Profile of Water Quality and Plant Populations in Four North-Temperate Lakes

BIOS 569 - Practicum in Aquatic Biology

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ABSTRACT

Macrophytes were identified and counted in four neighboring lakes in the Upper Peninsula of Michigan. Also, physical and chemical profiles of these four lakes were also taken for light penetration, dissolved oxygen/water temperature, alkalinity, apparent color, conductivity, nitrate, phosphate, and hydrogen sulfide. Two of the lakes were high in nutrient concentration, light penetration, and dissolved oxygen concentration, and distinctive macrophyte species flourished in these conditions. Two of the lakes were much lower in nutrient concentrations, and their macrophyte speciation was different and much less varied than those of the other two lakes. This experiment concluded that the physical and chemical characteristics of the lakes determined the abundances and the species of the macrophytes present in each lake.

INTRODUCTION

The term "aquatic macrophyte" refers to the macroscopic forms of aquatic vegetation, including macroalgae, mosses, ferns, and true angiosperms (Wetzel, 1975). Macrophytes may be divided into four basic classes: emergent, floating-leaved, submersed, and free-floating. Emergent, floating-leaved and free-floating plants are the most productive in terms of biomass because they have an unlimited supply of free CO_2 from the air, they receive the same light intensities as terrestrial plants, and their root systems provide excellent access to sediment nutrients (Pieterse and Murphy, 1990). Submersed plants, on the other hand, are the least productive because they are limited by carbon uptake in the water, they do not receive as much light under the water, and they generally have weak root systems that cannot utilize nutrients in the sediments (Wetzel, 1975).

Even though water depth is the major environmental factor influencing the zonation of macrophytes, changes in water chemistry are also correlated with changes in the composition of the vegetation (van der Valk, 1987). Nutrients in the water can "change" a lake's plant composition when they become limiting nutrients--those which determine a plant's growth rate. Limiting nutrients can change populations when they become too minute for a species to continue reproducing.

A profile was made of the macrophyte composition and of physical characteristics of four lakes in the University of Notre Dame's Environmental Research Center (UNDERC) in the Upper Peninsula of Michigan. The area is geographically positioned in the Highland Lake District because its glacial deposits are young and the drainage system is poorly developed (UNDERC, 1992). UNDERC is at 46 degrees north latitude, and has a cool, wet climate. Annual precipitation consists of between 50 and 100 cm of rain and snow (UNDERC, 1992).

Four lakes on the property were studied: Morris, Ward, Mullahy, and Reddington Lakes (see Figures 1-4). Morris Lake has a surface area of 12 acres, and is 6 meters at its deepest point (UNDERC, 1992). Ward Lake has a surface area of 2.7 acres, and is 7 meters at its deepest point (UNDERC, 1992). Mullahy Lake has a 1.2 acre surface area, and is 2 meters deep at its maximum (UNDERC, 1992). Reddington Lake has a maximum depth of 15 meters, and a surface area similar to Mullahy's.

Reddington and Mullahy had never previously been studied, and Morris and Ward mainly have been used for fishing. All four lakes are no more than 1 km apart from each other, and they have been virtually unaffected by humans since the area was logged in the early 1900's, and therefore provided valuable research sites as "natural" lakes. Since the lakes were so geographically close to one another and since human disruption was generally not a problem at these lakes, it was assumed that the same plants would be found at each lake unless the lake's chemical or physical characteristics determined otherwise.

Even though the lakes were so close to one another, they did indeed have distinctive physical, chemical, and biological characteristics. This paper examines the relationships between the physical and chemical environments and the abundance of macrophytes in these four lakes.

MATERIALS AND METHODS

Secchi readings were taken on June 5, June 19, and July 8 at each of the four lakes. At a buoy marking the deepest part of each lake, a Secchi disk was lowered into unshaded water until it could not be seen. Then it was brought up slowly until the white disk could be seen again. That distance was measured in meters from the top of the disk to the water surface. Secchi depths were only were taken on sunny days.

Dissolved oxygen/water temperature (DO/temp.) profiles were taken at the buoy of each lake three or four times during the summer, depending on the lake. Before taking the readings, the DO/temp. meter was calibrated to air temperature and adjusted for altitude. The probe was lowered into the water in 1.0 meter increments down to the lake bottom, and readings for dissolved oxygen and water temperature were taken at each meter from the water surface.

The following water chemistry tests were performed once on each lake. Two samples were tested per lake: a shallow (less than 1m from the surface) sample and a deep (about 1m from the bottom) sample. Samples were taken with a Kemmerer sampler rinsed in each lake's water, and were kept in opaque 300mL plastic bottles until testing. The tests were performed within an hour of the sampling.

Alkalinity: Alkalinity was determined using the Buret Titration Method 8221 for Total Alkalinity in the Hach manual (Hach, 1992). The procedure is equivalent to USEPA method 310.1 and Standard Method 2320-B for wastewater.

Water Quality and Plant Populations

Color: The apparent color was determined using the Platinum-Cobalt Standard Method 8025 in the Hach manual (Hach, 1992).

Conductivity: Conductivity was determined using the Direct Measurement Method 8160 outlined in the Hach manual (Hach, 1992).

Nitrate: Nitrate was determined from following the High Range Cadmium Reduction Method (8039) with powder pillows(Hach, 1992).

Phosphate: Phosphate was determined using the Reactive Phosphorus PhosVer 3 Method (8048) in the Hach manual (Hach, 1992). The procedure is equivalent to the USEPA method 365.2 for wastewater and Standard Method 4500-P-E for drinking water.

Hydrogen sulfide: Hydrogen sulfide was determnined using the Lead Sulfide Method for Water in the Hach DR-EL/2 Manual (Hach, 1974).

From mid-May to the first week of July, macrophytes were collected weekly at each of the four lakes to be identified and pressed. The four lakes were divided into eight equal pie-shaped sections (see Figures 1-4), based on compass measurements 22.5 degrees apart, and the sections were marked off with fluorescent marking tape on the shores. Macrophyte counts were recorded from a boat on sunny days in July when the lake bottoms were clearly visible. One section was counted at a time, and approximate counts were taken for all submersed, floating-leaved, and emergent plants in the lake and up to one meter inland from the water's edge. The exception to this "1m rule" was with Reddington Lake, where all plants on the bog mat within 5m of the water's edge were counted.

For large, distinguishable plants, individual counts were taken. For small plants or those in overwhelming abundance, such as grasses and sedges, counts of the flowers were taken in multiples of ten. For plants that were not identifiable in the field, samples were collected and a number was assigned to each. The numbered samples were later identified and matched up to the corresponding abundances.

Statistical analysis was done to determine: a.) the total abundance of each species in each lake, b.) the minimum and the maximum abundances of each species in each section of each lake, c.) the mean abundance of each species per section per lake, and d.) the standard deviation of each species in each lake.

FIGURE 1: DEPTH AND SECTIONING OF MORRIS LAKE

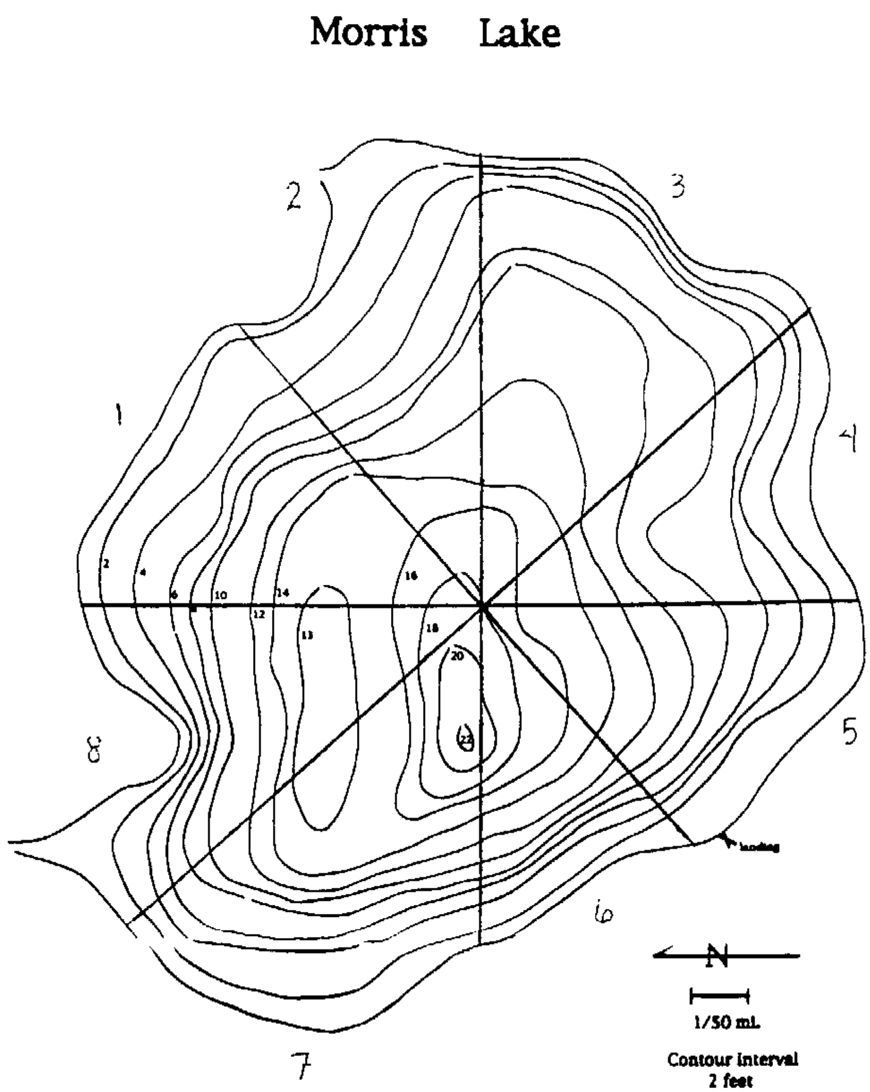

Fig. 1: The depth (in feet) and the partitioning of Morris Lake for macrophyte counting.

FIGURE 2: DEPTH AND SECTIONING OF WARD LAKE

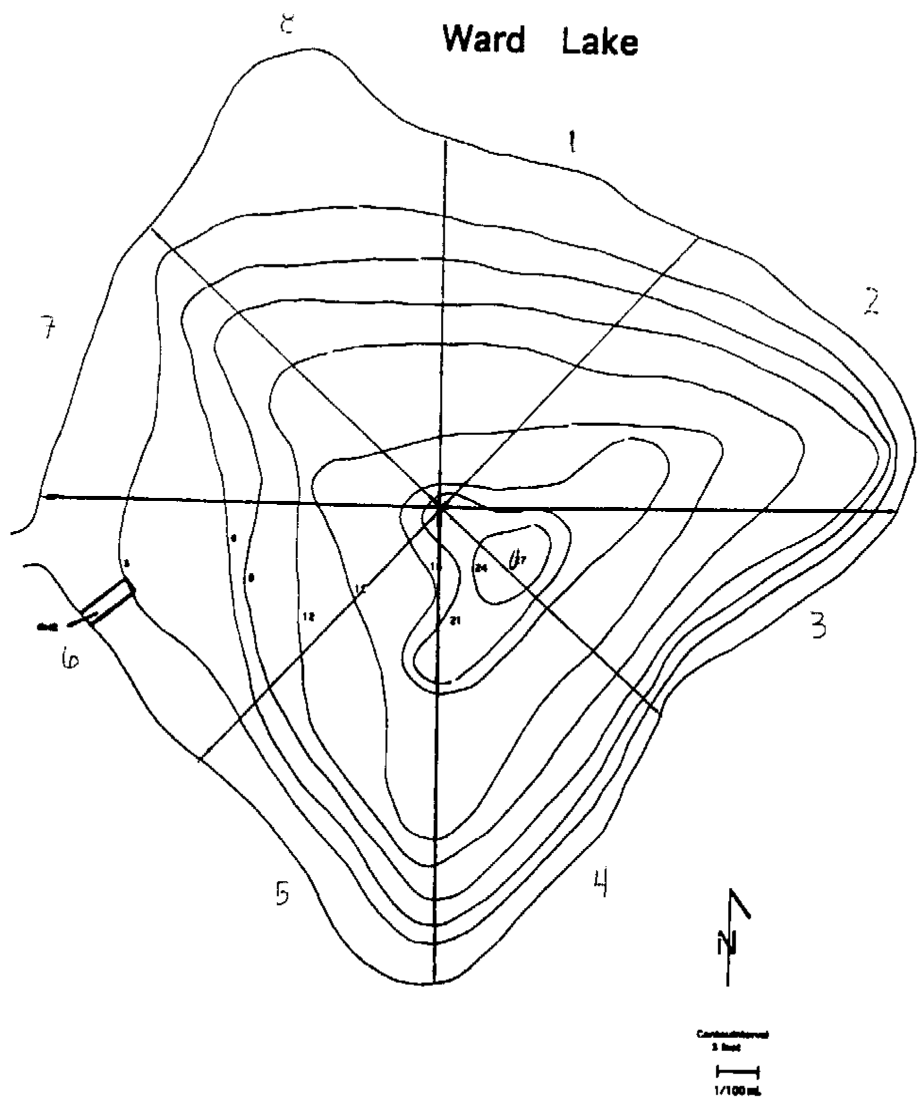

Fig. 2: The depth (in feet) and sectioning of Ward Lake for macrophyte counting.

FIGURE 3: DEPTH AND SECTIONING OF REDDINGTON LAKE

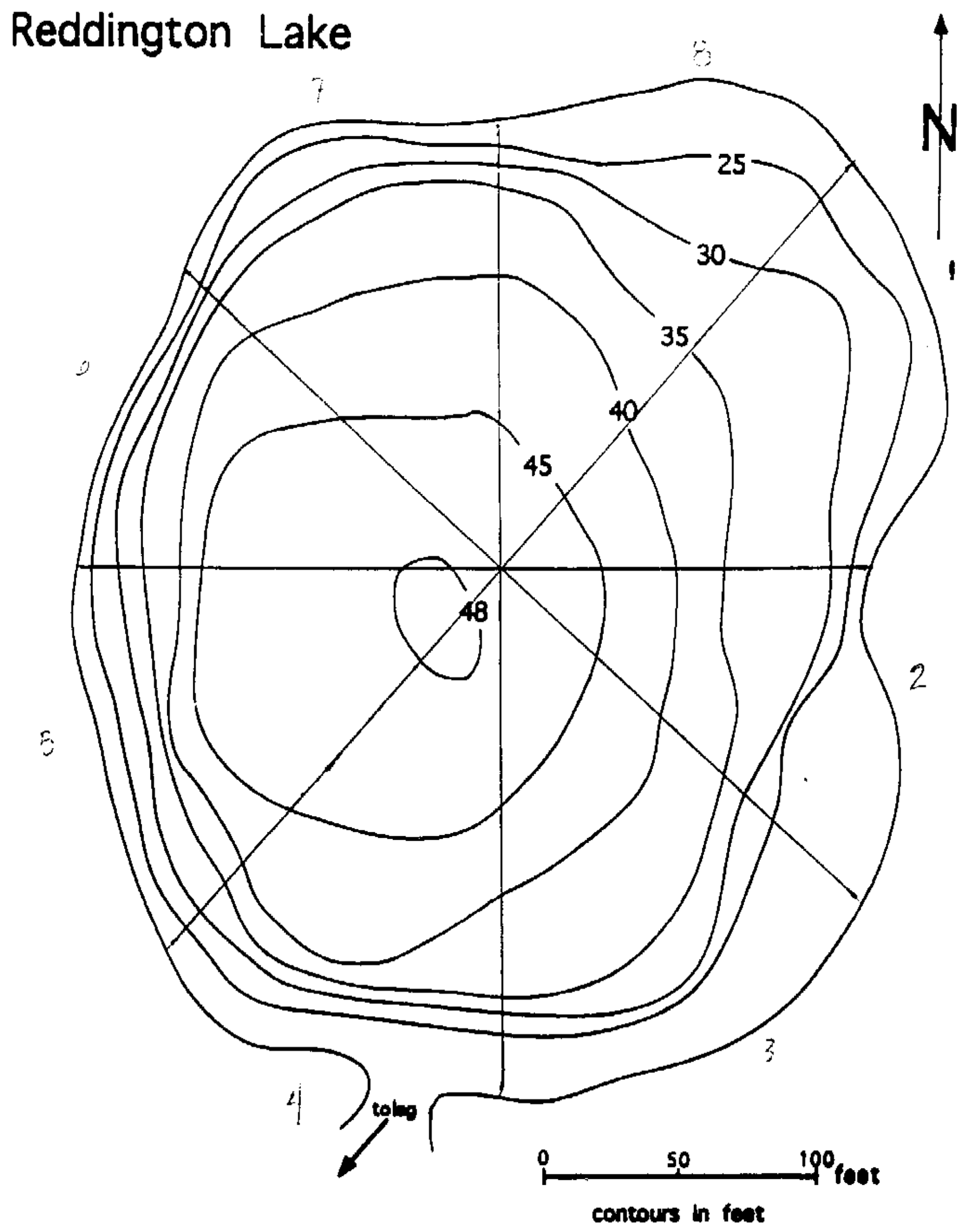

Fig.3: Depth (in feet) and sectioning for macrophyte counting of Reddington Lake

FIGURE 4: DEPTH AND SECTIONING OF MULLAHY LAKE

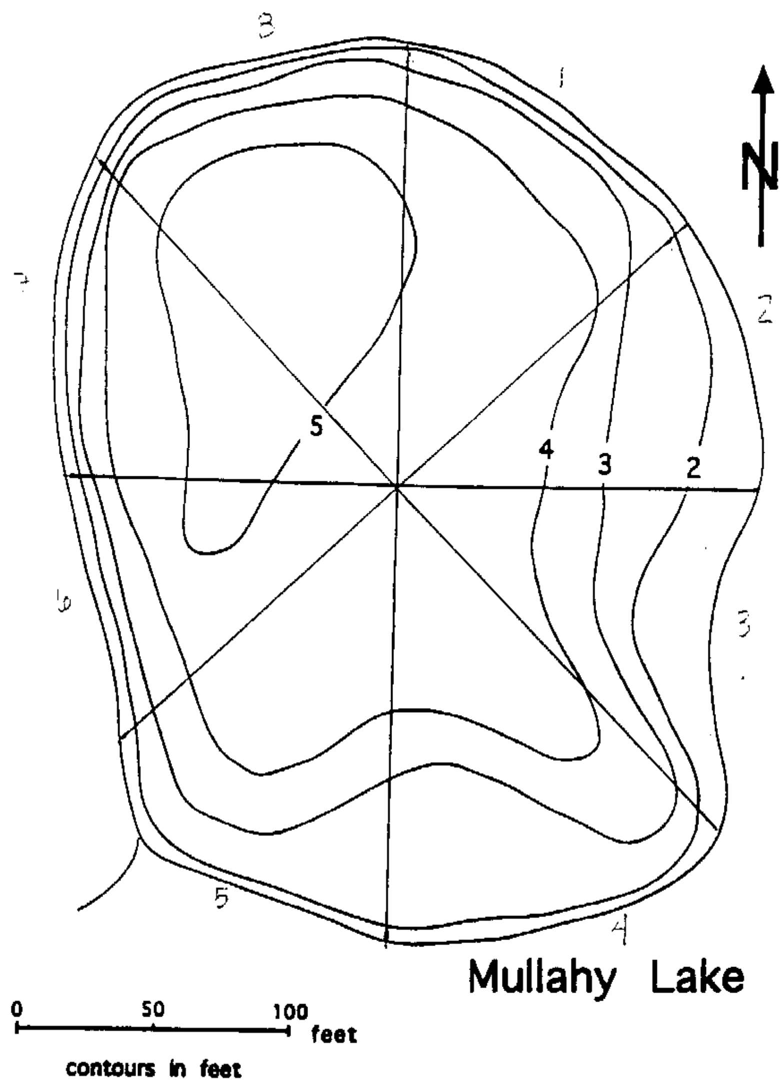

Fig. 4: Depth (in feet) and sectioning of Mullahy Lake for macrophyte counting.

RESULTS

TABLE 1: DISSOLVED OXYGEN/TEMPERATURE PROFILE FOR MORRIS LAKE

DATE	5/22		6/5		6/18		7/6	
TIME	1:00 p.m.		12 noon		2:00 p.m		10 a.m	
AIR TEMP	17 C		20 C		20 C		20 C	
WEATH.	cloudy windy		sunny, windy		sunny		sunny	
DEP.	TEMP	DO	TEMP	DO	TEMP	DO	TEMP	DO
1m	16.0	9.0	16.0	10.5	17.5	7.6	20.0	7.3
2m	13.0	8.5	13.5	9.6	16.0	5.6	15.0	0.3
3m	8.0	2.0	11.0	1.9	10.2	0.5	10.0	0.4
4m	6.0	1.2	7.0	0.5	7.2	0.3	7.0	0.3
5m	6.0	0.8	6.0	0.5	6.0	0.3	5.5	0.4
6m	5.5	0.7	6.0	0.4	5.6	0.3	5.0	0.3

Table 1: Dissolved oxygen content and water temperature of Morris Lake throughout the summer. "Weath." refers to the general weather conditions of the day. "Dep." means depth. "Temp." is the temperature in degrees Celsius of the water. "DO" is the dissolved oxygen content of the water in mg/L.

TABLE 2: DISSOLVED OXYGEN/TEMPERATURE PROFILE FOR WARD LAKE

DATE	5/22		6/5		6/18		7/7	
TIME	2:00 p.m.		1:00 p.m.		2:00 p.m.		3:00 p.m.	
AIR TEMP	16 C		20 C		18 C		22 C	
WEAT.	cloudy windy		sunny, windy		sunny		sunny	
DEPTH	TEMP	DO	TEMP	DO	TEMP	DO	TEMP	DO
1m	15.2	9.5	16.0	11.5	18.0	8.7	21.8	9.0
2m	13.5	9.6	14.0	10.4	16.3	9.3	17.0	11.2
3m	9.2	4.0	10.5	8.8	11.5	8.1	17.0	12.7
4m	7.0	0.3	9.0	4.5	8.5	1.2	11.2	6.4
5m	6.5	0.2	NC	NC	NC	NC	7.0	0.4
6m	7.0	0.2	NC	NC	NC	NC	6.5	0.3

Table 2: Dissolved oxygen content and temperature of Ward Lake throughout the summer. "Air temp." is in degrees Celsius, "Weat." means the weather conditions, "temp" is the water temperature in degrees Celsius, and "DO" is the dissolved oxygen in mg/L.

TABLE 3: DISSOLVED OXYGEN/TEMPERATURE PROFILE FOR REDDINGTON LAKE

DATE	5/25		6/5		6/19		7/7	
TIME	3:00 p.m.		1:00 p.m		2:00 p.m.		3:00 p.m.	
AIR TEMP	17 C		20 C		16 C		26 C	
WEATHER	sunny		sun wind		rain		sun	
DEPTH	TEMP	DO	TEMP	DO	TEMP	DO	TEMP	DO
1m	13.0	7.1	13.0	6.1	15.5	4.0	19.5	2.4
2m	7.0	0.5	7.5	0.5	9.5	0.6	9.5	0.7
3m	5.5	0.5	5.5	0.5	6.5	0.6	6.0	0.8
4m	5.0	0.4	5.0	0.4	5.2	0.4	5.5	0.8
5m	4.5	0.4	4.5	0.4	4.8	0.7	4.0	0.8
6m	4.5	0.3	4.5	0.4	4.5	0.7	4.0	0.8
7m	4.5	0.3	4.5	0.4	4.5	0.7	4.0	0.8
8m	4.5	0.3	4.5	0.4	4.5	0.7	4.0	0.8
9m	4.5	0.3	4.5	0.4	4.5	0.7	4.0	0.8
10m	4.5	0.3	4.5	0.4	4.5	0.7	4.0	0.8
11m	5.0	0.3	4.5	0.4	4.5	0.7	4.0	0.8

12m	5.0	0.3	4.5	0.4	4.5	0.7	4.0	0.8
13m	5.0	0.3	4.5	0.4	4.5	0.6	4.0	0.8

Table 3: Water temperature and dissolved oxygen content of Reddington Lake throughout the summer. Air temperature is in degrees Celsius, "temp" is the water temperature in degrees Celsius, and "DO" is in mg/L.

TABLE 4: DISSOLVED OXYGEN/TEMPERATURE PROFILE FOR MULLAHY LAKE

DATE	5/23		6/19		7/7	
TIME	2:00 p.m.		2:00 p.m.		3:00 p.m.	
AIR TEMP	15 C		16 C		27 C	
WEATHER	rain		rain		sunny	
DEPTH	TEMP	DO	TEMP	DO	TEMP	DO
1m	16.5	4.0	17.3	9.3	22.5	8.2
2m	15.5	2.7	16.5	0.7	21.0	2.3

Table 4: Water temperature and dissolved oxygen levels for Mullahy Lake. Temperatures are in degrees Celsius, and the dissolved oxygen is in mg/L.

FIGURE 5:

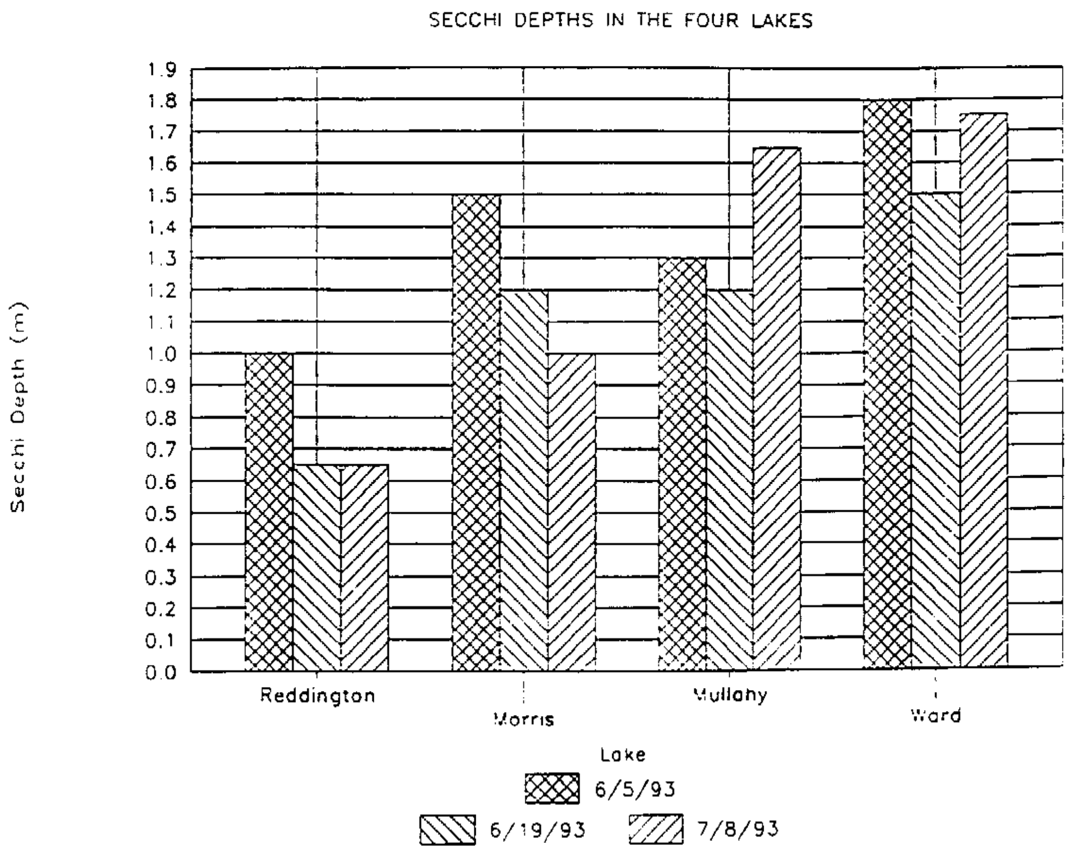

Fig.5: Relative transparencies of each lake throughout the summer.

FIGURE 6:

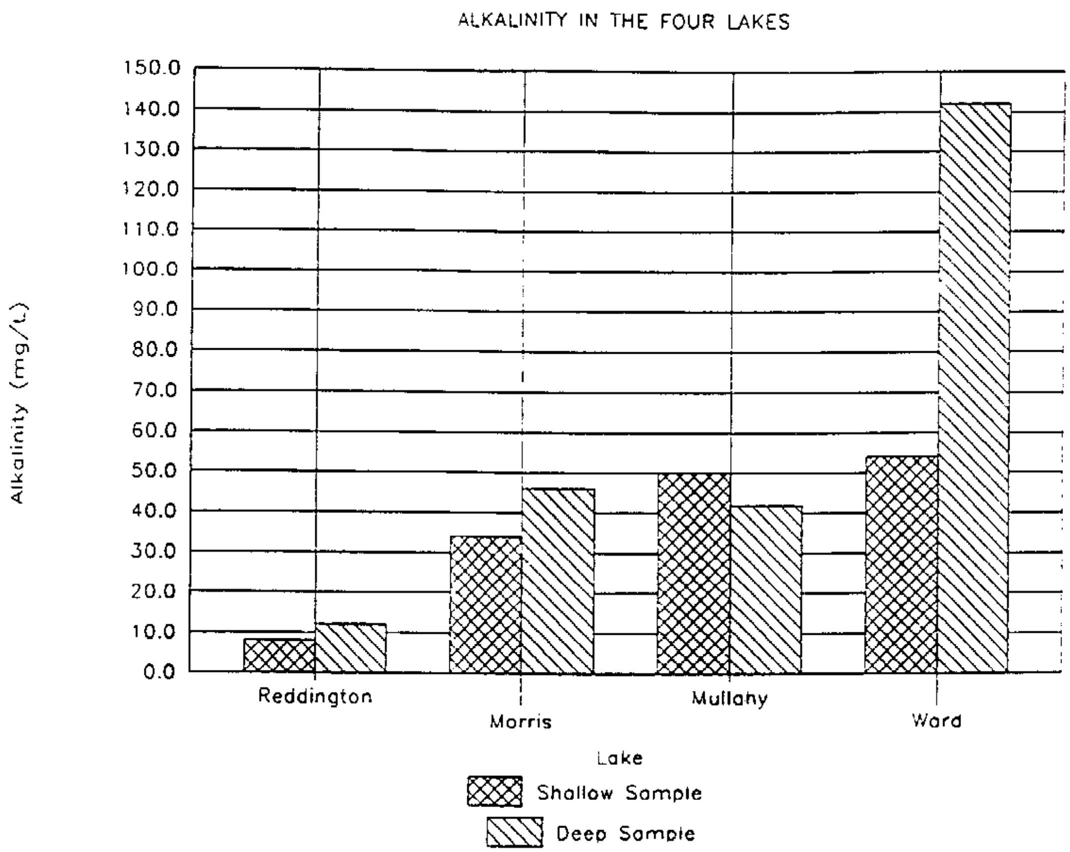

Fig.6: Comparison of the alkalinity of the four lakes.

FIGURE 7:

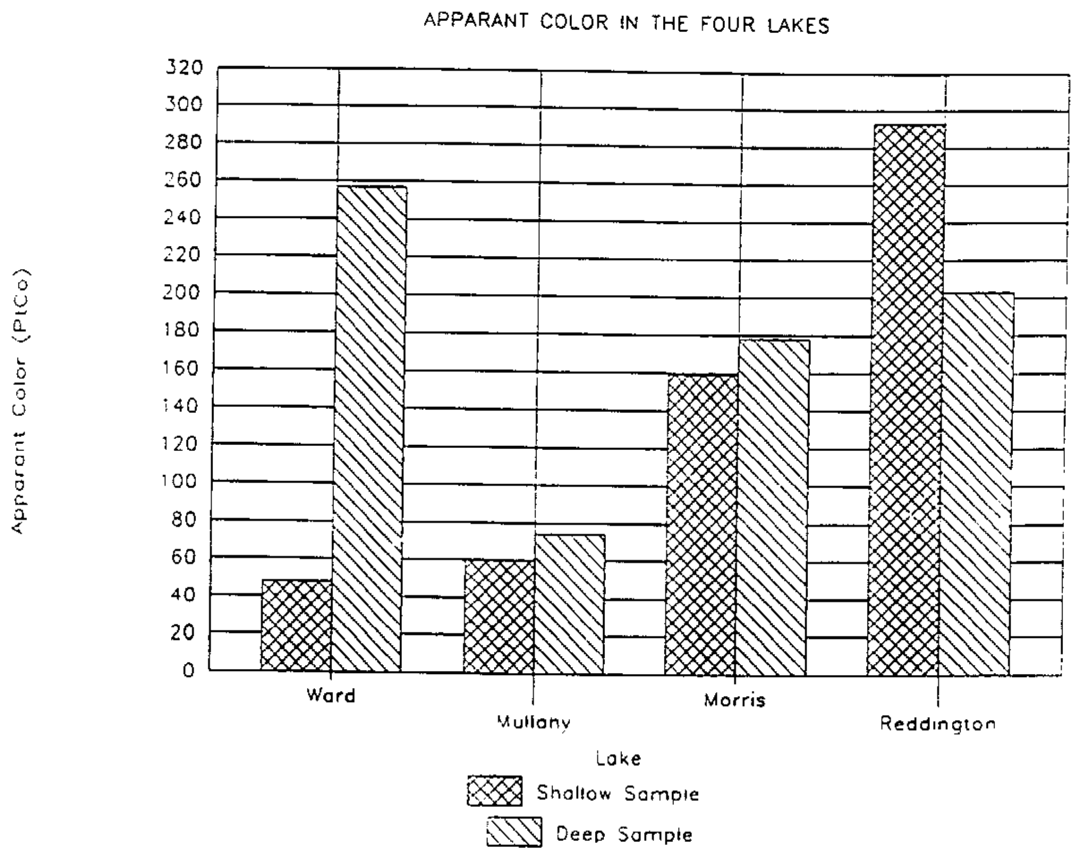

Fig. 7: Relative color of the four lakes.

FIGURE 8:

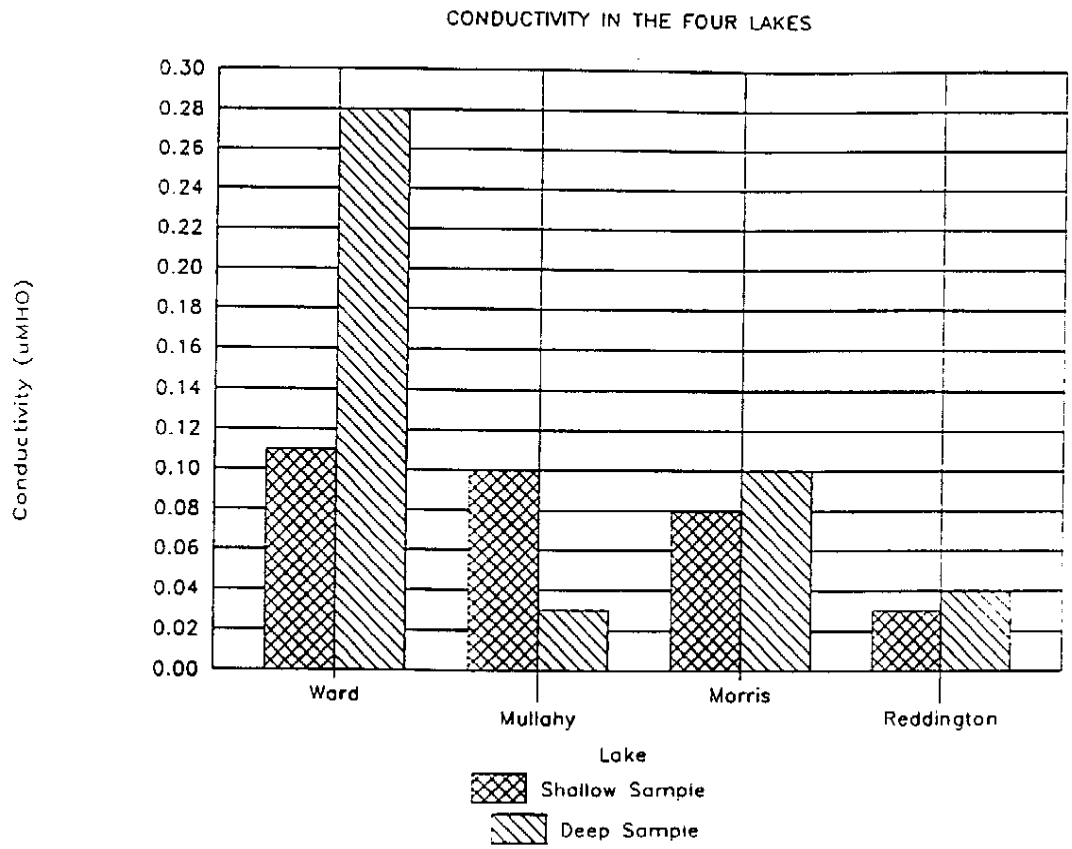

Fig. 8: Comparison of the conductivity of the four lakes.

FIGURE 9:

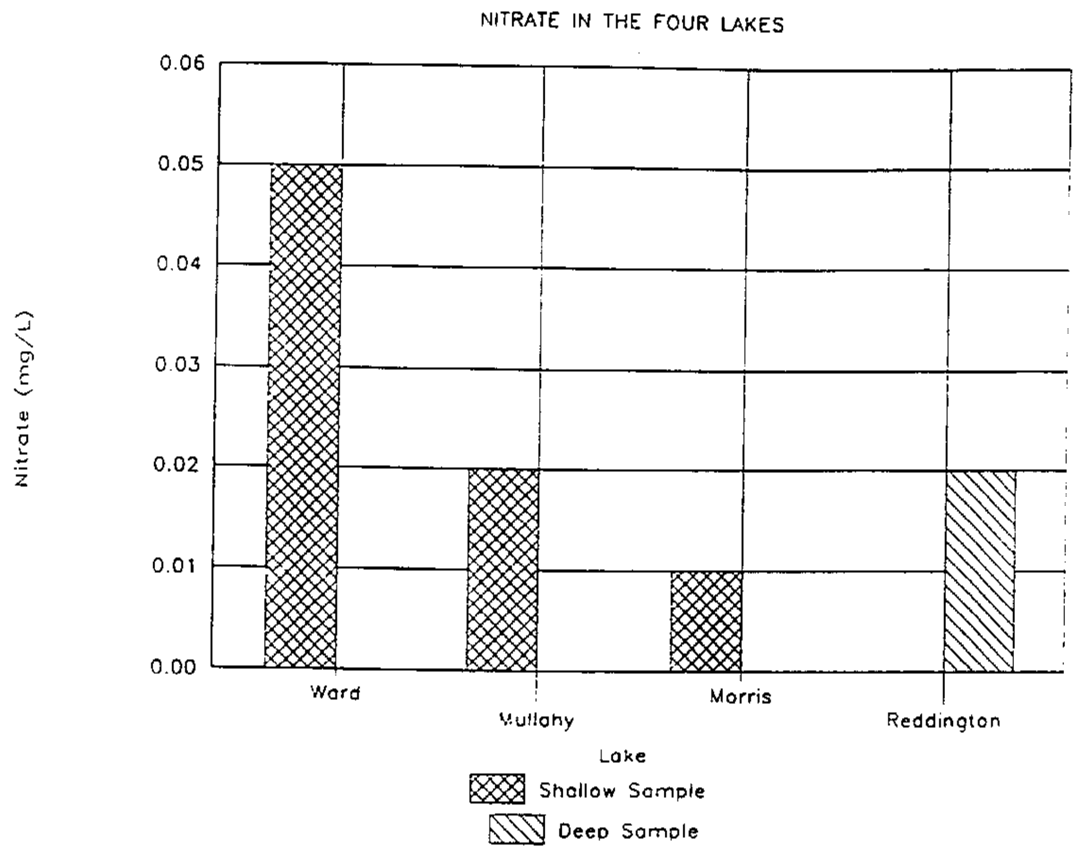

Fig. 9: A comparison of the nitrate of the four lakes.

FIGURE 10:

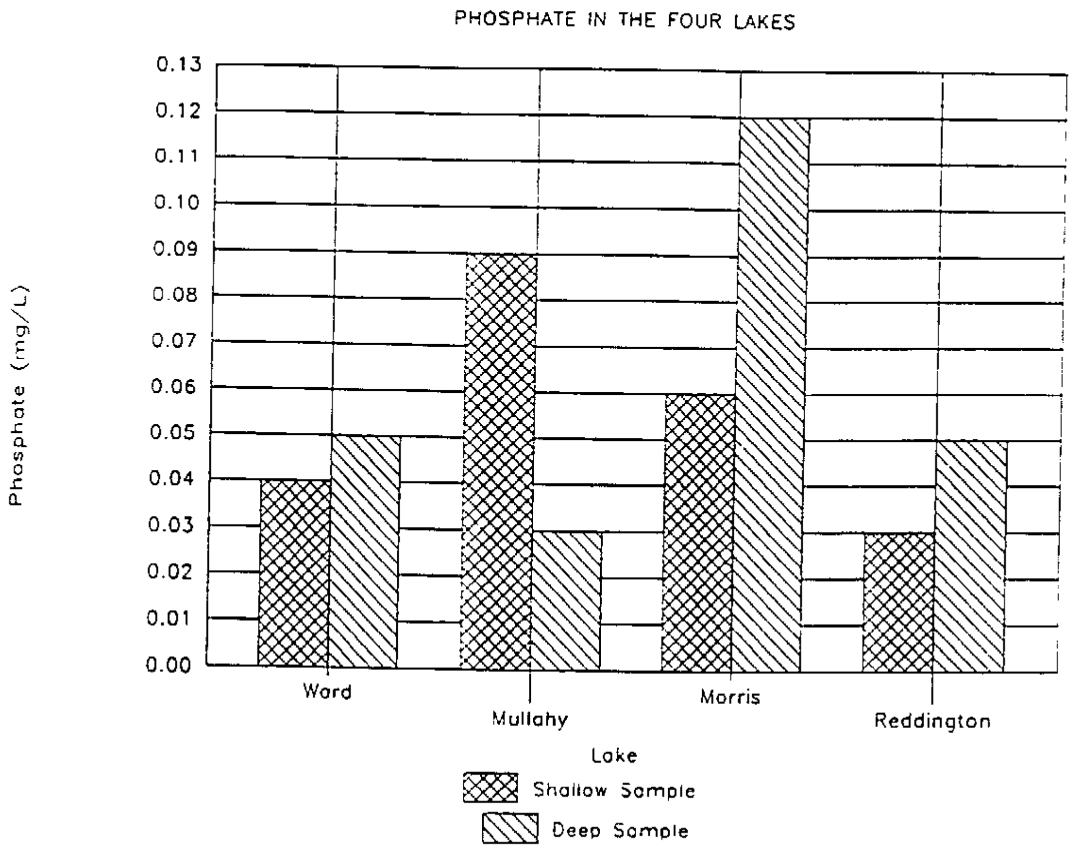

Fig. 10: A comparison of the phosphate levels in the four lakes.

FIGURE 11:

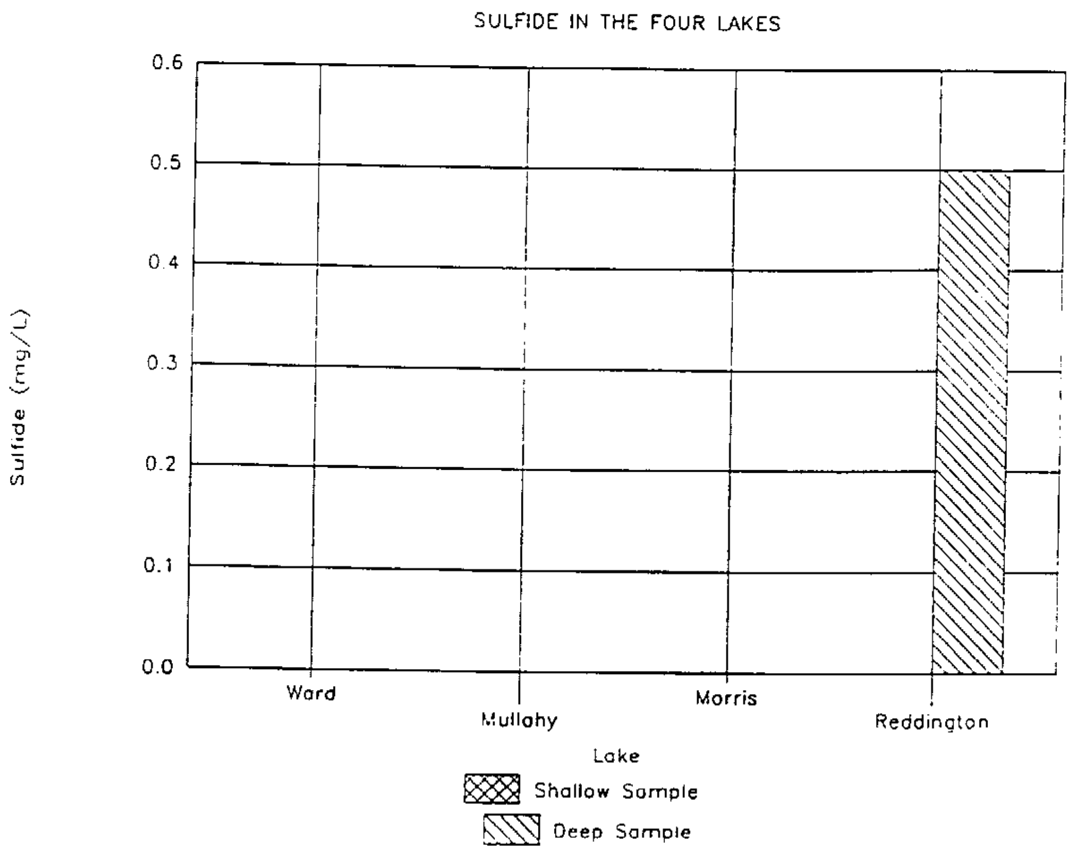

Fig. 11: A comparison of the hydrogen sulfide concentration in the four lakes. The presence of hydrogen sulfide indicates toxic and anoxic conditions.

SPECIES	Morris Lake	Ward Lake	Mull-ahy Lake	Redd-ing-ton
Alnus incana	840	1040	233	579
Asclepias incarnata	514	139	175	12
Andromeda polifolia	0	0	88	233
Acer rubrum	4	1	0	0
Brasenia schreberi	5	117	0	8
Carex sp.	1690	1135	280	0
Campanula aparinoides	66	0	0	0
Chamaedaphne calyculata	264	242	242	**
Ceratophyllum demersum	1360	0	0	278
Carex diandra	270	0	0	260
Carex lasiocarpa	1510	1425	940	0
Calla palustris	0	0	0	7
Carex pseudo-cyperus	297	235	0	234
Carex rostrata	130	0	0	0
Carex stricta	4680	0	0	0
Dryopteris carthusiana	56	610	563	121
Drosera rotundifolia	0	0	162	0
Eleocharis sp.	0	0	0	275
Equisetum fluviatile	470	0	0	0
Eupatorium purpureum	96	85	55	0
Galium tinctorium	230	0	0	10
Habernaria dilatata	0	0	23	0
Iris versicolor	408	113	24	59
Juncus canadensis	0	0	30	0

SPECIES	Morris Lake	Ward Lake	Mull-ahy Lake	Redd-ing-ton
Juncus effusus	25	60	0	0
Larix laricina	3	16	0	229
Lobelia puberula	199	97	0	0
Lysimachia terrestris	31	0	0	0
Nuphar luteum	2790	245	11	20
Nymphaea odorata	743	1166	1669	0
Onoclea sensibilis	193	129	4	15
Potamogeton amplifolius	2570	3000	940	0
Pontederia cordata	494	155	82	0
Potamogeton epihydrus	179	25	0	0
Picea mariana	0	0	0	197
Potamogeton natans	1	0	6	0
Pogonia ophioglossoides	0	0	24	0
Potentilla palustris	245	593	743	432
Potamogeton pusillus	965	2930	570	0
Spirea alba	10	0	0	0
Sparganium americanum	100	0	0	0
Sagittaria graminea	75	141	37	0
Sagittaria latifolia	171	180	0	0
Sarracenia purpurea	0	0	35	0
Typha latifolia	42	13	81	0
Trisetum melicoides	565	535	0	0
Utricularia vulgaris	0	0	0	19

SPECIES	Morris Lake	Ward Lake	Mull-ahy Lake	Redd-ing-ton
Vaccinium macrocarpon	0	0	188	0
Xyris montana	500	325	250	0

Table 5: Total abundance of each species in each of the four lakes. The "**" for Chamaedaphne calyculata point out that it was not counted in Reddington because of the high abundance.

TABLE 6: SPECIES ABUNDANCE AND ANALYSIS BY SECTIONS IN MORRIS LAKE

SPECIES	1	2	3	4	5	6	7	8	SUM	MIN	MAX	MEAN	SD
Alnus	155	145	96	86	126	124	64	44	840	44	155	105.00	39.18
Asclepias	105	105	12	11	96	91	49	45	514	11	105	64.25	40.02
Acer	0	0	0	4	0	0	0	0	4	0	4	.50	1.41
Brasenia	0	0	0	0	0	5	0	0	5	0	5	.62	1.77
Carex sp.	360	180	160	330	340	110	90	120	1690	90	360	211.25	113.1
Camp.	7	0	0	0	15	9	14	21	66	0	21	8.25	8.00
Chama.	79	47	0	1	34	70	21	12	264	0	79	33.00	30.19
Ceratop.	45	220	60	10	380	45	300	300	1360	10	380	170.00	146.0
C.diand.	270	0	0	0	0	0	0	0	270	0	270	33.75	95.46
C. lasio.	120	120	130	160	510	190	170	110	1510	110	510	188.75	132.8
C. pseu.	50	55	65	55	20	5	20	30	295	5	60	36.88	20.69
C. rost.	0	0	130	0	0	0	0	0	130	0	130	16.25	45.96
C. stricta	510	530	360	230	560	230	1200	1060	4680	230	1200	585.00	361.7
Dryopter.	6	6	7	6	14	2	10	5	56	2	14	7.00	3.59
Equiset.	0	98	67	140	40	0	5	120	470	0	140	58.75	56.19
Eupator.	12	15	7	20	8	15	9	0	96	0	20	12.00	6.28
Galium	10	50	30	10	50	40	30	10	230	10	50	28.75	17.27
Iris	74	16	8	47	28	115	85	35	408	8	115	51.00	37.14
Juncus	0	25	0	0	0	0	0	0	25	0	25	3.12	8.84
Larix	0	0	0	1	0	2	0	0	3	0	2	.38	.74

Lobelia	16	32	23	19	24	22	18	45	199	16	45	24.88	9.48
Lysima.	15	3	0	0	5	3	5	0	31	0	15	3.88	4.97
Nuphar	190	220	175	205	600	200	600	600	2790	175	600	348.75	208.4
Nymph.	300	12	0	0	46	105	90	190	743	0	300	92.88	105.9
Onoclea	25	13	19	32	28	39	14	23	193	13	39	24.12	8.89
P.ampli.	300	55	220	320	380	300	300	200	2570	200	550	321.25	108.3
Ponted.	9	32	23	0	240	35	75	80	494	0	240	61.75	77.41
P. epihy.	0	60	19	30	0	0	0	70	179	0	70	22.38	28.68
P. natans	0	0	0	0	0	0	1	0	1	0	1	.12	.35
Potentilla	42	24	11	19	26	67	36	20	245	11	67	30.62	17.65
P.pusillus	90	0	75	180	90	110	320	100	965	0	320	120.62	94.36
Spirea	0	0	0	0	0	0	10	0	10	0	10	1.25	3.54
Sparg.	0	22	46	17	10	0	0	5	100	0	46	12.50	15.88
S.gram.	0	75	0	0	0	0	0	0	75	0	75	9.38	26.52
S.latifolia	0	0	75	23	19	14	40	0	171	0	75	21.38	25.79
Typha	0	6	3	0	8	18	0	7	42	0	18	5.25	6.11
Trisetum	80	50	50	60	80	40	185	20	565	20	185	70.62	50.32
Xyris	0	0	0	0	140	0	90	270	500	0	270	62.5	99.54

Table 6: The abundances of each species in each of eight sections of Morris Lake (see Fig. 1). The numbers at the top of the table indicate the section. "Sum" is the total number of that species in Morris Lake. "Min" is the least number of a species in a section, and "max" is the largest number of a species

in a section. "Mean" is the average number of that species in each section, and "sd" is the standard deviation away from that number.

TABLE 7: SPECIES ABUNDANCE AND ANALYSIS BY SECTION IN MULLAHY LAKE

SPECIES	1	2	3	4	5	6	7	8	SUM	MIN	MAX	MEAN	SD
Alnus	21	21	15	22	34	38	41	41	233	15	41	29.12	10.47
Asclepias	45	39	31	9	0	0	8	43	175	0	45	21.88	19.54
Androm.	4	0	0	8	26	19	31	0	88	0	31	11.00	12.59
Carex sp.	60	30	30	20	10	70	20	40	280	10	70	35.00	20.70
Chama.	17	9	19	3	58	26	49	61	242	3	61	30.25	22.62
C.lasio.	310	130	170	160	90	10	50	20	940	10	310	117.5	98.67
Dryopter.	56	80	155	140	89	4	7	32	563	4	155	70.38	56.76
Drosera	40	20	50	45	3	4	0	0	162	0	50	20.25	21.61
Eupator.	9	11	10	6	2	0	2	15	55	0	15	6.88	5.25
Habern.	0	0	0	23	0	0	0	0	23	0	23	2.88	8.13
Iris	1	8	4	5	0	0	3	3	24	0	8	3.00	2.73
Juncus	30	0	0	0	0	0	0	0	30	0	30	3.75	10.61
Nuphar	0	3	2	2	3	0	1	0	11	0	3	1.38	1.30
Nymph.	205	245	240	150	195	124	290	220	1669	124	290	208.6	53.26
Onoclea	0	0	0	0	0	0	4	0	4	0	4	.50	1.41
P.amplif.	60	20	20	20	130	150	290	250	940	20	290	117.5	107.14

Ponteder.	0	82	0	0	0	0	0	0	82	0	82	10.25	28.99
P.natans	0	6	0	0	0	0	0	0	6	0	6	.75	2.12
Pogonia	6	3	2	2	4	7	0	0	24	0	7	3.00	2.56
Potentilla	125	95	85	65	118	113	91	51	743	51	125	92.88	25.83
P.pusillus	30	10	10	80	110	70	20	240	570	10	240	71.25	77.36
S.gram.	5	4	0	0	0	0	5	23	37	0	23	4.62	7.78
Sarracen.	3	6	8	6	2	0	2	8	35	0	8	4.38	3.02
Typha	5	12	18	9	16	0	7	14	81	0	18	10.12	6.03
Vaccin.	19	15	0	42	20	24	16	52	188	0	52	23.5	16.34
Xyris	30	220	0	0	0	0	0	0	250	0	220	31.25	76.99

Table 7: The abundance of each species by section in Mullahy Lake. The numbers 1 through 8 refer to the section of the lake (see Fig.4). "Sum" is the total number of that species in Mullahy. "Min" is the smallest number of that species found in a section, and "max" is the largest number of that species found in a section. "Mean" is the average number of that species found in a section, and "sd" is the standard deviation away from that mean.

TABLE 8: SPECIES ABUNDANCE AND ANALYSIS BY SECTION IN REDDINGTON LAKE

SPECIES	1	2	3	4	5	6	7	8	SUM	MIN	MAX	MEAN	SD
Alnus	105	76	124	125	85	27	4	33	579	4	125	72.38	46.22
Asclepias	0	12	0	0	0	0	0	0	12	0	12	1.50	4.24
Andromeda	36	32	20	2	7	49	30	57	233	2	57	29.12	19.04
Brasenia	0	0	0	0	0	6	5	0	8	0	5	1.00	1.93
Ceratoph.	30	40	35	15	35	33	50	40	278	15	50	34.75	10.02
C.diandra	10	10	0	0	85	10	70	45	260	0	85	32.50	31.40
Calla	0	1	0	3	0	1	1	1	7	0	3	.88	.99
C.pseudo.	40	17	16	3	17	5	10	5	113	3	40	14.12	11.93
Dryopteris	15	23	5	60	10	0	0	0	113	0	60	14.12	20.29
Eleocharis	0	0	0	0	0	30	240	5	275	0	240	34.375	83.73
Galium	0	0	0	10	0	0	0	0	10	0	10	1.25	3.54
Iris	40	1	0	3	12	0	0	3	59	0	40	7.38	13.77
Larix	28	45	46	8	31	21	23	27	229	8	46	28.62	12.50
Nuphar	1	4	0	6	9	0	0	0	20	0	9	2.50	3.46
Onoclea	0	0	2	13	0	0	0	0	15	0	13	1.88	4.55
Picea	9	31	33	0	13	29	42	40	197	0	42	24.62	15.37
Potentilla	131	41	64	22	42	51	120	61	432	22	120	54	30.19
Utricularia	0	0	0	0	0	5	7	7	19	0	7	2.38	3.34
Vaccinium	0	0	0	0	20	0	0	0	20	0	20	2.50	7.07

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Table 8: The number of each species present in each section of Reddington Lake. The numbers in the first row tell which section number (see Fig.3). The "sum" is the total abundance of a species in Reddington. The "min" is the least number of a species in a section, and the "max" is the greatest number of a species in a section. The "mean" is the average abundance of a species in one section, and the "sd" is the standard deviation.

TABLE 9: SPECIES ABUNDANCE AND ANALYSIS BY SECTION IN WARD LAKE

SPECIES	1	2	3	4	5	6	7	8	SUM	MIN	MAX	MEAN	SD
Alnus	140	130	60	120	180	195	115	100	1040	60	195	130.00	43.01
Asclepias	85	100	130	65	150	170	39	100	839	39	170	104.88	43.56
Acer	0	0	0	0	0	1	0	0	1	0	1	.12	.35
Brasenia	0	3	0	3	10	75	17	9	117	0	75	14.62	25.08
Carex sp.			150	100	320	340	105	120	1135	0	340	141.88	128.12
Chamaed.	41	36	10	0	18	65	45	27	242	0	65	30.25	20.96
C.lasioc.	240	300	280	120	140	60	75	210	1425	60	300	178.12	92.19
C.pseudo.	40	20	75	70	20	10	0	20	255	0	75	31.88	27.51
Dryopteris	130	75	90	17	140	40	43	75	610	17	140	76.25	43.22
Eupatorium	0	0	10	0	5	22	23	25	85	4	25	10.62	6.57

Iris	0	0	10	0	30	60	5	8	113	0	60	14.12	21.02
Juncus	0	0	0	30	30	0	0	0	60	0	30	7.50	13.89
Larix	0	2	0	0	0	8	3	1	16	0	8	2.00	2.67
Lobelia	5	2	40	25	0	0	0	25	97	0	40	12.12	15.60
Nuphar	14	11	35	73	20	49	35	9	245	9	73	30.62	22.19
Nymphaea	114	133	190	100	170	260	119	80	1166	80	260	145.75	58.43
Onoclea	10	20	25	2	45	15	9	3	129	2	45	16.12	14.09
P.amplifo.	401	25	255	360	165	950	632	467	3000	25	950	375.00	306.68
Pontederia	0	150	0	5	0	0	0	0	155	0	150	19.38	52.81
P.epihydrus	0	0	0	0	25	0	0	0	25	0	25	3.12	8.84
Potentilla	75	35	85	33	75	105	85	100	593	33	105	74.12	26.95
P.pusillus	410	85	100	195	415	520	530	675	2930	85	675	366.25	216.92
S.graminea	0	20	50	52	13	0	0	6	141	0	70	17.62	26.39
S.latifo.	0	20	50	50	50	0	0	10	180	0	50	22.50	23.76
Typha	0	5	2	1	5	0	0	0	13	0	5	1.62	2.2
Trisetum	0	0	120	320	35	20	10	30	535	0	320	66.88	109.31
Xyris	0	0	75	180	0	0	0	70	325	0	180	40.62	65.16

Table 9: The abundance of each species in each of eight sections of Ward Lake (see Fig. 2). The numbers 1 through 8 at the top of the table indicate which section is being counted. The "sum" is the total number of a species in all of Ward Lake. The "min" is the least number of a species in a section, and the "max" is the greatest number of a species in a section.

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The "mean" is the average number of a species in a section, and the "sd" is the standard deviation away from that mean.

DISCUSSION

High dissolved oxygen readings and water temperatures were mainly found in the first two meters of Morris Lake (Table 1). Then the water temperature fell and the dissolved oxygen concentration dropped off sharply, as well. The DO profiles can show where photosynthetic production is taking place by showing where the most dissolved oxygen is present. For Morris Lake, the most photosynthesis was taking place in the first two meters. Over the course of the summer, the temperatures generally rose, and the dissolved oxygen concentrations generally fell. This was likely due to the fact that oxygen is less soluble in warm water than in cold water (Wetzel, 1975).

Ward Lake had high DO readings and high temperatures for the first two meters (Table 2). The third meter had lower readings, and after the third meter, both measurements fell sharply. The most photosynthesis was going on in the first two or three meters. Generally, the dissolved oxygen levels stayed about the same or rose a little over the summer, despite the warmer temperatures. This oversaturation could have been caused by very active photosynthesis.

Reddington Lake dissolved oxygen and water temperatures were only taken down to 13 meters because the DO/temperature probe was not long enough to reach the bottom (Table 3). High DO levels were only in the first meter before the water dropped to nearly anoxic conditions, so photosynthesis must have mainly been taking place within that first meter. Throughout the summer, though, the DO concentrations fell dramatically.

The DO/temperature profile of Mullahy Lake shows a growth in DO levels throughout the summer despite the corresponding temperature increases (Table 4). For the first date, the water was essentially mixed according to the dissolved oxygen levels--photosynthesis was taking place in all depths of the lake. The other two dates, though, showed that photosynthesis was mainly taking place in the first meter.

Secchi depths were measured three times in each of the four lakes to show the changes in light penetration throughout the summer (Figure 5). The Secchi depth measures in situ light penetration, and takes into account the effects of both suspended and dissolved particles. Dissolved organic compounds dramatically reduce transmission of light and shift absorption selectivities--ultraviolet, blue, and green light are most affected by these compounds (Wetzel, 1975). At high levels, suspended particles have significant effects on absorption as well (Wetzel, 1975). Overall, light reached the furthest in Ward Lake and the least in Reddington Lake. Therefore, Reddington should have a much greater concentration of dissolved colored organic compounds and particulate matter than Ward. Ward Lake would be expected to have submersed plants at the greatest depth since light can reach further than in the other lakes. Over the summer, the light penetration diminished in all four of the lakes. This was likely due to the increase in dissolved organic colored compounds and particulate matter over the course of the summer.

The alkalinity readings in each of the four lakes varied dramatically (Figure 6). Alkalinity is the combined concentration of anions of weak acids, or the acid-combining capacity (Mackereth et. al., 1978). $CaCO3$ is usually the main component of alkalinity (Crum, 1988). Alkalinity also relates to buffering capacity--buffering capacity is essentially the alkalinity times 2.3 (Morel, 1983). Overall, Ward Lake had the highest alkalinity, and, therefore, the greatest buffering capacity against changes in pH. Reddington Lake, with such low alkalinity readings, would be vulnerable to massive pH changes with only small changes in [H+] because of its low buffering capacity. In bog lakes such as Reddington, the water is often low in electrolyes and relatively unbuffered (Crum, 1988). Humic acids, which are from dissolved and suspended organic matter, play an important part in removing ions (especially the phosphate ion) from solution, and also contribute to acidity when they dissociate (Crum, 1988).

Apparent color describes the color of the unfiltered lake water by taking into account both the dissolved compounds and the suspended materials (Figure 7). Most of the color of lake waters results from its dissolved organic matter and humic acids and not from the suspended matter, though (Wetzel, 1975). Apparent color is also indirectly related to the dissolved oxygen, since photosynthesis cannot take place at high rates in darkly stained waters with little light. This can especially be seen in Reddington Lake, which had the darkest apparant color and the lowest DO levels (Table 3). In all of the lakes but Reddington, the deep samples had higher color readings. This was most likely due to suspended organic compounds which can "sink" over time. Once they near the bottom, where little degradation goes on, they tend to stay there.

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Conductivity in all of the lakes was relatively low (Figure 8). Conductivity is the measure of ion concentrations in a body of water, and, specifically, the ability of a solution to carry an electric current (Mackereth et. al., 1978). The higher the content of ionized salts, the lower the water's resistance to electrical current (Wetzel, 1975). Since many plant nutrients are in the form of dissolved ions, this measurement can be used to give a general indication of nutrient abundance. In every lake but Mullahy, the conductivity was greater in the deep sample than in the shallow sample. This was probably due to the small demand for ions near the bottom of the lake, and the high demand for ions near the surface by phytoplankton, zooplankton, and macrophytes.

Nitrogen can often be a major nutrient that affects the productivity of lakes (Wetzel, 1975). Specifically, nitrate concentrations are important to determine in a lake because plants assimilate nitrogen for protein formation in the form of nitrate. Three of the lakes had substantial nitrate concentrations in their epilimnion, but, interestingly, nitrate was only found in the deep sample of Reddington (Figure 9). A possible reason for these substantial nitrate readings is that all four lakes are bordered by <u>Alnus incana</u>, a shrublike tree which can fix nitrogen from the atmosphere (Wetzel, 1975). Although <u>Alnus</u> usually assimilates most of this nitrate itself, its leaves release contain considerable amounts of nitrate upon decomposition.

Phosphorus is the least abundant of the major nutrients, and it commonly limits biological productivity (Wetzel, 1975). Fortunately, most macrophytes can take up phosphorus from both the sediments and the water, depending on the phosphorus concentrations in each (Wetzel, 1975). Even though bog lakes rich in organic matter usually have high total phosphorus concentrations (Wetzel, 1975), phosphorus is still often a limiting nutrient for bog plants since little is present in usable form as phosphate under the bog's acidic conditions (Crum, 1988). Mullahy and Morris had the highest total phosphate concentrations of the four lakes (Figure 10). A reason for the higher concentrations of phosphate in the deep samples of each lake may be that the demand for phosphate is not as high in the deeper waters than in the shallow waters.

Hydrogen sulfide is produced by decomposition of organic matter, and it is oxidized rapidly by dissolved oxygen (Wetzel, 1975). Since so little of it is found in aerated zones, it is often a clear indicator of anoxic conditions. Reddington Lake was the only lake to show sulfide concentrations, and even then, only in the deep sample (Figure 11). The hypolimnion of Reddington, therefore, should be relatively anoxic. This can be checked by the dissolved oxygen readings of the deep waters of Reddington (Figure 3).

pH, the concentration of hydronium ions in the water, was not reported because of faulty equipment. The problem was not discovered until after the experiment had finished.

From looking at Figures 6 through 11, Morris and Ward Lakes can be classified as hard water lakes--those with large concentrations of alkaline earths (Wetzel, 1975). They were rich in nutrients compared to the other two lakes. The importance of these nutrients can be seen with a closer examination of the macrophytes of these two lakes (Table 5). First of all, Morris and Ward had the highest species diversity of the four lakes. Ceratophyllum demersum and Nuphar luteum are often found in hard water lakes (Fassett, 1957), and indeed were found in great abundance in Morris and Ward. Nymphaea odorata and Iris versicolor are other macrophytes commonly found in mineral-rich places (Fassett, 1957). Sedges such as Carex, which require large quantities of nutrients (Wetzel, 1975), were most abundant in these two lakes as well.

Mullahy and Reddington Lakes, on the other hand, were lacking in nutrients compared to the other two lakes (Figures 6-11). This determined their macrophyte speciation. Reddington and Mullahy Lakes, with the lowest phosphate levels, were composed of the greatest amount of Ericacids. These shrubs can cope very well with low phosphate levels and with acidic waters (Crum, 1988). Andromeda polifolia is commonly found in Sphagnum peat bogs (Szczawinski, 1962), and it was most abundant in Reddington Lake. Vaccinium macrocarpon was found only in Mullahy Lake. Chamaedaphne calyculata, the leatherleaf completely dominated the bog mat of Reddington Lake in numbers too high to be counted. The Ericacids are the best-adjusted plants to these environments, so it was fitting that they were the most abundant here.

Other macrophytes affected by the low nutrients in Reddington and Mullahy were the insectivorous ones: Drosera rotundifolia, Sarracenia purpurea, and Utricularia vulgaris. They use digested animal proteins for nutrient supplements, and especially for phosphate and nitrate supplement (Crum, 1988). The harsh nutrient-limiting conditions at these two lakes dictate the macrophyte speciation: only those which have adapted to such conditions can survive there.

Six macrophytes were not included in these counts because their numbers were simply too high. Lemna sp. was present in Morris Lake only. It was the only free-floating macrophyte at any of the lakes. Although the reproductive form of Sagittaria graminea was counted, its numbers in vegetative form were too staggering. This macrophyte lined the shallow (0.5 meters to 2.0 meters of water) bottoms of Morris, Ward, and Mullahy Lakes. Najas flexilis also covered the bottom of the same lakes in a carpet-like fashion. Chara sp. is a macroalgae common in hard waters, often covered with lime encrustations (Fassett, 1957). It was found with Sagittaria graminea and Najas flexilis, lining the bottom of the shallow areas of Ward Lake. In many cases, Chara and Najas were so photosynthetically productive that the oxygen they produced made them more buoyent than the substrate, and they floated to the surface in huge clumps (Carlton, 1993). Chamaedaphne calyculata was counted in all of the lakes but Reddington Lake because it totally dominated the bog mat surface (Table 5).

The sixth macrophyte not counted is likely the most important of them all. It is the Sphagnum sp. moss. According to Andrus, no other group of mosses is as ecologically dominant (1986). It was present on hte shorelines of all four lakes, with the greatest dominance in Mullahy, then Ward and Reddington, and finally Morris Lake. Sphagnum is a high capacity cation exchanger: it releases H+ in exchange for dissolved cations (Andrus, 1986). It plays a major role in creating its own acidic and poorly mineralized conditions (Andrus, 1986).

Not just the total number of macrophytes in each lake were analyzed, but so were the records of how many macrophytes were in each of the eight sections of each of the lakes. These numbers are useful for determining whether a macrophyte species grows in patches or clumps, or whether it grows uniformly in a lake. The standard deviation, in particular, can be used to determine the uniformity of the distribution of a species. If the standard deviation is only a small fraction of the mean abundance, then the species was most likely distributed equally in the lake. If the standard deviation is as large as the mean abundance, however, this shows that the species has a wide range of variability in where it lives and that it probably was only found in a few patches.

Potamogeton pusillus in Mullahy Lake serves as an example. Its standard deviation was 77.36, and its mean abundance per section was only 71.25, so it would be expected to be a macrophyte that occurs in patches and clumps. Examining the raw data from each section of Mullahy confirms this: there was as little as 10 plants or as many as 240 plants within one section of this lake.

Alnus incana in Ward Lake serves as another example. Its standard deviation was 43.01, and its mean abundance per section was 130.00. There was little "deviation" from the mean in this case, so Alnus would be expected to occur uniformly around the lake. Actually, that was exactly the case. There was one low section with only 60 trees, but the other seven had similar abundances.

Another interesting analysis is to look at each species' uniformity in all of the lakes. In every case of Potamogeton pusillus, the standard deviation is very close to the mean value. From data such as this, it can be hypothesized that this macrophyte does not occur uniformly, but that it does occur mainly in patches. On the other hand, the standard deviation of Alnus incana in every case is well below the mean abundance. Alnus can be hypothesized to be a macrophyte that occurs with uniformity around lakes.

This data should be analyzed in more detail to find more trends such as the two that were briefly mentioned. Other similar relationships undoubtedly exist. This data on macrophyte speciation and abundance holds promise for future analyzation and further re-testing. Ideas for future re-testing would include: better characterization of each section, and doing more chemistry tests for more repetitions to better characterize each lake.

To summarize the experiment, four neighboring lakes were found to have different chemical characteristics. Two of the lakes were high in nutrient concentration, light penetration, and dissolved oxygen concentration. Specific macrophyte species flourished in these conditions. Two of the lakes were much lower in nutrient concentrations, and their macrophyte speciation was different and much less varied than those of the other two lakes.

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REFERENCES CITED

Anonymous. 1992. Guide to UNDERC: University of Notre Dame's Environmental Research Center.

Anonymous. 1992. Hach DR/200 Spectrophotometer Procedures Manual.

Anonymous. 1974. Hach DR-EL/2 Methods Manual.

Andrus, R.E. 1986. Some aspects of Sphagnum ecology. Can. J. Bot. 64:416-426.

Carlton, R.C. 1993. Personal communication.

Crum, H. 1988. A focus on peatlands and peat mosses. University of Michigan Press, Ann Arbor.

Fassett, N.C. 1957. A manual of aquatic plants. U. of Wisc. Press.

Mackereth, F.J.H., Heron, J., and Talling, J.F. 1978. Water analysis: Some revised methods for limnologists. Titus Wilson, England.

Morel, F. 1983. Principles of aquatic chemistry. John Wiley, New York.

Ed. Pieterse, A.H. and Murphy, K.J. 1990. Aquatic weeds: The ecology and management of nuisance vegetation. Oxford U. Press, New York.

Schwintzer, C.R. and Tomberlin, T.J. 1982. Chemical and physical characteristics of shallow ground waters in northern Michigan bogs, swamps, and fens. Amer. J. Bot. 68(8): 1231-1239.

Szczawinski, A.F. 1962. The heather family (Ericaceae) of British Columbia. A. Sutton Press.

van der Valk, A.G. 1987. Vegetation dynamics of freshwater wetlands: A selective review of the literature. Advances of Limnology. 27:29-32.

Wetzel, R. G. 1975. Limnology. W.B. Saunders Co. Philadelphia.