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CHLOROPHYLL *a* IN THE PLANKTON
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[signature]
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CHLOROPHYLL *a* IN THE PLANKTON AND MACROPHYTES OF TWO LAKES

By

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ABSTRACT

CHLOROPHYLL *a* IN THE PLANKTON
AND MACROPHYTES OF TWO LAKES

By

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The phytoplankton and macrophyte chlorophyll *a* and secchi disc transparency of Skinner Lake, Indiana, and Lake Lansing, Michigan, were examined during 1978 and 1979. Chlorophyll *a* was used as an indicator of standing crop. Phytoplankton chlorophyll *a* values of these lakes were within the range typical of freshwaters, with the exception of those from the hypolimnion of Lake Lansing. Here, the values were high due to the presence of photosynthetic bacteria. Transparency values for both lakes were low. A comparison of phytoplankton chlorophyll *a* and transparency values of these lakes to trophic classification schemes indicated that both lakes were eutrophic. Macrophyte chlorophyll *a* values were expressed on an areal and lake total basis. In a comparison of the two lakes, Lake Lansing had relatively low standing crops of primary producers.

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INTRODUCTION

Under the Clean Lakes Program, the U.S. EPA has chosen Lake Lansing, Michigan, and Skinner Lake, Indiana, to test the effectiveness of various lake restoration methods. Lake Lansing is undergoing hydraulic dredging to deepen the littoral zone and improve shorelines. The practices used at Skinner Lake are designed to hold nutrients and soil on the watershed. These practices include sediment basins, minimum tillage, livestock exclusion, group tile mains, terraces, tree planting, vegetative cover and grassed waterways. One evaluation of these practices will be to compare the standing crop of the primary producers of these lakes before and after the application of the treatments.

Few studies on the primary producers of Lake Lansing have been conducted. Jackson (1963) found a diverse algal flora in Lake Lansing with bluegreen algal blooms occurring occasionally, generally in the fall. Young *et al* (1974) quantified phytoplankton production in that lake using CO_2 data. They found secchi disc depths of 1-3m during the growing season. Neither of these studies used chlorophyll *a* as an indicator of the primary producers.

Chlorophyll *a* is found in all photosynthetic organisms which are known to give off oxygen in photosynthesis. It has been used as an index of photosynthetic capacity (Manning and Juday 1941; Verduin 1956; Ryther 1956), and recently as a measure of phytoplankton abundance in empirical models interrelating lake trophic status parameters (Dillon and Rigler 1974; Carlson 1977; Nicholls and Dillon 1978). In this study, chlorophyll *a* was used as a measure of phytoplankton and macrophyte standing crops in Skinner Lake and Lake Lansing. The purpose of this study was to characterize and to compare the phytoplankton chlorophyll *a*, secchi disc transparency, and macrophyte chlorophyll *a* of the two lakes, as well as to serve as a data base for the assessment of the effectiveness of the restoration methods.

DESCRIPTION OF STUDY AREA

Skinner Lake is located in Noble County, in northeast Indiana. The lake has a surface area of 49.4 hectares and an average depth of 4.6m. Its morphometry is shown in Figure 1. Residences rim the lake except for an area in the southwest quadrant which is used as cropland. The watershed has an area of 3,813 hectares, 68% of which is used for crops and livestock. The remaining 32% is in woodlots and wetlands. The lake has considerable overland inputs, in the form of runoff throughout the year, and a nearly continuous discharge. It typically stratifies thermally from May to September.

During the summer of 1978, a preliminary mapping study showed that the littoral zone of Skinner Lake was inhabited by macrophytes from the shoreline to a depth of approximately 3m. Nearly all the area within this zone appeared suitable for growth. Four distinct vegetation types occurred in Skinner Lake (McNabb 1978). Location of these vegetation types are shown in Figure 1. Type 1 vegetation consisted of a horizontal zonation of *Scirpus americanus* Pers., *Nymphaea odorata* Ait., and *Ceratophyllum demersum* L. Type 2 vegetation occupied the Rimmel inlet delta located at the southern end of the lake. This vegetation type included *Potamogeton pectinatus* L., *Zanichellis palustris* L., and a film of *Spirogyra* lying on the deeper sediments. Type 3 vegetation was made up of a low density-high diversity group of plants. These included *Chara globularis* Thuill., *Lyngbya* sp., *Scirpus validus* Vahl., *Pontederia*

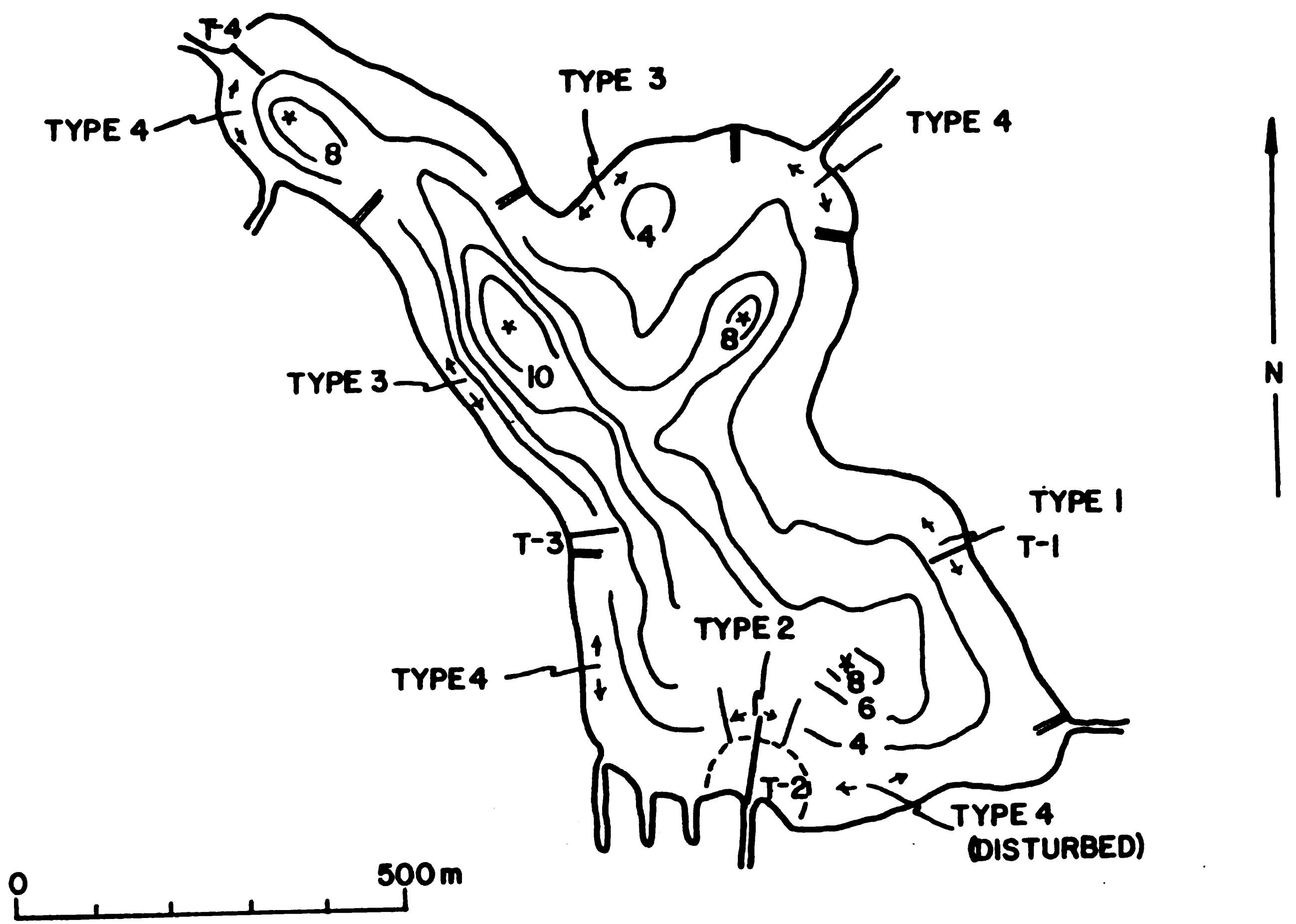

Figure 1. Basin morphometry of Skinner Lake, Indiana, showing sampling stations for phytoplankton chlorophyll *a* (*), limits of vegetation types and macrophyte sampling transects (T_1-T_4). Depth contours are in meters.

cordata L., *N. odorata*, *Nuphar advena* Ait., *Potamogeton nodosus* Poir., and *Potamogeton crispus* L. in the inshore area, and *C. demersum* in the deeper water. Type 4 vegetation consisted of the water lilies (*N. advena* and *N. odorata*) and *C. demersum*. This type was disturbed along the east portion of the south shore by boating pathways leading to shoreline residences.

Lake Lansing is located in Ingham County, Michigan, northeast of the Michigan State University campus. It has a surface area of 182 hectares. The lake is divided into two basins as shown in Figure 2. It is shallow, averaging less than 3m in depth, with a maximum depth of 11m. Water enters the lake through seepage, precipitation, and overland flow from urban and agricultural areas. Runoff from 80% of the watershed passes through extensive marshlands before entering the lake. The lake has a relatively long retention time; the water in the basin is essentially standing. It was stratified thermally from May to September of 1978 and from June to September of 1979.

A preliminary mapping of Lake Lansing vegetation conducted during the summer of 1978 showed that the plants did not form such discrete types as those of Skinner Lake. Still, the littoral zone of the lake could be divided into five areas based on the plant communities found there. These are shown in Figure 2. The south basin (A), was occupied mainly by *C. globularis*, and *Najas flexilis* (Willd.) Rosth. and Schmidt. *C. globularis* grew almost exclusively in area B, while a vascular hydrophyte mixture consisting of *C. globularis*, *Heteranthera dubia* (Jacq.) MacM., *Vallisneria americana* Michx., *C. demersum*, *Myriophyllum sp.*, and *N. flexilis* existed in area C. A mixture of these species, with a higher per cent cover, was found in area D. Area E was occupied by a *C.*

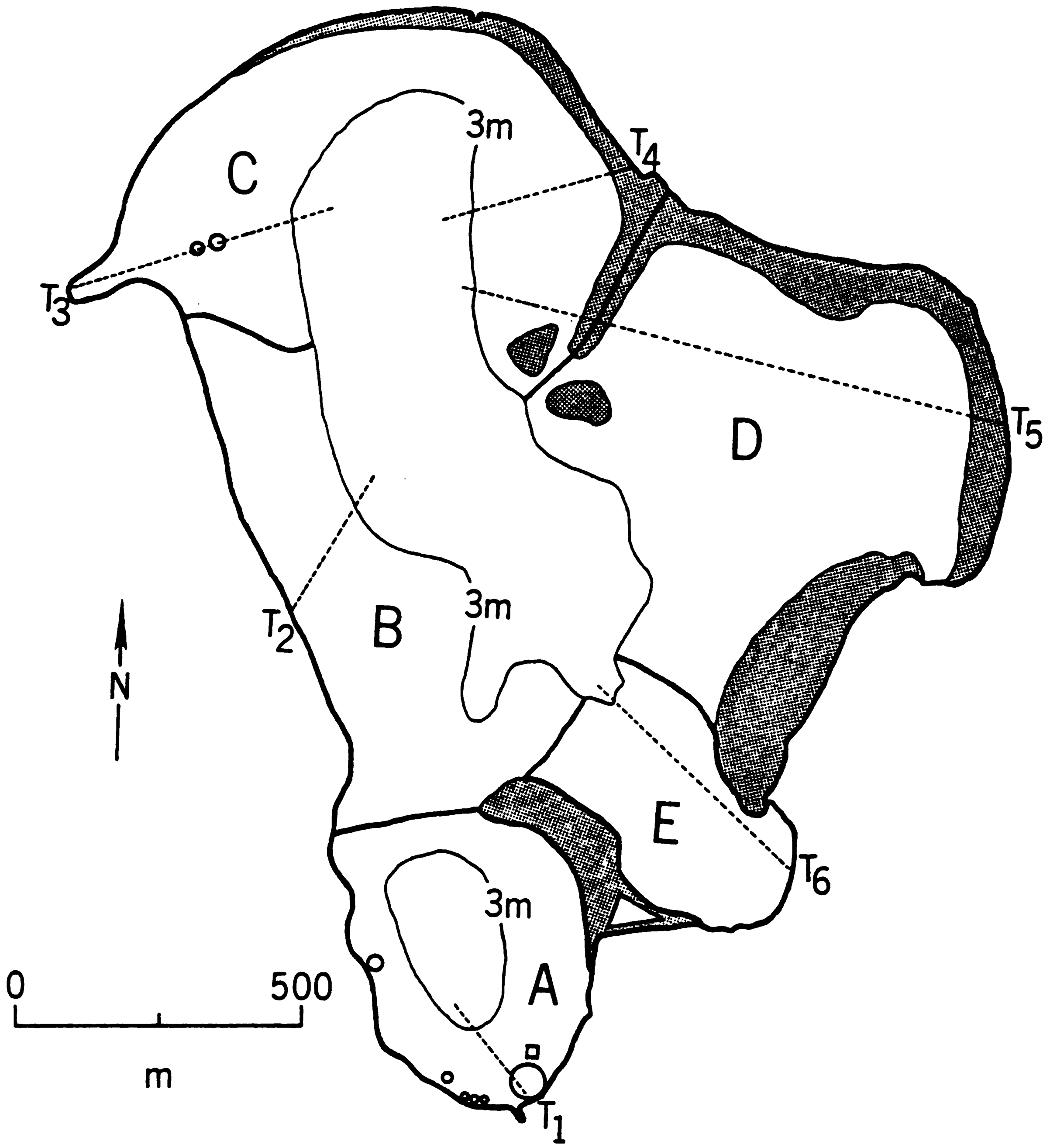

Figure 2. Macrophyte sampling zones (A-E) for Lake Lansing, September 8-13, 1978. Circles represent stands of *Nuphar sp.*, the square, *Pontederia cordata*, and the triangle, a mixed stand of *Scirpus*. Description of the zones is in the text. Sampling stations for phytoplankton chlorophyll *a* samples were located along the transects T_1 through T_6.

globularis-N. flexilis association. Beds of *Nuphar advena*, *Pontederia cordata*, *Scirpus americanus* and *S. validus* were present along the inshore areas of the south basin and along Transect 3. Shaded portions of Figure 2 indicate areas of the littoral zone of the lake which were not colonized by plants.

METHODS

Phytoplankton chlorophyll *a* determinations were made for Skinner Lake and Lake Lansing during the 1978 and 1979 growing seasons. Water samples from Skinner Lake were collected at stations shown in Figure 1. Composite samples were made up to represent the trophogenic and tropholytic zones. These were assumed to be those areas above and below the growing season metalimnion. In 1978, water was taken from 0.5, 1.5, and 2.5m depths at each of the four stations with a plastic Kemmerer bottle and equal volumes from each depth were used to make a composite sample. This was done in duplicate. Water samples were also taken in duplicate at 0.5, 1.5, and 2.5m from the bottom of the lake at each of the four stations. Composites were made of these using volumes proportional to the volumes of the sampled strata as determined from hypsographic data on the lake. During the 1979 sampling period, only one composite sample was made up for each of the two zones. At the time of sampling for chlorophyll, transparency measurements were made with a standard 20cm secchi disc.

Phytoplankton chlorophyll *a* estimates were made for the littoral as well as the pelagial zones of Lake Lansing. During the 1978 sampling period, samples from the littoral zone were composited to represent the 0-1, 1-2, 2-3, and 3-4.5m contour intervals. Equal volumes were combined from the mid-point of each of the above contours on each of the six transects shown in Figure 2. Samples representing the upper pelagial zones of each of the two basins in the lake were composited from equal volumes of water taken at depths of 0.5, 2.0, and 3.75m from the surface. The north basin lower pelagial zone sample was composited from water taken from 5.0, 6.0, 7.0, and 8.0m depths in proportion to the volumes of the 4.5-5.5m, 5.5-6.5m, 6.5-7.5m and greater than the 7.5m strata, as determined from hypsographic data on the lake. The south basin lower pelagial sample was composited from volumes of water from 5.0 and 6.0m depths in proportion to the volumes of the 4.5-5.5m and greater than 5.5m strata. Due to lack of meaningful differences in the individual chlorophyll *a* values from the littoral zone and the upper pelagial zones of both basins, waters from these locations were collected as above and composited by equal volume into one sample representing the trophogenic zone during the 1979 sampling period. Hydraulic dredging began in late June of 1979. In mid-August of 1979, chlorophyll *a* sampling was terminated because of interference in the analysis caused by turbidity in the samples.

In the laboratory, 500ml replicate aliquots of well mixed sample were filtered through Metricel-Gelman filters with 0.8micron pores at a vacuum of less than 20cm of mercury. Filters were placed in dark bottles containing 25ml of 90% distilled-in-glass acetone for 20 hours under refrigeration. Pigment extraction was completed by macerating the sample using a hand glass-to-glass tissue grinder. The extract was then cleared by centrifugation. A recording absorbance scan from 800nm to 400nm was obtained using a Varian Super-Scan 3 spectrophotometer with a 2.0nm bandwidth through a 10cm pathlength cell. SCOR/UNESCO trichromatic equations given by Strickland and Parsons (1972) were used to calculate concentrations of chlorophyll *a*.

Littoral zone macrophyte communities of the lakes were characterized by physiognomy and chlorophyll *a* studies. The physiognomy of the vegetation types of Skinner Lake was described by observers moving along 60m lines marked at 5m intervals laid over the water along transects shown in Figure 1. Voucher specimens were collected, identified, and placed in the permanent herbarium research collection of the Limnological Research Laboratory. Physiognomic records and a list of aquatic macrophytes in Skinner Lake are presented in Tables A-1 and A-2 of the Appendix. Samples for chlorophyll *a* determinations were collected from macrophytic vegetation in horizontal and vertical zones along the transects. Four samples were taken from each major vegetational zone on a transect. Bulrushes were taken from 10 x 10cm plots. Submersed vegetation within bulrush stands was sampled with the cylindrical sampler shown in Figure 3. The sampler was made of an iron cylinder with stabilizing fins. A plastic collecting chamber was placed along the inside of the cylinder and folded outward underneath the attached cutting band. After free-fall, vegetation inside the cylinder was collected by tightening a noose around the plastic chamber at the sediment surface, and placing the contents on a No. 30 U. S. standard sieve. The sampler has a cross section of $181.4cm^2$. Four petioles with leaves were collected as separate samples from lily and pickerel weed beds. Chlorophyll *a* per m^2 was obtained from the product of the chlorophyll content of the petiole and leaf and the number of these per m^2. The vegetation beneath the lilies and pickerel weeds and the submersed vegetation outside these stands was taken with the sampler. For these, chlorophyll *a* per m^2 values were obtained from the product of the total amount of pigment in the sample and the cross sectional area of the sampler. The

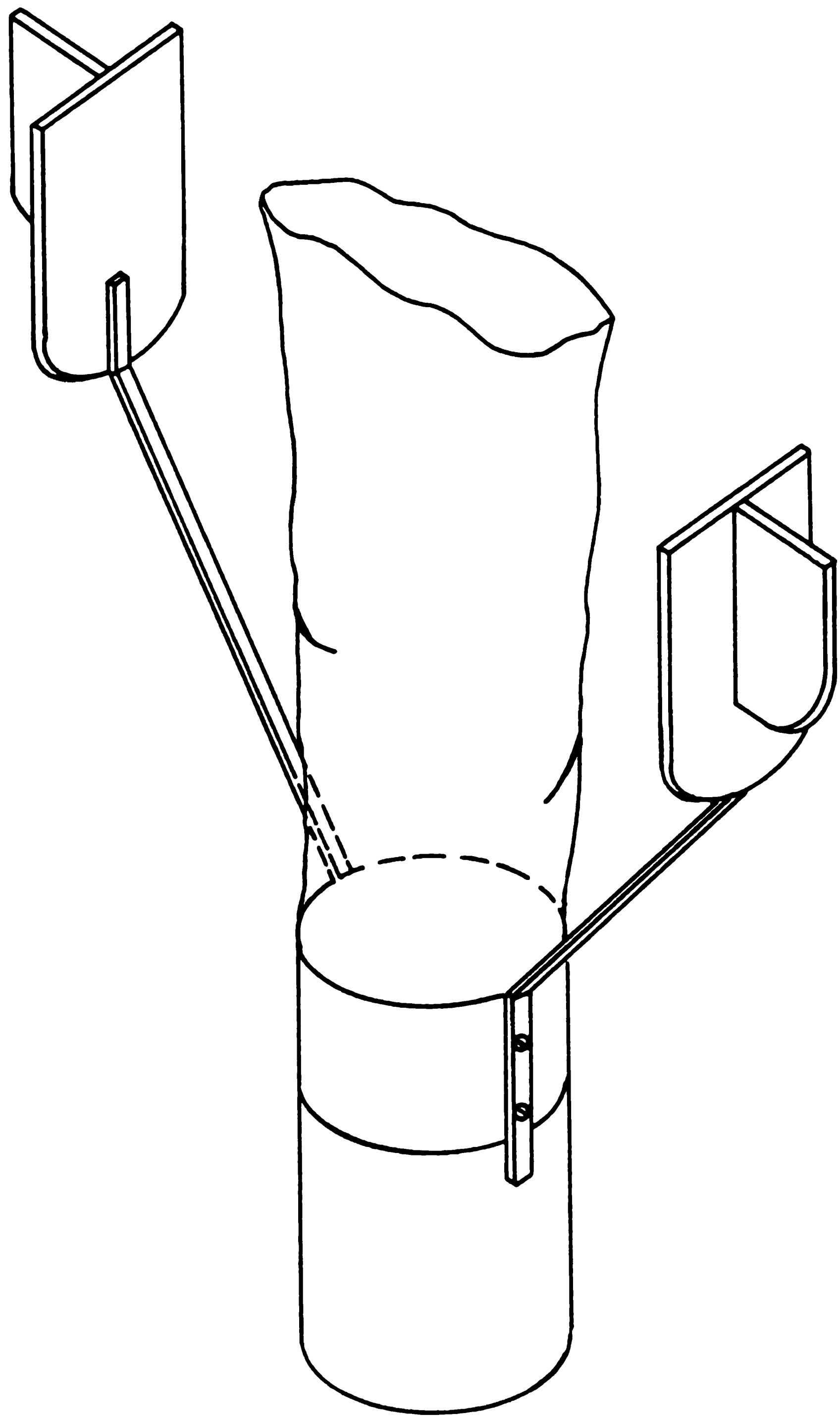

Figure 3. Aquatic plant sampler, shown with plastic collecting chamber.

area covered by the vegetation was estimated from Figure 1, by multiplying the length of the shoreline occupied by the width of the zone of occurrence. The diverse vegetation of the inshore area of the east shore (type 3) was treated as a unit, with the mean chlorophyll *a* representing the vegetation extending from 0-3.5m depths. Transect 4 represented the areas occupied by type 4 vegetation, except the disturbed area of the south shoreline. Here, the area covered was estimated to be 50%.

The physiognomy of the macrophytes of Lake Lansing was described along the six transects used in water sampling (Figure 2). The data from these observations and the list of macrophyte species of Lake Lansing are given in the Appendix, Tables A-3 and A-4.

For chlorophyll *a* analysis, samples of the vegetation in Lake Lansing were taken from within the zones mapped in Figure 2. The number of samples was dependent upon the heterogeneity and per cent cover of the vegetation found there. A total of 176 samples were taken. Submersed vegetation was taken with the cylindrical sampler. Petioles with leaves were taken as separate samples from the water lily, pickerel weed and bulrush stands. Chlorophyll *a* values per m^2 were calculated as above. Areas covered by the vegetation zones were estimated by planimetry of Figure 2.

Samples were drained of water in the field, placed in marked plastic bags and stored in styrofoam coolers on the return trip to the laboratory. Samples were then frozen until they could be handled. On analysis, plant samples were ground in a measured volume of deionized-distilled water using a Waring blender. Distilled-in-glass acetone (100%) was then added to a 10ml aliquot of the mix until the specific gravity, as measured with a calibrated hydrometer, reached that of 90% acetone. Pigment extraction was completed under refrigeration for 20 hours. The same spectrophotometric procedure described above was used on the macrophyte samples. The trichromatic equations of SCOR/UNESCO were again used to calculate chlorophyll *a* concentrations. Knowing the volume of water used in blending, the volume of the aliquot taken after blending, and the degree of dilution of the aliquot with acetone, chlorophyll *a* concentrations were converted to quantities per sample.

RESULTS

Seasonal phytoplankton biomass estimates for Skinner Lake and Lake Lansing are presented in Figures 4 and 5, respectively. Chlorophyll *a* values for both lakes are recorded with standard errors in the Appendix, Tables A-5 and A-6. Biomass estimates for the trophogenic zone of Skinner Lake ranged from 6.27 to 35.50mg/m^3 chlorophyll *a*, averaging 16.59mg/m^3. In Lake Lansing, values ranged from 4.75 to 20.97mg/m^3 chlorophyll *a*, in the trophogenic zone, averaging 14.18mg/m^3. The seasonal tropholytic phytoplankton biomass estimates of Skinner Lake generally followed the pattern seen in the trophogenic zone (Figure 4). These values ranged from 3.05 to 17.10mg/m^3 chlorophyll *a*, with an average value of 8.28mg/m^3. In Lake Lansing, the seasonal biomass estimates for the phytoplankton of the tropholytic zone of the north basin, were slightly higher than those of the trophogenic zone, ranging from 5.15 to 20.30mg/m^3 chlorophyll *a*, with an average value of 14.99mg/m^3. Estimates for the biomass of the tropholytic zone of the south basin were over ten times higher than those of the trophogenic zone during July and August of 1978, and over three times higher during July, 1979. Chlorophyll *a* values of this region dropped with those of the rest of the lake during September, 1978 and May, 1979. Values for the south basin ranged from 3.20 to 263.1mg/m^3 chlorophyll *a*, averaging 48.59mg/m^3 for the sampling period. Water sampled from this location appeared dark green in color, and contained H_2S during periods of stratification.

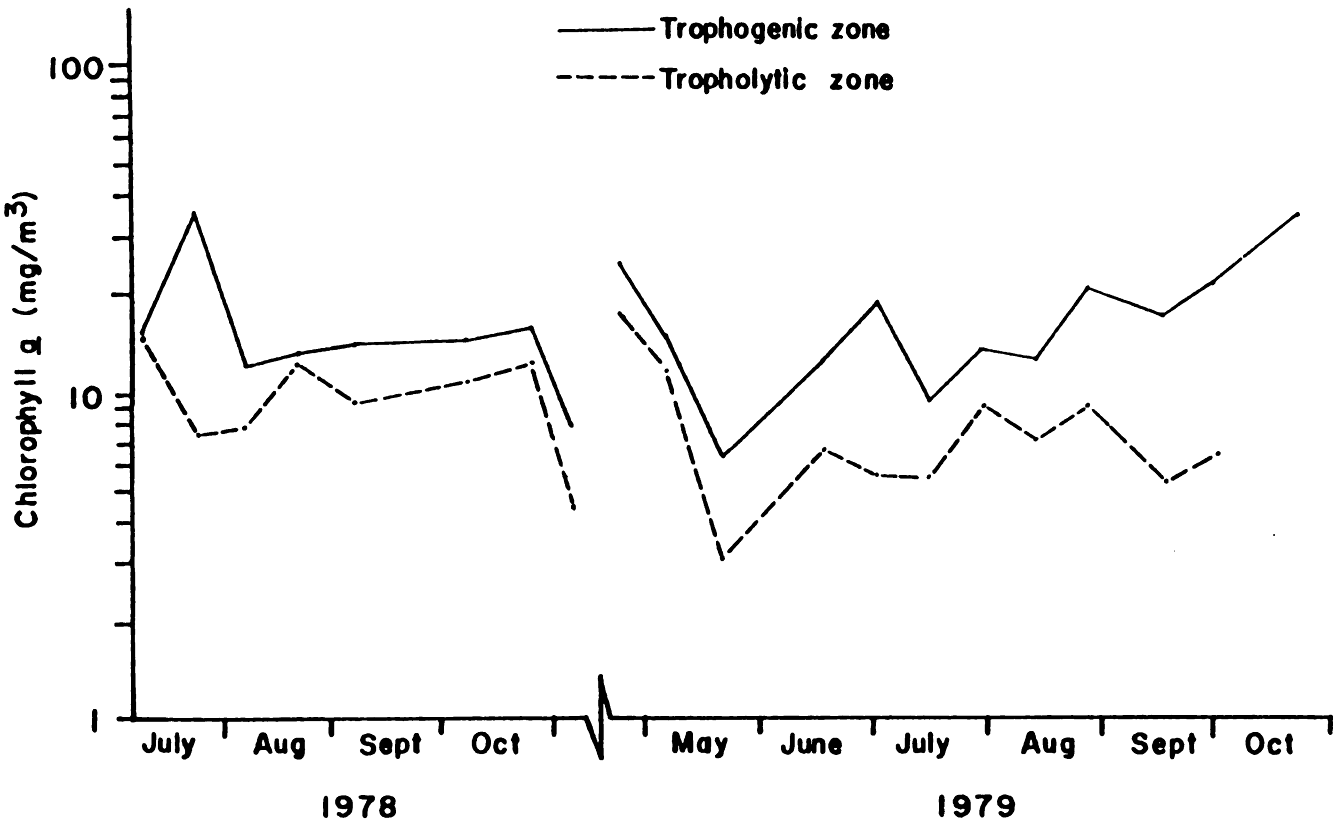

Figure 4. Seasonal phytoplankton abundance in Skinner Lake, Indiana, as determined from chlorophyll *a* values.

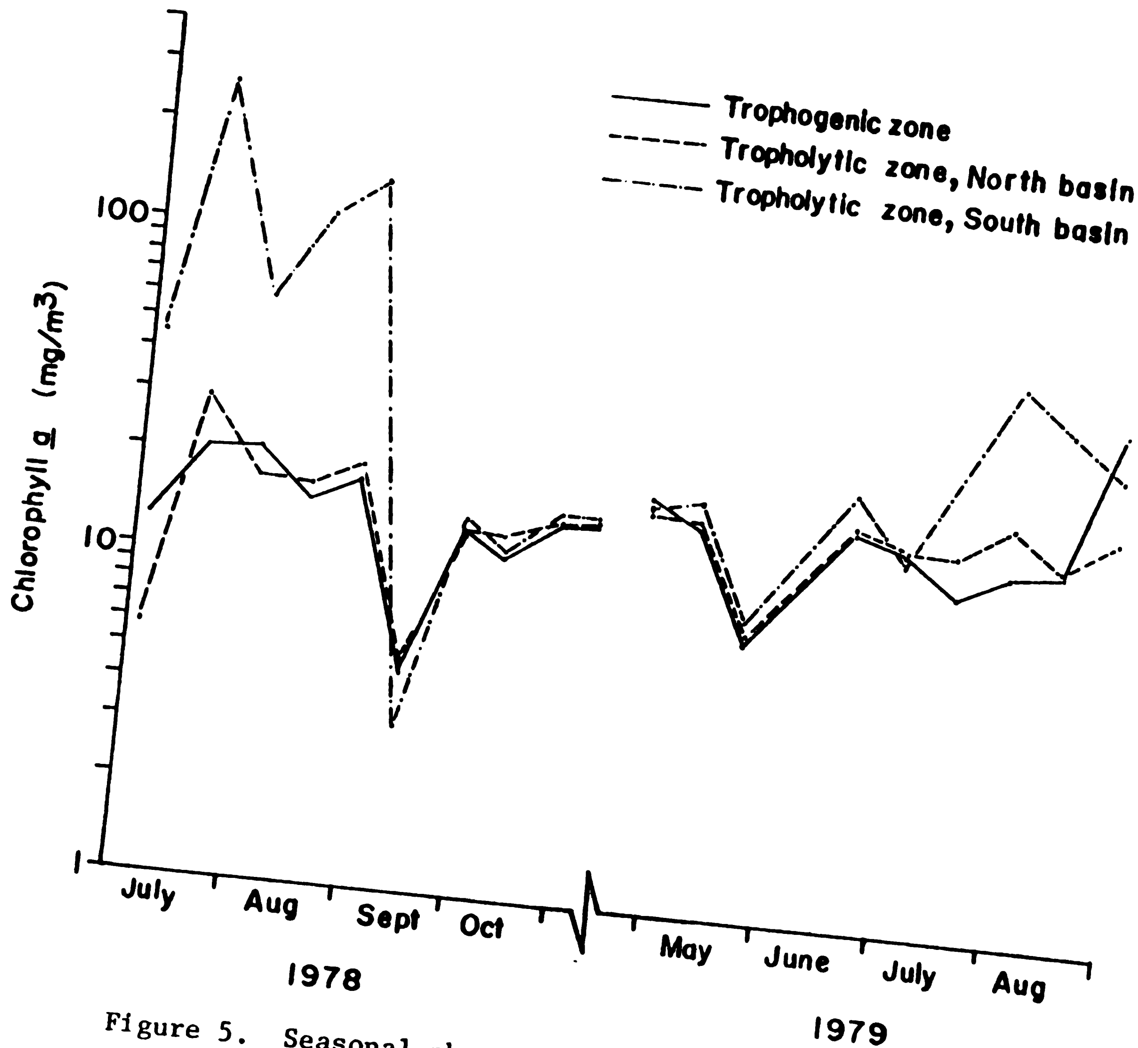

Figure 5. Seasonal phytoplankton abundance in Lake Lansing, Michigan, as determined from chlorophyll *a* values.

The chlorophyll scans showed a peak at 654nm rather than the characteristic phytoplankton peak at 663nm as seen for the waters from other locations in the lake.

Water transparency determinations for Skinner Lake and Lake Lansing are presented in Table 1. The average secchi disc value for Skinner Lake during the 1978-79 sampling period was 1.37m. The values ranged from a low of 0.72m on 2 July 1979 to a high of 2.48m on 16 July 1979. An average value of 0.95m was found for Lake Lansing. Values ranged from 0.66m taken 18 June 1979 to 1.14m taken 7 May 1979.

Estimates of the chlorophyll *a* content of vegetation types found in the littoral zone of Skinner Lake are found in Table 2. Total area covered was 13.4ha or 27% of the lake's surface (McNabb 1978). Chlorophyll *a* content was estimated by multiplying the average chlorophyll *a* value of the vegetation by the area estimated to be covered by that vegetation type. The sum of values for the vegetation types represents the total macrophyte chlorophyll *a* value in Skinner Lake at the time of sampling. This was estimated to be 1.9kg chlorophyll *a*.

The estimates of the macrophyte chlorophyll *a* content of the littoral sampling zones of Lake Lansing during September 8-13, 1978, are presented in Table 3. The total area suitable for inhabitation by macrophytes was estimated to be 118ha or 65% of the lake's surface. Total chlorophyll *a* values for the sampling zones were calculated in the manner given above for Skinner Lake. The total lake macrophyte chlorophyll *a* value was estimated to be 6.1kg. Chlorophyll *a* content of individual samples from Skinner Lake and Lake Lansing are found in the Appendix, Tables A-7 and A-8.

Table 1. Water transparency determinations for Skinner Lake and Lake Lansing, expressed in meters.

Date	Transparency	
	Skinner Lake	Lake Lansing
7/10/78	1.48	
7/14/78		1.07
7/24/78	0.94	
8/7/78	1.25	
8/14/78		0.94
8/21/78	1.22	
9/6/78	1.38	
9/25/78	1.44	0.93
10/9/78		0.96
10/23/78	1.55	
11/6/78	1.93	1.14
4/23/79	0.87	1.11
5/7/79	1.40	1.14
5/21/79	2.18	0.94
6/18/79	1.55	0.66
7/2/79	0.72	0.93
7/16/79	2.48	0.83
7/30/79	0.96	0.85
8/13/79	1.48	0.84
8/27/79	1.27	0.90
9/17/79	1.20	
10/3/79	1.03	
10/24/79	1.09	

Table 2. Estimates of the chlorophyll *a* content of vegetation types in the littoral zone of Skinner Lake, August 8-9, 1978. Vegetation types are shown in Figure 1. Values given are the mean ± one standard error of the mean estimate.

Vegetation Type	Plant Aggregation	Chl *a* (mg/m^2)	Estimated Area Covered (ha)	Total Chl *a* (kg)
1	*Scirpus americanus* and understory	37.5[1]	0.62	0.233
	Nymphaea odorata and understory	18.6[1]	0.37	0.069
	Nuphar advena and understory	9.5[1]	1.15	0.109
	Ceratophyllum demersum	12.9±5.78	1.56	0.201
2	*Potamogeton pectinatus*	9.3±0.90	0.06	0.006
3	*Scirpus validus*	17.5±2.02		
	Potamogeton nodosus	4.0±2.17		
	Ceratophyllum demersum	13.9±6.11	3.44	0.406
4	*Nuphar advena* and understory	12.2[1]	3.10	0.378
	Pontederia cordata and understory	19.3[1]	0.69	0.133
	Ceratophyllum demersum	13.6±5.03	2.75	0.374
Lake total				1.9

[1]These values represent the sum of the mean chlorophyll *a* values of the emergent or floating-leaved species and the understory of the submersed plants.

Table 3. Estimates of the macrophyte chlorophyll *a* content of littoral sampling zones in Lake Lansing, September 8-13, 1979. Sampling zones are shown in Figure 2. Values given are the mean ± one standard error of the mean estimate.

Sampling Zone	Mean Chl *a* (mg/m^2)	Estimated Area (ha)	Total Chl *a* for Sampling Zone (kg)
A	8.5±3.2	13.27	1.128
B	7.7±1.5	23.38	1.800
C	2.2±0.6	29.13	0.641
D	4.1±0.3	38.52	1.579
E	6.2±1.8	12.98	0.805
EMERGENTS			
Pontederia cordata	12.4±1.2	0.03	0.004
Nuphar advena S basin	4.1±0.9	0.99	0.041
Nuphar advena N basin	4.4±0.8	0.04	0.002
Mixed *Scirpus* sp.	7.2±3.3	0.84	0.060
Lake total			6.1

DISCUSSION

With the exception of the tropholytic zone of the south basin of Lake Lansing, phytoplankton chlorophyll *a* concentrations of the two lakes were within the range of values commonly found for natural waters (Talling 1974; Wetzel 1975). Vertical distributions of chlorophyll *a* in Skinner Lake followed the pattern described by Ichimura (1955), in which higher levels of chlorophyll *a* were noted in the epilimnion. In Lake Lansing, these higher levels were found in the hypolimnion. Because of the specialized conditions of the south basin of Lake Lansing, it will be treated later in the discussion. Secchi disc depths were generally low for both lakes. In Lake Lansing, this was thought to be due to wind-induced mixing of the loose organic sediments. In Skinner Lake, high silt loading may have contributed to the low secchi transparencies.

Chlorophyll *a*-secchi disc relationships have been used to typify lake trophic status. In efforts toward a state inland lake management program, a eutrophication warning system was established in 1974 by the Inland Lake Management Unit of the Michigan Department of Natural Resources. The purpose of this program is to assess the trophic status of Michigan's lakes by gathering annual baseline trophic level data, using citizens as active participants. With these data, changes over time may be noted, causes identified, and recommendations made. The rate of eutrophication is dependent upon the amount of nutrients entering a lake and their retention time there. As these increase, there is usually a related increase in the algal standing crop and a decrease in water transparency. This self-help program monitors the eutrophication of lakes through chlorophyll *a* estimates from the epilimnion and water transparency values (Anon. 1978). Samples are taken by members of the lake associations from May through September, and analyses are performed at the Department of Natural Resources Laboratory. Trophic classification, chlorophyll *a* and secchi disc criteria used in this program are given below.

Table 4. Michigan self-help chlorophyll *a* and secchi disc criteria used for trophic classification (Anon. 1978).

Trophic condition	Chlorophyll *a* (ug/l)	Transparency (feet)
oligotrophic	0- 4	> 15
mesotrophic	4-10	6.5-15
eutrophic	> 10	< 6.5

According to this scheme, both Skinner Lake and Lake Lansing are eutrophic lakes. Figure 6 shows the curvilinear relationship between water transparency and chlorophyll *a* observed in the lakes of the self-help program during 1978. Data points for both Skinner Lake (SL) and Lake Lansing (LL), fell below the curve, suggesting that, for Lake Lansing in particular, the turbidity was due to nonalgal sources. It is of interest to note that Figure 6 indicates that as chlorophyll *a* values approach values greater than 30ug/l, secchi disc depths remain unchanged. This is not reflective of what actually occurs in lakes (R. Mikula, pers. comm.). The secchi disc values should continue to decrease as the chlorophyll values increase. In that case, Skinner Lake and Lake Lansing would better fit the curve.

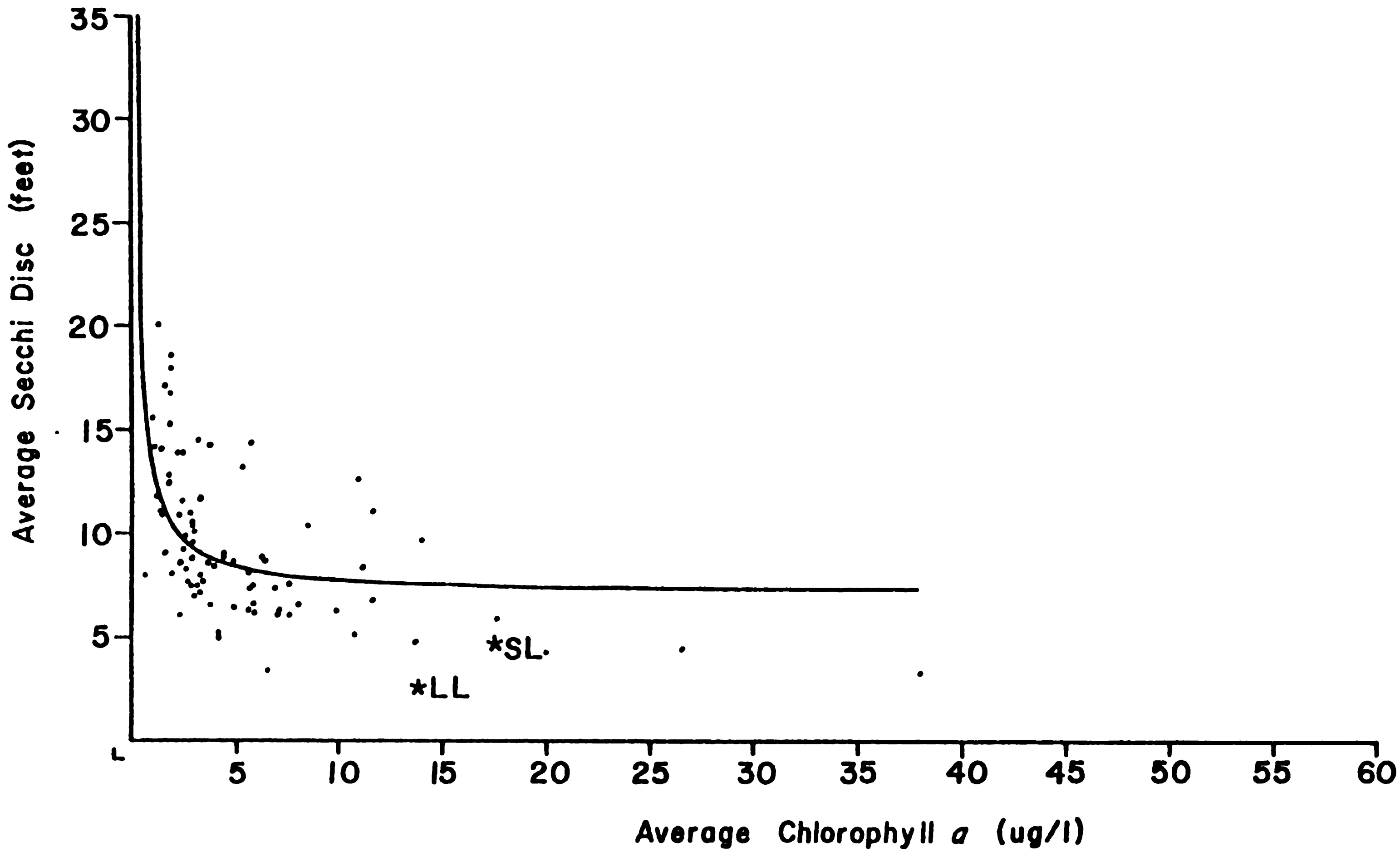

Figure 6. Average summer secchi disc and chlorophyll *a* values of 80 Michigan lakes (84 basins) in 1978 Self Help water quality monitoring program. From the 1978 Annual report.

A similar classification scheme was developed by Carlson (1977). In order to more clearly delineate the divisions of the trophic continuum, oligotrophic-mesotrophic-eutrophic, he developed a trophic state index (TSI) for lakes using a scale of 0-100. This index may be calculated from any of the following parameters: summer secchi depth (SD), chlorophyll *a* (C), and total phosphorus (TP). Values for these from Skinner Lake and Lake Lansing are given below. Carlson included the three variables because he felt that secchi disc values may be misleading as a trophic indicator in colored or highly turbid (nonalgal) lakes; that chlorophyll *a* may be the best estimator of algal populations during the growing season; and that phosphorus may not be a good indicator of growth in lakes that are not phosphorus limited.

Table 5. Trophic state index parameters for Skinner Lake and Lake Lansing, 1979.

	Secchi disc (m)	Chlorophyll *a* (mg/m^3)	Total phosphorus (mg/m^3)
Skinner Lake	1.48	13.7	40.67
Lake Lansing	0.85	12.7	49.67

Calculated TSI values for Skinner Lake are 54.3(SD), 56.2(C), and 57.6(TP); for Lake Lansing: 62.3(SD), 55.5(C), and 60.5(TP). Assuming that a lake with Carlson's TSI <40 is oligotrophic and >50 is eutrophic (Reckhow 1978), both Skinner Lake and Lake Lansing are eutrophic, as seen above using the self-help program classification. In Lake Lansing, the TSI value from the summer chlorophyll value (55.5) is lower than those based on secchi disc and total phosphorus. This may have been due to the high nonalgal turbidity.

The relationship between phosphorus and chlorophyll *a* is the basis of many lake models, since phosphorus is a commonly limiting nutrient. The development of models such as that of Dillon and Rigler (1974), allows predictions to be made about the effects of various stresses on the environment. This model compares the average summer chlorophyll *a* concentration to the spring total phosphorus concentration, giving a regression line with the formula:

$$\log_{10}[\text{Chl } a] = 1.449 \log_{10}[\text{P}] - 1.136$$

Spring total phosphorus values from samples collected 23 April 1979 were $31mg/m^3$ for Skinner Lake and $41mg/m^3$ for Lake Lansing. From these values, calculated chlorophyll values for Skinner Lake and Lake Lansing were $10.6mg/m^3$ and $15.9mg/m^3$, respectively. The average measured summer (May-September) chlorophyll *a* values for Skinner Lake and Lake Lansing were $13.7mg/m^3$ and $12.7mg/m^3$, respectively. Considering possible sampling error, these lakes show a reasonably good fit to the model. The classification schemes and models mentioned do not take into consideration the chlorophyll *a* levels of the hypolimnion, which as seen for Lake Lansing, may be an important factor.

The presence of high levels of chlorophyll *a* in the hypolimnetic regions of lakes has been observed in previous studies (Manning and Juday 1941; Czeczuga 1965; Takahashi and Ichimura 1968; Brooks and Torke 1977). In their studies, Czeczuga, Takahashi and Ichimura found chlorophyll *a* absorbance peaks at 654nm as compared to 663nm for phytoplankton. This peak was thought to be due to the absorption of chlorobium chlorophyll 650 (Stanier and Smith 1960; Jensen *et al* 1964) similar to the *Chlorobium limicola* Nads. chlorophyll found by Czeczuga (*Ibid*).

C. limicola is a photosynthetic bacterium which uses hydrogen from the decomposition of H_2S, the presence of which regulates their growth. Other requirements are the presence of light, which is usually at intensities of less than 10% of surface illumination, and pH values of 6.5-8.0 (Takahashi and Ichimura 1968). Hypolimnetic waters from lakes of Czeczuga's study were dark green in color. Conditions similar to these were found in the hypolimnion of the south basin of Lake Lansing. The pH values for this region were near neutral, ranging from 7.1 to 7.9 during stratification, while pH values for the rest of the lake ranged from 8.0 to 9.1 (Siami 1979). It is thought then, that the chlorophyll *a* levels of the tropholytic zone of the south basin are due to a bacterium not unlike *C. limicola*. Inspection of the plankton samples from Lake Lansing during the 1978 sampling period showed a dominance of a sulfur-containing bacteria. The chlorophyll values of the lower north basin did not reach the levels of the south basin, probably because thermal stratification and H_2S persistance in that basin was periodically disrupted by storms (Figures 7-10 and Siami 1979). South basin chlorophyll *a* values of 1979 were also not as high as those seen during 1978. Stable stratification did not develop here until late in the sampling period of that year. Diminished water transparency suggested in Table 1 may have been an important factor as well.

The average growing season trophogenic phytoplankton chlorophyll was expressed on a per m^2 basis by multiplying the values per volume by the depth of the trophogenic zone. The depth of the trophogenic zone was defined as the depth of the mixing zone on the assumption that phytoplankton within this layer were periodically brought up to the surface where light was available for photosynthesis. The depth of the

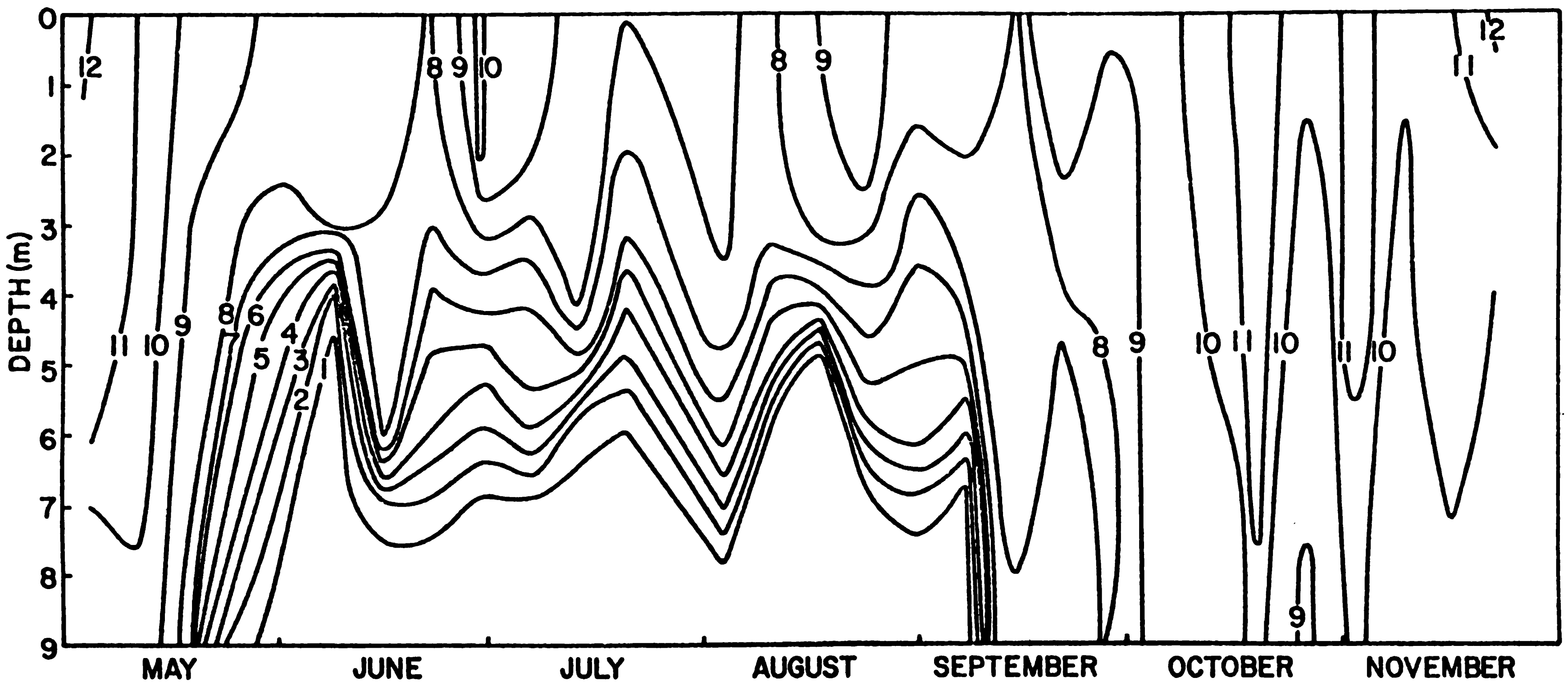

Figure 7. Depth-time diagrams of isopleths of dissolved oxygen (mg/l) for the north basin of Lake Lansing, 1978.

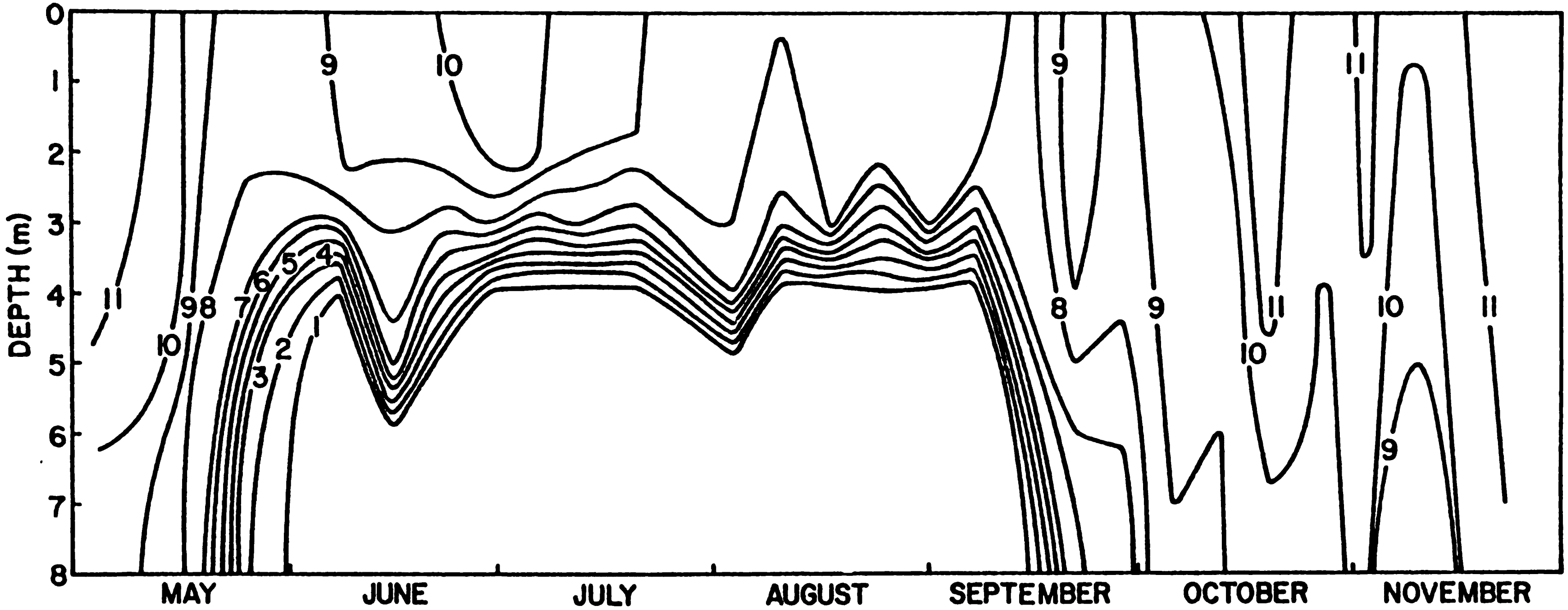

Figure 8. Depth-time diagrams of isopleths of dissolved oxygen (mg/l) for the south basin of Lake Lansing, 1978.

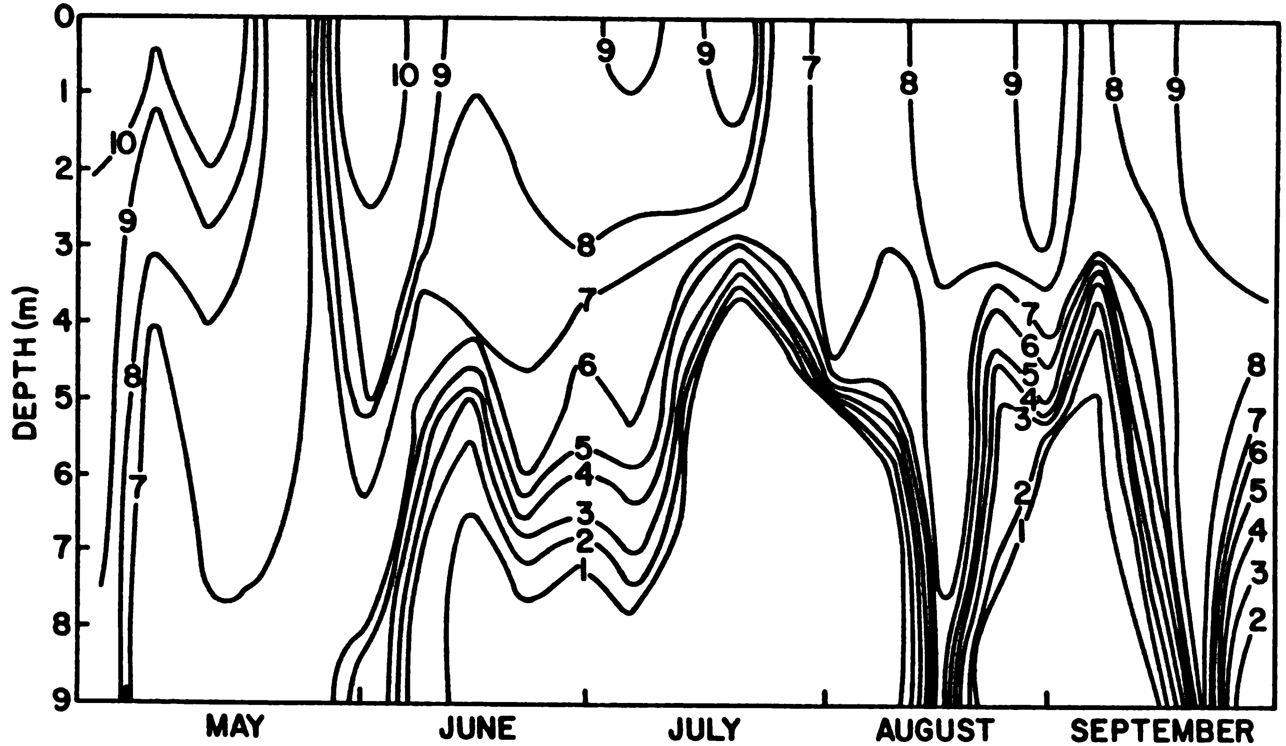

Figure 9. Depth-time diagrams of isopleths of dissolved oxygen (mg/l) for the north basin of Lake Lansing, 1979.

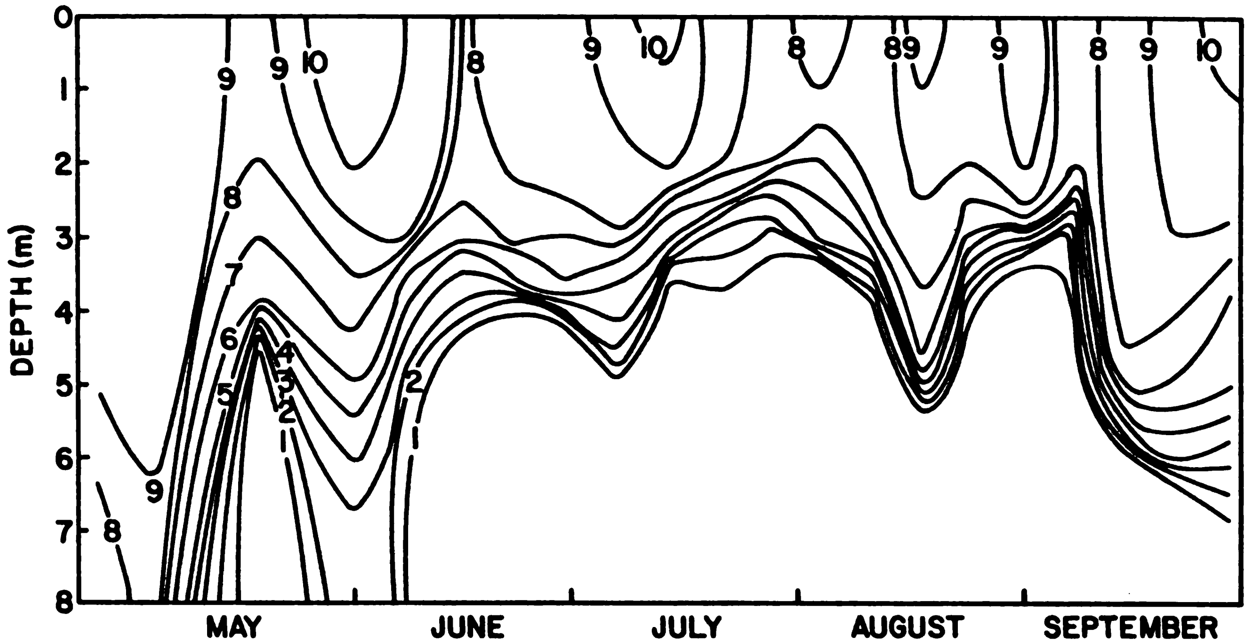

Figure 10. Depth-time diagrams of isopleths of dissolved oxygen (mg/l) for the south basin of Lake Lansing, 1979.

trophogenic zone during the growing season on Skinner Lake was taken as 4.0m; on Lake Lansing as 3.8m. These chlorophyll *a* values for Skinner Lake and Lake Lansing were $66.4mg/m^2$ and $53.9mg/m^2$, respectively. Growing season phytoplankton chlorophyll *a* totals were calculated by multiplying mean values per unit volume by the volume of the trophogenic zone; $1.14 \times 10^6 m^3$ for Skinner Lake and $2.0 \times 10^6 m^3$ for Lake Lansing. Totals for Skinner Lake and Lake Lansing were 17.91kg and 28.36kg chlorophyll *a*, respectively. Comparing these values, and total macrophyte chlorophyll *a* (Tables 2 and 3), Lake Lansing had relatively low standing crops of primary producers. This may have been due to the differences in watershed and nutrient loadings of the two lakes. The agricultural watershed of Skinner Lake is over 4.5 times larger than the predominantly marshland watershed of Lake Lansing. A study of growing season rain-related loading from urban, wetland and agricultural sources of the watersheds of these lakes by Glandon *et al* (1979) showed that agricultural watersheds exported approximately 10 times the nutrient levels per hectare as those observed for marshlands.

In the macrophyte standing crop study, chlorophyll *a* values in Skinner Lake and Lake Lansing were measured in August and September, 1978. Sampling was done at this time to correspond as close as possible to the time of peak standing crop. This method also serves for ease of replication in post-treatment studies. The use of pigment analysis in macrophyte standing crop studies is not well known. Studies using this approach have found highly significant correlations between the aboveground dry weight and chlorophyll *a* content (Bray 1960; Boyd 1970). The study by Boyd also indicated that maximum quantities of pigments/m^2 in *Typha sp.* are found just before peak dry matter standing crop. Total chlorophyll *a* values for the macrophytes (Tables 2 and 3), normalized to the area of the littoral zones of the lakes showed that Lake Lansing appeared to have relatively low standing crops of macrophytes (5.2mg/m^2 chlorophyll *a*) in comparison to the Skinner Lake (1.4mg/m^2 chlorophyll *a*). Differences in watershed and nutrient loading may have had an effect on the differences in the macrophyte and plankton standing crops of these lakes.

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APPENDIX

Table A-1. Record of observations on the physiognomy of vegetation on transects in Skinner Lake, Noble County, Indiana, on August 8-9, 1978.

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE[1]	SPECIES	% COVER	HEIGHT	REMARKS
1	0	0	0-5	Bulrush overstory with mixed[2] submersed plant understory	Overstory:			Sediments organic sand
	5	0.25						
	10	0.6			<u>Scirpus americanus</u>	50	120 cm from sediments	
	15	0.9						
	20	0.95						
	25	1.1			Mixed[2] understory:	70	sediments to 0-3 cm of water surface	
	30	1.5						
	35	1.7			<u>Ceratophyllum demersum</u>			
	40	2.3						
	45	2.7			<u>Chara globularis</u>			
	50	3.2			<u>Myriophyllum sp.</u>			
	55	3.5			<u>M. spicatum</u>			
	60	3.8			<u>Najas guadalupensis</u>			
			5-7.5	Bulrush and submersed plants as above but grading into white water lily with a broad-leafed potamogeton added to mixed submersed understory	Overstory			Sediments as above
					<u>S. americanus</u>	20	110 cm from sediments	
					<u>Nymphaea odorata</u>		at surface	
					Mixed understory:	70	25 cm	
					<u>C. demersum</u>			
					<u>C. globularis</u>			
					<u>Myriophyllum sp.</u>			
					<u>M. spicatum</u>			
					<u>N. guadalupensis</u>			
					<u>Potamogeton alpinus</u>			

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
			7.5-12	White water lily overstory with mixed submersed plant understory	Overstory:			Sediments as above
					N. odorata	80	at surface	
					Mixed understory	50	at surface	
					C. demersum P. alpinus			
			12-20	Yellow water lily overstory with coontail understory	Overstory:			Sediment organic sand
					Nuphar advena	100	40 cm above surface with occasional leaf at surface or submersed	
					Understory:			
					C. demersum	20	at surface	
					Present:[3]			
					M. spicatum			
			20-26	Yellow water lily grading into submersed coontail bed	Overstory:			Sediments as above
					Nuphar advena	30	20 cm above surface with some leaves at surface and occasional submersed leaf	

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
					Understory:			
					C. demersum	50	sediments to 10 cm of water surface	
					Present:			
					M. spicatum			
			26-42	Coontail	C. demersum	80	mostly 1 m tall with occasional plant rising to 10 cm of surface	Sediment loose sand
					Present:			
					M. spicatum			
			42-45	Coontail	C. demersum	2	lying on bottom	Sandy organic sediment
			45-60	None				Sediment as above

Note: Transect 1 has vegetational zonation typical of the southern one-half of the east shoreline of the lake; bulrush-coontail zones are obvious and quite discrete when viewing this region over the surface of the lake. A small (ca. 0.2 ha) stand of Typha sp. existed at the southern limit of this vegetation, just to the north of the Riddle Drain Inlet. Species in addition to those listed above, except for Typha sp., were not observed in the southeast shoreline region. The vegetation as described for the transect is taken to represent the southern one-half of the east shoreline of the lake as shown on Figure 1. This region is largely undisturbed; the density of residences is low and only narrow channels for boat traffic break the aquatic vegetation.

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
2	0	0	0-9	Sago pondweed in spaced out tufts with occasional cluster of horned pondweed	Potamogeton pectinatus	80	at surface	Sediment brown clay
	5	0.15			Present:			
	10	0.5			Zanichellia palustris			
	15	1.4			Lemna minor			
	20	1.7						
	25	2.1						
	30	2.4						
	35	2.6						
	40	2.9						
	45	3.2	9-25	Spirogyra in fine film over the sediments with occasional vascular plant	Present: C. demersum, M. spicatum, N. odorata, Spirogyra sp., Z. palustris			Plant biomass very low; C. demersum in flower. Sediment soft clay
	50	3.7						
	55	4.1						
	60	4.4						
			25-60	None				

Note: Transect 2 runs lakeward from the edge of the delta of sediments deposited from the discharge of the Rimmell Drain (cf Figure 1). The shoreline point on the transect was 55m across the sand-clay delta from a point on the west shore of the Rimmell Drain where a perpendicular to the direction of flow of the drain intersects a 4m high weeping willow tree on the point of the east shore of the drain. Since this area is unstable, the willow can be used as a reference point for location of the transect. Vegetation described for this transect is typical of the "leading edge" of the Rimmell delta; species other than those listed were not observed in the area.

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
3	0	0	0-6	Bulrush overstory with sparse mixed submersed plant understory	Overstory:			sediments a sand-gravel-organic mix
	5	0.20						
	10	0.9			Scirpus validus	30	standing 1 m above water	
	15	1.7						
	20	2.3			Understory:			
	25	3.0						

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
	30	3.5			Present:			
	35	3.8						
	40	4.1			C. demersum			
	45	4.4			Potamogeton foliosus			
	50	5.0			Potamogeton nodosus			
	55	5.6						
	60	5.9						
			6-11	Floating-leafed potageton bed	Potamogeton nodosus Present: M. spicatum P. pectinatus	80	leaves and flowers at surface	Sediments sand-gravel-organic mix
			11-21	Coontail	C. demersum	50	up to 1.5 m	Sediments as above. Blue-green epipelic algae loosened from bottom to float profusely at surface (Lyngbya sp.)
			23-30	Coontail	C. demersum		up to 1.25 m	Sandy organic sediment
			30-60	None				

Note: Transect 3 is located along that portion of the west shore that is densely occupied by year-around residences. The vegetation is highly disturbed by boat traffic, swimming, and plant control programs. A water lily-coontail zonation, like that of transect 4, comes to the northern and southern boundaries of the residential strip on this shoreline. This zonation also occurs in front of several residences within this west shore area, stopping abruptly at lot-lines. These observations suggest that a water lily-coontail zonation like that of transect 4

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
	would occur in this region in the absence of disturbance. Transect 3 is taken as typical of residence-related disturbed portions of the shore. In addition to the plants listed above, the following were collected in the vicinity of the transect: Heteranthera dubia, Najas guadalupensis, Nymphaea odorata, Pontederia cordata, Potamogeton crispus, Sagittaria sp., and Chara globularis.							
4	0 5 10 15 20 25 30 35 40 45 50 55 60	0.1 0.25 0.7 1.0 1.4 1.7 2.0 2.6 3.0 3.4 3.5 3.8 4.1	0-5	Yellow water lily overstory with coontail understory	Overstory:			Transect originated at edge of woody vegetation at shore. Loose organic sediment with fine particle-coarse particle mix.
					Nuphar advena	90	40 cm above surface with occasional submersed leaf	
					Understory:			
					C. demersum	50	at surface	
					Present:			
					M. spicatum			
			5-9	Pickerel weed stand with sparse coontail understory	Overstory:			Sediments as above
					Pontederia cordata	80	35 cm above surface with occasional submersed leaf	
					Understory:			
					Present:			
					C. demersum			
			9-22	Yellow water lily overstory with coontail understory	Overstory:			Sediments as above

Table A-1 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	HEIGHT	REMARKS
					Nuphar advena	60	30 cm above surface with occasional floating and submersed leaves	
					Understory:			
					C. demersum	30	at surface	
					Present:			
					Heteranthera dubia M. spicatum			
			22-34	Coontail	C. demersum	60	plants lying along bottom 40 cm high-plants standing to 1.2 m high in 2:1 mix	Organic-sand sediments
					Present:			
					M. spicatum			
			34-38	Coontail	C. demersum	20	1 m high	Sediments as above
			36-60	None				

Note: Transect 4 has vegetation zonation typical of non-residential shorelines in the northwest arm of the lake, the southwest corner of the lake, and the shoreline next to the inlet (cf. Figure 1); this is also the dominant vegetation along the residential south shore. Here, it is interrupted by the delta of the Rimmell drain, and paths of movements of boats. The lily and coontail zones are easily seen in all these areas when viewing the lake's surface. Species other than those listed above were not observed near the transect, except a stand of Polygonum sp. occupying the shallow delta region of the drain to the northwest of the transect.

1. A general description of the dominant plant types in included in this column.
2. "Mixed" as used in this table indicates no clear dominant species.
3. "Present" used in this table indicates an occasional shoot, not significant in terms of total biomass.

Table A-2. Species of aquatic macrophytes in Skinner Lake during 1977 and 1978.

Ceratophyllum demersum L.
Chara globularis Thuill.
Heteranthera dubia Jac Q.
Lemna minor L.
Myriophyllum sp.
Myriophyllum spicatum
Najas guadalupensis (Speng.) Morong.
Nuphar advena Ait.
Nymphaea odorata Ait.
Pontederia cordata L.
Polygonum sp.
Potamogeton alpinus Balbis.
Potamogeton foliosus Raf.
Potamogeton nodosus Poir.
Potamogeton pectinatus L.
Scirpus americanus Pers.
Scirpus validus Vahl.
Spirogyra sp.
Zanichellia palustris L.

Table A-3. Record of observations on the physiognomy of vegetation on transects in Lake Lansing, Michigan, on September 8-13, 1978.

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
1	0-5 92 152 212	0 1.0 1.2 4.4	0-32	_Nuphar_		85	Exposed sediments 0-5m. Understory is negligible; if present, _Ceratophyllum_. The _Nuphar_ has non-overlapping notch and is in poor shape.
			32-92	Heterogeneous mix of _Heteranthera dubia_, _Najas flexilis_. _Elodea canadensis_, _Ceratophyllum demersum_, water milfoil, _Chara_ sp., and _Potamogeton zosteriformis_.		5	
			92-142	_Heteranthera dubia_		20	Also present: water milfoil _Najas flexilis_
			142-152	Water milfoil		10	Also present: _Heteranthera dubia_

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
1			152-182	Water milfoil and Heteranthera dubia		20-30 of equal mix	Very patchy
			182-190	Ceratophyllum demersum		50	
			190-212	No plants observed			
2	0-3 17 60 120 180	0 0.25 0.75 1.30 1.40	0-17	Typha, Nymphaea, Chara	Typha Nymphaea Chara	50 30 50	Exposed sediments 0-3m. Chara present as an understory.
			17-155	Chara		95	Plants 30-50cm tall
			155-185	Heteranthera dubia and Chara	H. dubia Chara	40 95	H. dubia overstory; Chara understory. H. dubia is 0.7-0.8m tall
			185-205	Same as 155-185, but total cover has dropped to 80% and the 2 plant types are in an equal mix			

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
2			205-220	Ceratophyllum demersum		50	Plants growing up to .5m from the water surface
			220-240	No plants observed			
3	45	1.0	0-15	Chara		80	0-230 very loose, organic sediments
	60	1.1					
	120	1.3					
	180	1.2	10-25	Nuphar		100	No understory
	240	0.75					
	300	1.0	25-40	Chara		80	
	360	1.4					
	400	1.5	40-190	Najas flexilis and Chara		<1	Plants in tufts
			190-230	Chara		100	Occasionally Najas is present In place of Chara
			230-240	Nuphar		85	No understory
			240-260	Chara		100	Also present: Vallisneria

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
3			260-280	Nuphar and Nymphaea		80	Nuphar is the predominant plant
			280-330	Chara		100	Also present: Najas flexilis and Vallisneria
			330-345	Chara and Najas flexilis		80	Equal mix of both plants
			345-395	Najas flexilis		50	
			395-420	Najas flexilis		100	Also present: Heteranthera dubia, Myrio-phyllum sp., Vallisneria, Chara
			420-435	Vallisneria, Heteranthera, Najas, Ceratophyllum, and Myriophyllum		80	Very hetero-geneous mix
			435-450	Ceratophyllum demersum		50	
			450-480	No plants observed			

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
4	0	0.20	0-40	_Chara_			4 plants/m^2
	60	0.71					
	90	1.0	40-60	_Chara_ and _Eleocharis_			_Chara_: 4 plants/m^2 _Eleocharis_: 6 plants/.01m^2
	125	1.5					
	190	2.0					
	255	2.3					
	320	2.75					
			60-90	No plants observed			
			90-125	_Chara_ and _Najas flexilis_		15-20	Equal mix of 2 plant types, low biomass
			125-140	_Myriophyllum_, _Heteranthera_, _Ceratophyllum_, _Najas_		60-70	Very heterogeneous with each plant species represented equally
			145-255	_Heteranthera_, _Myriophyllum_, _Ceratophyllum_, _Najas_, _Potamogeton crispus_		20	Quite heterogeneous, plants are in clumps. Environment very patchy
			255-258	_Ceratophyllum demersum_		20	
			258-320	No plants observed			

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
5	0-20	0	0-65	No plants observed			Exposed sandy sediments 0-20m
	65	0.8					
	130	1.3					
	195	1.45	65-85	Chara and Vallisneria		80	Equal mix of the 2 species
	260	1.20					
	325	1.5					
	390	1.7	85-105	Chara and Vallisneria		50	Equal mix
	455	1.3					
	520	1.5	105-130	Chara and Heteranthera		50	No Vallisneria, some Myriophyllum and Najas
	585	1.65					
	650	1.46					
	715	1.0					
	780	0.8	130-240	Chara and Heteranthera		100	From 130-195m
	845	1.7				80	From 195-240m
	915	1.2				80	From 130-240m, understory of Chara.
	985	2.0					
	1050	4.25					
						50	From 130-195m, overstory of Heteranthera.
						10	From 195-240m
							Also present: Vallisneria, Myriophyllum, Heteranthera Najas, Potamogeton alpinus.

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
5			240-260	No plants observed			Shallow and sandy
			260-290	Chara and Najas		50	Also present: Heteranthera
			290-710	Najas, Heteranthera and Chara		95-100	80% understory cover of Najas flexilis and 10% understory cover of Chara. A 20-50% overstory of Heteranthera. Najas marina an occasional understory plant. Myriophyllum and Ceratophyllum are occasional overstory plants.
			710-715	Chara		100	
			715-780	No plants observed			Sand and gravel sediments

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
5			780-790	Najas flexilis and Chara		30	Equal mix of the 2 plants
			790-845	Najas flexilis, Chara Heteranthera, Myriophyllum		50	Understory of which 30% is Najas flexilis and 20% is Chara.
						30	Overstory Heteranthera and Myriophyllum.
			845-855	Najas flexilis and Chara		20	
			855-860	Vallisneria		40	
			860-900	No plants observed			Sandy sediments
			900-950	Chara and Vallisneria		100	Understory of Chara.
						60	From 920-950m, overstory of Vallisneria.

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
5			950-995	Ceratophyllum, Heteranthera, and Myriophyllum		60-80	Overstory cover. No understory present. Also present: Potamogeton alpinus.
			995-1050	Barren except for one small patch of Ceratophyllum			
6	60	0.55	0-20	Nuphar (open-notched type)		60-80	Also present: Water milfoil, Heteranthera, Vallisneria, Eleocharis, Utricularia.
	120	0.55					
	185	1.2					
	245	0.83					
	305	1.8					
	365	2.0					
	425	2.0					
	485	3.66	20-52	Chara, Najas, Juncus, and Utricularia		20-50	Very patchy and quite heterogeneous.
			52-150	Heterogeneous mix of: Potamogeton pectinatus, Elodea canadensis, Vallisneria, Najas flexilis, Chara, Heteranthera dubia, Potamogeton alpinus			Very low density

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
6			150-192	Chara		100	
			192-200	Chara		20	
			200-245	No plants observed			Barren sandy sediments
			245-275	Chara		20 100	From 245-260m From 260-275m
			275-290	Potamogeton zosteriformis and Heteranthera dubia		100	Equal mix of the 2 species. P. zosteriformis in poor condition. Also present: Water milfoil, Chara and Elodea.
			290-317	Potamogeton zosteriformis		100	No other plant species observed. P. zosteriformis In very poor condition.
			317-355	Heterogeneous mix of: Heteranthera dubia, Chara, Elodea canadensis, and Ceratophyllum demersum		50-100	

Table A-3 (con't.)

TRANSECT NUMBER	DISTANCE FROM SHORE (m)	DEPTH (m)	TRANSECT INTERVAL (m)	COMMUNITY TYPE	SPECIES	% COVER	REMARKS
6			355-365	Ceratophyllum demersum		20-80	Plants are 0.6-0.8m tall
			365-380	Heteranthera dubia and milfoil		5	
			380-425	No plants observed			
			425-440	Heterogeneous mix of: Elodea canadensis, Heteranthera dubia, Ceratophyllum demersum and Water milfoil		5	
			440-455	Heteranthera dubia and Water milfoil		80	Equal mix of the 2 plant species
			455-465	Ceratophyllum demersum and Heteranthera dubia		80	Equal mix of the 2 plant species
			465-485	No plants observed			

Table A-4. Species of aquatic macrophytes in Lake Lansing during 1977 and 1978.

Aphanothece stagnina (Spreng.)A. Braun
Brasenia schreberi Gmel.
Ceratophyllum demersum L.
Chara globularis Thuill.
Cladophora glomerata (L.)Kuetzing
Cyperus filiculmis Vahl.
Cyperus flavescens L.
Eleocharis acicularis (L.)R.&S.
Elodea canadensis (Michx.)Planchon
Heteranthera dubia (Jacq.)MacM.
Heteranthera dubia forma terrestris (Farwell)Vict.
Juncus alpinus Vill.
Juncus effusus L.
Myriophyllum cf. exalbescens (not in flower)
Najas flexilis (Willd.)Rost. & Schmidt
Najas marina L.
Nitella teniussima (Desr.)Kuetzing
Nuphar advena Ait.
Nuphar variegatum Engelm.
Nymphaea tuberosa Paine
Polygonum coccineum var. pratincola (Greene)Stanford
Polygonum pennsylvanicum var. laevigatum forma albineum Farwell
Pontederia cordata L.
Potamogeton alpinus Balbis
Potamogeton amplifolius Tuckerm.
Potamogeton crispus L.
Potamogeton foliosus Raf.
Potamogeton gramineus L.
Potamogeton illinoensis Morong.
Potamogeton pectinatus L.
Potamogeton richardsonii (Benn.)Rydb.
Potamogeton zosteriformis Fernald
Ranunculus sp.
Sagittaria sp.
Scirpus americanus Pers.
Scirpus validus Vahl.
Spirogyra sp.
Utricularia sp.
Vallisneria americana Michx.

Table A-5. Phytoplankton biomass estimates for Skinner Lake, expressed as mg/m^3 chlorophyll *a*. Values given are the mean ± one standard of the mean estimate.

Date	Trophogenic Zone	Tropholytic Zone
7/10/78	15.45±2.30	14.85±0.39
7/24/78	35.50±1.84	7.55±0.04
8/7/78	12.10±0.28	7.90±0.78
8/22/78	13.37±0.69	12.51±0.39
9/7/78	14.10±1.63	9.30±0.00
10/9/78	14.50±0.57	10.90±0.99
10/27/78	15.85±0.88	12.35±0.18
11/6/78	7.92±0.04	4.40±0.78
4/24/79	24.80±0.57	17.10±0.35
5/7/79	14.64±0.30	11.59±0.004
5/21/79	6.27±0.32	3.05±0.17
6/18/79	12.05±0.36	6.63±0.18
7/2/79	18.96±0.02	5.50±0.04
7/16/79	9.36±0.02	5.43±0.51
7/30/79	13.26±0.15	8.98±0.15
8/13/79	12.21±0.004	7.04±0.11
8/27/79	20.42±0.14	8.96±0.09
9/17/79	16.70[1]	5.29±0.04
10/3/79	21.00±0.35	6.36±0.42
10/24/79	33.26±1.71	-

[1]Replicate lost

Table A-6. Phytoplankton biomass estimates for Lake Lansing, expressed as mg/m^3 chlorophyll *a*. Values given are the mean ± one standard error of the mean estimate.

Date	Trophogenic Zone	Tropholytic Zone North Basin	Tropholytic Zone South Basin
7/5/78	12.46±0.48	5.80±1.84	42.60[1]
7/18/78	20.59±1.23	29.30±0.07	263.10±23.4
8/1/78	20.97±1.05	17.14±0.77	61.48±0.01
8/15/78	15.00±0.80	16.81±0.70	110.51±3.42
8/29/78	17.56±0.92	19.90±3.61	144.00[1]
9/11/78	4.75±0.42	5.15±0.25	3.20±0.49
9/23/78	13.32±0.56	13.00±1.77	14.45±1.24
10/9/78	10.99±0.96	13.00±0.14	11.65±0.46
10/27/78	14.68±0.29	14.70[1]	15.45±0.53
11/6/78	14.65±0.78	14.88±0.71	15.54±0.84
4/24/79	18.30±2.69	16.80±1.98	17.55±1.38
5/7/79	15.52±0.61	16.38±0.05	18.87±0.07
5/21/79	7.07±0.12	7.44±0.37	8.04±0.09
6/18/79	16.61±1.93	16.78±0.28	21.88±1.96
7/2/79	14.65±0.56	14.70±0.18	13.43±0.60
7/16/79	11.02±0.41	14.90±1.40	25.08±0.71
7/30/79	13.21[1]	18.80±0.50	50.48±4.08
8/13/79	13.92±1.12	14.37±0.39	37.34±2.27

[1]Replicate lost

Table A-7. The occurrence of chlorophyll *a* in littoral plants of Skinner Lake. August 8-9, 1978.

Transect Number	Transect Interval (m)	Species or Plant Aggregation	Chl *a* in Sample (mg)	Chl *a* (mg/m²)	Mean Chl *a* (mg/m²)
1	0-7.5	Emergent	0.253	25.3	28.5
		Scirpus	0.618	61.8	
		americanus	0.056	5.6	
			0.211	21.1	
		Mixed Understory	0.271	14.9	9.0
			0.181	10.0	
			0.088	4.9	
			0.112	6.2	
	7.5-12	Floating-Leafed	0.428	10.3	9.1
		Nymphaea odorata	0.497	11.9	
			0.306	7.3	
			0.291	7.0	
		Mixed Understory	None[1]	0.0	9.5
			None	0.0	
			0.633	34.9	
			0.052	2.9	
	12-26	Emergent	0.381	8.8	6.7
		Nuphar advena	0.111	2.6	
			0.171	3.9	
			0.496	11.4	
		Understory	0.028	1.5	2.8
		Ceratophyllum	0.054	3.0	
		demersum	0.105	5.8	
			0.016	0.9	
	26-45	Submersed	0.539	29.7	12.9
		Ceratophyllum	0.096	5.3	
		demersum	0.108	5.3	
			0.205	11.3	
2	0-9	Submersed	0.131	7.2	9.3
		Potamogeton	0.190	10.4	
		pectinatus	0.202	11.1	
			0.153	8.4	
3	0-6	Emergent	0.158	15.8	17.5
		Scirpus validus	0.125	12.5	
			0.207	20.7	
			0.208	20.8	

Table A-7 (con't.)

Transect Number	Transect Interval (m)	Species or Plant Aggregation	Chl *a* in Sample (mg)	Chl *a* (mg/m^2)	Mean Chl *a* (mg/m^2)
3	6-11	Floating-Leafed	0.022	1.2	4.0
		Potamogeton	0.014	0.8	
		nodosus	0.185	10.2	
			0.065	3.6	
	11-30	Submersed	0.176	9.7	13.9
		Ceratophyllum	0.023	1.3	
		demersum	0.552	30.4	
			0.256	14.1	
4	0-5	Emergent	0.295	8.3	8.1
	and	*Nuphar advena*	0.392	11.0	
	9-22		0.174	4.9	
		Understory	None	0.0	4.1
		Ceratophyllum	0.124	6.9	
		demersum	0.057	3.1	
			0.119	6.5	
	5-9	Emergent	0.153	13.5	14.9
		Pontederia	0.233	20.5	
		cordata	0.123	10.8	
			0.167	14.7	
		Understory	0.263	14.5	4.4
		Ceratophyllum	0.012	0.7	
		demersum	0.045	2.5	
			0.002	0.1	
	22-38	Submersed	0.108	6.0	13.6
		Ceratophyllum	0.148	8.1	
		demersum	0.513	28.2	
			0.222	12.2	

[1]"None" indicates no plant material in the sampler upon retrieval.

Table A-8. The occurrence of chlorophyll *a* in random samples of littoral plants in Lake Lansing, September 8-13, 1978.

Sampling Zone	Principle Plant Association	Sample Number	Chl *a* Sample (mg)	Areal Chl *a* Estimate (mg/m^2)
A	*Chara - Najas*	1	0.058	3.2
		2	0.058	3.2
		3	0.222	12.2
		4	0.079	4.3
		5	0.356	10.6
		6	0.096	5.3
		7	0.344	18.9
		8	0.172	9.4
		9	1.176	64.8
		10	0.114	6.3
		11	0.032	1.8
		12	0.027	1.5
		13	0.018	1.0
		14	0.009	0.5
		15	0.257	14.2
		16	0.067	3.7
		17	0.016	0.9
		18	0.011	0.6
		19	0.061	3.4
		20	0.069	3.8
B	*Chara - Najas*	1	0.015	0.8
		2	0.373	20.6
		3	0.371	20.4
		4	0.060	3.3
		5	0.270	14.9
		6	0.018	1.0
		7	0.074	4.0
		8	0.048	2.6
		9	0.184	10.1
		10	0.099	5.4
		11	0.198	10.9
		12	0.181	10.0
		13	0.018	1.0
		14	0.148	8.2
		15	0.316	17.4
		16	0.072	4.0
		17	0.002	0.1
		18	0.004	0.2
		19	0.166	9.1
		20	0.166	9.2

Table A-8 (con't.)

Sampling Zone	Principle Plant Association	Sample Number	Chl *a* Sample (mg)	Areal Chl *a* Estimate (mg/m^2)
C	Mixed Vascular Hydrophyte Population	1	0.010	0.5
		2	0.008	0.4
		3	0.029	1.6
		4	0.091	5.0
		5	0.084	4.6
		6	0.010	0.6
		7	0.081	4.5
		8	0.030	1.6
		9	0.017	0.9
		10	0.038	2.1
D	Mixed Vascular Hydrophyte Population	1	0.094	5.2
		2	0.069	3.8
		3	0.104	5.7
		4	0.028	1.6
		5	0.038	2.1
		6	0.144	7.9
		7	0.068	3.7
		8	0.070	3.8
		9	0.150	8.3
		10	0.064	3.5
		11	0.025	1.4
		12	0.099	5.5
		13	0.042	2.3
		14	0.051	2.8
		15	0.003	0.2
		16	0.001	0.1
		17	0.002	0.1
		18	0.002	0.1
		19	0.009	0.5
		20	0.028	1.6
		21	0.002	0.1
		22	0.037	2.1
		23	0.040	2.4
		24	0.029	1.6
		25	0.049	2.9
		26	0.083	4.6
		27	0.129	7.1
		28	0.043	2.3
		29	0.074	4.1
		30	0.043	2.4
		31	0.154	8.5
		32	0.049	2.7
		33	0.059	3.2

Table A-8 (con't.)

Sampling Zone	Principle Plant Association	Sample Number	Chl *a* Sample (mg)	Areal Chl *a* Estimate (mg/m^2)
D	Mixed Vascular Hydrophyte Population	34	0.097	5.3
		35	0.056	3.1
		36	0.088	4.8
		37	0.056	3.1
		38	0.058	3.2
		39	0.081	4.5
		40	0.237	13.5
		41	0.081	4.5
		42	0.041	2.3
		43	0.058	3.2
		44	0.039	2.1
		45	0.065	3.6
		46	0.084	4.6
		47	0.150	8.3
		48	0.060	3.3
		49	0.116	6.4
		50	0.126	6.9
		51	0.065	3.6
		52	0.042	2.3
		53	0.026	1.4
		54	0.131	7.2
		55	0.050	2.8
		56	0.045	2.5
		57	0.055	3.0
		58	0.034	1.9
		59	0.029	1.6
		60	0.048	2.7
		61	0.086	4.7
		62	0.104	5.7
		63	0.121	6.7
		64	0.071	3.9
		65	0.063	3.4
		66	0.053	2.9
		67	0.126	6.9
		68	0.123	6.8
		69	0.146	8.1
		70	0.110	6.1
		71	0.128	7.1
		72	0.213	11.8
		73	0.092	5.1
		74	0.139	7.7
		75	0.086	4.7
		76	0.090	5.0

Table A-8 (con't.)

Sampling Zone	Principle Plant Association	Sample Number	Chl *a* Sample (mg)	Areal Chl *a* Estimate (mg/m^2)
E	*Chara - Najas*	1	0.034	1.9
		2	0.412	22.7
		3	0.167	9.2
		4	0.023	1.3
		5	0.013	0.7
		6	0.018	1.0
		7	0.095	5.2
		8	0.072	3.9
		9	0.117	6.4
		10	0.038	2.1
		11	0.124	6.8
		12	0.297	16.4
		13	0.056	3.1
Emergent Stands	*Pontederia cordata*	1	0.159	11.1
		2	0.195	13.6
	Nuphar advena South Basin	1	0.146	3.8
		2	0.281	7.3
		3	0.196	4.9
		4	0.173	4.3
		5	0.196	3.3
		6	0.052	0.9
	Nuphar advena North Basin	1	0.191	3.4
		2	0.087	1.0
		3	0.088	1.6
		4	0.261	3.1
		5	0.258	5.2
		6	0.245	4.9
		7	0.094	2.8
		8	0.047	1.4
		9	0.285	8.5
		10	0.260	7.8
	Mixed *Scirpus americanus* and *Scirpus validus*	1	0.262	10.5
		2	0.052	3.9