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THE ABUNDANCE AND DISTRIBUTION
OF BENTHIC MACROINVERTEBRATES
IN LAKE LANSING

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Mehdi Siami

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THE ABUNDANCE AND DISTRIBUTION
OF BENTHIC MACROINVERTEBRATES
IN LAKE LANSING

By

Mehdi Siami

A THESIS

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in partial fulfillment of the requirements
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ABSTRACT

THE ABUNDANCE AND DISTRIBUTION OF BENTHIC MACROINVERTEBRATES IN LAKE LANSING

By

Mehdi Siami

The benthic macroinvertebrate composition and abundance of Lake Lansing was investigated during the ice-free season in 1978. The major groups found were Chironomidae, Chaoboridae, Amphipoda, Isopoda, Trichoptera, Odonata, Coleoptera, Ephemeroptera and Annelidae. Chironomidae and Chaoboridae larvae were most abundant; Ephemeroptera were encountered least often.

Chironomidae populations in deep portions of Lake Lansing were at maximum observed density and biomass in May. During summer, when the oxygen concentration dropped to zero in the hypolimnion, Chironomidae larvae were absent there. Larvae returned to deep parts of the lake during fall overturn. Three transects in shallow portions of the lake on sandy organic, fibrous organic, and fine organic sediments differed from one another in regard to density and biomass. The highest measurements were on fine organic sediments on each sampling date.

Mehdi Siami

Compared to published data on eutrophic lakes in North America, the standing crops of benthic fauna in Lake Lansing were low.

ACKNOWLEDGMENTS

I would like to thank Dr. Niles R. Kevern for serving as my major professor and for his assistance in arranging my graduate program within the Fisheries and Wildlife Department.

I wish to thank my committee members, Dr. Kenneth W. Cummins and Dr. Clarence D. McNabb. Special acknowledgment is due Dr. McNabb who advised and encouraged me and for providing invaluable assistance and time throughout this study.

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Finally, I wish to express special thanks to my wife, Lili and daughter Saghar, for without their support this undertaking would not have been made.

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INTRODUCTION

Over the past decades Lake Lansing in Ingham County, Michigan, has become gradually eutrophic with intensive use. The economic and aesthetic value of the resource has declined concurrently. Lake Lansing is the only major surface-water resource for recreation in the Lansing metropolitan region and has been chosen by the U. S. Environmental Protection Agency as a site to demonstrate the efficacy of hydraulic dredging as a lake restoration technique. Although the ecological effects of hydraulic dredging of lakes are not well known, it is apparent that it will have an impact on the lake's biota. This study covers a seasonal survey of benthic macroinvertebrates existing in Lake Lansing before the commencement of dredging. This information can be used to assess the impact of dredging on that component of lake ecosystem.

The community structure of benthic macroinvertebrates has been widely used as an indicator of environmental conditions in streams and lakes (Simpson, 1949; Gaufin, 1956). Much of the early classical work on freshwater lake communities attempted to classify lakes according to the composition and abundance of macroinvertebrate groups in relation to dissolved oxygen concentration,

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trophic status, substrate types and other factors (Crips and Gledhill, 1970). Brinkurst (1974) discussed the manner in which depth, temperature, food supply, predatory interaction, current and substrate types shape benthic distribution and abundance in lakes.

Qualitative and quantitative data of the benthic macroinvertebrates of Lake Lansing have been entirely lacking. The first objective of this study was to identify the dominant types of organisms during an ice-free season before the lake was dredged. The second objective was to estimate the relative density of individuals and biomass for the dominant types.

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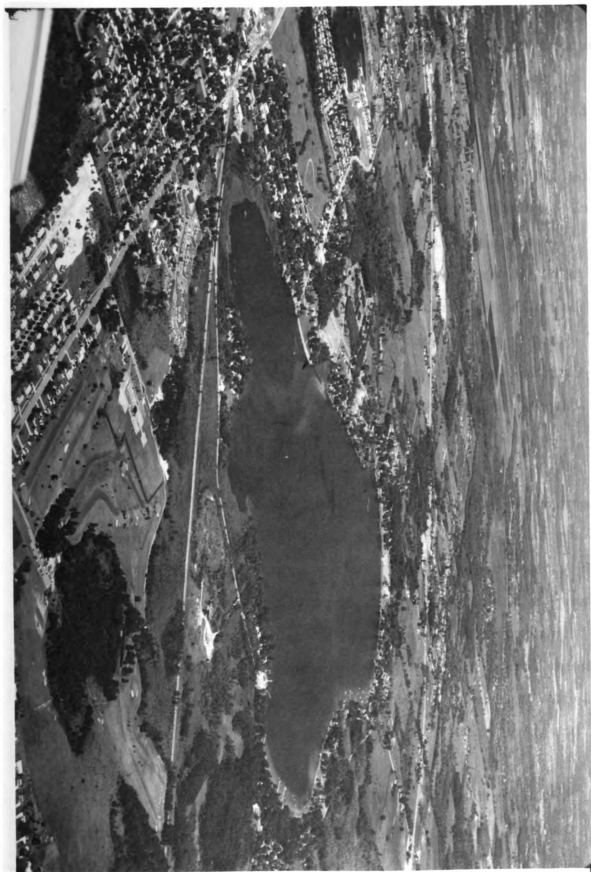
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DESCRIPTION OF STUDY AREA

Lake Lansing (Figure 1) is located approximately 5.6 kilometers northeast of the city of East Lansing in Meridian Township, Ingham County, T4N, R1W, Sections 2, 3, 10 and 11. It occupies an area of 181.3 ha when the water level is at the elevation of the sill of the dam. An estimate, based on U.S.G.S. lake levels, gave a surface area of 172.2 ha at the lake's lowest elevation in the first week of November, 1978. The lake has a north and a south basin with maximum depths of 11.0 and 8.0 meters. During the summer the lake tends to stratify thermally and chemically. The combined area of hypolimnetic surface over two deep portions totaled 23% of the total lake surface during the study. The littoral region lay beneath 77% of the surface area, and extended to a 3.0 m contour.

Lake Lansing was created through the natural process of glacial scouring and recession. The lake lies in the Pennsylvanian Saginaw Parma geologic rock formation and on LaGrange moraine of the glacial front known as the Saginaw Lobe (Martin, 1955). The sand-gravel-clay soil deposited around the lake was formed during the Pleistocene glaciation (U.S. Army Corps of Engineers, 1970).

Figure 1. Aerial view of Lake Lansing.



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Features of drainage patterns in the watershed have been identified by Marsh and Borton (1974). In addition to precipitation on the surface, water enters the lake via culverts that drain surrounding marsh lands, and from street drains. The retention time was calculated to be 23.4 years according to the annual hydrologic budget for 1978-79 calculated as part of the overall lake study.

During the summer of 1978 the macrophytes of Lake Lansing were mapped, and the littoral zone was divided into five areas based on the plant communities found there (Figure 2). Area A, the south basin, was occupied mainly by *Chara globularis* Thuill and *Najas flexilis* (Willd.) Rostk. and Schmidt; B, was almost exclusively *Chara globularis*; C, had a hydrophyte mixture consisting of *Chara globularis*, *Heteranthera dubia* (Jacq.) MacM., *Vallisneria americana* Michx., *Ceratophyllum demersum* L., *Myriophyllum* sp. and *Naja flexilis*; D, had the same hydrophyte mixture as C, but was characterized by a higher percent cover; and E, was occupied by a *Chara globularis*-*Najas flexilis* association. Groups of *Nuphar advena* Ait., *Pontedaria cordata* L. (Pickerel weed) and the bulrushes (*Scirpus validus* Vahl. and *S. americanus* Pers.) were present along the inshore areas of the south basin and in the area of Transect 3.

Fish populations in Lake Lansing were first quantitatively sampled in 1938 by Ball (1938) and more

Figure 2. Zones of aquatic vegetation in Lake Lansing in 1978. Stippled areas are unoccupied sand, circles are *Nuphar advena*, squares are *Pontederia cordata*, and triangles are species of *Scirpus*.

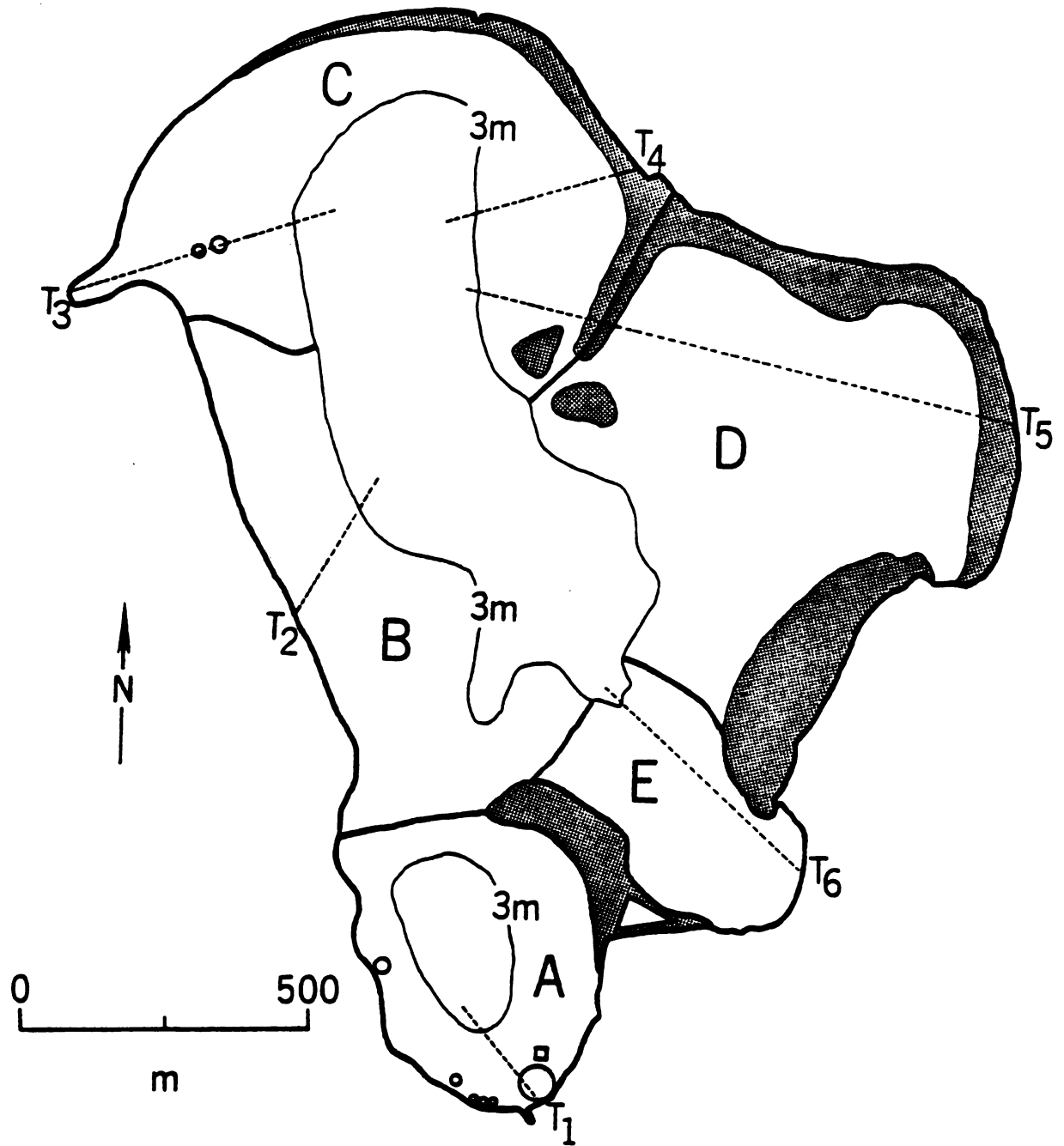


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than 20 species were identified. Roelofs (1941) also conducted a survey of Lake Lansing fish. The most common species found were: yellow perch [*Perca flavescens* (Mitchill)], largemouth bass [*Micropterus salmoides* (Lacepede)], bluegill [*Lepomis macrochirus* Rafinesque], pumpkinseed [*Lepomis gibbosus* (Linnaeus)]. Species less frequently found were northern pike (*Esox lucius* Linnaeus), warmouth [*Chaenobryttus gulosus* (Cuvier)], black crappie [*Pomoxis nigromaculatus* (LeSueur)], brown bullhead [*Ictalurus nebulosus* (LeSueur)], yellow bullhead [*Ictalurus natalis* (LeSueur)], and golden shiner [*Notemigonus crysoleucas* (Mitchill)].

METHODS AND MATERIALS

Transects for sampling purposes in the Lake Lansing Project were made through littoral communities from shore to the 4.5 meter contour (Figure 2). These locations were selected over major sediment types in the lake and through areas in which dredging will be done. Two of the transects (1 and 6) were located over fibrous peat, two over fine organic ooze (2 and 3) and two (4 and 5) over sand with a mixture of fine organic particles. Sediments in the deep portions of the north and south basins of the lake were composed of fine particles of organic material (Figure 3).

For studies of the benthos, five stations were chosen. The sample sites were located on transects 1, 3 and 4 and in the north and south deep basins of the lake. Transects were sampled in the vicinity of the two meter contour. The samples from the north (NDB) and south (SDB) deep basins of the lake were taken at 9 and 7 meter depths respectively. A ponar grab of a known area was used to take the benthos samples at monthly intervals from May through October, 1978. The ponar grab was dropped to appropriate depths and

Figure 3. The sediment on the left is fibrous peat representative of transects 1 and 6 and the material on the right is fine organic sediment from deep portions of the lake.

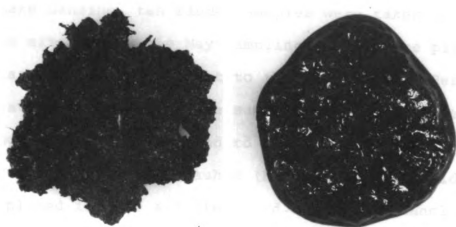


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retrieved using a winch mounted on a pontoon boat (Figure 4).

In order to determine a representative sample size for Lake Lansing, ten random samples were taken at each sample site during the May sampling. They were placed in plastic bags and brought to the Limnological Research Laboratory (Figure 5). The samples were then sieved through a No. 30 U.S. standard sieve, (0.595mm opening). After the samples were washed (Figure 6), the residues were placed in jars and preserved with 95% ethanol. These were then sorted and the macroinvertebrates stored in 90% ethanol. The microinvertebrates were then separated into family groups with the use of a dissecting microscope. Each taxon was counted and mean values and variance for the number of individuals per sample site were calculated to determine the type of distribution found at the particular site.

Following the procedures of Elliott (1977), for those sites which had negative binominal or aggregated distribution (T4, NDB and SDB), a k value was computed. The k statistic is related to the spatial distribution of the tendency of clumping of the bottom organisms; the higher the k value, the lower the degree of clumping. The calculation for the estimate of k for a small number of samples was

$$\hat{k} = \frac{\bar{X}^2 - \left(\frac{s^2}{n}\right)}{s^2 - \bar{X}}$$

Figure 4. Ponar grab sampler used with a winch.

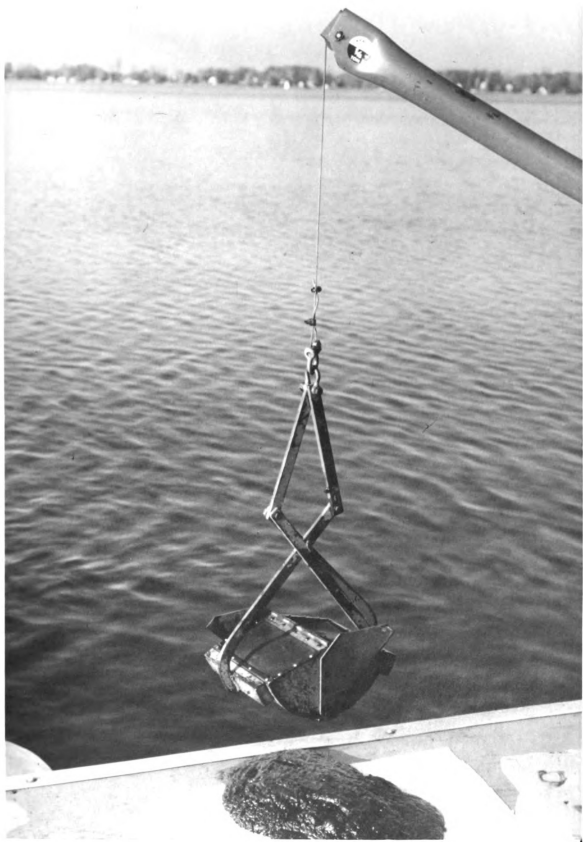


Figure 5. A typical collection of Lake Lansing sediments.



Figure 6. Washing Lake Lansing sediments through
a No. 30 U.S. standard mesh screen.



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The sample size was calculated for a specific degree of precision. An index of precision (D) is

$$D = \frac{\text{standard error}}{\bar{X}} = \frac{1}{\bar{X}} = \sqrt{\frac{s^2}{n}}$$

A standard error equal to 20% of the mean was allowed for this study. Therefore, for negative binomial distributions, sample size (n) was calculated as:

$$n = \frac{1}{D^2} \left(\frac{1}{\bar{X}} + \frac{1}{k} \right) = \frac{1}{0.2^2} \left(\frac{1}{\bar{X}} + \frac{1}{k} \right) = 25 \left(\frac{1}{\bar{X}} + \frac{1}{k} \right).$$

Sample size needed for random distributions (T_1 and T_4) was calculated as:

$$n = \frac{s^2}{D^2 \bar{X}^2} = \frac{s^2}{.2^2 \bar{X}^2} = \frac{25 s^2}{\bar{X}^2}$$

The results are given in Table 1. Because of seasonal variation in population distributions, the same calculations were made to determine the sample size for a particular time at a particular site. The calculated sample size sufficient for each sampling site for the period of study and number of samples used for describing the populations at those sites are presented in Table 2.

In order to identify Chironomidae larvae at lower level (genus and species for some) the head capsules were separated from the body and mounted on slides, ventral side up, along with the body in euporal (Turtor). The cover slips were pressed down gently in order to expose those structures necessary for identification.

An Introduction to Identification of Chironomid Larvae

Table 1. Mean ($\bar{X}$) for number of individuals, variance (s^2), and excessive variance or "clumping" (k) of Lake Lansing benthic macroinvertebrates in May, 1978.

Sample Location	$\bar{X}$	s^2	k
T_1	3.60	1.80	-
T_3	4.70	14.20	1.71
T_4	0.60	0.59	-
SDB	19.60	91.38	5.35
NDB	48.10	176.78	18.00

Table 2. Calculated sample size sufficient for each sampling site and number of samples used for describing the population at those sites for Lake Lansing.

Sample Locations } Date	T ₁		T ₃		T ₄		NDB		SDB	
	Calc.	Used	Calc.	Used	Calc.	Used	Calc.	Used	Calc.	Used
May	1	10	25	10	10	10	3	10	8	10
June	5	5	25	28	9	10	9	9	5	6
July	5	5	25	25	10	9	5	9	5	5
August	5	5	23	25	10	10	5	5	5	5
September	5	5	22	23	10	10	7	5	8	5
October	5	5	18	20	10	10	8	7	5	8

(Mason, 1973) was used in the classification of Chironomidae (Tribe Chironomini) and Tanypodinae.

Key to the Larvae of the Chironomidae (Tribe Tanytarsini) in the Larvae Stage (Mozley, 1973) was used for the classification of Chironomidae. Photographs were taken of mounted Chironomidae head capsules with the use of an Olympus photomicrographic system (Model PM-10-m) on Ektachrome 50 professional film. These are appended.

The distribution of biomass among several weight categories was established for each genus with the aid of a body length-weight function. To obtain dry weight of the main chironomid genera (*Chironomus*, *Procladius*, *Tanytarsus* and *Glyptotendipes*) and the non-chironomid dipteran, *Chaoborus* sp., the organisms were oven-dried to a constant weight at 105°C for four hours. They were then cooled to room temperature in a dessicator and weighed on an electrobalance. The weights were then regressed on the length. To obtain dry weight of less common groups, all organisms for each transect for a particular time were oven-dried under the above conditions.

Dissolved oxygen and temperature were measured *in situ* with a Yellow Springs Instrument Company (Yellow Springs, Ohio) model 54A oxygen meter with a pressure-compensated Clark-type polarographic oxygen sensor and submersible stirrer. Integral thermistors permitted

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temperature readout and corrected for temperature-dependent membrane diffusion effects and for differential oxygen solubility with temperature. The dissolved oxygen probe was standardized against the azide modification of the Winkler method (APHA, AWWA, WPCF, 1975). The thermistor was checked in laboratory for accuracy against two mercury thermometers. Dissolved oxygen and temperature readings were taken at mid-depth on two-meter contours along each transect. In addition, temperature and dissolved oxygen were measured through depth in two deep portions of the lake in order to plot vertical profiles.

Water samples were taken at mid-depth on the two-meter contour along with the transects, and in the surface and bottom portions of the limnetic region of the lake. The samples were placed in plastic bottles and brought to the laboratory where the pH was measured with a Beckman Expandomatic pH meter using a combination electrode with a silver/silver chloride reference element. The pH meter was calibrated against pH 7 and pH 10 standard buffer solutions. These instruments were calibrated before each series of measurements. Conductivity was measured with an Industrial Instruments, Inc. model RC 16B₂ Conductivity Bridge and a YSI (model 3403) dip-type conductivity cell ($K = 1.0$). The free carbon dioxide (CO_{2f}) concentrations

were calculated from the pH, temperature and carbonate-bicarbonate alkalinity profiles. Tables for these parameters are included in the Appendix.

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RESULTS

Dissolved Oxygen and Water Temperature

Figures 7 and 8 illustrate the dissolved oxygen profiles in the south and north deep basins of the lake. The most striking feature of these data is the extensive depletion of dissolved oxygen experienced in the hypolimnion during the summer period of stagnation. Oxygen depletion begins in late spring with the onset of thermal stratification. During the spring of 1978, this depletion appeared somewhat earlier at the shallower south deep basin of the lake than at the north deep basin. Once stratification was established, this depletion extended downward from the bottom of the metalimnion and remained until the onset of autumn overturn. This occurred in early September, 1978. Bottom strata in deep portions of the basin were anerobic from June 1 to September 7. Oxygen concentrations measured in the littoral zone (cf. Appendix) were spatially variable but were generally the same range as those measured at the same depth in the limnetic zone during the same sampling interval.

In the treatment similar to that described for dissolved oxygen, the values of water temperature were

Figure 7. Dissolved oxygen concentrations (mg l^{-1}) in the south basin of
Lake Lansing during 1978.

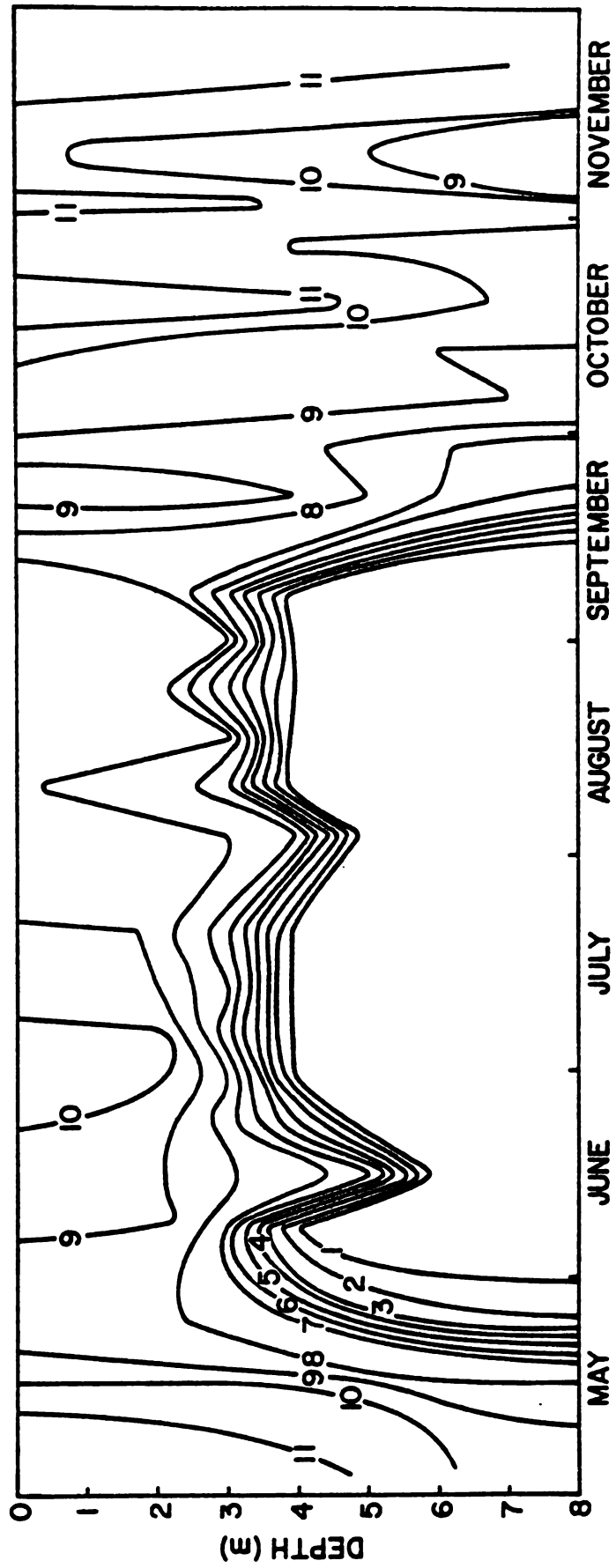


Figure 7.

Figure 8. Dissolved oxygen concentrations (mg l^{-1}) in the north basin of
Lake Lansing during 1978.

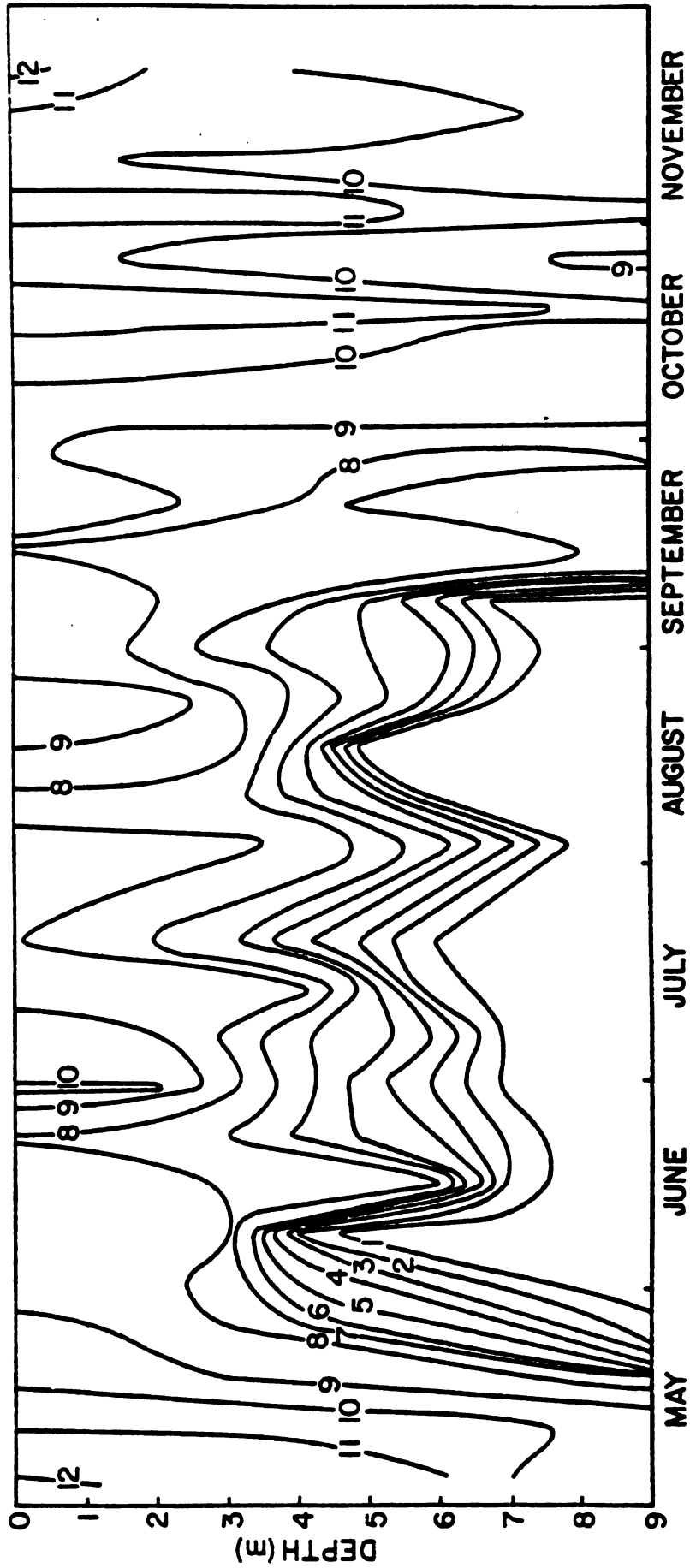


Figure 8.

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used to produce temperature profiles in the south and north deep basins of the lake. Because temperatures at similar depths on transects and in deep basins of the lake did not differ appreciably on 1978 sampling dates (cf. Appendix), temperatures along transects at two meter depths were taken to be the same at that depth in limnetic region. Figures 9 and 10 illustrate the temperature profiles in the south and north deep basins of the lake.

Seasonal patterns of temperature variation were similar between the north and south sites, as a comparison of Figure 9 with Figure 10 demonstrates. At the beginning of this investigation, Lake Lansing was in a well-mixed, homothermal state; ice cover was gone and temperatures were beginning to increase. Stratification occurred about the first week of June, 1978 and remained into September. Fall overturn began in early September, 1978, and the accompanying homothermal conditions extended through the fall season.

Invertebrate Abundance

Tables 3-7 illustrate the macroinvertebrate groups samples from Lake Lansing during the period of study. Both sites, deep and shallow portions of the lake, were characterized by an abundance of Chironomidae and Chaoboridae larvae. The deep portions of the lake showed considerably fewer taxa than shallow parts of the lake.

Figure 9. Temperatures ($^{\circ}\text{C}$) in the south basin of Lake Lansing during 1978.

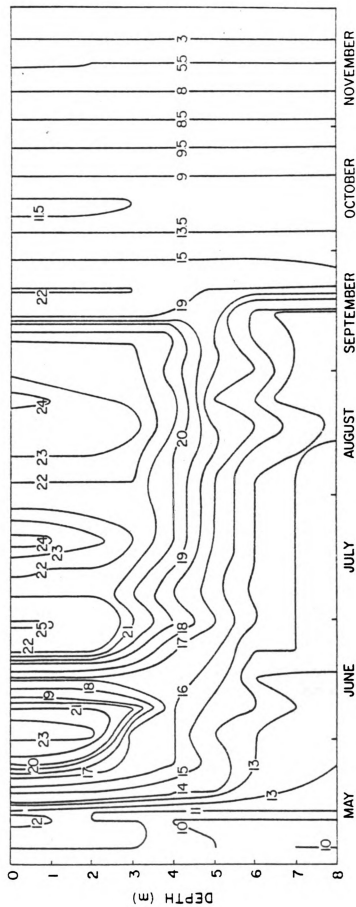


Figure 9.

Figure 10. Temperatures ($^{\circ}\text{C}$) in the north basin of Lake Lansing in 1978.

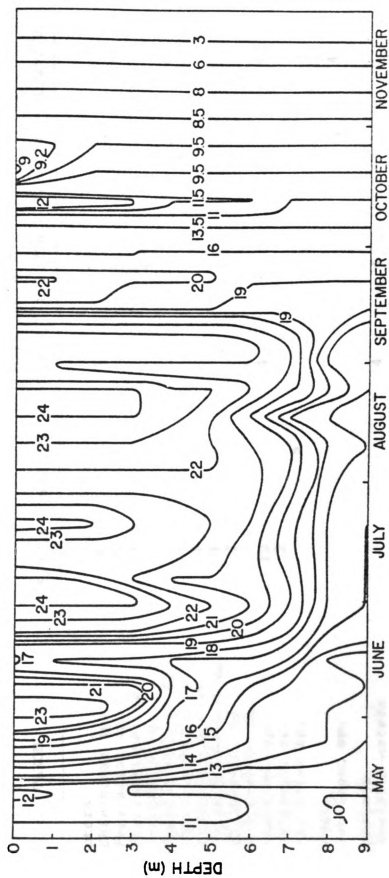


Figure 10.

Table 3. Species collected from two meters depth on Transect 1.

Table 3. Species collected from two meters depth on Transect 1.

TAXON	MEAN NO. m ⁻²				
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78 10/29/78
Diptera					
<i>Chironomus</i> sp.	6		4		15
<i>Procladius</i> sp.	15	14		4	4
<i>Dicerotendipes</i> sp.	13				
<i>Tanytarsus</i> sp.	2	3		4	
<i>Thienemannimyia</i> sp.	2				
<i>Rheotanytarsus</i> sp.	2				
<i>Parachironomus</i> sp.	4	5			
<i>Cryptochironomus</i> sp.	4				
<i>Ablabesmyia</i> sp.	2				
<i>Polypedilum</i> sp.			4		
<i>Chaoborus</i> sp.	13		4		4
<i>Palpomyia</i> sp.	2		4		
<i>Anopheles</i> sp.		5			
Odonata					
<i>Enallagma</i> sp.					4
Amphipoda					
<i>Hyalella asteca</i>			4	4	
Isopoda					
<i>Aseilus</i> sp.					8
Gastropoda					
<i>Physa</i> sp.				4	15

Table 4. Species collected from two meters depth on Transect 3.

Table 4. Species collected from two meters depth on Transect 3.

TAXON	MEAN NO. m ⁻²					
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78	10/29/78
Diptera						
<i>Chironomus</i> sp.	8	69	22	6	24	20
<i>Procladius</i> sp.	36	16	5	34	27	26
<i>Dicroendipes</i> sp.	2	5	2		11	
<i>Tanytarsus</i> sp.	6	169	1		2	
<i>Polypedilum</i> sp.	2	1				
<i>Thienemannimyia</i> sp.	6	1	1		2	1
<i>Ablabesmyia</i> sp.		1		1		
<i>Microsepectra</i> sp.	2					
<i>Cryptochironomus</i> sp.		1	1	1	2	1
<i>Glyptotendipes</i> sp.			1	2		142
<i>Lauterborniella</i> sp.		1				
<i>Rheocricotopus</i> sp.					1	
<i>Cricotopus</i> sp.					1	
<i>Anopheles</i> sp.			2		2	
<i>Palpomyia</i> sp.	8	1			5	1
<i>Chaoborus</i> sp.	14	1	5	1	38	11
Ephemeroptera						
<i>Caenis</i> sp.					1	20
<i>Baetis</i> sp.						1
Trichoptera						
<i>Polycentropus</i> sp.					13	12
<i>Psychomyia</i> sp.					13	8
<i>Chimarra</i> sp.					2	

continued

Table 4. continued

TAXON	MEAN NO. m ⁻²					
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78	10/29/78
Odonata						
<i>Enallagma</i> sp.					1	1
<i>Ladona</i> sp.					1	
<i>Argia</i> sp.					1	
<i>Coenagrion</i> sp.					1	
Amphipoda						
<i>Hyallella azteca</i>		1	3			
Basommatophora						
<i>Physa</i> sp.			3			
Coleoptera						
<i>Troisternus</i> sp.			1			
Isopoda						
<i>Asellus</i> sp.					1	45
Annelida						
<i>Helobdella stagnalis</i>					2	

Table 5. Species collected from two meters depth on Transect 4.

TAXON	MEAN NO. m ⁻²					
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78	10/29/78
Diptera						
<i>Chironomus</i> sp.	2	8	4	2	8	4
<i>Procladius</i> sp.	2	35	32	47	108	55
<i>Dicrotendipes</i> sp.	2	17		4		
<i>Tanytarsus</i> sp.		146	36	8	15	
<i>Thienemannimyia</i> sp.		2			2	
<i>Rheotanytarsus</i> sp.		2				
<i>Cryptochironomus</i> sp.		2	2		2	
<i>Glyptotendipes</i> sp.		2				
<i>Rheocricotopus</i> sp.					2	
<i>Parachironomus</i> sp.					2	
<i>Anopheles</i> sp.		2				
<i>Chaoborus</i> sp.						19
<i>Palpomyia</i> sp.		2			34	
Ephemeroptera						
<i>Caenis</i> sp.	2					
<i>Heragenia</i> sp.		2		2		
Amphipoda						
<i>Hyalella azteca</i>		2				
Basommatophora						
<i>Physa</i> sp.			8	4	2	
Coleoptera						
<i>Hydrochus</i> sp.	2					

Table 6. Species collected from deep portions of the north basin (9m).

TAXON	MEAN NO. m ⁻²					
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78	10/29/78
Diptera						
Chironomus sp.	110	10				40
Procladius sp.	110	3			4	5
Tanytarsus sp.		3				
Cladotanytarsus sp.		3				
Anopheles sp.	10	13	4			
Palpomyia sp.						5
Chaoborus sp.	678	152	11	19	216	39
Annelida						
Helobdella stagnalis	2					

Table 7. Species collected from deep portions of the south basin (7m).

TAXON	MEAN NO. m ⁻²				
	5/2/78	6/21/78	7/25/78	8/18/78	9/22/78
Diptera					
<i>Chironomus</i> sp.	76				14
<i>Procladius</i> sp.	32				
<i>Chaoborus</i> sp.	289	46	2	3	281
<i>Anopheles</i> sp.	2	2			141
Amphipoda					41
<i>Hyalella azteca</i>	2				
Gastropoda					
<i>Gyraulus</i>	2				

The dominant types at the deep parts of the lake were *Chironomus* sp., *Procladius* sp., (Chironomidae); and *Chaoborus* sp. (Chaoboridae). In the north deep basin, *Tanytarsus* sp., *Glyptotendipes* sp., *Palpomyia* sp., and *Helobdella stagnalis* were also found during sampling in May and June. In the south deep basin *Hyaella azteca* and *Gyraulus* sp. were found during May.

At littoral zone stations, besides those families mentioned previously, *Caenis* sp., *Baetis* sp., *Hexagena* sp. (Ephemeroptera), *Enallagma* sp., *Ladona* sp., *Coenagrion* sp. (Odonata), *Polycentropus* sp., *Psychomyia* sp., and *Chimarra* sp. (Trichoptera) were found. None of these were abundant enough during all sampling dates to be considered dominant. The dominant species in shallow portions of the lake were *Procladius* sp., *Chironomus* sp., and *Chaoborus* sp. *Tanytarsus* sp. was a dominant species in transect 3.

Since Chironomidae larvae dominated the macroinvertebrate groups in Lake Lansing during the period of study, a review of the morphological characters of those genera, based on the general characteristics of the larvae and head capsule structures, is provided and the Figures included in the Appendix.

Density Fluctuation

Table 8 illustrates the mean densities and number of species in the deep portions of the lake during the period

Table 8. Mean densities and number of species of benthic macroinvertebrates of deep portions of Lake Lansing. One standard error is given in the table.

DATE OF SAMPLING	STATIONS	MEAN NO. m ⁻² IND.	NO. OF SPP.
May	SDB	404.7 ± 65.60	7
	NDB	912.9 ± 79.35	5
June	SDB	48.5 ± 16.84	2
	NDB	183.3 ± 50.75	6
July	SDB	8.4 ± 3.32	1
	NDB	15.2 ± 11.15	2
August	SDB	30.4 ± 9.46	2
	NDB	19.0 ± 8.49	1
September	SDB	209.0 ± 44.68	1
	NDB	224.2 ± 40.59	2
October	SDB	155.8 ± 44.31	2
	NDB	159.1 ± 67.92	4

of study. The number of individuals collected varied among the study sites as well as between times of collection. The south deep basin had the greatest density in May, 1978 and then decreased rather sharply during June to a low in July. In September, the mean density reached a second peak and dropped in the October sampling. The north deep basin of the lake showed similar patterns, but the mean number of individuals was higher in the north deep basin than in the south deep basin on most sampling dates. During the May through June sampling period, the decrease in density was slower in the north deep basin than in the south deep basin.

The changes in density of benthic macroinvertebrates dwelling in the shallow portions of the lake are shown in Table 9. Transect 1 showed two peaks; one in the May-June interval and a second during the October sampling. Transect 3 had maximum densities in June and in the September-October interval. The pattern for transect 4 was similar to the others. The mean population densities on transect 1 tended to be lower than on transects 3 and 4. The number of species encountered tended to be highest on transect 3.

Biomass Estimation

Table 10 illustrates mean biomass for deep portions of Lake Lansing. During the period of study, mean biomass

Table 9. Mean densities and number of species of benthic macroinvertebrates of shallow portions of Lake Lansing. One standard error is given in the table.

DATE OF SAMPLING	STATIONS	MEAN NO. IND. m ⁻²	NO. OF SPP.
May	T ₁	68.4 ± 8.15	10
	T ₃	87.5 ± 25.74	9
	T ₄	13.3 ± 4.15	5
June	T ₁	66.5 ± 31.50	4
	T ₃	274.1 ± 81.65	13
	T ₄	300.2 ± 94.80	12
July	T ₁	15.2 ± 7.15	4
	T ₃	56.2 ± 10.35	12
	T ₄	91.0 ± 22.50	5
August	T ₁	19.0 ± 8.46	3
	T ₃	48.6 ± 9.30	9
	T ₄	77.9 ± 16.91	6
September	T ₁	26.6 ± 16.34	4
	T ₃	229.9 ± 48.54	19
	T ₄	190.0 ± 30.54	9
October	T ₁	68.4 ± 39.15	6
	T ₃	315.4 ± 56.73	13
	T ₄	99.7 ± 34.93	3

Table 10. The mean biomass as dry weight (mg m^{-2}) of benthic macroinvertebrates of deep portions of Lake Lansing. One standard error is given in the table.

DATE OF SAMPLING	STATIONS	MEAN BIOMASS mg m^{-2}	% CHIRONOMIDAE BIOMASS
May	SDB	280.6 $\pm$ 120.25	89
	NDB	420.4 $\pm$ 180.42	86
June	SDB	40.3 $\pm$ 9.50	0
	NDB	410.6 $\pm$ 180.25	68
July	SDB	2.5 $\pm$ 0.54	0
	NDB	10.4 $\pm$ 4.15	0
August	SDB	1.2 $\pm$ 0.45	0
	NDB	1.0 $\pm$ 0.40	0
September	SDB	19.5 $\pm$ 5.25	0
	NDB	17.8 $\pm$ 4.15	22
October	SDB	85.5 $\pm$ 20.32	98
	NDB	168.5 $\pm$ 35.45	98

in the deep basins of the lake showed two peaks. In the south deep basin after the first peak in May, the mean biomass dropped and reached a low in August. In the October sampling a second peak was found. During both peaks, Chironomidae larvae comprised 86% and 90% of the biomass. Between the peaks, no Chironomidae larvae were found. The north deep basin showed a similar pattern, but the sharp summer decrease of biomass was found later than in the south basin. In the June sampling, chironomid larvae comprised 68% of the biomass in the north and 0% in the south deep basin of the lake.

Mean biomass measurements for shallow portions of the lake are shown in Table 11. These showed different patterns than in the deep portions. Chironomidae larvae accounted for nearly all of the biomass in the littoral, the exception being on transect 1 in May. The biomass on each transect peaked in June, decreased to a low in August, then increased in September and October samples. Transect 3 tended to have the greatest mean biomass on each sampling date. Transects 1 and 4 were more similar to each other than they were to transect 3.

Table 11. The mean biomass as dry weight (mg m^{-2}) of benthic macroinvertebrates of shallow portions of Lake Lansing. One standard error is given in the table.

DATE OF SAMPLING	STATIONS	MEAN BIOMASS mg m^{-2}	% CHIRONOMIDAE BIOMASS
May	T ₁	170.4 $\pm$ 60.35	12
	T ₃	160.4 $\pm$ 40.25	94
	T ₄	10.5 $\pm$ 4.25	100
June	T ₁	290.5 $\pm$ 80.75	98
	T ₃	3230.5 $\pm$ 800.45	98
	T ₄	750.4 $\pm$ 310.35	99
July	T ₁	156.5 $\pm$ 98.12	98
	T ₃	1150.5 $\pm$ 300.25	100
	T ₄	640.2 $\pm$ 200.15	100
August	T ₁	4.4 $\pm$ 1.00	100
	T ₃	40.5 $\pm$ 10.24	100
	T ₄	2.5 $\pm$ 0.75	100
September	T ₁	4.5 $\pm$ 1.45	93
	T ₃	98.5 $\pm$ 20.25	80
	T ₄	40.5 $\pm$ 8.33	88
October	T ₁	50.6 $\pm$ 21.23	100
	T ₃	157.2 $\pm$ 34.20	78
	T ₄	58.5 $\pm$ 10.60	99

DISCUSSION

A lake's oxygen and temperature regimes are very useful parameters for describing lake-type. Yearly extremes, and distribution of oxygen and temperature at any given time reveal much about a lake. Indeed, the kind of life and its spatial and temporal distribution is usually determined in part by the oxygen and temperature regimes. In Lake Lansing during 1978, oxygen was typically depleted in the hypolimnion by late spring. Anaerobic conditions appeared somewhat sooner in the deep water of the south basin than in the north basin. Once stratification stabilized, hypolimnetic waters remained anaerobic until the onset of autumn overturn which occurred in late September. Young *et al* (1974) reported depletion of oxygen in the lower part of the hypolimnion during February, 1972, in the south basin. Anaerobic conditions lasted until spring overturn. In the north basin anaerobic conditions were not so extensive during the winter and they occurred only during March.

Seasonal patterns of temperature variation were similar between the north and south sites during the

open-water season in 1978. Initially the lake was well-mixed and homothermal. Permanent stratification occurred during the first week of June and remained that way until September. Young *et al* (1974) found similar temperature patterns during 1971. They reported surface temperature varying from 10°C in mid-May to a maximum of 26°C during mid-July with a minimum of 0°C in mid-January, 1972. Bottom water temperatures varied from a minimum of 4°C in mid-April to a maximum of 14°C in late September, decreasing to 4°C in late January.

The nine major benthic macroinvertebrate groups sampled from the lake were Chironomidae, Chaoboridae, Odonata, Trichoptera, Ephemeroptera, Isopoda, Amphipoda, Coleoptera and Annelidae. Chironomidae and Chaoboridae larvae were the dominant groups in abundance and regularity in samples from the lake.

The Chironominae and Tanypodinae were the dominant Chironomidae sub-families represented in benthic samples collected from deep portions of the lake. These two sub-families and species of family Chaoboridae (Diptera) accounted for approximately 95% of the individuals in the deep basins. The Chironomidae showed two peaks of abundance. These occurred earlier in the south deep portion of the lake than in the north deep portion. However, during the period of thermal stratification no single chironomid larvae was found in

deep portions of the lake.

There are several possible ways to explain the disappearance of chironomid larvae in deep portions of the lake during certain periods of time. Borutsky (1939), Lellak (1953a, b) and Kajak (1958) have suggested that they may be due to differential mortality in response to seasonal changes in environmental conditions. However, Hruska (1961), investigating the influence of fish predation on density of pond benthos, noted a great loss of *Chironomus* larvae from experimental unprotected areas compared with protected areas and concluded that the observed fluctuation in larval densities were caused by larval migration rather than differential mortality. Several authors have recorded shifts in maximum chironomid density from profundal to sublittoral and littoral regions in lakes during summer stratification (Davis, 1976a; Eggleton 1931, 1934), and all instars in this family are known to migrate from deteriorating environments to areas offering more favorable conditions (Davis, 1976a). Chironomidae larvae which were mostly last instars at the beginning of summer could have migrated to shallow portions of the lake. If this was the case, some last instars should have been subsequently sampled in shallow water. The data indicate this was not the case and no single last instar was found in shallow water during May-July sampling period. Alternatively, it is

possible that widespread adult emergence in May could have been followed by extensive re-colonization by Chironominae and Tanypodinae in shallow portions of the lake. Young instars were abundant there in June-July.

Thut (1969) reported that the peak of emergence in one species of *Procladius* in Lake Washington was found between May through June, and the time after through September small numbers emerged. He also noted that a higher percentage of fourth instars of this species was found to be in deep water (>10m). Carter (1976) studied the larval chironomid population of Laug Neagh. He reported that the peak of emergence in *Procladius* occurred in a short period in May and June, 1971. The peak emergence for *Chironomus* sp. occurred during the May-June period. In this study, the corresponding increase in densities for Tanypodinae and Chironominae in shallow portion indicates that most of the larvae hatching from eggs laid by new adults occurred in shallow parts.

Jonasson (1972) reported that the dipteran detritivore *Chironomus anthracinus* in Lake Esrom, a dimictic lake of Denmark, was found to feed at the sediment surface. Its growth was limited to two very short periods; one in spring during the phytoplanktonic maximum when the hypolimnion was oxygen rich, and the other after the fall overturn when oxygen was available but food production was declining. Growth continued during winter under

ice-cover. During the summer, growth stopped when oxygen concentrations of the hypolimnion were slightly below 1 mg l^{-1} . Oxygen availability very likely also influenced the growth and distribution of Chironominae and Tanypodinae in deep portions of Lake Lansing during late spring through summer of 1978.

Much higher *Chaoborus* larvae population sizes were estimated from deep portions of the lake than from the shallows. A maximum population size of 500 individuals m^{-2} was estimated during the June sampling. This dropped to a minimum of ten individuals m^{-2} during August sampling. A second peak was found in September. Since the larvae of this genus live in bottom sediments part of the day and among the plankton at other hours, their numbers may change depending on the sampling time. Work by Roth (1968) indicates that some larvae do not migrate every day. Stahl (1966a) reported that the proportion migrating may be related to temperature. Northcote (1964) and Teragchi and Northcote (1966a) reported that in lakes with pronounced oxygen deficits in deep water, all four instars of *Chaoborus* remain in the water and not nestled in the sediments during the day. Compared with studies where the Ekman dredge was used, the high number of *Chaoborus* in this study may be due to the use of ponar grab that sampled the water column as well as the sediments.

A comparison with data reported from deep parts of other lakes shows that values of total density and total biomass found in this study are considerably lower. For example, Sapkrev (1975) sampled deep regions of Lake Dojran monthly from January through December of 1967. The number of one species of *Chironomus* varied between 200 and 2,000 individuals m^{-2} . This value for *Chaoborus* was between 1,500 to 10,000 individuals m^{-2} . Density and biomass of the benthic fauna in deep portions of Lake Lansing during this study were relatively low.

The shallow portions of the lake showed quite a different pattern compared to deep areas. Chironomid larvae made up, on the average 90% of the biomass and 75% of number of individuals. *Procladius* sp., *Tanytarsus* sp. and *Chaoborus* sp. were dominant on transect 1. The mean density on this fibrous-peat sediment ranged from 66 individuals m^{-2} in May to 15 individuals m^{-2} in July. Relatively large numbers of chironomid larvae and other groups inhabited the littoral bottom of transect 3. This transect with fine organic sediment supported the greatest densities and biomass on nearly all sampling dates. Transect 4 showed a similar composition of chironomid larvae as transect 1. On this transect a population increase of *Tanytarsus* occurred in June, and *Chironomus* became the most abundant genus in September. The mean density of chironomid larvae on this transect

with sandy sediment type and a mixture of fine organic particles ranged from ten individuals m^{-2} in May to 222 individuals m^{-2} in June. Since dissolved oxygen and water temperature in shallow portions show no significant differences in all sampling dates, other factors such as food supply and sediment type could be important factors in abundance of different species.

A comparison with data reported from shallow parts of other lakes shows that values of density and biomass found in this study are relatively low. For example, Okland (1964) sampled the littoral zone of Lake Borrevann in southern Norway and reported an average density of 1138 chironomid larvae m^{-2} at two meters depth. This value for *Chaoborus* was two individuals m^{-2} . Buscemi (1961) sampled bottom of Parvin Lake, Colorado. The density for Chironomidae larvae in shallow portions of the lake with sandy organic sediments was much higher than those found in this study (ranged from 108 to 703 chironomid/ m^2). Anderson and Hooper (1961) reported much higher standing crop of Chironomidae in the shallow portion of Sugarloaf Lake, Michigan than found in Lake Lansing.

The general pattern of benthic macroinvertebrate occurrence in Lake Lansing was one in which a relatively small number of species showed a degree of spatial separation occurring either in the littoral or limnetic

benthos. The inshore areas sampled supported a greater number of species and individuals than observed in the deep. The standing crops of benthic macro fauna in the lake were relatively low.

APPENDIX

Table A-1. Dissolved oxygen concentration in milligrams liter⁻¹ of Lake Lansing during the open-water season of 1978.

	May 4 Dawn	May 4 Dusk	May 5 Dawn	May 11 Dawn	May 11 Dusk	May 12 Dawn
Transect 1	11.2	11.1	9.8	11.4	11.7	10.7
Transect 2	10.7	11.8	10.3	10.7	11.6	9.2
Transect 3	9.9	9.7	9.9	9.7	11.7	10.1
Transect 4	11.8	12.1	10.1	10.9	11.5	10.9
Transect 5	11.8	12.2	10.7	10.9	11.5	10.3
Transect 6	12.1	12.2	10.5	10.7	11.1	9.7
North Basin						
Surface						
1.0	12.1	12.1	8.9	10.9	11.7	10.5
2.0	11.4	11.6	9.9	10.7	11.4	10.1
3.0	11.4	11.2	9.8	10.5	10.9	9.9
4.0	11.4	11.2	9.7	10.6	10.7	9.9
5.0	11.4	11.2	9.7	10.6	10.7	9.8
6.0	11.2	11.4	9.7	11.2	10.7	9.9
7.0	10.1	11.4	9.7	10.5	10.5	9.8
8.0	4.0	8.7	9.6	3.1	10.7	9.9
9.0					10.5	9.3
10.0						
Bottom at				8.0m		
South Basin						
Surface						
1.0	11.5	11.8	10.3	11.1	11.7	9.9
2.0	11.2	11.4	9.9	10.7	11.4	9.9
3.0	11.4	11.1	9.7	10.8	10.9	9.3
4.0	11.2	11.1	9.6	10.5	10.2	9.6
5.0	10.8	10.9	9.6	10.1	10.5	9.1
6.0	10.1	10.5	9.5	9.9	4.6	8.7
7.0	9.7			8.9		6.5
8.0						
Bottom at				7.0m		

Table A-1. Dissolved oxygen continued.

	May 18 Dawn	May 18 Dusk	May 19 Dawn	May 25 Dawn	May 25 Dusk	May 26 Dawn
Transect 1	9.7	9.8	11.8	9.5	10.9	10.6
Transect 2	9.3	9.7	12.0	8.9	9.8	9.7
Transect 3	9.5	9.6	11.9	8.5	9.6	9.6
Transect 4	9.3	9.5	11.9	8.2	10.5	9.6
Transect 5	9.3	9.5	11.6	9.5	10.6	10.2
Transect 6	9.7	9.5	11.6	9.3	11.7	10.4
North Basin						
Surface		9.1		9.3	10.5	9.9
1.0	9.8	9.4	12.0	9.1	10.1	9.6
2.0	9.5	9.4	11.8	8.7	9.3	9.2
3.0	9.1	9.3	11.6	8.1	8.5	8.0
4.0	8.5	9.1	11.4	7.2	7.4	6.5
5.0	8.5	8.9	10.9	6.4	6.3	5.8
6.0	8.1	8.6	10.5	5.3	5.6	5.6
7.0	8.1	8.3	10.1	4.4	4.7	3.9
8.0	7.9	8.1	9.5	2.9	1.7	<1.0
		at 8.5m				
9.0	7.8	6.7	8.9	1.5	0.6	<0.5
10.0						
Bottom at		9.0m		9.2m	9.6m	9.0m
South Basin						
Surface		10.1		8.2	10.3	9.9
1.0	9.5	10.1	11.3	8.1	10.9	9.8
2.0	9.3	10.1	11.6	8.4	10.5	9.9
3.0	9.0	9.4	11.5	7.7	8.5	8.8
4.0	8.6	9.1	11.1	7.2	7.3	6.4
		at 4.5m				
5.0	7.6	6.9	10.5	4.4	3.1	2.0
6.0			3.4	2.1		<1.0
7.0						<1.0
8.0						
Bottom at		5.0m		6.3m	6.0m	7.2m

Table A-1. Dissolved oxygen continued.

	June 1 Dawn	June 1 Dusk	June 2 Dawn	June 8 Dawn	June 8 Dusk	June 9 Dawn
Transect 1	9.1	9.4	9.1	9.1	9.6	9.5
Transect 2	8.5	8.9	8.1	8.6	8.9	8.5
Transect 3	8.1	10.1	9.6	8.9	9.0	8.6
Transect 4	8.8	9.0	8.0	8.7	8.7	8.6
Transect 5	8.2	8.9	8.8	9.1	9.2	8.9
Transect 6	9.2	9.2	9.2	8.9	8.9	8.4
North Basin						
Surface	8.4	8.7	9.3	9.3	8.6	8.8
1.0	8.9	8.8	9.0	8.9	8.9	8.6
2.0	8.2	8.7	8.9	8.7	8.8	8.5
3.0	7.7	7.3	7.6	8.1	8.8	8.4
4.0	4.8	4.1	4.3	1.7	3.1	3.9
5.0	3.7	2.5	3.1	0.5	0.4	0.3
6.0	2.4	2.1	2.2	0.4	0.4	0.3
7.0	1.4	<1.0	1.4	0.4	0.4	0.3
8.0	0.4	<1.0	0.5	0.4	0.4	0.3
9.0	0.2	<1.0	0.5	0.4	0.4	0.3
10.0						
Bottom at	9.2m	9.5m	9.5m	9.2m	9.8m	9.3m
South Basin						
Surface	7.6	9.1	9.9	9.9	9.3	9.1
1.0	8.5	9.1	9.6	9.5	9.4	9.1
2.0	8.5	9.2	9.5	9.5	9.3	9.1
3.0	7.0	7.1	8.4	7.4	6.4	7.3
4.0	2.7	1.8	4.4	0.6	0.4	0.3
5.0	1.2	<1.0	1.2	0.4	0.4	0.3
6.0	0.8	<1.0	0.8	0.4	0.4	0.3
7.0		<1.0	0.6	0.4	0.4	0.3
8.0				0.4		
Bottom at	5.6m	7.5m	7.5m	7.8m	7.2m	7.5m

Table A-1. Dissolved oxygen continued.

	June 15 Dawn	June 15 Dusk	June 16 Dawn	June 22 Dawn	June 22 Dusk	June 23 Dawn
Transect 1	9.2		9.6	8.4	10.8	9.7
Transect 2	9.7		9.3	6.7	10.8	9.2
Transect 3	8.7		8.3	8.0	11.0	10.1
Transect 4	8.5		9.0	7.6	10.1	9.6
Transect 5	8.7		9.6	8.1	9.9	9.6
Transect 6	8.7		9.6	7.7	11.1	10.2
North Basin						
Surface	8.7		9.7	7.9	10.7	10.0
1.0	8.5		10.2	7.6	10.7	9.9
2.0	8.3		8.3	7.4	10.5	9.8
3.0	7.9		7.4	7.0	8.7	9.7
4.0	7.6		6.2	5.9	7.4	7.4
5.0	7.4		5.1	4.8	5.8	5.4
6.0	7.0		4.9	3.8	3.9	4.0
7.0	1.7		3.7	1.7	0.7	1.4
8.0	0.3		0.4	0.2	0.1	0.4
				at 8.5m		
9.0	0.2		0.2	0.2	0.1	0.3
					at 9.5m	
10.0					0.1	
Bottom at	9.2m		8.4m	8.5m	9.5m	9.0m
South Basin						
Surface	9.2		10.9	10.1	11.6	11.1
1.0	9.1		10.5	9.7	11.4	11.0
2.0	9.1		10.1	9.5	11.7	10.9
3.0	8.1		9.4	7.6	10.1	10.0
4.0	7.5		7.8	4.3	4.1	5.4
5.0	6.4		5.6	0.5	0.4	0.4
6.0	0.4		0.4	0.3	0.2	0.3
				at 6.5m		
7.0	0.4			0.2	0.1	0.3
8.0						
Bottom at	7.0m		6.2m	6.5m	7.0m	7.5m

Table A-1. Dissolved oxygen continued.

	June 29 Dawn	June 29 Dusk	June 30 Dawn	July 6 Dawn	July 6 Dusk	July 7 Dawn
Transect 1	9.1	8.8	8.1	10.5	9.7	9.9
Transect 2	10.9	9.2	8.7	9.1	9.2	9.0
Transect 3	8.9	9.7	8.9	9.9	10.3	9.7
Transect 4	8.2	8.5	8.1	9.5	9.7	9.0
Transect 5	8.9	8.7	8.6	9.3	9.3	8.4
Transect 6	9.7	9.7	9.9	8.9	9.2	9.1
North Basin						
Surface	10.3	9.0	9.4	9.3	9.5	9.1
1.0	10.1	9.0	9.3	9.1	9.5	9.1
2.0	10.1	8.1	9.0	9.1	9.2	9.0
3.0	8.3	6.5	6.7	7.8	8.2	8.0
4.0	6.5	5.0	4.8	6.1	5.8	5.7
5.0	4.4	3.7	3.5	5.6	4.5	5.1
6.0	2.8	1.3	0.7	3.8	4.0	3.2
7.0	0.7	0.4	0.2	0.7	0.4	0.2
8.0	0.6	0.4	0.2	0.6	0.4	0.2
9.0	0.6	0.4	0.2	0.6	0.3	0.2
10.0						0.2
Bottom at	9.1m	9.1m	9.2m	8.9m	9.0m	10.5m
South Basin						
Surface	10.5	9.5	9.9	10.3	10.1	9.9
1.0	10.3	9.5	9.8	10.1	10.1	10.1
2.0	10.3	9.3	9.5	10.1	9.9	10.1
3.0	8.3	7.3	7.1	6.5	6.7	6.8
4.0	0.7	0.9	0.4	0.5	0.3	0.2
5.0	0.6	0.3	0.3	0.5	0.2	0.2
6.0	0.6	0.3	0.3	0.5	0.2	0.2
7.0	0.7	0.3	0.3	0.5		0.2
				at 7.1m		
8.0				0.5		
Bottom at	7.3m	7.5m	7.3m	7.1m	6.5m	7.5m

Table A-1. Dissolved oxygen continued.

	July 13 Dawn	July 13 Dusk	July 14 Dawn	July 20 Dawn	July 20 Dusk	July 21 Dawn
Transect 1	9.1	9.7	7.4	8.8		8.7
Transect 2	8.7	8.5		8.1		7.9
Transect 3	8.8	8.7	7.7	7.8		8.3
Transect 4	8.3	8.2	7.8	7.9		8.1
Transect 5	8.2	7.9		7.9		7.9
Transect 6	7.9	8.6	7.5	8.0		8.1
North Basin						
Surface	8.7	8.8	8.0	8.05		8.1
1.0	8.7	8.5	7.8	7.9		7.9
2.0	8.6	8.1	7.6	6.9		7.3
3.0	8.6	7.7	7.3	6.3		6.6
4.0	8.4	6.9	7.2	4.2		4.5
5.0	5.5	5.8	6.0	2.8		2.1
6.0	0.7	3.3	3.3	0.6		0.3
7.0	0.6	0.9	1.0	0.6		0.2
8.0	0.6	0.8	0.9	0.6		0.2
9.0	0.6	0.8	0.8	0.6		0.2
						at 9.5m
10.0						0.2
Bottom at	9.5m	9.0m	9.1m	9.0m		9.5m
South Basin						
Surface	9.1	9.2		9.3		8.6
1.0	9.1	9.4		8.9		8.4
2.0	9.0	9.4		8.6		7.9
3.0	7.1	7.4		6.4		5.3
4.0	0.4	0.7		0.7		0.4
5.0	0.5	0.6		0.7		0.2
6.0	0.4	0.6		0.7		0.2
				at 6.5m		
7.0	0.5	0.6		0.7		0.2
		at 7.5m				
8.0		0.6				
Bottom at	7.1m	7.5m		6.5m		7.3m

Table A-1. Dissolved oxygen continued.

	August 8 Dawn	August 8 Dusk	August 9 Dawn	August 10 Dawn	August 10 Dusk	August 11 Dawn
Transect 1	8.2	8.8	7.85	8.3	8.7	8.4
Transect 2	7.8	9.0	7.25	7.6	4.25	8.1
Transect 3	8.1	9.9	8.4	8.0	9.8	7.9
Transect 4	9.3	8.8	8.1	7.6	9.1	8.6
Transect 5	7.45	9.2	7.5	7.55	9.9	9.1
Transect 6	7.5	9.0	7.8	8.0	9.05	8.6
North Basin						
Surface	8.1		7.8	7.8		8.6
1.0	8.0	8.6	7.8	7.6	9.0	8.7
2.0	8.0	8.6	7.8	7.6	9.1	8.6
3.0	8.1	8.2	7.7	7.5	8.8	8.2
4.0	7.9	7.5	7.7	5.5	7.35	8.0
5.0	6.7	7.0	7.2	4.0	6.1	5.3
6.0	5.3	6.0	7.8	40.2	4.3	1.1
7.0	3.2	4.8	6.2	0.1	3.7	0.4
8.0	0.5	0.0	0.0	0.1	0.0	0.0
		at 8.5m				at 8.5m
9.0		0.0	0.0	0.1		0.0
10.0						
Bottom at	9.5m	8.5m	9.0m	9.0m	9.0m	8.9m
South Basin						
Surface	8.15		7.9	8.1		
1.0	8.25	9.1	8.2	7.8	9.1	8.8
2.0	8.10	9.3	8.0	7.8	9.0	8.8
3.0		8.8	7.5	6.3	8.0	
4.0	7.05	4.8	6.05	0.1	3.45	
5.0	0.2	0.0	0.0	0.1	3.25	7.8
	at 5.5m					
6.0	0.0	0.0	2.8	0.1	0.0	3.7
		at 6.5m	at 6.5m	at 6.5m		
7.0		0.0	0.0	0.1		0.0
8.0						
Bottom at	5.5m	6.5m	7.0m	6.5m	7.0m	5.7m

Table A-1. Dissolved oxygen continued.

	August 17 Dawn	August 17 Dusk	August 18 Dawn	August 24 Dawn	August 24 Dusk	August 25 Dawn
Transect 1	8.1	9.5	8.9	8.8	9.3	8.9
Transect 2	7.1	9.5	7.3	7.8	9.5	7.5
Transect 3	9.0	11.0	8.5	9.1	9.3	7.7
Transect 4	9.0	8.9	8.0	9.2	9.4	8.3
Transect 5	9.1	10.4	8.5	8.1	9.7	8.5
Transect 6	8.4	9.7	8.0	8.3	9.5	8.1
North Basin						
Surface	9.0	9.0	8.2	9.2	9.5	8.8
1.0	8.9	9.0	8.1	9.5	9.7	8.7
2.0	8.9	8.5	8.1	9.5	9.3	8.4
3.0	8.5	7.5	8.0	8.1	7.2	6.8
4.0	5.7	6.7	6.6	6.8	5.6	5.5
5.0	0.1	5.8	5.9	5.5	4.9	4.8
6.0	0.1	0.1	0.4	3.7	0.9	1.7
7.0	0.0	0.0	0.0	0.6	0.2	0.4
8.0	0.0	0.0	0.0	0.3	0.2	0.3
				at 8.5m		
9.0	0.0	0.0	0.0	0.25	0.2	0.3
		at 9.5m			at 9.5m	
10.0		0.0			0.2	
Bottom at	9.0m	9.5m	9.1m	8.5m	9.5m	9.2m
South Basin						
Surface	9.0	9.6	8.8	9.5	9.1	8.6
1.0	9.0	9.5	8.7	9.2	9.0	9.0
2.0	9.0	8.5	8.6	8.5	8.8	9.4
3.0	8.75	6.8	5.3	5.2	5.1	5.6
4.0	0.2	0.3	0.0	0.9	0.6	0.4
5.0	0.0	0.0	0.0	0.6	0.1	0.3
6.0	0.0	0.0	0.0	0.4	0.1	0.3
7.0		0.0	0.0	0.3	0.1	0.3
		at 7.5m				
3.0		0.0				
Bottom at	6.5m	7.5m	7.2m	7.0m	7.0m	

Table A-1. Dissolved oxygen continued.

	August 31 Dawn	August 31 Dusk	Sept. 1 Dawn	Sept. 7 Dawn	Sept. 7 Dusk	Sept. 8 Dawn
Transect 1	8.5	9.9	9.9	8.6	9.4	9.1
Transect 2	8.0		9.1	7.8	11.9	8.7
Transect 3	8.3	9.9	8.9	7.3	10.1	8.5
Transect 4	8.4	9.2	9.1	8.5	9.5	8.6
Transect 5	9.7	11.5	10.0	7.1	10.1	8.8
Transect 6	8.7	9.7	8.9	5.8	9.3	8.2
North Basin						
Surface	8.7	9.4	9.3	8.8	9.45	9.3
1.0	8.4	9.6	9.0	8.2	9.4	9.2
2.0	7.7	8.3	7.7	8.0	9.2	9.1
3.0	6.4	7.8	7.7	7.6	7.6	8.2
4.0	5.7	7.5	7.6	6.7	6.6	7.1
5.0	5.0	7.2	6.8	5.1	5.8	4.8
6.0	4.5	6.0	5.5	2.8	1.9	1.6
7.0	1.5	0.6	0.4	0.4	0.4	0.4
8.0	0.4	0.3	0.3	0.3	0.35	0.3
	at 8.5m		at 8.8m	at 8.5m		
9.0	0.3	0.2	0.2	0.3	0.4	0.3
10.0						
Bottom at	8.5m	9.0m	8.8m	8.5m	9.25m	9.5m
South Basin						
Surface	9.2	9.2	9.6	9.0	9.9	9.0
1.0	8.7	9.1	9.6	8.9	10.1	8.5
2.0	8.7	7.8	9.0	8.4	9.5	7.6
3.0	8.3	6.6	7.8	5.4	7.85	4.9
4.0	0.6	3.5	4.5	0.4	0.4	0.3
5.0	0.4	0.4	0.4	0.4	0.4	0.3
	at 5.5m					
6.0	0.3	0.3	0.3	0.4	0.35	0.3
7.0		0.2	0.3	0.4	0.35	0.3
					at 7.5m	
8.0					0.35	
Bottom at	5.5m	7.5m	7.0m	7.0m	7.5m	7.0m

Table A-1. Dissolved oxygen continued.

	Sept. 14 Dawn	Sept. 14 Dusk	Sept. 15 Dawn
Transect 1	7.5	8.8	8.3
Transect 2	8.1	9.1	7.6
Transect 3	8.6	9.4	8.4
Transect 4	8.05	9.4	8.1
Transect 5	8.05	9.6	8.0
Transect 6	8.05	9.5	6.6
North Basin			
Surface	8.0	9.3	8.2
1.0	7.7	9.2	8.1
2.0	7.6	9.0	8.1
3.0	7.3	8.5	8.1
4.0	7.3	8.0	8.0
5.0	7.25	8.0	7.7
6.0	7.3	6.1	7.2
7.0	7.15		6.6
8.0	7.05		6.0
9.0	0.4		0.1
10.0			
Bottom at	9.2m		9.5m
South Basin			
Surface	7.6	8.7	8.2
1.0	7.5	8.5	8.1
2.0	7.35	7.9	7.9
3.0	7.35	6.6	7.7
4.0	7.2	6.6	7.0
5.0	5.5	6.0	5.3
6.0	0.5	0.0	
7.0	0.5	0.0	
8.0			
Bottom at	7.5m		7.5m

Table A-2. Water temperature ($^{\circ}\text{C}$) of Lake Lansing during the open-water season of 1978.¹

	April 24	May 4	May 11	May 18	May 25	June 1	June 8
Transect 1		11.8	13.0	16.0	18.0	24.0	21.0
Transect 2		10.8	12.0	15.0	19.5	23.0	21.0
Transect 3		11.0	12.0	15.5	19.0	23.5	21.5
Transect 4		11.0	12.0	15.0	19.0	23.0	21.5
Transect 5		11.0	12.0	15.5	19.0	23.5	22.0
Transect 6		11.0	12.0	15.2	20.0	23.5	21.0
North Basin							
Surface	10.5				19.0	23.5	21.0
1.0		11.0	12.0	15.0	19.0	23.0	21.5
2.0		11.0	11.5	13.5	18.0	24.0	21.5
3.0		11.0	11.0	14.5	17.5	20.0	21.0
4.0		11.0	11.0	14.0	16.8	17.0	18.0
5.0	8.8	11.0	11.0	13.0	15.0	16.0	16.5
6.0		10.5	10.5	13.0	14.0	14.0	15.0
7.0	8.5	10.2	10.5	13.0	13.2	13.5	14.0
8.0		10.2	10.0	12.8	13.0	13.0	13.5
9.0	8.2			12.5	13.0	13.0	13.0
10.0							
Bottom at			8.0m		9.2m	9.2m	9.2m
South Basin							
Surface	12.0				20.0	22.0	21.0
1.0		11.0	12.0	15.0	20.0	23.0	21.0
2.0		11.0	11.0	15.0	18.0	23.0	21.0
3.0	10.5	11.0	11.0	14.5	16.5	16.5	20.0
4.0		10.5	10.0	14.0	16.0	16.0	16.0
5.0		10.0	10.0	14.0	14.5	14.0	14.5
6.0	7.5	10.0	10.0		13.0	13.0	14.0
7.0		10.0	9.5				13.0
8.0							13.0
Bottom at			7.0m		6.3m	6.6m	7.3m

1. Values from the first dawn sampling date.

Table A-2. Water temperature continued.

	June 15	June 22	June 29	July 6	July 13	July 20
Transect 1	16.5	24.0	25.0	22.0	21.5	23.5
Transect 2	17.0	21.0	24.0	22.5	22.0	23.5
Transect 3	17.0	22.0	23.0	23.0	23.0	23.5
Transect 4	17.0	21.0	24.0	22.5	22.0	24.0
Transect 5	17.0	21.5	25.0	23.0	22.0	23.5
Transect 6	17.0	21.0	26.0	22.0	22.0	23.5
North Basin						
Surface	17.0	22.0	24.0	24.0	22.0	24.0
1.0	18.0	21.0	24.0	24.0	22.0	24.0
2.0	18.0	22.0	24.0	23.5	22.5	24.0
3.0	17.5	22.0	24.0	22.0	22.5	23.0
4.0	17.0	20.5	23.0	21.0	22.5	22.5
5.0	17.0	20.0	22.0	21.0	21.5	22.0
6.0	17.0	19.0	21.0	20.5	20.5	21.0
7.0	16.0	18.0	19.0	19.0	18.5	18.5
8.0	13.0	13.0	16.0	16.0	16.0	16.0
		at 8.5m		at 8.9m		
9.0	12.0	14.5	15.0	15.0	15.0	15.0
10.0						
Bottom at	9.2m	8.5m	9.1m	8.9m	9.5m	9.0m
South Basin						
Surface	17.0	21.5	25.0	22.0	20.0	23.5
1.0	17.0	22.0	25.0	22.5	22.0	24.0
2.0	17.0	22.0	24.0	22.0	22.0	23.5
3.0	16.5	19.0	21.0	20.0	21.0	22.0
4.0	16.5	17.0	19.0	18.0	19.0	20.0
5.0	15.5	16.0	17.0	16.5	16.5	17.0
6.0	13.0	14.0	15.0	14.5	15.0	15.0
		at 6.5m				at 6.5m
7.0	12.0	14.0	14.0	14.0	14.0	14.5
				at 7.1m		
8.0				14.0		
Bottom at	7.0m	6.5m	7.3m	7.1m	7.1m	6.5m

Table A-2. Water temperature continued.

	August 3	August 10	August 17	August 24	August 31	Sept. 7
Transect 1	22.0	22.5	23.5	22.5	21.5	23.0
Transect 2	21.5	23.0	22.5	23.0	21.0	21.5
Transect 3	21.5	22.0	23.5	24.0	21.0	22.0
Transect 4	21.5	23.0	23.5	24.0	21.5	22.0
Transect 5	21.5	23.0	22.5	24.0	21.0	22.5
Transect 6	21.5	23.0	22.0	23.5	20.5	22.0
North Basin						
Surface	22.0	23.0	24.0	24.0	21.5	22.5
1.0	22.0	23.0	24.0	24.5	22.0	22.5
2.0	22.0	23.0	24.0	24.5	22.0	23.0
3.0	22.0	23.0	24.0	23.5	22.0	23.0
4.0	22.0	22.5	23.5	23.0	22.0	22.5
5.0	22.0	22.0	22.0	23.0	22.0	22.0
6.0	21.5	21.0	20.0	22.0	22.0	21.5
7.0	20.0	20.0	17.0	20.5	21.0	20.5
8.0	16.2	17.0	16.0	18.0	17.0	18.0
				at 8.5m	at 8.5m	at 8.5m
9.0	15.6	16.0	16.0	17.0	16.0	16.0
10.0						
Bottom at	9.5m	9.0m	9.0m	8.5m	8.5m	8.5m
South Basin						
Surface	21.5	23.0	23.5	24.0	22.0	22.5
1.0	21.5	23.0	23.5	24.0	22.5	22.5
2.0	21.5	23.0	23.5	23.5	22.5	23.0
3.0	21.5	22.5	23.5	22.5	22.5	22.0
4.0	20.0	20.0	21.0	21.5	20.5	21.0
5.0	17.0	18.0	18.0	17.0	18.0	18.0
					at 5.5m	
6.0	15.0	15.5	17.0	16.0	17.5	16.0
7.0		15.0		14.0		15.0
8.0						
Bottom at	5.5m	6.5m	6.5m	7.0m	5.5m	7.0m

Table A-2. Water temperature continued.

	Sept. 14	Sept. 21	Sept. 28	October 5	October 12	October 19
Transect 1	19.0	21.5	14.5	13.5	12.0	9.5
Transect 2	18.8	21.5	15.0	12.5	11.5	9.0
Transect 3	17.2	22.0	14.5	13.5	11.5	9.0
Transect 4	19.0	22.5	16.0	13.2	12.0	9.5
Transect 5	18.5	22.5	14.5	13.0	12.0	9.0
Transect 6	18.5	22.0	14.0	13.0	11.0	9.0
North Basin						
Surface	19.0	22.0	16.0	13.5	12.0	9.0
1.0	19.0	22.5	16.0	13.5	12.0	9.5
2.0	19.0	21.5	16.0	13.5	12.0	9.5
3.0	19.0	20.0	16.0	13.5	12.0	9.5
4.0	19.0	20.0	16.5	13.5	11.5	9.5
5.0	19.0	20.0	16.5	13.5	11.5	9.5
6.0	18.5	19.5	16.0	13.5	11.5	9.5
7.0	18.5	19.5	16.5	13.5	11.0	9.5
8.0	18.5	19.0	16.5	13.2	11.0	9.5
9.0	18.0		at 8.5m 16.0			
10.0						
Bottom at	9.2m	8.5m	8.5m	8.5m	8.5m	8.25m
South Basin						
Surface	19.0		15.0	13.2	11.5	9.0
1.0	19.0	21.5	15.0	13.5	11.5	9.0
2.0	19.0	22.0	15.5	13.5	11.5	9.0
3.0	19.0	22.0	15.5	13.5	11.5	9.0
4.0	19.0		15.5	13.5	11.0	9.0
5.0	18.5		15.0	13.5	10.5	9.0
6.0	15.5		15.0	13.5	10.0	9.0
7.0	14.5		14.5		at 6.3m 10.0	9.0
8.0						
Bottom at	7.5m		7.0m	6.0m	6.3m	7.5m

Table A-2. Water temperature continued.

	October 26	November 2	November 9	November 16	November 22
Transect 1	10.0	9.0	8.5	5.0	3.5
Transect 2	9.5	8.0	8.0	5.0	2.0
Transect 3	9.0	8.0	8.0	5.0	3.0
Transect 4	9.5	8.5	8.0	6.0	3.0
Transect 5	9.5	8.0	8.0	5.0	3.0
Transect 6	9.5	8.0	7.0	4.0	2.5
North Basin					
Surface	9.2	8.5	8.0	6.0	3.0
1.0	9.2	8.5	8.0	6.0	2.5
2.0	9.5	8.5	8.0	6.0	3.0
3.0	9.5	8.5	8.0	6.0	3.0
4.0	9.5	8.5	8.0	6.0	3.0
5.0	9.5	8.5	8.0	6.0	3.0
6.0	9.5	8.5	8.0	6.0	3.0
7.0	9.5	8.5	8.0	6.0	3.0
8.0	9.5	8.5	8.0	6.0	3.0
9.0					
10.0					
Bottom at	8.0m	8.25m	8.0m	8.5m	8.5m
South Basin					
Surface	9.0	8.0	7.5	4.5	3.5
1.0	9.5	8.5	8.0	5.0	3.0
2.0	9.5	8.5	8.0	5.5	3.0
3.0	9.5	8.5	8.0	5.5	3.0
4.0	9.5	8.5	8.0	5.5	3.0
5.0	9.5	8.5	8.0	5.5	3.0
6.0	9.5	8.5	8.0	5.5	3.0
7.0	9.5	8.5	8.0	5.5	
8.0					
Bottom at	7.0m	7.0m	7.0m	7.0m	6.5m

Table A-3. PH for Lake Lansing during the open-water season of 1978.¹

	May 4	May 11	May 18	May 25	June 1	June 8
Transect 1	9.1	8.8	8.3	8.4	8.4	8.4
Transect 2	9.1	8.9	8.5	8.3	8.4	8.5
Transect 3	8.5	8.9	8.4	8.4	8.3	8.3
Transect 4	9.0	8.9	8.0	7.8	8.3	8.4
Transect 5	9.0	8.9	8.1	8.4	8.2	8.6
Transect 6	9.0	8.9	8.3	8.3	8.4	8.5
North Basin						
Surface						
1.0	8.1	8.9	8.3	8.5	8.4	8.5
2.0						
3.0						
4.0						
5.0						
6.0						
7.0	8.7	8.8				
8.0			8.1	7.6	7.4	7.4
9.0						
10.0						
South Basin						
Surface						
1.0	9.0	8.8		8.4	8.3	8.4
2.0						
3.0						
4.0			7.8			
5.0		8.9		7.5	7.5	
6.0	8.8					
7.0						7.3
8.0						

1. Values from the first dawn sampling date.

Table A-3. PH continued.

	June 15	June 22	June 29	July 6	July 13	July 20
Transect 1	8.7	8.7	8.9	8.7	8.4	8.5
Transect 2	8.7	8.5	8.9	8.7	8.4	8.4
Transect 3	8.6	8.5	8.7	8.7	8.4	8.2
Transect 4	8.7	8.7	8.8	8.7	8.4	8.5
Transect 5	8.8	8.6	8.8	8.7	8.3	8.4
Transect 6	8.6	8.7	8.8	8.6	8.4	8.4
North Basin						
Surface						
1.0	8.7	8.5	8.8	8.7	8.4	8.4
2.0						
3.0						
4.0						
5.0						
6.0		8.2				
7.0						
8.0	7.8		7.6	7.6		7.2
9.0					7.3	
10.0						
South Basin						
Surface						8.5
1.0	8.7	8.8	8.5	8.7	8.5	
2.0						
3.0						
4.0						
5.0		7.7				
6.0	7.9		7.5	7.4	7.1	7.2
7.0						
8.0						

Table A-3. PH continued.

	August 3	August 10	August 17	August 24	August 31	Sept. 7
Transect 1	8.4	8.8	8.8	9.2	8.6	8.9
Transect 2	8.4	8.9	8.5	9.0	8.5	8.6
Transect 3	8.5	8.8	8.8	9.0	8.6	8.6
Transect 4	8.6	8.8	8.9	9.2	8.6	8.8
Transect 5	8.4	8.8	8.9	9.1	8.7	8.7
Transect 6	8.4	8.9	8.7	9.1	8.6	8.4
North Basin						
Surface						
1.0	8.5	8.9	8.8	9.1	8.7	8.8
2.0						
3.0						
4.0						
5.0						
6.0						
7.0				7.9		
8.0	7.3	7.7	7.4		7.4	7.3
9.0						
10.0						
South Basin						
Surface					8.5	
1.0	8.5	8.8	8.8	9.1		8.9
2.0						
3.0						
4.0						
5.0	7.4				7.3	
6.0		7.8	7.4	7.6		7.1
7.0						
8.0						

Table A-3. PH continued.

	Sept. 14	Sept. 21	Sept. 28	October 5	October 12	October 19
Transect 1	8.3	8.9	8.1	8.6	8.6	8.6
Transect 2	8.3	8.8	8.4	8.7	8.7	8.6
Transect 3	8.1	8.8	8.3	8.7	8.7	8.6
Transect 4	8.2	9.0	8.4	8.8	8.7	8.7
Transect 5	8.3	9.0	8.5	8.8	8.7	8.7
Transect 6	8.3	9.0	8.4	8.7	8.7	8.6
North Basin						
Surface						
1.0	8.3	9.0	8.4	8.8	8.7	8.6
2.0						
3.0						
4.0						
5.0						
6.0						at 7.5m
7.0						8.5
8.0	8.2	8.3	8.4	8.8	8.5	
9.0						
10.0						
South Basin						
Surface						
1.0	8.0	8.9	8.1	8.7	8.4	8.6
2.0						
3.0						
4.0				at 5.5m		
5.0				8.6		at 6.5m
6.0			8.0		8.6	8.3
7.0	7.2					
8.0						

Table A-3. PH continued.

	October 26	November 2	November 9	November 16	November 22
Transect 1	8.35	8.6	8.55	8.3	8.0
Transect 2	8.70	8.7	8.8	8.1	8.0
Transect 3	8.85	8.8	8.9	8.4	8.1
Transect 4	8.50	8.8	8.7	8.2	8.2
Transect 5	8.40	8.8	8.7	8.3	8.1
Transect 6	8.35	8.7	8.7	8.2	8.1
North Basin					
Surface					
1.0	8.40	8.7	8.55	8.1	8.2
2.0					
3.0					
4.0					
5.0					
6.0		at 7.5m			
7.0		8.6	8.55		8.1
8.0	8.50			8.1	
9.0					
10.0					
South Basin					
Surface					
1.0	8.50	8.6	8.55	8.2	8.2
2.0					
3.0					
4.0					
5.0					
6.0		8.7	8.9	8.0	8.1
7.0	8.40				
8.0					

Table A-4. Alkalinity in milligrams CaCO_3 liter⁻¹ of Lake Lansing during the open-water season of 1978.¹

	May 4	May 11	May 18	May 25	June 1	June 8
Transect 1	122	124	125	125	117	119
Transect 2	124	127	123	121	122	125
Transect 3	114	126	125	125	126	122
Transect 4	123	125	123	127	123	125
Transect 5	124	122	124	128	128	121
Transect 6	122	126	125	123	121	121
North Basin						
Surface						
1.0	111	125	124	125	124	124
2.0						
3.0						
4.0						
5.0						
6.0						
7.0	120	126				
8.0			124	126	132	135
9.0						
10.0						
South Basin						
Surface						
1.0	121	126	121	124	119	121
2.0						
3.0						
4.0			123			
5.0				125	126	
6.0	121	127				
7.0						145
8.0						

1. Values from the first dawn sampling date.

Table A-4. Alkalinity continued.

	June 15	June 22	June 29	July 6	July 13	July 20
Transect 1	119	109	105	108	110	99
Transect 2	118	118	106	112	104	107
Transect 3	122	121	111	107	107	107
Transect 4	122	119	112	113	109	109
Transect 5	117	119	112	111	111	103
Transect 6	122	110	110	112	108	102
North Basin						
Surface						
1.0	122	120	112	110	111	108
2.0						
3.0						
4.0						
5.0						
6.0		122				
7.0						
8.0	140		138	131		139
9.0					139	
10.0						
South Basin						
Surface						103
1.0	119	116	100	105	104	
2.0						
3.0						
4.0						
5.0		126				
6.0	128		133	139	141	133
7.0						
8.0						

Table A-4. Alkalinity continued.

	August 3	August 10	August 17	August 24	August 31	Sept. 7
Transect 1	114	108	104	97	104	112
Transect 2	111	111	106	96	101	105
Transect 3	112	110	104	96	104	107
Transect 4	108	112	105	105	102	107
Transect 5	110	109	103	106	104	106
Transect 6	109	107	104	107	106	110
North Basin						
Surface						
1.0	107	110	104	104	106	105
2.0						
3.0						
4.0						
5.0						
6.0						
7.0				141		
8.0	156	167	153		138	145
9.0						
10.0						
South Basin						
Surface					108	
1.0	107	109	104	107		108
2.0						
3.0						
4.0						
5.0	105				133	
6.0		167	160	170		185
7.0						
8.0						

Table A-4. Alkalinity continued.

	Sept. 14	Sept. 21	Sept. 28	October 5	October 12	October 19
Transect 1	114	113	108	111	110	118
Transect 2	110	110	108	108	112	117
Transect 3	110	106	109	108	110	117
Transect 4	110	108	103	111	111	116
Transect 5	109	107	106	111	112	117
Transect 6	111	109	110	110	111	120
North Basin						
Surface						
1.0	110	111	106	109	109	116
2.0						
3.0						
4.0						
5.0						
6.0						at 7.5m
7.0						117
8.0	108	109	105	109	113	
9.0						
10.0						
South Basin						
Surface						
1.0	109	111	105	110	124	117
2.0						
3.0						
4.0				at 5.5m		
5.0				110		at 6.5m
6.0			107		111	118
7.0	169					
8.0						

Table A-4. Alkalinity continued.

	October 26	November 2	November 9	November 16	November 22
Transect 1	119	120	126	125	123
Transect 2	118	122	124	119	122
Transect 3	122	120	129	121	126
Transect 4	118	118	119	121	127
Transect 5	118	121	126	121	125
Transect 6	118	121	125	119	125
North Basin					
Surface					
1.0	116	121	127	121	127
2.0					
3.0					
4.0					
5.0					
6.0		at 7.5m			
7.0		122	126		122
8.0	118			120	
9.0					
10.0					
South Basin					
Surface					
1.0	115	121	134	123	125
2.0					
3.0					
4.0					
5.0					
6.0		121	124	122	126
7.0	117				
8.0					

Table A-5. Free carbon dioxide concentration in micromoles liter⁻¹ of Lake Lansing during the open-water season of 1978.

	May 4 Dawn	May 4 Dusk	May 5 Dawn	May 11 Dawn	May 11 Dusk	May 12 Dawn
Transect 1	5.08	14.67	67.22	10.45	11.02	17.24
Transect 2	5.28	13.87	9.38	10.93	8.28	13.52
Transect 3	20.39	14.67	11.64	10.85	8.30	21.30
Transect 4	6.66	11.02	470.47	13.66	8.15	17.14
Transect 5	6.72	13.42	24.48	10.50	8.08	13.60
Transect 6	6.61	13.87	378.87	70.87	8.32	13.38
North Basin						
Surface						
1.0	50.48	85.47	29.74	8.46	8.44	17.10
2.0						
3.0						
4.0						
5.0						13.71
6.0					10.85	
7.0	13.59	11.11	11.39	11.18		
8.0						
9.0						
10.0						
South Basin						
Surface						
1.0	6.55	27.89	11.42	10.85	10.67	17.45
2.0						
3.0						
4.0						
5.0		22.43	28.41		8.55	13.55
6.0	10.84			18.30		
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	May 18 Dawn	May 18 Dusk	May 19 Dawn	May 25 Dawn	May 25 Dusk	May 26 Dawn
Transect 1	32.50	25.04	39.87	25.04	23.36	30.76
Transect 2	20.27	41.70	50.88	30.77	23.17	244.22
Transect 3	25.89	40.51	53.86	24.71	29.30	30.89
Transect 4	65.12	32.76	51.21	101.46	23.56	38.57
Transect 5	51.72	40.46	52.55	25.30	29.32	38.59
Transect 6	32.84	39.82	51.80	30.31	23.17	78.79
North Basin						
Surface						
1.0	32.66	32.50	64.59	19.52	24.50	197.04
2.0						
3.0						
4.0						
5.0						
6.0		55.41				
7.0						4554.28
8.0	54.44		140.50	175.26		
9.0					361.30	
10.0						
South Basin						
Surface						
1.0		40.25	49.73	24.17	23.98	64.43
2.0						
3.0		26.38				
4.0	105.63				50.97	
5.0			85.51	212.50		1770.76
6.0						
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	June 1 Dawn	June 1 Dusk	June 2 Dawn	June 8 Dawn	June 8 Dusk	June 9 Dawn
Transect 1	26.94	17.21	18.44	22.81	18.43	9.67
Transect 2	22.60	17.96	46.72	18.93	24.17	15.47
Transect 3	56.58	13.63	47.10	29.33	30.77	15.52
Transect 4	45.97	18.06	19.02	23.76	23.75	12.08
Transect 5	47.43	13.79	23.71	14.21	14.93	9.46
Transect 6	28.10	16.47	22.05	18.33	29.28	14.62
North Basin						
Surface						
1.0	35.52	13.87	17.99	18.62	24.76	15.41
2.0						
3.0						
4.0						
5.0						
6.0						
7.0		182.80				
8.0	2917.58		311.16	294.97		119.17
9.0					249.50	
10.0						
South Basin						
Surface						
1.0	44.48	10.85	23.14	23.20	23.72	11.59
2.0						
3.0						
4.0						
5.0	343.25					
6.0			486.48		240.04	
7.0		160.57		402.99		157.85
8.0						

Table A-5. Free carbon dioxide continued.

	June 15 Dawn	June 15 Dusk	June 16 Dawn	June 22 Dawn	June 22 Dusk	June 23 Dawn
Transect 1	11.96		18.87	9.73	7.15	13.15
Transect 2	11.78		19.21	17.87	13.15	14.58
Transect 3	15.46		14.81	18.02	13.39	10.73
Transect 4	12.18		19.81	11.20	10.82	13.03
Transect 5	9.19		18.12	14.10	13.04	7.62
Transect 6	15.46		15.06	10.35	13.15	9.22
North Basin						
Surface						
1.0	12.02		15.06	18.17	13.98	
2.0						
3.0						
4.0						
5.0						16.48
6.0			at 7.5m	38.50		
7.0			26.19			58.44
8.0	122.67					
9.0					315.81	
10.0						
South Basin						
Surface						
1.0	11.88		18.71	8.43	7.71	
2.0						
3.0						
4.0			at 5.5m			23.40
5.0			50.97	131.91		
6.0	88.99				457.13	6.94
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	June 29 Dawn	June 29 Dusk	June 30 Dawn	July 6 Dawn	July 6 Dusk	July 7 Dawn
Transect 1	5.66	11.07	9.04	9.99	7.24	12.47
Transect 2	5.32	12.38	9.72	10.27	9.64	10.08
Transect 3	10.09	12.36	12.89	9.72	9.37	15.89
Transect 4	7.85	12.49	7.85	10.36	9.72	7.71
Transect 5	7.70	12.29	7.63	10.09	9.91	20.75
Transect 6	7.51	8.77	5.66	13.47	7.71	15.80
North Basin						
Surface						
1.0	7.85	12.31	10.35	9.82	15.39	12.70
2.0						
3.0						
4.0						
5.0						
6.0						
7.0						
8.0	182.02	216.27	103.67	172.78	229.29	
9.0						408.46
10.0						
South Basin						
Surface						
1.0	14.12	8.89	5.79	9.63	7.36	11.32
2.0						
3.0						
4.0						
5.0						
6.0	223.79	218.74	227.15	297.63	389.69	
7.0						600.54
8.0						

Table A-5. Free carbon dioxide continued.

	July 13 Dawn	July 13 Dusk	July 14 Dawn	July 20 Dawn	July 20 Dusk	July 21 Dawn
Transect 1	20.91	16.23	15.75	14.36		13.98
Transect 2	19.60	20.36		19.56		18.58
Transect 3	19.82	20.17	32.19	31.40		24.43
Transect 4	20.55	16.24	26.66	15.67		19.18
Transect 5	26.46	26.93		18.92		18.92
Transect 6	20.36	20.17	25.42	18.64		13.91
North Basin						
Surface						
1.0	20.92	16.08	25.74	19.66		18.73
2.0						
3.0						
4.0						
5.0						
6.0						
7.0		at 8.5m				
8.0		194.39	859.55	461.36		
9.0	369.67					722.12
10.0						
South Basin						
Surface				14.94		
1.0	15.48	15.34				17.88
2.0						
3.0						
4.0						
5.0						
6.0	594.67			447.04		606.93
7.0		1176.02				
8.0						

Table A-5. Free carbon dioxide continued.

	August 3 Dawn	August 3 Dusk	August 4 Dawn	August 10 Dawn	August 10 Dusk	August 11 Dawn
Transect 1	21.49	9.28	32.46	7.78	3.60	3.67
Transect 2	21.10	7.78	30.77	6.18	3.53	7.99
Transect 3	16.82	5.87	32.77	7.96	3.60	7.99
Transect 4	12.80	7.92	10.63	7.99	2.73	24.79
Transect 5	20.91	5.54	25.69	7.78	5.71	24.55
Transect 6	20.72	5.70	32.46	5.98	3.53	7.85
North Basin Surface						
1.0	15.93	6.21	30.11	6.15	3.14	20.37
2.0						
3.0						
4.0						
5.0						
6.0						
7.0						at 8.5m
8.0	110.12	192.57	723.06	165.91	248.51	330.65
9.0						
10.0						
South Basin Surface						
1.0	16.07	6.26	25.72	7.78	3.51	15.94
2.0						
3.0						
4.0						
5.0	216.94	at 6.5m	at 6.5m			
6.0		372.05	894.76	146.23	330.61	294.46
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	August 17 Dawn	August 17 Dusk	August 18 Dawn	August 24 Dawn	August 24 Dusk	August 25 Dawn
Transect 1	7.36	5.45	6.94	3.33	7.17	9.10
Transect 2	15.65	5.05	11.90	4.19	7.16	11.90
Transect 3	7.36	3.84	7.36	4.11	7.15	15.24
Transect 4	5.82	4.41	5.82	2.70	6.89	11.90
Transect 5	5.78	3.37	5.71	3.53	5.50	9.10
Transect 6	9.57	3.74	7.43	3.60	7.11	11.90
North Basin						
Surface						
1.0	7.29	4.41	5.82	3.43	5.60	9.28
2.0						
3.0						
4.0						
5.0						
6.0						
7.0				87.45	at 8.5m	
8.0	320.19		307.93		742.77	450.18
9.0		311.82				
10.0						
South Basin						
Surface						
1.0	7.36	4.88	5.71	3.56	5.56	11.68
2.0						
3.0						
4.0						
5.0		at 6.5m				
6.0	330.58	521.10	567.57	224.22	544.52	568.05
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	August 31 Dawn	August 31 Dusk	Sept. 1 Dawn	Sept. 7 Dawn	Sept. 7 Dusk	Sept. 8 Dawn
Transect 1	12.32	2.40	19.53	6.26	3.38	7.50
Transect 2	15.30	1.72	36.25	12.44	3.42	8.54
Transect 3	13.99	1.64	35.08	12.57	3.36	6.95
Transect 4	12.08	1.65	23.58	7.78	3.22	6.70
Transect 5	9.11	1.22	28.41	9.72	2.85	7.78
Transect 6	12.77	1.43	39.80	20.73	3.48	10.96
North Basin						
Surface						
1.0	11.05	1.62	35.95	7.56	3.03	7.49
2.0						
3.0						
4.0						
5.0						
6.0						
7.0						
8.0	285.13	152.95	445.67	372.46	234.69	246.25
9.0						
10.0						
South Basin						
Surface	16.08					
1.0		2.43	37.03	6.09	3.38	6.89
2.0						
3.0						
4.0						
5.0	341.64					
6.0		242.43	710.82	773.21	553.63	266.65
7.0						
8.0						

Table A-5. Free carbon dioxide continued.

	Sept. 14 Dawn	Sept. 14 Dusk	Sept. 15 Dawn
Transect 1	28.48	29.82	43.08
Transect 2	27.56	8.26	21.24
Transect 3	44.88	9.46	34.59
Transect 4	34.72	9.34	20.78
Transect 5	27.42	8.20	16.98
Transect 6	27.92	12.19	27.35
North Basin			
Surface			
1.0	27.48	10.53	16.73
2.0			
3.0			
4.0			
5.0			
6.0		15.13	
7.0			
8.0	34.31		43.31
9.0			
10.0			
South Basin			
Surface			
1.0	54.78	13.59	27.02
2.0			
3.0			
4.0			
5.0			
6.0		330.47	651.93
7.0	573.90		
8.0			

Table A-5. Free carbon dioxide continued.

	June 8	June 15	June 22	June 29	July 6	July 13	July 20
Transect 1	235	220	217	240	225	231	245
Transect 2	245	225	223	220	231	240	250
Transect 3	240	230	226	240	215	240	250
Transect 4	245	225	224	245	235	250	250
Transect 5	240	220	224	240	230	245	250
Transect 6	235	205	224	245	240	245	245
North Basin							
Surface							
1.0	250	225	231	245	233	245	250
2.0							
3.0							
4.0							
5.0							
6.0			239				
7.0							
8.0	245	240		260	252		280
9.0						260	
10.0							
South Basin							
Surface							250
1.0	245	230	227	250	229	240	
2.0							
3.0							
4.0							
5.0			237				
6.0		235		260	261	262	275
7.0	250						
8.0							

1. Values from the first dawn sampling date.

Table A-6. Conductivity in micromhos cm^{-1} of Lake Lansing during the open-water season of 1978.¹

	August 3	August 10	August 17	August 24	August 31	Sept. 7	Sept. 14
Transect 1	235	225	234	240	230	220	250
Transect 2	240	235	240	245	225	245	235
Transect 3	240	235	240	245	225	242	250
Transect 4	235	230	245	245	225	240	250
Transect 5	241	234	240	248	220	245	250
Transect 6	240	232	240	240	230	225	260
North Basin							
Surface							
1.0	242	235	236	240	225	245	260
2.0							
3.0							
4.0							
5.0							
6.0							
7.0				270			
8.0	272	275	275		250	280	280
9.0							
10.0							
South Basin							
Surface					230		
1.0	245	240	240	240		245	260
2.0							
3.0							
4.0							
5.0	271				260		
6.0		285	290	280		310	
7.0							270
8.0							

Table A-6. Conductivity continued.

	Sept. 21	Sept. 28	October 5	October 12	October 19
Transect 1	210	182	185	197	175
Transect 2	205	180	182	195	177
Transect 3	205	180	180	195	178
Transect 4	210	185	180	195	176
Transect 5	205	180	182	195	175
Transect 6	210	183	185	195	180
North Basin					
Surface					
1.0	205	181	180	200	178
2.0					
3.0					
4.0					
5.0					
6.0					at 7.5m
7.0					180
8.0	210	180	182	197	
9.0					
10.0					
South Basin					
Surface					
1.0	215	190	185	197	180
2.0					
3.0					
4.0			at 5.5m		
5.0			190		at 6.5m
6.0		190		195	185
7.0					
8.0					

Table A-6. Conductivity continued.

	October 26	November 2	November 9	November 16	November 22
Transect 1	185	175	180	165	220
Transect 2	175	155	180	168	220
Transect 3	175	175	180	167	225
Transect 4	175	180	176	172	215
Transect 5	178	180	180	170	220
Transect 6	180	180	180	172	230
North Basin					
Surface					
1.0	180	180	180	175	220
2.0					
3.0					
4.0					
5.0					
6.0		at 7.5m			
7.0		180	180		224
8.0	175			172	
9.0					
10.0					
South Basin					
Surface					
1.0	180	180	180	176	222
2.0					
3.0					
4.0					
5.0					
6.0		185	180	176	225
7.0	180				
8.0					

Figure A-1. View of the head capsule of *Procladius* sp.

Figure A-2. Enlargement of lingua of *Procladius* sp. shown in Figure A-1 showing five dark teeth used as a key character.

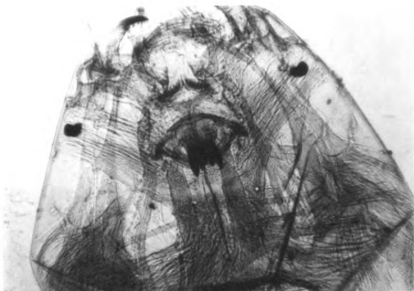


Figure A-1.

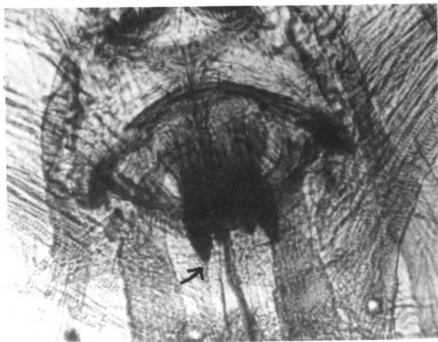


Figure A-2.

Figure A-3. Enlargement of paralabial combs of
Procladius sp. shown in Figure A-1.



Figure A-3.

Figure A-4. View of head capsule of *Chironomus* sp.

Figure A-5. Enlargement of labial plate of *Chironomus* shown in Figure A-4. Thirteen dark pointed teeth and completely trifid middle tooth are characteristic of the genus.



Figure A-4.

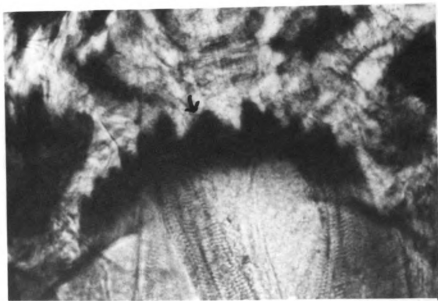


Figure A-5.

Figure A-6. View of head capsule of *Parachironomus* sp.

Figure A-7. Enlargement of labial and paralabial plates of *Parachironomus* sp. shown in Figure A-6. The recurved striations on the paralabial plate and the large, peaked middle tooth of the labial plate are distinctive of the genus.



Figure A-6.

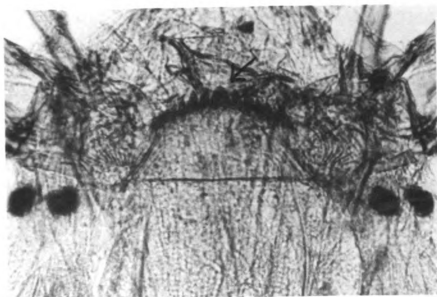


Figure A-7.

Figure A-8. View of head capsule of *Tanytarsus* sp.
showing the long, curved first antennal
segments.

Figure A-9. View of head capsule of *Ablabesmyia* sp.
showing ensheathed antenna.

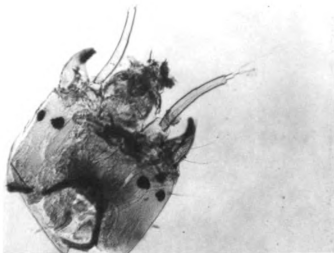


Figure A-8



Figure A-9

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