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POPULATION OF BENTHIC MACROINVERTEBRATES IN HAM'S LAKE

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PREFACE

This research is part of a continuing study of the effects of artificial destratification on physiocochemical and biological conditions in Ham's Lake. The lake was destratified from 1972-1976 by a pump developed by Dr. James Garton, Department of Agricultural Engineering, Oklahoma State University. Various research projects have been supported by the Office of Water Research and Technology, the Oklahoma Water Resources Research Institute (OWRRI), and the Bureau of Reclamation. Mr. Howard Jarrell, Associate Director of the OWRRI, coordinated the research. Dr. Dale Toetz directed studies on water chemistry, productivity, and algal species composition and diversity. Dr. Robert Summerfelt and Dr. Toetz performed some studies on fish distribution. Dr. Jerry Wilhm conducted studies on the zooplankton and benthic macroinvertebrate distribution. The major emphasis in the present study is on changes produced in the sediments resulting from artificial destratification.

This project would not have been possible without the cooperation of the following professors at Oklahoma State University in providing direction, equipment, and laboratory space:

Dr. John Sauer, Department of Entomology - hemolymph and osmoregulation studies
Drs. Robert Reed and Lester Reed, Department of Agronomy - particle size analyses and organic carbon in the sediments

In addition to the graduate research assistants who co-authored the report, the following people assisted in the project:

Steve Monn - benthic macroinvertebrate sampling
Rick Fehler - heavy metal analyses
Robert Mahnken - field and laboratory assistant
Robert Clay - field and laboratory assistant
Kathryn Turner - laboratory assistant
Pam Guenther - laboratory assistant
Mike Gaskins - laboratory assistant

Steve Monn and Rick Fehler will co-author a supplement to this report:

A complete description of the pumping operations and the various research projects is given in Garton et al. (1976).

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

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Population of Benthic Macroinvertebrates in Ham's Lake

Jerry L. Wilhm

Oklahoma Water Resources Research Institute

A-067-OKLA

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Ham's Lake, Oklahoma, was destratified during summer 1976 by pumping surface water to the bottom. Number of species, diversity, and density of benthic macroinvertebrates were significantly correlated with the concentration of dissolved oxygen, while none of the biotic variables were correlated with temperature. Percent loss on ignition and $CaCO_3$ of the sediments generally decreased with increasing sediment depth. During 1977 pumping was not applied. The variables measured will be compared with values obtained in 1978 when the lake will again be destratified. In 1977 the lake had stratified thermally and chemically by 15 April. The depth of sediment deposited averaged 3.6 mm/month or 261 g/m^2 per month. Sediment particle size was less at the 8 m stations than at the 2 m stations. Percent organic carbon in the sediments ranged from 1.0-8.6. A gradual decrease in hemolymph ions (Na^+, K^+, CL^-) in Chaoborus punctipennis was observed from May through September and a return to higher concentrations in October. The lake water at the bottom contained low concentrations of these ions until August. A decrease in osmotic pressure was measured in C. punctipennis during the summer reflecting the trends in fluctuation of hemolymph ions.

Measurements were also made of the concentration of copper, iron, manganese, and phosphorus of the water and sediments and the distribution and diversity of benthic macroinvertebrates. These data will be reported in a supplement to this report.

17a. Descriptors

artificial destratification*, dissolved oxygen concentration*, sediments, sedimentation rate, sediment particle size, percent organic carbon of sediments, hemolymph ions, osporegulation

17b. Identifiers

Ham's Lake, Oklahoma

V-c

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Oklahoma State University

INTRODUCTION

Many lakes stratify during summer resulting in depletion of oxygen in the hypolimnion (Hutchinson 1957). Reduced forms of nitrogen and sulfur accumulate as ammonia and sulfide, respectively, and manganese and iron go into solution. The concentration of dissolved hydrocarbons may also increase. Anoxic conditions and the increase of certain chemicals in the hypolimnion of stratified lakes influence distribution and density of the biota and may result in fish kills.

Artificial mixing of lakes has been attempted by mechanical pumping of water or compressed air to improve water quality and extend the depth distribution of the biota (Robinson et al. 1969, Inland Fisheries Branch 1970, Anon 1971, Fast 1971, Lackey 1971, Malueg et al. 1971). Many of these studies have concentrated on only one aspect of the environment and have lacked adequate controls. The studies of the effects of artificial destratification in Ham's Lake have included measurements of physicochemical conditions of the water, distribution and biomass of the algae, productivity, species composition and diversity of the zooplankton and benthic macroinvertebrates, and standing crop of fish.

The objective of the study in summer and fall, 1976, was to compare the vertical variation in temperature, dissolved oxygen, and the diversity of benthic macroinvertebrates in an area of Ham's Lake artifically destratified by mechanical pumping of surface water to the bottom with an arm of the lake not destratified. Pumping was not used in the lake in 1977 and the objective was to provide background data that will be compared with values obtained in 1978 when the lake will again be destratified. The following variables were sampled in 1977.

Water
- Temperature
- Dissolved oxygen
- pH
- Conductivity
- Turbidity
- Copper, iron, manganese

Sediments
- Sedimentation rate
- Sediment particle size
- Percent organic carbon
- Phosphorus
- Copper, iron, manganese
- pH

Organisms
- Diversity of benthic macroinvertebrates
- Hemolymph ion concentration and osmoregulation of *Chaoborus punctipennis* (phantom midge)

DESCRIPTION OF HAM'S LAKE

Ham's Lake is located in Payne County, Oklahoma, about 8 km W of Stillwater (Figure 1). The lake was constructed in 1965 by the Soil Conservation Service as a flood prevention reservoir. Morphometric features of the lake are as follows:

Drainage area	-	14.7 km^2
Pool length	-	1.2 km
Shoreline length	-	11.2 km
Shoreline development	-	5.0 km
Surface area	-	40 ha
Maximum depth	-	10 m
Mean depth	-	2.9 m
Volume	-	115 ha-m
Lake area: watershed area	-	1.37

Although Ham's Lake is relatively shallow with a mean depth of 2.9 m, it stratifies thermally from May through October (Steichen 1974). The lake was used for a caged catfish farming operation during 1971 and 1972 resulting in an input of large quantities of organic matter in the form of uneaten food and catfish feces. Following a week of cloudy, cool weather in August, 1972, a sudden overturn resulted in the death of 150,000 caged catfish. Steichen reported that after the overturn dissolved oxygen was nearly zero and ammonia and hydrogen sulfide were mixed throughout the water column.

During the summer, 1972, a Garton pump was installed in Ham's Lake (Strecker 1976) and some preliminary tests were conducted. The pump also operated for a month following the death of the catfish to oxidize the heavy organic load at the bottom of the lake. During 1973 further improvements were made in the pump and the lake was destratified. Ham's Lake was prevented from stratifying in 1974 by the pump and destratified in 1975 and 1976. Pumping was not applied in 1977.

A number of studies of physicochemical and biological conditions have been conducted in the lake (e.g. Wilhm 1975, Ferraris and Wilhm 1977, McClintock and Wilhm 1977). A description of all the projects is given in Garton et al. (1976).

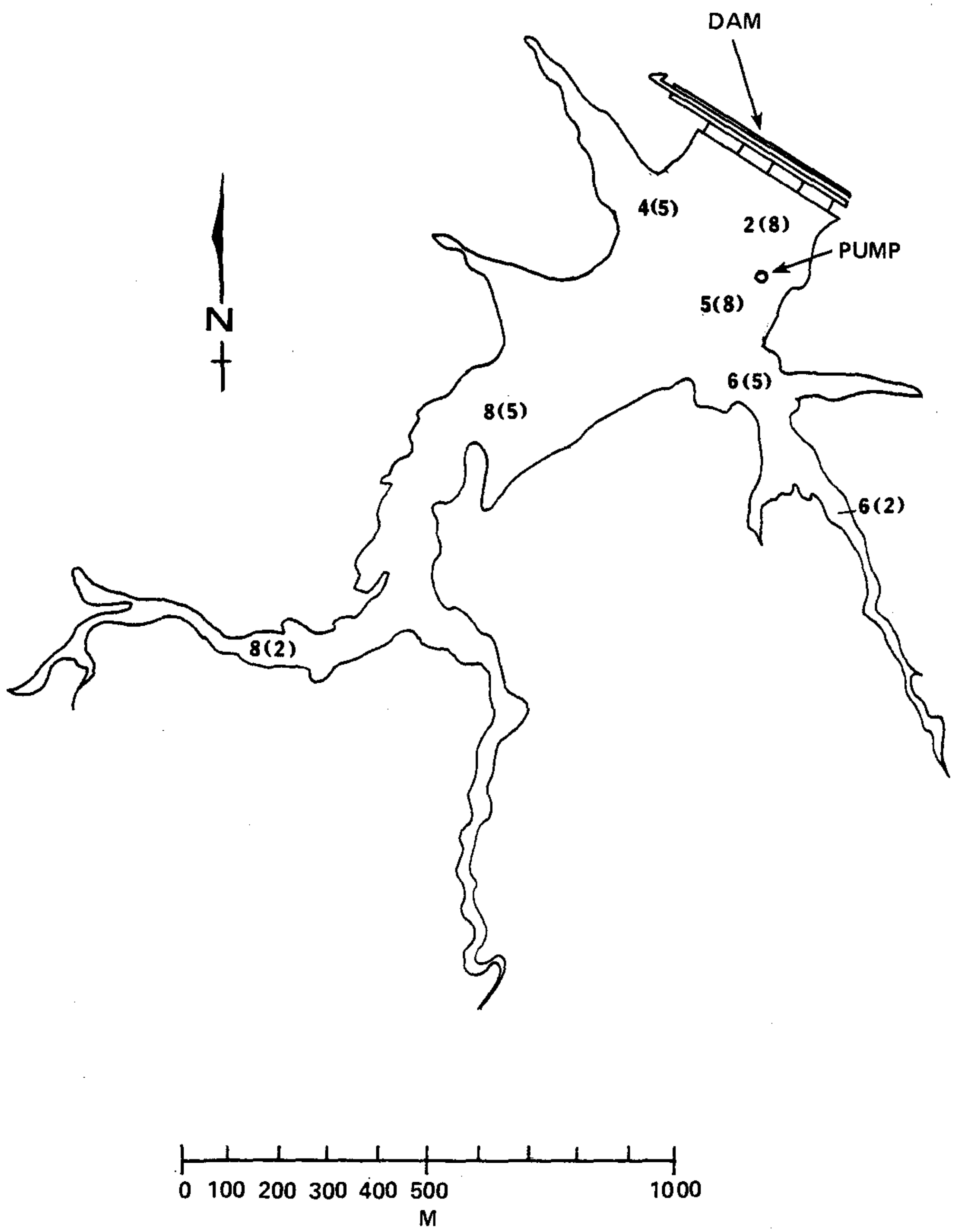


FIGURE 1. HAM'S LAKE SHOWING SAMPLING STATIONS

METHODS

1976 Study

We measured temperature, dissolved oxygen, and diversity of benthic macroinvertebrates on 2 June, 18 June, and 2 July in two adjacent channels in the central pool of Ham's Lake. The two channels, each about 9 m deep, are about 75 m apart and are separated by a ridge about 5 m below the water surface. The channels are connected near the dam. The pump was placed over the channel nearest the east bank of the lake and one station was located in this channel about 10 m from the pump (station 5 E). Pumping began on 3 June. We expected that the channel nearest the west bank (station 5 W) would be anoxic most of the summer, permitting comparisons of the effects of pumping on diversity of macroinvertebrates in an aerated and an anoxic area. However, by 2 July temperature and the concentration of dissolved oxygen (DO) were similar on the bottom in both channels and most of the lake was mixed.

On 2 July, we found an arm of the lake that was still stratified. This area is about 5 m deep and separated from the central pool by a ridge about 1.5 m below the water surface preventing the arm from being mixed by the pump. The ridge is the dam of a farm pond which was submerged when Ham's Lake was filled. The dam blocks the flow of density currents which are created during pumping operations. Thus, the lake retains a small area of anaerobic hypolimnion isolated from the main body of the lake. The station in this arm (station 4) was about 50 m from the station in the east channel in the central pool (station 5 W). Measurements were made in these two areas on 7 July, 3 August, 20 August, and 25 October. The latter sample was taken after the arm had destratified naturally.

Temperature and DO were measured with a Yellow Springs Instrument (YSI) model 54 oxygen meter at 1 m intervals from the surface to the bottom. To measure the variation in the composition and diversity of benthic macroinvertebrates, six Ekman dredge hauls were taken from each channel. Organisms were analyzed by standard techniques (Weber 1973) and the pooled diversity ($\bar{d}$) of the six samples was calculated by the entropy expression of Shannon and Weaver (1963). Six replicate cores were taken with a benthic corer and analyzed for loss on ignition and $CaCO_3$ at sediment depths of 0-2, 8-10, and 18-20 cm. Loss on ignition was determined gravimetrically by drying samples at 105°C and ashing at 550°C. Ignition loss between 550°C and 1000°C was assumed to represent loss of CO_2 from carbonate minerals and percent calcium carbonate was calculated by multiplying the percent ignition loss between this range by 2.27 as described by Dean (1974).

1977 Study

Sampling Stations and Times. We established two stations at depths of 2 m in two arms of the lake, two 5 m stations in the lake where the arms enter, and two 8 m stations in the central pool. Samples were also taken in the anoxic area described in the 1976 study. Thus, the following stations were established (station numbers correspond to those used in concomitant studies; numbers in parentheses denote approximate depth) (Figure 1).

6 (2)	6 (5)	5 (8)	4 (5)
8 (2)	8 (5)	2 (8)	

Station 4 (5) and two areas in the vicinity of 5 (8) were the stations sampled in 1976.

Most variables were measured in the middle of the month in,

1) April
2) May
3) June
4) August
5) October

The lake had destratified naturally prior to the October sample.

Water. We measured temperature, DO, and conductivity at 1 m intervals from the surface to the bottom at the three 5 m depths, at the two 8 m depths, and at mid-depth at the two 2 m depths. Measurements were made with a YSI model 54 oxygen meter and a YSI model 33 conductivity meter. pH of the water was measured with a Corning model 610 pH meter at the surface and bottom at the 5 and 8 m depths and at mid-depth at the two 2 m areas. Turbidity was established at the same depths by collecting three replicates each and analyzing on a Bausch and Lomb Spectronic 20.

The concentrations of copper, iron, and manganese were determined by collecting three replicate samples each of surface and bottom water at stations 5 (8), 2(8), and 4 (5) and mid-depth samples at the two 2-m stations. Samples were analyzed by atomic absorption for total and soluble metals. The complete description of the method will be described in a supplement to this report.

Sediments. The rate of sedimentation was estimated by installing traps, suspended 1 m from the bottom, at Stations 6 (5), 8 (5), 5 (8), 2 (8), and 4 (5) from 5 July - 4 August. Traps consisted of eight nalgene wide mouth plastic collecting bottles (mouth = 43 mm) attached to two crossed cedar boards 3.7 x 8.8 cm and 60 cm in length. Four bottles were upright to estimate sedimentation and periphyton growth and four were upside down to provide a correction for periphyton growth. After an exposure of 30 days, the bottles were collected and the material in the upright bottles was washed into a shell vial (mouth = 23 mm) to estimate the depth of sedimentation. It was then analyzed gravimetrically to determine oven dry weight. The material in the upside down bottle was removed by scraping and analyzed gravimetically. Oven dry weight of the sediments was determined as the difference between the mean of the four upright bottles and the mean of the four upside down bottles. After drying the sediments in the upright bottles were analyzed for percent organic carbon by the Schollenberger oxidation procedure.

Particle size of the sediments was estimated at stations 6 (2), 8 (2), 5 (8), and 4 (5) by collecting four Ekman dredge samples from each station and using a hydrometer to estimate the percent of the different sized particles. Samples were collected in all months except May. The top 2 cm of sediment was scooped from each of the four replicate samples. Sediments were oven dried at 60°C, ground to a size 60 mesh, and sieved to remove leaf litter. A mixture of 25 g of sediment and 50 ml of distilled water was brought to a pH of 9 by adding a 2% of sodium carbonate-sodium bicarbonate ($Na_2CO_3 \cdot Na\,H\,CO_3$). The mixture was transferred to a dispersal cup and enough distilled water was added to make a 1000 ml volume. After dispersal with a Hamilton Beach mixer, samples were transferred to a 1000 ml cylinder and placed in a constant temperature room. Hydrometer readings were made at 0.5, 1, 3, 10, 20, 120, and 720 min. Percentages of soil in suspension at the different times were calculated by the formula described in the American Standards Testing Manual (1977) and the diameter of the soil particles calculated by Stokes Law.

Organic carbon of the sediments was determined at the same stations sampled for particle size. Four replicate samples were obtained by pushing four polyethylene tubes, 2.5 cm in diameter, into an Ekman dredge sample. The cores were sealed with cork stoppers, placed on ice, and frozen until analyzed. Samples were oven dried at 60° C and analyzed by the Schollenberger method.

pH of the sediments was estimated by collecting sediments with an Ekman dredge and measuring with a Corning model 610 pH meter. pH was measured at all stations.

The concentrations of copper, iron, and manganese were determined by collecting three replicate samples with a benthic corer at the same stations analyzed for particle size. Samples were frozen and analyzed later by atomic absorption for soluble, sorbed, and total metals. The concentration of inorganic phosphorus was also determined by collecting three replicate cores and analyzing chemically by measuring the reactivity with molybdate. The complete description of the methods used for determining the concentration of heavy metals and phosphorus will be in a supplement to this report.

Benthic Macroinvertebrates. Species composition and diversity of the macroinvertebrates was estimated by collecting four replicate samples with an Ekman dredge at all stations. In addition, samples were collected at 1 m station farther upstream in the arms from stations 6(2) and 8 (2). The samples are currently being sorted and analyzed.

Hemolymph Ions. Larval *Chaoborus punctipennis* and *Chironomus* sp. were collected with an Ekman dredge from stations 6 (2), 5 (8), and 4 (5) in May, June, August, September, and October. Before collecting the benthic macroinvertebrates, bottom water was collected with a Van Dorn sampler and placed in prelabeled glass jars (900 ml). The larvae were placed in the jars with water from their natural habitat. The jars were transported in ice chests to the laboratory. All organisms were maintained in the laboratory at ambient temperature as recorded at the time of sampling.

Organisms were weighed on a Mettler balance. Hemolymph was obtained from both dipteran larvae for analyses of sodium (Na), potassium (K) and chloride (Cl) concentrations. Under a dissecting microscope (100 X), the larvae were surface dried and placed on masking tape. A dorsal mesothoracic punture was made with a #2 insect pin. The hemolymph which issued from the wound was collected in disposable glass micro-pipettes (microcaps). All samples were analyzed immediately after collection.

Hemolymph Na and K samples (0.5 µl) were transferred into 300 µl of deionized water for analysis with a Beckman 400 atomic absorption (AA) spectrophotometer. Measurement of Na and K were made on individual insects. Chloride analysis was made directly without dilution using 10.0 µl of hemolymph from several larvae. Chloride concentrations were measured with a Fiske/Marius microchlor-o-counter. Lake water obtained from each sampling station was analyzed for Na, K, and Cl using the AA spectrophotometer and chlor-o-counter.

The freezing point depressions of the hemolymph and lake water were measured with a Clifton technical physics nanoliter osmometer, sensitive to the nearest ± 0.001° C (Frick and Sauer 1973). Less than 0.5 µl of fluid was required for an assay.

RESULTS AND DISCUSSION

1976 Study

Samples collected on 2 June revealed little difference in temperature, dissolved oxygen (DO) concentration, or diversity of benthic macroinvertebrates in the two 8 m channels in Ham's Lake (Table 1). Coelotanypus sp. was the most abundant organism in both channels. Pumping began on 2 June and on 18 June vertical variation in temperature and DO was small in the channel containing the pump (station 5 E). However, DO was still limiting on the bottom in the adjacent channel and diversity decreased sharply resulting from low equitability. Although number of species did not change between 2 and 18 June in this channel, the density of Chaoborus punctipennis increased from 244 to 1663 individuals/m and this species comprised 94% of the total density.

On 2 July, little difference existed in temperature or DO on the bottom in the two channels. On 7 July we initiated a study comparing variables at the maximum depth of 5 m in the arm that was not mixed by pumping (station 4) with measurements made at the same depth in the destratified portion of the lake (station 5 W). The stations were about 20 m apart and separated by a ridge which prevented the arm from being mixed as described in the METHODS. DO averaged 5.7 mg/l at 5 m at station 5 W. Fifteen taxa were collected. C. punctipennis was the most abundant species comprising 42% of the total density. Three other species, Hexagenia limbata, Ablabesmyia sp., and Coelotanypus sp., made up 35% of the assemblage. At the stratified station, (Station 4), DO averaged 0.1 mg/l and diversity was 0.2. Only two species were collected and C. punctipennis comprised 96% of the total density. Density was considerably less on the bottom at station 4.

On 3 August, benthic samples were taken from areas that were 1, 3, and 5 m deep at both stations. Little difference existed in temperature or DO at the different depths at station 5 W. Numbers of species decreased with depth; however, minimum diversity existed at 3 m. C. punctipennis was the most abundant organism at 5 m, while Aulodrilus pigueti was the most common at 1 and 3 m. C. punctipennis midge was rare at 1 m, while A. pigueti was not collected at 5 m. In the stratified arm DO was relatively high at 1 and 3 m. Numbers of species and diversity at 1 and 3 m were similar at the two stations; however, density was less at all depths in the stratified arm. DO was extremely low at 5 m at Station 4 and diversity was 0.3. Only four taxa were collected and C. punctipennis comprised 96% of total density.

Between 3 and 20 August, the number of species and diversity increased at the destratified station. DO and diversity remained relatively low in the stratified arm.

Samples were taken on 25 October after the stratified arm had turned over. DO had increased to 9.2 mg/l at 5 m at Station 5 W and to 10.1 on the bottom at Station 4. Although numbers of species and diversity decreased to 12 and 1.5, respectively, in the destratified area, values increased to 4 and 1.9 at Station 4 and density doubled. C. punctipennis was still the most abundant species at each station, but several other species were also common.

Although the depth distribution of benthic macroinvertebrates is influenced by a number of environmental factors, the DO of the water adjacent to the bottom is a major limiting factor (Ruttner 1963). Benthic macroinvertebrates differ in their rate of oxygen consuption (Olson and Rueger 1968) and in their ability to withstand anoxic conditions (Walshe 1947, Thienemann 1954). A limited benthic fauna

Table 1. Temperature (^{o}C), dissolved oxygen (mg/1), total number of species (s), individuals/m^2 (n), and pooled diversity* of benthic macroinvertebrates in Ham's Lake in 1976.

Date	Water Depth (m)	Station 5 E**					Station 5 W**					Station 4**				
		Temp	DO	s	n	$\bar{d}$	Temp	DO	s	n	$\bar{d}$	Temp	DO	s	n	$\bar{d}$
2 Jun	1	24	9.8				24	10.1								
	8	16	0.2	7	538	1.9	16	0.4	7	387	2.1					
18 Jun	1	25	7.8				25	7.5								
	8	24	6.0	6	366	1:6	22	0.8	7	1785	0.1					
2 Jul	1	26	6.4				26	6.5								
	8	26	5.2				26	5.1								
7 Jul	1						26	7.0				26	7.1			
	5						25	5.3	15	1283	2.8	19	0.1	2	409	0.2
3 Aug	1						27	5.7	15	1850	2.7	28	6.3	13	609	3.0
	3						27	5.4	10	1455	1.7	27	5.4	8	344	1.6
	5						27	5.6	8	1326	2.1	20	0.2	4	910	0.3
20 Aug	1						28	5.9				29	8.3			
	5						28	4.5	16	1792	3.0	22	0.1	4	961	0.8
25 Oct	1						12	9.5				12	11.0			
	5						12	9.2	12	1448	1.5	11	10.1	11	1957	1.9

* Total numbers of species, mean density, and pooled diversity of six replicate samples

** Stations 5 E was in a channel in the central pool containing the pump; station 5 W was in an adjacent channel; Station 4 was in an anoxic arm.

in areas below impoundments was attributed to seasonally low oxygen tension (Isom 1971). Dispersal of chironomid larvae from areas of low oxygen concentration has been reported (Bay et al. 1966, Hilsenhoff 1966). The distribution of benthic macroinvertebrates has also been related to the temperature near the bottom.

In the 1976 study numbers of species and diversity were correlated with DO at the 0.01 level of significance and density at the 0.05 level (Table 2). None of the biotic variables were correlated with temperature. Although a variety of factors influence the variety and density of benthic macroinvertebrates, the importance of the concentration of DO as a limiting factor was clearly demonstrated in Ham's Lake during artificial mixing.

Loss on ignition of the sediments varied from 2.2 - 9.9% (Table 3). Values generally decreased with sediment depth. It was expected that the percents would increase significantly in the surface sediments at Station 4, the anoxic arm, during summer. However, values were similar to those measured at Station 5 W. $CaCo_3$ varied from 1.0 to 9.0% dry weight and values generally decreased with depth. No definite trends were observed.

1977 Study

Water. On 15 April vertical variation of temperature and DO were relatively small at the 5 m depths in the central pool (Station 6, 8) and larger at the 8 m depths (Stations 5, 2) and at the 5 m depth in the arm that remained stratified in 1976 (Station 4) (Table 4). Conductivity was relatively uniform at all stations. By 27 May temperature had increased and DO decreased at all stations. DO was strongly stratified at the 5 m stations as well as at 8 m and 4 (5). DO was 0.1 on the bottom at Station 4 (5). pH was generally lower at the bottom than at the surface reflecting an increase in CO_2 at the bottom. At the 8 m stations conductivity decreased abruptly between 15 April and 27 May in the bottom water. These low values were not expected in this eutrophic lake. Values remained high in the bottom water at Station 4 (5). Turbidity of the bottom water was extremely high at the 8 m stations, reflecting heavy spring precipitation and runoff. By 23 June, DO was near zero at the 5 and 8 m stations and pH was still generally lower in the bottom water than at the surface. Although turbidity was still somewhat higher at the bottom than at the surface, values decreased abruptly between 27 May and 23 June on the bottom water. Temperature continued to increase between 23 June and 15 August, while temporal changes in DO were relatively small. pH continued to be lower and conductivity lower at the bottom than at the surface at the 8 m stations. Conductivity was higher at the bottom at Station 4 (5) than at the surface which is what was expected because of the accumulation of ions in the hypolimnion. By 26 October the lake had turned over as evidenced by the temperature and dissolved oxygen values, conductivity generally decreased between 15 August and 26 October and was relatively uniform throughout the reservoir.

Sediments. The depth of sediment deposited between 5 July and 4 August ranged from 3.1 - 4.3 mm/month representing a weight from 192-409 g/m^2 per month (Table 5). Little variation existed in the per cent organic carbon.

The mean of all sediment samples taken during the study demonstrated that particle size was less at the 8 m stations than at the 2 m stations (Table 6). After 12 h (720 min), 56 and 60% of the particles remained in solution at Stations 5 (8) and 2 (8), respectively, while 31 and 22% remained at Stations 6 (2) and 8 (2). The particle size at Station 4 (5) was intermediate. The percent remaining after 12 h was comprised of particle < 0.002 mm. The relationship between the percentage of finer particles remaining in solution and the diameter of the particles is

Table 2. Correlation coefficients between temperature and dissolved oxygen and the number of taxa, density, and diversity of benthic macroinvertebrates in Ham's Lake in 1976.

Independent Variable	Number of Taxa	Density	Diversity
Temperature	.34	.05	.39
Dissolved Oxygen	.67**	.47*	.57**

* p= .05
** p= .01

Table 3. Vertical variation in percent loss on ignition (LI) and percent $CaCO_3$ in sediments collected at a water depth of 5 m in Ham's Lake.

Station*	Variable**	Sediment depth (cm)	Collecting Date			
			18 Jun	20 Jul	3 Aug	1 Nov
5 E	LI	0-2	6.7	-	-	-
		8-10	5.6	-	-	-
		18-20	4.0	-	-	-
	$CaCO_3$	0-2	7.9	-	-	-
		8-10	7.8	-	-	-
		18-20	3.7	-	-	-
5 W	LI	0-2	7.9	9.9	8.4	8.2
		8-10	3.4	8.5	6.0	6.0
		18-20	4.7	6.6	3.2	6.9
	$CaCO_3$	0-2	7.4	2.6	4.9	1.9
		8-10	3.7	2.1	4.2	2.4
		18-20	3.8	2.0	3.0	3.0
4	LI	0-2	9.9	6.5	8.0	8.6
		8-10	8.5	4.4	5.9	7.0
		18-20	6.6	2.2	8.6	5.1
	$CaCO_3$	0-2	2.6	4.2	9.0	6.0
		8-10	2.1	2.3	8.7	4.6
		18-20	2.0	1.0	7.0	6.9

* Stations described in footnote (**) in Table 1

** Values are means of six replicate cores

\- Samples not obtained

Table 4. Physicochemical conditions of the water in *Ham's Lake* in *1977*.

Variable	Station*	Depth**	Collecting Date				
			15 Apr	27 May	23 Jun	15 Aug	26 Oct
Temperature (°C)	6(2)	M	20.4	24.2	29.5	30.0	18.5
	6(5)	S	21.5	24.5	31.0	31.0	20.0
		B	18.0	19.5	28.0	27.5	18.0
	8(2)	M	20.4	23.5	29.5	29.8	17.8
	8(5)	S	20.9	24.0	27.5	32.0	19.0
		B	17.7	19.0	20.1	27.0	18.0
	5(8)	S	21.5	24.0	27.5	30.0	19.0
		B	15.5	17.8	18.0	18.1	16.5
	2(8)	S	21.2	24.0	27.5	29.8	18.5
		B	15.8	18.0	18.5	19.0	16.5
	4(5)	S	20.2	24.0	27.5	30.0	19.0
		B	17.5	19.0	19.5	21.9	16.5
Dissolved Oxygen (mg/l)	6(2)	M	9.2	5.9	7.8	5.8	8.7
	6(5)	S	9.4	7.1	7.8	7.0	8.7
		B	7.1	2.4	0.8	2.0	6.6
	8(2)	M	9.2	5.8	5.8	5.7	8.6
	8(5)	S	9.2	6.4	5.4	7.0	8.6
		B	7.4	1.6	0.0	0.3	6.4
	5(8)	S	9.5	7.2	6.0	6.5	8.8
		B	2.8	1.0	0.0	0.2	7.1
	2(8)	S	9.5	7.2	6.1	6.7	8.6
		B	2.6	0.6	0.0	0.2	7.2
	4(5)	S	9.4	6.8	5.8	6.9	9.5
		B	3.4	0.1	0.0	0.2	6.9
pH	6(2)	M	-	7.9	8.0	7.7	8.0
	6(5)	S	-	8.0	8.0	7.7	7.8
		B	-	7.6	8.0	7.6	7.5
	8(2)	M	-	8.0	8.0	7.8	7.6
	8(5)	S	-	8.0	8.0	7.7	7.7
		B	-	7.8	7.8	7.5	7.4
	5(8)	S	-	8.0	8.0	7.7	7.6
		B	-	7.7	7.8	7.5	7.4
	2(8)	S	-	8.1	8.0	7.8	7.6
		B	-	7.8	7.6	7.5	7.3
	4(5)	S	-	8.0	8.0	7.7	8.2
		B	-	7.6	7.8	7.5	7.7
Conductivity (µmhos/cm)	6(2)	M	388	355	-	420	295
	6(5)	S	-	-	-	-	-
		B	-	-	-	-	-
	8(2)	M	-	365	-	425	295
	8(5)	S	-	-	-	-	-
		B	-	-	-	-	-
	5(8)	S	385	385	-	430	290
		B	380	135	-	300	295
	2(8)	S	385	380	-	430	285
		B	380	145	-	295	290
	4(5)	S	385	375	-	440	290
		B	380	345	-	580	293

Table 4. (Continued)

Variable	Station	Depth	Collecting Date				
			15 Apr	27 May	23 Jun	15 Aug	26 Oct
Turbidity (JTU)	6(2)	M	-	8	9	8	6
	6(5)	S	-	-	-	-	-
		B	-	-	-	-	-
	8(2)	M	-	8	5	6	6
	8(5)	S	-	-	-	-	-
		B	-	-	-	-	-
	5(8)	S	-	7	4	8	8
		B	-	227	70	13	7
	2(8)	S	-	7	4	8	7
		B	-	247	52	13	8
	4(5)	S	-	7	3	-	7
		B	-	26	37	-	7

* Numbers in parenthese denotes approximate station depth (See Figure 1 for locations)

** S-Surface, B-Bottom, M-Mid-depth

\- Data not measured

Table 5. Depth, oven-dry weight, and % organic carbon of sediments * deposited in Ham's Lake in 1977.

Date	Station	mm/mo	g/m^2 per mo	Organic Carbon (%)
5 Jul-4 Aug	6(5)	3.4	252	6.8
	8(5)	4.3	409	5.8
	5(8)	4.3	249	6.7
	2(8)	3.1	192	6.8
	4(5)	3.1	206	7.1

* Values are means of four replicate samples

Table 6. Hydrometric analyses of the sediments in Ham's Lake in 1977.*

Station	Variable**	Time (min)							
		0.5	1	3	5	10	20	120	720
6(2)	P	85	79	74	71	62	56	40	31
	D	.069	.050	.033	.022	.016	.012	.004	.002
8(2)	P	76	67	55	50	42	37	27	22
	D	.071	.051	.030	.023	.014	.012	.005	.002
5(8)	P	92	90	89	88	87	84	74	60
	D	.069	.049	.028	.022	.016	.011	.005	.002
2(8)	P	93	91	89	88	87	84	78	56
	D	.069	.049	.028	.022	.016	.011	.005	.002
4(5)	P	87	85	82	80	76	72	60	50
	D	.070	.050	.030	.022	.015	.011	.005	.002

* Values are the means of four replicate cores each collected on 17 Apr, 22 Jun, 8 Aug, and 26 Oct.

** P-Percent of soil remaining in suspension
D-Maximum diameter of particles remaining in suspension (mm)

shown in Figure 2. This figure demonstrates the variation in particle size of the different depths. Particle size generally decreased between 17 April and 22 June probably reflecting the input of particles from the watershed and sediments into the central pool (Table 7).

Percent organic carbon of the sediments ranged from 1.0 - 8.6 (Table 8). Carbon increased at all stations between 15 April and 23 June reflecting the low DO and the reduction in decomposition. Values generally remained high throughout the summer. Values decreased between 15 August and 26 October at the 8 m stations reflecting the turnover and increase in DO. Variation among stations was generally less than temporal variation. It is expected that the percent organic carbon of the sediments will not increase during summer 1978 when the lake is mixed.

pH of the sediments ranged from 6.4 - 8.0 (Table 8). pH decreased at all stations between 23 June and 15 August reflecting the increase in the concentration of CO_2. Values again exhibited alkaline conditions on 26 October after the lake had turned over. It is expected that the pH of the sediments will not become acid during summer 1978 when the lake is mixed.

Temporal and spatial variation of the phosphorus, copper, iron, and manganese in the sediments will be discussed in the supplement.

Benthic Macroinvertebrates. Species composition and diversity of macroinvertebrates will be discussed in the supplement.

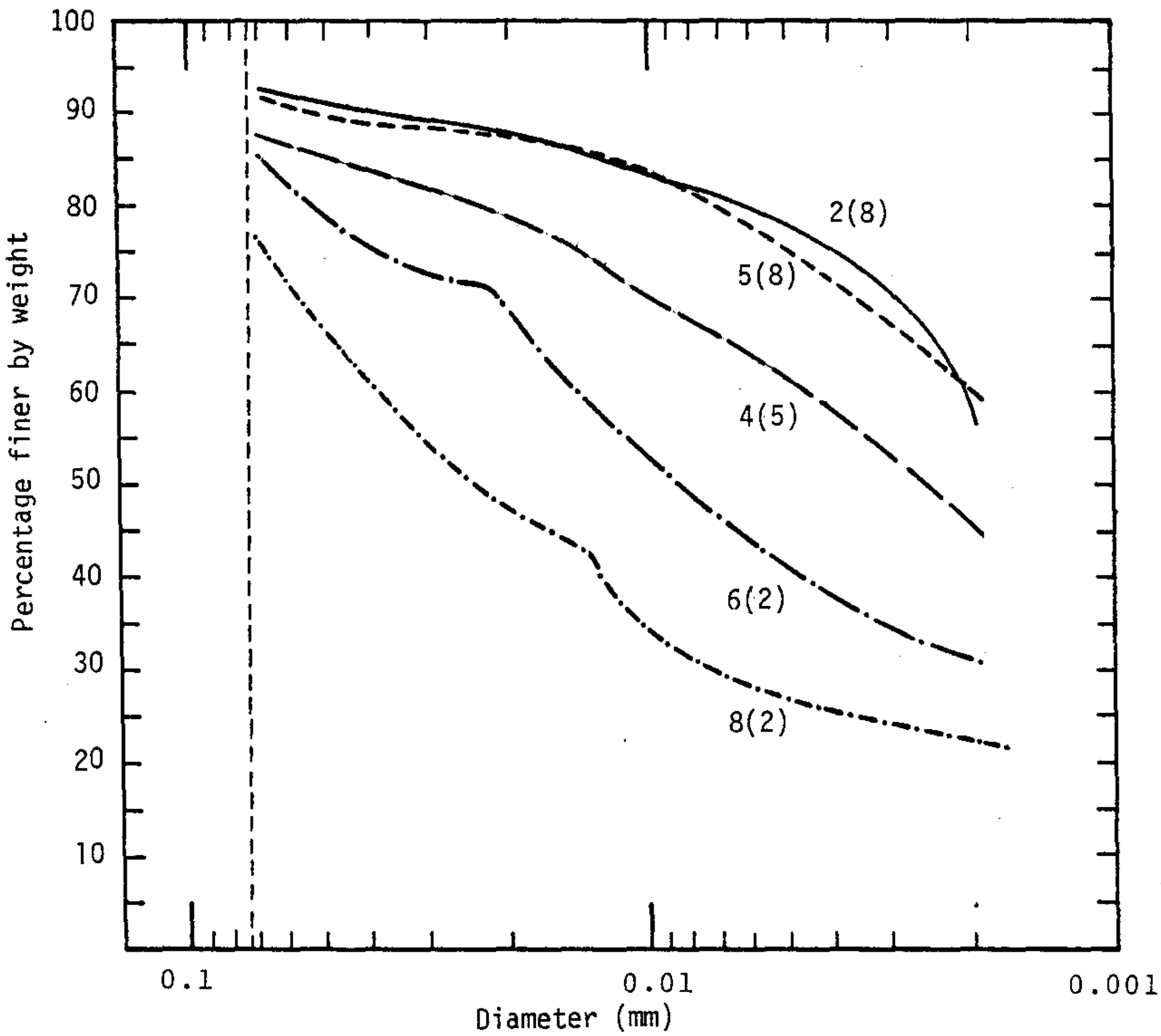
Hemolymph Ions. The fluctuation of hemolymph ions in *Chaoborus punctipennis* exhibited the same trends at all three stations (Table 9). A gradual decrease in all hemolymph ions was observed from May through September. This decrease in internal ion concentrations may be caused by low DO levels, warmer water, salinity or a combination of these variables. Sodium decreased from 79-58 mM between 20 June and 1 August and increased to 120 mM on 15 October. Potassium concentration were maintained at an average ($\bar{x}$) of 10 mM at all stations. Chloride concentrations in the organisms were also relatively stable throughout the sampling period ($\bar{x}$ of 47 mM).

The lake water contained low concentrations of all the ions until August. During August, the Na increased to an average of 25 mM. Chloride also increased but not as dramatically as sodium. This increase in water Na probably caused a stressful situation to the organism as reflected by the hemolymph osmotic pressure. Before August, the mean hemolymph osmotic pressure in *C. punctipennis* was ca 0.540 Δ °C. The mean osmotic pressure decreased from August to September, 0.462 to 0.336 Δ ° C. The decrease in osmotic pressure from August to September (0.450 to 0.424 Δ °C) was not significant ($P < .05$). The osmotic pressure increased in October with the corresponding increase in sodium.

The organisms collected at Station 6 in August and September appeared lethargic. A greater decrease in osmotic pressure was observed in these organisms throughout the summer. Hemolymph osmotic pressure values for both organisms reported in the literature generally range from 0.350 to 0.450 Δ °C.

The hemolymph osmotic pressure from *C. punctipennis* at Station 6 decreased from 0.321 to 0.206 mM from August to September. The combination of increased sodium, lower DO, and warmer epilimnetic waters apparently affected the organisms adversely by causing them to become quiescent.

The trends will be examined monthly in Ham's Lake until May, 1978, and again during summer when the lake is mixed.



SAND	FINES	
FINE	SILT SIZES	CLAY

Figure 2. MEAN GRAIN SIZE DISTRIBUTION OF SAMPLES TAKEN IN APRIL, JUNE, AUGUST, AND OCTOBER FROM THE COLLECTING STATIONS IN HAM'S LAKE. NUMBERS IN PARENTHESES AFTER STATION NUMBER DENOTES APPROXIMATE DEPTH.

Table 7. Percent of particles remaining in suspension after 12 h in Ham's Lake sediment samples collected in 1977.*

Station	Collecting Date 17 Apr	22 Jun	8 Aug	26 Oct
6(2)	22	35	28	30
8(2)	27	26	19	21
5(8)	42	70	67	59
2(8)	40	70	61	61
4(5)	48	56	49	48

* Values are means of four replicate cores

Table 8. Percent organic carbon and pH of the sediments in Ham's Lake in 1977.

Variable	Station	Collecting Date				
		15 Apr	27 May	23 Jun	15 Aug	26 Oct
C (%)	6(2)	1.0	-	7.5	7.4	4.2
	8(2)	3.7	-	6.1	2.0	3.1
	5(8)	3.7	-	6.8	6.8	4.1
	2(8)	3.5	-	8.6	7.6	5.6
	4(5)	4.3	-	5.1	4.6	6.3
pH	6(2)	-	7.8	7.8	6.5	8.0
	6(5)	-	7.6	7.8	6.7	7.3
	8(2)	-	7.8	7.8	6.7	7.9
	8(5)	-	7.5	7.7	6.5	7.3
	5(8)	-	7.3	7.7	6.6	7.5
	2(8)	-	7.5	7.6	6.6	7.7
	4(5)	-	7.7	7.6	6.4	7.3

\- Data not collected

Table 9. Ion concentrations and osmotic pressure of hemolymph in the water and *Chaoborus punctipennis* in Ham's Lake in 1977.

Station		Variable*	20 May	20 Jun	1 Aug	10 Sept	15 Oct
6(2)	Water	Na	5	3	22	0	0
		K	2	<2	0	0	0
		Cl	13	4	9	10	99
		Osm.	.022	.020	.066	.013	.009
	Chaoborus	Na	118	110	79	58	117
		K	8	12	12	6	8
		Cl	56	56	32	33	37
		Osm.	.490	.445	.321	.206	.003
5(8)	Water	Na	5	2	25	0	0
		K	1	<2	0	0	0
		Cl	13	3	11	9	129
		Osm.	.021	.013	.044	.011	.003
	Chaoborus	Na	137	131	136	97	43
		K	9	10	12	8	13
		Cl	52	48	44	42	113
		Osm.	.598	.537	.510	.396	.004
4(5)	Water	Na	5	2	29	0	0
		K	2	<2	0	0	0
		Cl	13	4	10	9	106
		Osm.	.020	.020	.046	.016	.003
	Chaoborus	Na	154	131	136	97	44
		K	8	9	13	8	14
		Cl	52	48	44	55	107
		Osm.	.628	.553	.556	.408	.009

* Ion values in mM
Osmotic pressure in $\Delta ^{o}C$

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