1978

water chem. 9

A Study of

BAY LAKE

and

FOREST SERVICE BOG

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BAY LAKE

I. Description

Bay Lake was studied by Ken Perentoni, Liz Cone, and myself on May 31, 1978. The lake is located on the eastern end of the Michigan portion of the University of Notre Dame Environmental Research Center (UNDERC). Water samples were taken at 9 a.m. at depths of one and five meters, refrigerated, and then analyzed that afternoon. Oxygen and temperature readings were taken every meter with an oxygen probe at a point between the northwest and south-west arms of the lake (see diagram). The depth at this point was eleven meters. The pH was taken in the field at one and five meters, with a portable PH meter and then retaken indoors in the afternoon with a more precise PH meter because of a zero alkalinity test reading. Also a two minute plankton-tow was done in the morning and in the evening (4 p.m.) and injected with formalin to be preserved for identification on the following week.

Bay Lake was formed by a glacier and is a drainage lake, receiving water from Tuesday Lake and Hummingbird Lake. It is a large lake of about 69 hectares ($10^4 m^2$) and is divided into four main arms. The lake has a very small littoral zone, i.e. little aquatic rooted plants in the peripheral shallows of the lake such as aquatic grass, rushes, sedges, or cattails, except for some grasses at the far end of the arms of the lake. Instead, the water was bordered by spruce, pine, maple, and a large amount of birch trees. The trees grew up to the water's edge and many were submerged and rooted under water as if the water level was too high. Many trees had died and fallen into the water, thus contributing organic matter to the lake from an outside source (allotrophic). There was little visible floating algae, floating leaf parts, submerged macrophytes, or other organic matter <u>within</u> the lake (autotrophic).

In the morning when we took our samples, there was no wind and it was overcast. The water was calm without waves. The temperature was in the low 60^{o}'s (^{o}f). In the evening, it was completely dark out when we took our plankton tow, and again the water was calm.

BAY LAKE

Date: 5/31/78

Time: 9:00 am

Secchi disk reading: 3.75 meters

Weather conditions: Overcast day with no wind; water calm with very few or no waves.

Depth (meters)	Oxygen ($mgO_{2/L}$)	Temperature (C^{O})
Surface	8.4	19.4
1	8.3	19.5
2	8.4	19.5
3	10.0	15.0
4	10.0	11.5
5	8.8	10.0
6	8.6	9.5
7	7.6	9.5
8	5.7	8.0
9	4.0	7.0
10	2.8	6.0
11	2.8	5.5

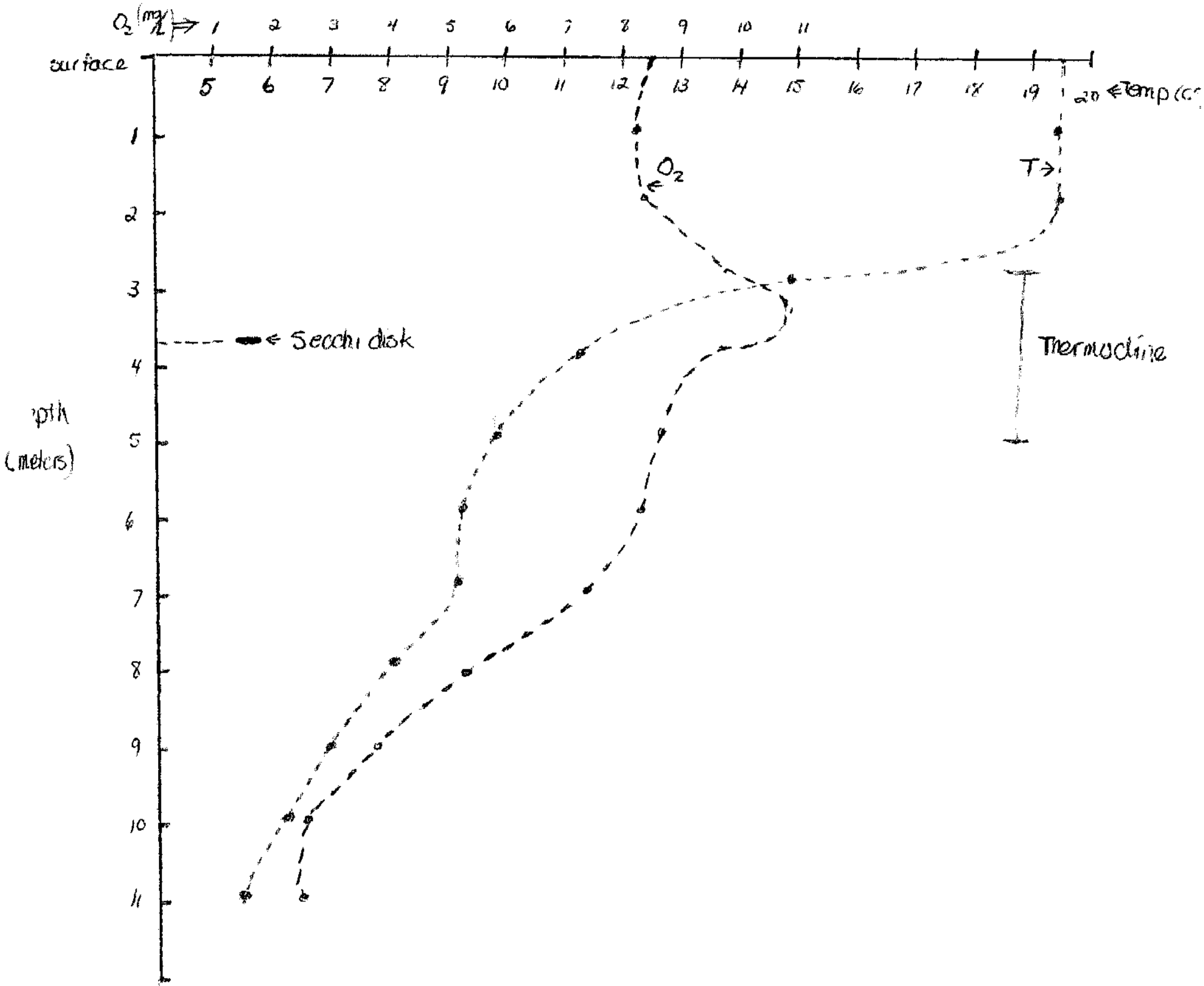
BAY LAKE

Date: 5/31/78

Time: 9 AM

Sample taken at: 1 and 5 meters.

Oxygen - Temperature Profile



BAY LAKE: Water Chemistry Data

Surface Area: 69 hectares (10^4 m^2)

Drainage Pattern:

Tuesday L. → Bay Lake → Emeline L. → Kickapoo L. → Brown Creek → Plum L.

Hummingbird L. ↗

	5/31/78				8/75	
	Tuesday Lake		Bay Lake		Bay Lake	Tuesday Lake
			8 am	4 pm		
Secchi Disk	1.75		3.75 m		-	-
Depth	18 m		11 m		11 m	18 m
P H	8.4 field/5.3 lab		6.4 field/5.6 lab		6.1	6.2
Phenylthalein	55	40	90	95	-	-
Acidity (mg/ℓ $CaCo_3$)						
Alkaline (mg/ℓ $CaCo_3$)	1	5	0	0	-	-
Specific Conductivity (μmho/cm)	19	22	18	16	20	16.9
True Color (445 nm)	95	120	35	30	47	70
Phosphate Total (mg/1)	.51	.90	.23	.25	-	-
Ca^{++}(mg/1)	25	20	10	10	-	-
Total Hardness (mg/1)	30	32	10	20	-	-
Nitrate Nitrogen ($NO_3^=$) mg/1	3.01	3.8	1.1	.88	-	-
H_2S	0	present	0	0	-	-
Oxygen Range	9	0	10	0	-	-
Depth Sampled	1.5m	9m	1m	5m	-	-

II. Water Chemistry Data Discussion

After obtaining an oxygen-temperature profile, we found that the lake was stratified into three layers. The uppermost layer, the epilimnion, was approximately two meters deep and uniformly heated to a temperature of 19.5°C. Then there was an intermediate zone, the thermocline, which has the maximum rate of decrease in temperature. It is approximately three meters deep and there is almost a 10°c drop in temperature within this region. The thermocline serves as a barrier between the epilimnion and the bottom layer of fairly uniform temperature, the hypolimnion. The hypolimnion is approximately six meters deep with a 4.0°c drop in temperature. This distinct stratification is a result of density differences caused by the different temperatures of the two layers. In the springtime, the water was uniformly heated and oxygen was evenly distributed. But as the sun becomes higher and the days longer, surface waters absorb the sunlight and heat rapidly, expand and become less dense than the colder water below. Initially this warm surface water will be circulated in currents caused by the wind which causes frictional differences between moving air and water. These currents travel until they reach the shore and then move down along the bottom causing an overturn. But, in the summer, the winds begin to die and the increased temperatures in the surface layer cause such a density gradent that there is resistance to mixing with lower, more dense, layers. This thermal stratification is so stable that not only are warm waters prevented from mixing, but also nutrients and dissolved gases are restricted. This would explain why the oxygen profile runs almost parallel to the temperature profile. Oxygen which is abundent in the epilimnion and upper thermocline because of oxygen supplied from the atmosphere and from photosynthesis, cannot circulate to replenish the depleted oxygen supply that exists in the hypolimnion. The oxygen shortage is due to the photosynthesis, and oxygen utilization for decomposition of organic matter, and animal respiration. Photosynthesis cannot occur in these deepest levels mainly because light cannot penetrate very far. Therefore, even though the colder, deeper waters could hold oxygen, particularly because colder waters can hold greater amounts of dissolved oxygen, no photosynthesis can produce the oxygen. Thus, as the summer progesses, the oxygen level in the hypolimnion should continue to decrease as long as respiration continues to take up oxygen which isn't being replaced. Since it was early summer, Bay Lake had not yet depleted its oxygen supply which was still relatively high, 7 $^{mg}/L$.

Another reason for this high oxygen reading may be that the lake was not a productive one (oligotrophic). Therefore, its intake of nutrients and O_2 for respiration would be low. Also, there would be less need for O_2 for decomposition because the amount of organic matter would be low.

The oxygen-temperature profile shows an oxygen maximum from three to four meters, i.e., in the upper portion of the thermocline. This is probably the result of active photosynthesis by a bloom of aquatic vegation located in this area causing an increase of oxygen.

Photsynthesis is higher in this region in particular because oxygen is circulated in the epilimnion by currents just as warm water is. But when the oxygen current touches shore and is deflected downward, it can only go down so far as the upper thermocline due to the barrier to mixing caused by density differences. Therefore, the oxygen is concentrated at this level and does not rise back up because of its slow rate of diffusion in water. Also, light, essential for photsynthesis, is effectively transmitted to this depth as was shown by the high secchi disk reading of 3.75 meters (thermocline ranged from 2-5 meters). This high oxygen level at a low depth is characteristic of an oligotrophic lake. In an unproductive lake, light can penetrate to greater depths for a number of reasons. An unproductive lake would be low in dissolved substances such as nutrients which are essential for high productivity, and also organic material such as plankton and other suspended organisms. A lake devoid of these materials would be relatively clear and, therefore, would not deflect the sun's rays from penetrating greater depths. In Bay Lake, this phenomena was verified by chemical analysis. Besides a high secchi disk reading, the color reading of 35 for one meter was relatively low. True color is a measure of dissolved substances in solution and materials in the colloidal state. This would include dissolved ions and nutrients necessary for photosynthesis, another measure of dissolved solids is specific conductivity. This test is a measure of the ability of the water to carry on electric currents which depends on the total concentration of ionized substances dissolved in water (not organic compounds which are poor conductors). These dissolved solids, in order of abundance, may include $CO_3^{=}$, Ca++, SO_4^{-}, SO_{2+}, Mg^{++}, which are all nutritionally important ions. Our reading of 18 microhos/cm of one meter indicated a low nutrient ion supply. The fact that electrolytic conductivity increases with temperature at a rate of 2%/C^o, probably explains the increase from 16 microhos/cm at five meters and 10^oc to 18 microhos/cm at 1 meter and 19.5^oc. Two ions in particular were also tested for and found to be low in quantity = Ca^{++} and Mg^{++}. The two combined contribute to the total hardness of water, with calcium the major contributor. Calcium is derived almost entirely from sedementary rock strata, particularly lime; when water passes over lime, it dissolves = $CaCO_3 \rightarrow CO_3^{=}$ +Ca++. But calcium was found to be low at one meter, 10 mg/l $CaCO_3$ and the same at five meters. Total hardness at one meter was negligible, and 10 mg/l $MgCO_3$ at five meters. Not only is the calcium level low, but it is also not stratified. This indicates that there is not a high amount of organic matter present to be decomposed which would deplete the calcium supply which is a necessary element in this process. The absence of magnesium at the surface and higher quantity at 5 meters indicates that the magnesium, not being used at the surface, fell to the hypolimnion and could not rise again due to density differences in the water. The hardness test which is a measure of $CaCO_3$ for calcium content, is also a measure of carbonate-bicarbonate-hydroxide content, coincided to a degree, with the hardness test. Low $CaCO_3$ content means low carbonate:

$$CaCO_3 \rightarrow Ca^{++} + CO_3^{=}.$$

which is necessary as a buffer for the system.

The order of this reaction is:

$$CO_2 + H_2O + CaCO_3 \rightarrow Ca(HCO_3)_2$$

$$Ca(HCO_3)_2 \rightleftarrows Ca^{++} + 2HCO_3^{-}.$$

The bicarbonate buffers the system by being hyrdrolyzed to give off OH - ions:

$$HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$$

or H^+ ions released when water combines with atmospheric CO_2.

$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-.$$

The reaction is determined entirely on the amount of CO_2 dissolved, and the pH would change when the slighest amount of acid or base was added.

In our sample, since the hardness was low, there would not be sufficient amount of calcium carbonate present to fix the CO_2 present. Therefore, CO_2 levels would be high which would cause a low pH reading of approximately 4-5. If carbonates were present the pH would be higher, i.e. the pH depends on the form present. But this is where our data is inconsistent. Our zero value for alkalinity would indicate CO_2 and no buffering carbonates or bicarbonates. This would mean the pH should be that of CO_2 (or 4-5). Instead the pH was 5.6 which is low but still not as low as would be in a totally unbuffered system. Thus, even though the acidity test was high, there was buffering action because the pH was not correspondingly low. Error possibilities could be that the water sample bottle had acid in it. Also the sample bottle was left open while we made the various tests and atmospheric CO_2 might have been absorbed during the standing period and also during the titration. This would cause a low alkalinity and high acidity.

Low calcium concentration would also affect other nutrients indirectly, particularly phosphates and nitrates. Although these two essential nutrients can be obtained from outside sources (allochthonus) such as the fallen trees at the waters edge, they are usually supplied by endogenous sources. That is, they are obtained from decaying organic matter. But in order for these nutrients to be recycled, calcium must be present for the decomposition process. Until decomposition occurs, nitrogen nutrients (ammonia, nitrate and nitrite) will be locked up, resulting in a nutrient deficiency which would curb productivity. Further evidence of low productivity is that the nitrates and phosphates which are present, are not stratified. If the lake were productive, these limiting nutrients would be low in the upper layers where they were needed for photosynthesis and high in lower layers where decompositon and regeneration of these nutrients occur.

Further evidence of low productivity is the large hypolimnion relative to the small epilimnion (3 : 1) volume. This indicates that there is little production occurring since photosynthesis cannot occur in the hypolimnion. Also the shape of the basin indicates low productivity. The basin sides drop off sharply allowing little space for littoral plant growth, therefore, less photosynthesis, and less productivity.

In summary, the majority of the data indicates low productivity and lack of nutrients in the waters of Bay Lake. But an important parameter must be considered. The lake is very large, so, therefore, its nutrients and plant growth would be much more dispersed than a smaller lake. Bay Lake also appears to be a young lake because of its depth, its lack of "filling-in" and little littoral vegetation, and the shape of the basin. Therefore, it hasn't had time to accumulate the biomass and nutrients that an older lake might have. From the data on Bay Lake taken in 1975, it can be seen from the little change in color and specific conductivity, dissolved nutrients, that the lake's productivity has not yet increased. It would be worthwhile to continue annual tests to determine if the lake is changing. Also, from its source lakes, [redacted] since Tuesday Lake has high-phosphate and nitrate readings, Bay Lake obtains little in the way of nutrients from runoff from this lake. A study of Hummingbird Lake and Emeline Lake could offer some information on possible supply or loss of nutrients from and to other sources. But from the data we did obtain, Bay Lake appears to be an oligotrophic lake.

BAY LAKE: PLANKTON TOW

Date: 5/31/78

I. Time: 9:00 am

A. Zooplankton

Genera	#organisms/ml sample
Daphnia	105
Keratella	105
Mesocyclops	63
Vorticella	21
total	294

B. Phytoplankton

Genera	#organisms/ml sample
Polycystis	3,738
Aphanocapsa	1,407
Anabaena	10,500
Kirchneriella	4,515
Mougeotia	273
Docidum	42
Gonatozygon	21
Asterionella	630
Diatoma	588
Quadrigula	2,310
Ceratium	21
Cosmocladum	3,087
	27,012

16 species total

total #species (AM+PM): Zoo: 7

Phyto: 16

23

BAY LAKE: PLANKTON TOW

Date: 5/31/78

II. Time: 11:00 pm

A. Zooplankton

Genera	#organisms/ml sample
Colonial Rotifer	3,528
Keratella	21
Daphnia	420
Bosmina	105
Diaptomus	231
total	4,305

B. Phytoplankton

Genera	#organisms/ml sample
Anabaena	52,500
Aphanocapsa	5,040
Polycystis	14,700
Nodula	1,050
Asterionella	21
Tabellaria	21
Ulothrix	8,400
Melosira	2,100
total	83,812

BAY LAKE: Plankton Tow Analysis

III. For our plankton sample we used a "plankton net" towed about 10 cm from the water surface. The net was towed behind a rowboat for 2 minutes in the northwestern arm of the lake both in the morning at 9:00 a.m. and 14 hours later at 11:00 p.m. These plankton samples were identified a week later.

Assessing the plankton population is important in a number of ways. First, the numbers and types of species may tell something about the quality of the water. Because plankton have such short life cycles, they respond quickly to environmental changes. Also they themselves may affect the quality of the water such as the pH, color, dissolved gases and taste because of their small size and great numbers. Also, in a large lake like Bay Lake, where there is less of a shoreline relative to the volume of the lake, macrophytes are less important in determining the total production. The plankton can grow at any position within the region of light penetration, while macrophytes only grow in water up to 10 feet deep.

Our sampling technique was very limited. It gathered only plankton in the epilimnion. It did not sample the bentho's where specially adapted organisms live. It does not sample the littoral zone which is a haven for diverse types of species to live because the grasses and other macrophytes offer a ~~new and~~ protected environment, safe from predators. Also psammon and periphyton samples were not taken. But still much information may be gained from analysing the surface sample.

First of all, large numbers of species of plankton in both the AM and PM sample and the relatively few types of each species is a good indication of an oligotrophic body of water. This is because the number of predators is small and the different species cannot try to survive by merely mass producing [redacted] for a good chance of certain % surviving. Instead, since nutrients are low, there is less competition between species. Now, organisms must be specially devloped which can adjust to low nutrients, different riches, etc.

Looking at the species list one can find a number of patterns. There were only two species of diatoms with 1,218 individuals Diatoma and Asterionella. These are known to exist in colder waters. Therefore, they either migrated from the deeper region of the thermalene or they are the remainder of the total population of diatoms from the colder water of spring. The most abundant species which is also typical of an oligotrophic body of water is the blue-green algae. They include Anabaena, Polycystis and Aphanocapta. These types can thrive on low oxygen and nutrients and warmer waters. They are adaptable and exist in a variety of environments. They are not very beneficial because they often choke out other species and often use more O_2 in respiration than they produce in photosynthesis.

They grow primarily at higher warmer levels according to Van't Hoff's principle. It states that the rate of which biological processes proceed is increased nearly twofold with each 10^{o}c rise in temperature. For every species there is some optimal temperature level at which the species remains because higher temperatures would denature their enzymes. According to the oxygen-temperature profile, this optimal temperature of 14^{o}c at the oxygen maximum is where most of the plankton are located.

Of course, sunlight will also determine the optimum level for the plankton. If the water is very turbid and no sunlight reaches the 14^{o}c level, the plankton will have to grow at a suboptimal temperature. Also, excessive sunlight can limit photosynthesis. That is why the zone of maximum plankton density is somewhat below the surface. It is particularly low in Bay Lake because of the high secchi disk reading, hence, transparent water. One exception is Anabaena which grows at the surface. Our extremely high value of Anabaena relative to any other species collected may have been because the plankton density was deeper than the plankton net could reach, except for the surface dwelling Anabaena.

There was also a lot of green algae, also characteristic of an oligotrophic lake such as Kirchneriella, Mougeotia, and the desmids Gonatozygen, and Docidum. Desmids are important here because they will determine the hardness of the water. Desmids can only survive in soft water at a low pH. The low hardness readings verify this.

A final determination of productivity is the Palmer test: if there are more than 10 species with greater than 50 per species, then the lake is eutrophic. This is a borderline test for Bay Lake because there are 10 such species.

Another observation is that there are many dynoflagellates collected including Ceratium, Vorticella, and Cosmocladium. This is necessary for plankton to maintain themselves within a region of light penetration. The density of the average plankton is 1.03, while the density of that is only 1.01 resulting in a negative buoyancy. Phyloplankton overcome these difficulties by propelling themselves with their flagella, holding oil droplets in order to float on water, or with gas vacucles (primarily in bluegreen algae).

Another important characteristic of plankton are daily vertical migrations of zooplankton which occur in response to sunlight. There were five times as many cladocerans in the PM sample than were in the AM sample. Furthermore, there were four times as many Daphnia as there were Bosmina. This is because Bay Lake is a large lake containing larger species of fish early in the season, i.e. before the fish hatch. Therefore, the Daphnia, which are the larger cladoceron, may survive without being preyed upon by smaller fish. The Daphnia, which feed on bluegreen algae, must rise up to the surface to feed during the night when they cannot be seen by their predators.

From the numbers and species, it can be concluded that these species represent a oligotrophic aquatic flora with a variety of species that adapt themselves to the limitations of the environment.

FOREST SERVICE BOG

I. Description

Forest Service Bog was sampled and analyzed at 8 a.m., June 1, 1978, in the same manner as Bay Lake except that one liter Kemmerer samples were taken at one and three meters. Also, the plankton tows were for a one minute period instead of two so as not to interfere with another study that was being done there.

The bog was small, approximately 100 meters in diameter, and had very little open water. Most of the water surface was covered by a bog mat, with a floating "island" bog mat in the center. The mats were covered with sphagnum moss, grasslike sedge, and low shrubs, all tangled together and floating in the water. Flowering plants were growing on the mat along with pitcher plants. Water lilies grew around the edge of the mat. Small trees grew on the mat such as spruce, tamarack and small pines. Also, there were many small, dead trees on the mat. Surrounding the mat (it was difficult to determine where the mat ended and solid ground began) were larger pine trees and evergreens. The bog itself was situated in a valley protected from high winds by a steep hill on one side (the road side). The bog was also formed by a glacier but has no drainage pattern or seepage, therefore is not influenced by any outside sources other than rain. It maintains its water level from the abundant precipitation that falls in the area, and also from the high atmosphere humidity. The bog is small and shallow, therefore easy to replenish its volume. The bog was approximately 3.5 meters deep before hitting bottom but it had a "false bottom" that was at least another half meter deep. This false bottom was dark brown and of a very fine material.

During our AM sampling and plankton tow, the skies were overcast and there was a fine drizzle (although there were heavy thunderstorms the night before), but the weather was very calm and clear with a secchi disk reading of 0.5 meters. During the evening plankton tow it was completely dark out and drizzling again having rained heavily all day. The liter water samples and plankton tow matter were preserved for later analysis in the lab.

FOREST SERVICE BOG

Date: 6/1/78

Time: 8:00 am

Secchi disk reading: 2.5 meters

Weather: Overcast with light drizzle (heavy showers occurred 5:31 pm), water calm.

Depth (meters)	Oxygen ($mgO_{2/L}$)	Temperature (c^{O})
Surface	6.4	19
1	6.3	19
1.5	5.5	16^{O}
2	4.1	13^{O}
3	1.35	8.5
4	1.35	8.5

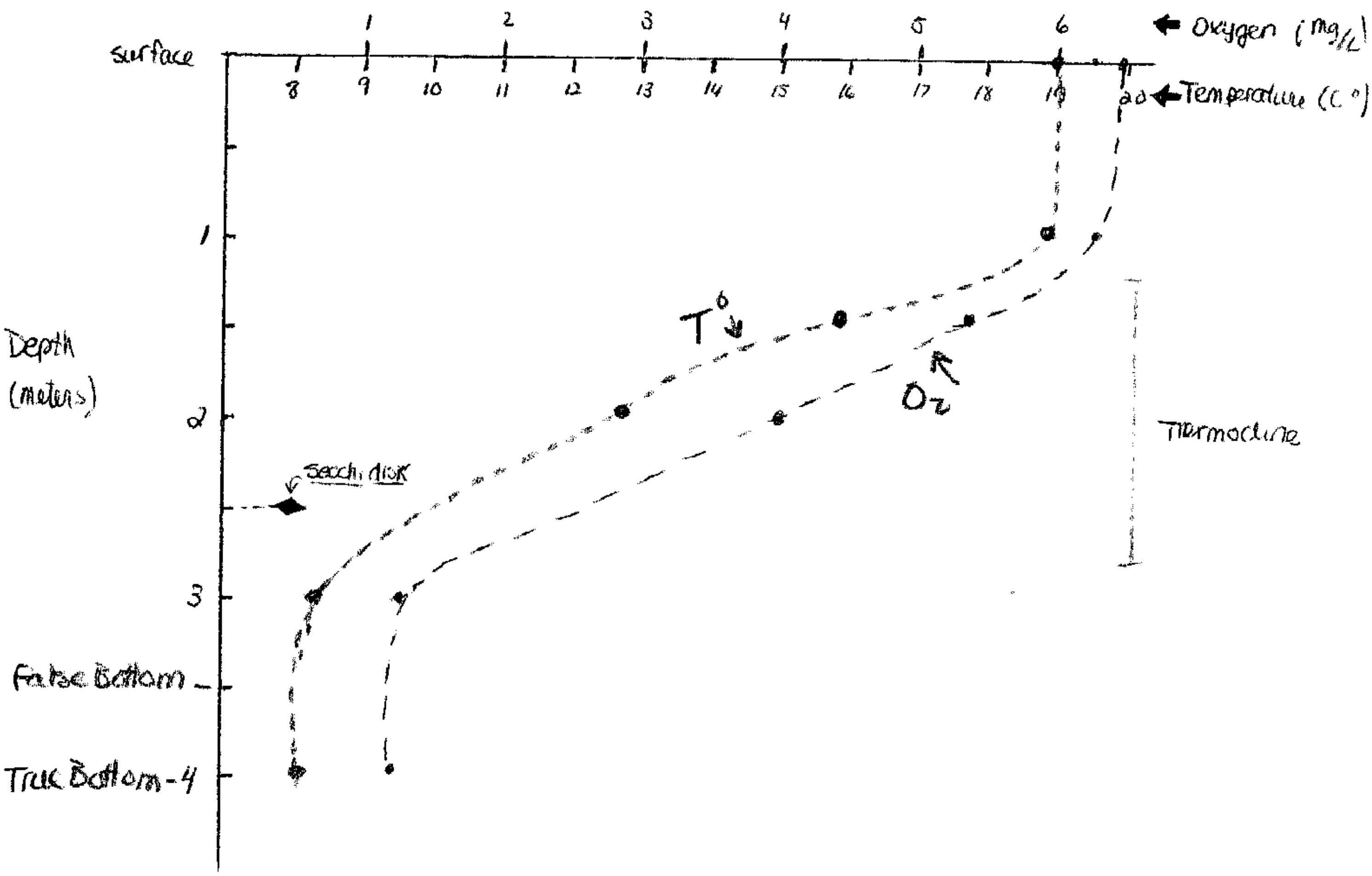
FOREST SERVICE BOG

Date: 6/1/78

Time: 8:08 AM

Sample taken at: 1 and 3 meters

Oxygen-Temperature Profile



FOREST SERVICE BOG: Water Chemistry Data

Date: 6/1/78

No drainage pattern

	Forest Service Bog		
	6/1/78		8/75
Secchi disk	2.5m		-
Depth	.4m		4m
P H	4.6		4.85
Phenylthalein Acidity (mg/l $CaCo_3$)	105	110	-
Alkalinity (mg/l $CaCo_3$)	0	0	-
Specific (µmho/cm) Conductivity	10.5	9.5	10
True color (445 nm)	20	40	200
Phosphate Total (mg/l)	.25	.25	-
Total Hardness (mg/l)	.05	.05	-
Ca++ (mg/l)	.05	.05	-
($NO_3^=$) Nitrate-Nitrogen (mg/l) ($NO_3^=$) = 4.4 x (nitrate)	.44	.44	
H_2S	none	none	none
Depth Sampled	1	3m	-

FOREST SERVICE BOG: Water Chemistry Analysis

II. From the water chemistry data, Forest Service Bog can be easily identified as a bog because of three main factors. It is low in dissolved electrolytes, it has a low pH, and is high in humic materials. Bogs usually have similar characteristics but Forest Service Bog has one distinctive feature. It is very clear relative to most bogs which are brownish-yellow due to humic materials. As a result, it is typically shallow, 4 meters, but has a secchi disk reading of 2.5 meters and low color reading at the surface. Therefore, light penetrates over half of the bogs depth. Normally (in a lake) this would result in high photosynthelic activity and oxygen production almost to the bottom, or at least as far as effective light can penetrate. But as can be seen from the oxygen-temperature profile, oxygen rapidly decreases along with the temperature. This is more than likely because factors other than light must be taken into consideration, particularly nutrient availability. The thermocline was not very distinct. This may be because the bog was so clear that energy from the deeply penetrating light rays was able to warm the water to greater depths. This decrease in temperature with increase in light penetration resulted in a more gradual change of temperature in the thermocline. Therefore, the epilimnion and hypolimnion were very small, one meter each.

The bog would be expected to have a more uniform temperature and oxygen reading due to mixing and therefore a narrower and deeper thermocline. Mixing is brought about by wind induced currents but Forest Service Bog is located in a low lying area protected by high trees and also a high embankment on one side. This may have prevented wind mixing from occuring.

Photosynthesis is low because of lack of the limiting nutrients, the nitrates and phosphates. These both were found to be low in both the epilimnion and hypolimnion. This was because calcium levels were extremely low, which in turn inhibits decomposition resulting in phosphate and nitrate storage in unusable forms at the bottom surface. The build up of detritus piles on until it forms a "false bottom" of debris. This debris probably contains much colloidal size humic particles which would cause the double color reading at 3 meters. These "particles" are not nutrients, because <u>none</u> of the 3 meter values for nitrates, phosphates, calcium, or dissolved solids (specific conductance) were greater than their one meter readings. This deficit in calcium is a result of calcium being leached out of any water entering the bog through the sphagnum bog mat. The mat ties up ions causing low conductivity and frees H^+ ions raising the PH:

$$-COOH^{+} \rightarrow COO^{-} \rightarrow \begin{array}{l} CA^{++} \\ Na^{+} \\ K^{+} \end{array} + H^{+}.$$

This leaching out of calcium increases the acidity in two ways. First it releases hydrogen ions as shown above. Also, it decreases the carbonate and biocarbonates which are necessary for buffering, causing an increase in CO_2, which is acidic. Also, since photosynthesis is low, CO_2 given off from respiration exceeds oxygen acids which are from carbon outside the bog, and are not broken down easily. This coincides with the high acidity results for both depths.

In this bog, again, the alkalinity test was zero. But this time the pH was low enough (4.6), that it was close enough to the pH of the methyl orange indicator (4.5) that the end point was reached with one drop during the titration. This means that there is no buffering carbonates in solution, only CO_2.

This also agrees with the data. The $CaCO_2$ concentration was low, therefore the carbonates were low, CO_2 was high causing a high PH, and all factors contributed to the high acidity. This body of water therefore is very unproductive because of its high acidity and PH which many organisms cannot tolerate, and the low supply of nutrients. Since the bog receives much organic material from outside (alltrophy) and is unproductive (oligotrophic), it may be classified as a dystrophic body of water.

FOREST SERVICE BOG: Plankton Tow

Date: 6/1/78

Plankton length: 1 minue

A. Zooplankton

Genera	#organisms/ml sample AM	PM
Rotatoria Conochilas (colonial)	4,940	3,340
Cladoceran	160	0
Keratella	840	180
Naupluis	180	100
Polyarthra	80	60
Senecella calanoides	20	140
TOTAL	6,220	~~4~~,3820

B. Phytoplankton

Genera	#organisms/ml sample AM	PM
Dinobryon (colonies)	700	860
Anabaena	20	0
Microspora	100	0
Asterionella	60	180
Staurastrum	40	40
Dactylococcus infusionum	80	0
Ankistrodesmus	60	20
Mougeotia	80	0
Ulothrix	0	40
Tabellaria	0	20
TOTAL	1,140	1,160

total #species: 16

FOREST SERVICE BOG- Plankton Sample Analysis

A one minute plankton tow was done on Forest Service Bog instead of two minutes so as not to affect a research project that was being conducted there. Both thee AM and PM samples contained a large number of species with few members in each. This is characteristic of an oligotrophic body of water. There was no particular relationship between the types of species in the AM and PM samples. There was no increase in clod-docerans at the surface at night because no fish could survive the low pH, therefore the clodocerans did not need to submerge below the lighted zone for protection. The number of clodocerans was low possibly because they could not survive the low acidity. THe bog also had species that were characteristic of an oligotrophic environment as did Bay Lake. There were desmids, Staurastrum, which are characteristic of soft water. This means, as was explained previously, that the $CaCo_3$ concentration would be low, thus the buffering capacity would be low,etc. The low acidity that would result would kill off fish and increase the CO_2 supply.

The vegetation around the bog was highly characterictic of all bogs. It was arranged in coencentric rings. The outer edge of the bog was surrounded by pine, while along the inner border of the bog was spruce. The spruce decreased in size as they approached the bog matt and some actually grew on the matt although they were stunted in size. The number of species of plants that can survive on the mat is small because most plants have a narrow range of pH tolerance. Thus although spruce seedlings readily germinate and grow abundantly up into plants a few cm. high, they rarely last very long because the defiency of oxygen and the scarcity of nutrients will not sustain the plant when its nutrient requirements increase too much. Therefore many dead trees were found of the mat. Other surface vegetation of the mat included pitcher plants and dwarf shrubs such as the labrador tea. The mat itself was built up by sphagnum moss and a loose tangle of shrub providing the framework of the mat. The sphagnum moss on the mat acts as a filter to rain water running over the surface and through the mat. The sphagnum absorbs the base, (for example the calcium) from dissolved salts, and sets the acids free from alkaline water. Thus the sphagnum acts to maintain the acidity of the bog. The sphagnum mat also blocks out any sun light from reaching the water under the mat. This prevents photosynthesis and allows for an even higher level of CO_2 and shortage of oxygen which would raise the acidity and lower the productivity. The mat also protects many organisms beneath it and serves as a nest for certain species of fish that can tolerate the low acidity such as sunfish. Bordering the mat were a few species of pond weeds and water lillies that had managed to secure them selves to the false bottom. The only vegetation that was able to survive in the open water was the phytoplankton.

Although the plankton did not show any relation between the AM and PM samples, there was a marked increase in the number of species of phytoplankton over zoopankton, more than likely due to the low level of dissolved oxygen and the high acidity. There is also a stiking difference between this bog and Bay Lake, even though the latter is also oligotrophic. The number of species present in the bog was 16 while in the lake it was 23. An interesting difference between the two is that the lake shows an extremely larger number of individual phytoplankters and zooplankters, while the bog has a greater number of zooplankters. I would have expected the reverse for the bog because the zooplankter need a greater number of phytoplankton in order to feed on them. This would signify though that conditions for nonphotosynthesising organisms are very poor, probably too poor for any fish to survive.

Therefore all data seems to indicate low photosynthetic productivity and and unsatisfactory conditions for zooplankton and particularly larger (fish) animals.

Note: the plankton tow results should not be heavily relied upon because the sample is not necessarily random; the net mesh was selctive for a certain size plankton, and some zooplankton are able to avoid being trapped.

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In order to make an accurate assesment of a fish population, many different parameters must be measured other than just the fish themselves. The fish belong to a complicated aquatic ecosystem and are directly or indirectly related to every part of the system.

The type of body of water is important to look at first. Is it an old lake with shallow sloping sides which provide a large littoral zone or a young lake with steep sides and few littoral macrophytes? Is it a small lake or a large lake in which the volume of water holding phytoplankton is so large that the phytoplankton as opposed to macrophytes contribute to the majority of the primary production. These factors must be considered in order to determine if the lake is a eutrophic or oligotrophic lake, if there is an abundant or limited food source available for the fish. Other measures of productivity include tests which measure the availability of nutrients such as ~~relative~~ specific conductance- a measure of dissolved ions(Ca, Mg, SO_4, etc.); color- a measure of dissolved and colloidal matter; hardness test- a measure of calciumcarbonate content, a substance essential for decomposition and for buffering. Also the limiting nutrients ~~must~~ can be measured, the phosphates and nitrates.The availability of these is essential for determining the rate of primary production. Another method of measureing primary production is the radioactive carbon 14 tracer method. It measures productivity as the rate at which inorganic carbon is converted to an organic form by primary producing chlorophyll containing phytoplankton, periphyton, and macrophytes as follows: $CO_2 + H_2O \rightarrow CH_2O + O_2$. This test will give the net photosynthesis, that is, the total or gross photosynthesis minus the respiration. The reason for measuring productivity at the plant level is that the entire ecosystem of the lake is ultimately dependent upon this level. But it must also be remembered that the amount of energy available to the plants is ~~less~~ greater than the energy that will be available to the herbivores and so on up the food chain because each level of the food chain must retain some of that energy in order to sustain itself. Likewise, the rates of production at each higher level from plants to herbivores to carnivores decreases.

Another way to determine productivity is just from the amount of biomass that is present in the lake. But this doesn't indicate the time factior involved, ie. the rate. A large biomass doesn't mecessarily mean that the lake has a high rate of production because the present abundant biomass may have taken a long time to build up, indication a low rate of nutrient intake and photosynthesis.

Another method would be to set traps, nets, etc at different periods to determine the yield of the lake over a period of time. The trouble with this is that if too much is removed , the biochemical cycles will be disturbed. Material must be replaced if the ecosystem is to be maintained. Furthermore a thorough harvest would be impossible because factors such as migration of organisms out of the area through effluent streams, predation by terrestrial animals, and escape from capture would all serve to remove various proportions of the yield.

Although the lake's productivity is an important parameter, there are other factors that are more directly related to the fish itself (at higher levels in the food chain),that must also be looked at. One should collect psammon and periphyton samples and identify the micro-organisms present and their abundance to see if they are a source of food for the fish, Plankton tows should also be made to identify a further possible food source and its abundance. Also an oxygen-temperature profile should be made in order to determine where the optimal oxygen levels are for fish respiration, and where the algal blooms are that cause oxygen maximums and are a source of food. The temperature profile would show the epilimnion, thermocline, and hypolimnion which is important because many fish prefer to live at a certain optimal temperature level if all other factors are also optimal (O_2,pH, etc.). The pH is also important because most fish can tolerate only a narrow pH range.

Once all the chemical and physical parameters have been studied, one must sample and study the fish themselves, to see how they have been affected by the water quality and the different variables of their environment. Sampling should be done yearly (at least) to see if their are any trends or patterns of change in the fish population. The lake should also be sampled twice a day in order to trap both the night feeders (which are sedentary in the day) in the morning nets, and the day feeders which need light to catch their prey, in the evening nets. In order to catch a random and representive sample, the obscure unlikly areas as well as the obvious locations should be sampled. For shallow water along the shoreline, haul seines should be used and the # of fish/area seined might be noted if possible. Three types of encirling nets may be used for this purpose: a minnow seine (of fine mesh), a hand seine, and a purse seine. For our purposes, a minnow seine would be the most practical to use. All depths should be measured in order to see which fish occupy which levels and their respective temperatures. Gill nets should be set in the large open areas where fish movement is expected (in order for them to swim into the net). Gill nets should be set at the surface and buoyed up by buoys; on the lake floor ie. the benthos of the hypilimnion, and maintained there by weights. Also a net should be suspended at any oxygen maximum found on the oxygen profile to see if a high oxygen supply and aplankton bloom are the optimal conditions or if the fish prefer a a certain temperature at a different level. The net should also be an experimental net so as not to be selective for a certain species or size. Another type of net for migrating fish are trapnets, in particular the fyke net or the hoop net. These wold be most effective if set at the bottom near the gill nets because fish that avoid the gill net and go deep will enter the fyke net. This net set at the bottom, of the gill net will capture fish that can tolerate low oxygen levels at the bottom. Minnow traps should also be set even though they will not reveal any quantiative information other than a species' possible food source. In large open areas a trewl net can be towed along the bottom, particularly to catch schools of fish, but such a net might be pretty impractcal because of its size relative to the size of the lake. If a single species is being studied, trot lines may be baited for that particular species. Or electrofishing may be used for a method that is not selective for any size or species.

After the species a have been collected, they should then be identified, weighed and measured (total length) from the anterior end to the tip of their fins, and then gutted for an analysis of their stomach and intestine.

This data should then be compiled to determine age and growth rates. A lenght frequency graph sould be made (length in mm.). The lengths tend to cluster in groups (size classes) permitting separation into age classes. This may show a cetain age to have more members than others which might indicate a particularly productive year for the lake as a whole. Also a random sample of about ten ofr more fish should be aged by the scale method. This will give some idea of the average lenght for each age fish. Also the width of the growth rings will say something about what type of year it was for the lake's ecosytem. And finally the condition factor should be determined for a few and averaged: $K=\frac{W(10^5)}{L^3}$.
This lenght weight relationship expresses the relative plumpness of the fish related to environmental conditions. It indicated what kind of condition the fish is in. The analysis of the intestine and stomach will also reveal the fish's relationship to its environment. One can determine from the food content if it is a herbivore or carnivore, what type of fish and insects it preys upon and therefore where it feeds and the relative abundance of its food supply.

The data thus obtained is fairly accurate but there is some chance of selctivity by the different types of nets, error in the scale readings because the growth rings are often indistinct, and large catches of certain species may be due to that species tendency to travel in schools, etc.

Hence after collecting all the previous data on the fish population and all other factors of the ecosystem, one can then begin to draw conclusions on the fish's position within the ecosystem of the lake. Again it must be emphasized that the "other factors" are important too because fish are at the peak of the aquatic food chain, hence their condition is the summation of the condition of all the lower biolgical forms.