
Chironomid pupae	11*	11*				22*		
Pisidium sp.		11	11	11	11			
Gyralus sp.	11							
Physa sp.	11							

*See footnote on Table 12.

Table 17. Density (individuals/m^2) of benthic macroinvertebrates by depth in Ham's Lake on 14 June 1975.

	Depth (m)							
Taxa	1	2	3	4	5	6	7	8
Dugesia sp.	366							
Nematoda	11	11	11					
Chaetogaster sp.	11							
Dero digitata	2400	183	226	54	11	11	22	11
Stylaria lacustris	1141							
Aulodrilus pigueti	75		11					
Limnodrilus hoffmeist.	86		108					
Tubifex tubifex	334			75				
Tubif. w/out cap. ch.	75*		75*	75*	32*			
Hydracarina	11				11			
Astacidae	32							
Hyalella azteca	635							
Hexagenia limbata	86	86	204	43				
Gomphus sp.	11							
Coenagrionidae	11							
Sialis sp.	75	108	237	32				
Molanna sp.	11							
Ceratopogonidae	312	43	129	32	11			11
Chaoborus punctipen.		43		22	22	581	775	646
Ablabesmia sp.	32	11	11	11				
Coelotanypus sp.			43	22		32	22	32
Procladius sp.	64	54	64	22				
Tanypus sp.			22			11	32	11
Dicrotendipes sp.	22							
Harnischia sp.		11						
Parachironomus sp.	32							
Paralauterborn. sp.		11						
Polypedilum sp.	64	11						
Stenochironomus sp.	11							
Tribelos sp.	22							
Rheotanytarsus sp.	108	11		11				
Tanytarsus sp.		22						
Pisidium sp.				54	32			

*See footnote on Table 12.

Table 18. Density (individuals/m^2) of benthic macroinvertebrates by depth in Ham's Lake on 10 July 1975.

Taxa	Depth (m) 1	2	3	4	5	6	7	8
Nematoda		11						
Dero digitata	344	904	527	97	43	32	11	
Limnodrilus cervix			32					
L. hoffmeisteri	11		11					
Tubifex tubifex	97							
Tubif. w/out cap. ch.			215*	43*	11*			11*
Hydracarina	22	11						
Hyalella azteca	11							
Hexagenia limbata		161	140	32		11		
Caenis sp.	11							
Epicordulia sp.	32							
Coenagrionidae	32							
Sialis sp.	129	183	215	32				
Oecetis sp.	11						11	
Halipus sp.	22							
Ceratopogonidae	108	86	32	43		11		32
Chaoborus punctipen.		11	43	43	75	140	226	420
Ablabesmia sp.	22	118	86	11		11		
Coelotanypus sp.	11	11	32	11	54		54	32
Procladius sp.	54	710	388	161	11			
Tanypus sp.			11				22	
Chironomus sp.								11
Dicrotendipes sp.	11							
Harnischia sp.		97						
Parachironomus sp.	11		11					
Paralauterborn. sp.		22						
Phaenopsectra sp.	118							
Polypedilum sp.	11		11	11				
Tribelos sp.	11							
Tanytarsus sp.		140	97	11				
Chironomini sp. F							11	
Chironomid pupae		11*	11*					
Pisidium sp.			43	11				

*See footnote on Table 12.

Table 19. Density (individual/m^2) of benthic macroinvertebrates by depth in Ham's Lake on 31 July 1975.

Taxa	Depth (m) 1	2	3	4	5	6	7	8
Dero digitata	NS	398	1270	151	32	22		11
Aulodrilus pigueti		11	151	11		11		
Limnodrilus cervix			54	11				11
Tubif. w/cap. ch.			11*	43*				
Tubif. w/out cap. ch.			237*					
Hydracarina			11			11		
Hexagenia limbata		22	32					
Caenis sp.			11					
Sialis sp.		64	118	11		118	22	11
Ceratopogonidae			22	43	32	43	54	204
Chaoborus punctipen.		11	22	22	11	140	344	215
Ablabesmia sp.		11	22	11				
Coelotanypus sp.		54	11	32		183	64	118
Procladius sp.		172	248	43		32	11	22
Tanypus sp.		43	11					11
Pentaneurini		11						
Chironomus sp.						22		
Dicrotendipes sp.		11						
Harnischia sp.		86						
Parachironomus sp.								
Paralauterborn. sp.		11						
Polypedilum sp.			32					
Rheotanytarsus			11					
Tanytarsus sp.		54	97	22				
Pisidium sp.			11			11		

NS - Not sampled due to dense growth of aquatic macrophytes.

*See footnote on Table 12.

VITA

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