A COMPARISON OF
ROACH AND HUMMINGBIRD LAKES

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The many different types of lakes on the University of Notre Dame's Environmental Research Center (UNDERC), provide an excellent opportunity to study the characteristics of the various stages of lakes and the ecosystems of lakes in general. Roach Lake and Hummingbird Lakes are interesting when presented as a comparison because, while Roach is a large, open lake, Hummingbird is a small, very protected bog.

UNDERC is located in Gogebic County, Michigan and in Vilas County, Wisconsin, Humming bird Lake is in Gogebic while Roach is on the border. All the lakes on UNDERC are the result of the last great ice age glacier, Pleistocene, which once covered the area. It carved out the depressions in the land which have served as lakes eversince. This last glacier receded 12,000 years ago and since then important changes were made in the lakes. Hummingbird Lake used to be an arm of Bay Lake but the lakes must have sunk sufficiently to uncover a strip of land that now separates the lakes.

The climate is relatively cool compared to the rest of the continental United States. The winters are long, cold, and snowy while the summers are long and cool. As there is no dry season, this area is refered to as "humid microthermal." Average summer temperatures range from 16 to 21 C and the relative humidity ranges from 60 to 70%. Between 50 and 100 cm of precipitation annually fall upon the lakes and land of UNDERC, The lakes freeze up usually in the beginning of November and remain frozen (sometimes more than 82 cm thick) until about May of the following spring. The average January temperature range of -20 to -10 C ensures the thickness of the ice. (1).

Roach Lake is a large lake with a surface area of 38.4 ha. It is surrounded by white birch trees(Betula papyrifera) and hardwoods. Very few conifers are among these trees. Although the surface area is large, it isn't an extremely open lake like Tenderfoot is. It contains two large bays jutting north and east. In the northern bay are two little islands.(Refer to figure 1). Roach seems to be strictly a seepage lake. There is no apparent drainage from this lake to any other body of water. The lake must simply slowly seep into the surrounding lake bed, while some evaporates into the air to make room for more precipitation. The incoming precipitation, besides falling directly into the water, also flows in through the surrounding vegetation. As Roach is partially banked by hills of hardwood forests, the watershed is from these hills.

Hummingbird Lake has only 1.0 ha of surface area. It is shaped ovally and is extremely well protected by tall black spruce(Picea mariana), Tamarack (Larix laricina), and other conifers. A narrow mat of Sphagnum moss surrounds the water's edge. As the land around Hummingbird is relatively flat, the watershed area isn't as large as Roach. Unlike Roach, Hummingbird flows into another lake; Bay Lake, which eventually ends up in Palmer Lake. Therefore, Hummingbird isn't a seepage lake.

The water chemistry of the two lakes is very different in many ways. For each lake, a sample of the epilimnion and the hypolimnion was tested for acidity, alkalinity, color, pH, conductivity and for certain chemicals. A dissolved oxygen study and a secchi disc reading was also performed on each lake. These tests were preformed on the week of June 2nd, 1981.

One of the most striking differences showed up in the secchi disc reading. In Hummingbird the white disc was visible only for 0.75 ~~three fourths of a~~ meter. In Roach, it was visible all the way to the bottom of the lake, which was 9 meters. These results correspond with the differences in the colors of the lakes. In Hummingbird, 150 units of color were found in the epilimnion and 160 units were in the hypolimnion. In Roach, however, the reading for color in the epilimnion was negligible and the hypolimnion had only 5 units.

The color of a lake is attributable to 2 sources; allochthonous matter and autochthonous matter. Allochthonous particles are those which come into the lake from the outside, for example, leaves and other terrestrial material, while autochthonous is produced within the lake. These suspended materials contribute to the apparent color of the water. The true color of the water is the color resulting from dissolved materials or materials in colloidal state. To measure these, the spectophotometercan measure the apparent color directly from a water sample, but the sample must be centrifuged before measuring the true color.

It is known that tea-colored water often results from a spruce-surrounded lake. Spruce needles stain the water this color. Hummingbird Lake is surrounded by spruce and other conifers. The water is a very dark tea color. It's small, oval shape contributes to a larger volume to perimeter ratio. This, along with a depth of 5.5 meters helps to concentrate the brown stain.

Roach, in contrast, is surrounded by hardwood which doesn't have the tendency to stain the water like conifers do. Therefore the true color of the water is extremely cl~~e~~ar. low Since this water is so clear, more light is allowed into the lake and thus, the phytoplankton bloom is much lower down. With little or no phytoplankton in the samples to influence the apparent color reading, this reading is also negligible

The dissolved oxygen determinations of the two lakes were also very different. As these determinations were made in the spring or early summer, after several violent storms, the possibility of a recent turnover in the lakes was very great.

Roach Lake showed a recent turnover. In figure 2, the steepness of the O_2concentration and the temperature verses the depth of the lake indicates that the water from top to bottom has just been mixed. Since Roach is such a wide, open lake, it wouldn't take too much wind energy to turnover. A wide lake allows the wind to flow over it, building up more and more energy, part of which facilitates the turnover.

The stratification in Roach started at about 5 meters of depth. This is the deepest stratification of any of the lakes or bogs tested on UNDERC. This may also correspond

Tenderfoot - had no thermocline at this time, (Infrared (heat) absorbed at surface) ~ 1cm

to the clearness of the water. The water allows sunlight (= heat) through to depths deeper than most lakes. Since there are no phytoplakton blooms until a depth of 4.5 meters is reached, the heat from the sun has a clear, unobstructed path through the water. At 5 meters, after the phytoplankton bloom, the water is cooler because the suspended matter above it won't admit as much heat. Since the water is cooler, the oxygen density ? is less, therefore, besides temperature stratification, oxygen startification is also observed.

The oxygen determination graph for Hummingbird Lake, figure 3, shows a wide, shallow stratification for O_2 concentration and temperature. This lake turnsover with much less frequency than Roach. It is so sheltered by the tall stand of conifers that very little wind energy can flow through this barrier to stir up the water. In the graph, the O_2 falls from 9.0 to 0.5ppm in a depth of only ~~three fourths of a~~ 0.75 meter. This sharp stratification shows how established the thermocline is. The dark color of the water won't allow much light in. Thus, the thermocline is very shallow. Since very little wind can influence this lake, the shallow thermocline isn't disturbed.

In lakes like Hummingbird and Roach for which no previous long term data exists and for which no duplicates of the data presented in this paper were made, it is extremely difficult to make solid conclusions on the water chemistry. So many subtle and unknown factors influence the chemistry of a lake that the results of just one sample per layer in each lake is subject to much speculation. On this type of study, for some reliable conclusion to be drawn, one should take several duplicate samples from several different parts of each lake, at least daily, for a long period of time. But, each study has its limitations and this one was limited in, of course, time and equipment so we will do our best on the data at hand.

The acidity is the measure of the ability of a sample of water to donate hydrogen ions. The more buffer in a sample, the greater its acidity because a buffer will donate hydrogen ions. The main buffer in freshwater aquatic systems is hydrogen bicarbonate:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

According to this equation, the more carbon dioxide dissolved in a lake, the greater its acidity. This carbon dioxide can come from a number of sources. In tropholytic zones, the respiration of plants and animals and bacterial decompostion all contribute to the carbon dioxide.(Therefore the carbon dioxide concentration is probably higher at night when the plants are contributing). Ground waters from rivers or watershed brings in dissolved gas extruding from decaying terrestrial vegetation. Rain water is especially important as it supplies carbon dioxide from the air. The amount of carbon dioxide dissolved in a lake also influences the water "hardness". This term describes the concention of calcium and magnesium ions in solution. The calcium ions are usually the more significant. A high concentration of carbon dioxide in the water corresponds to a high concentration of the weak acid, carbonic acid. In regions that limestone ($CaCO_3$) is present, the calcium ion can be dissolved into solution by the carbonic acid.

These interrelationships can help explain some of the data from Hummingbird Lake. The acidity was 30mg/L in the epilimnion and 90mg/L in the hypolimnion. This shows a relatively good buffering capacity in the hypolmnion, which indicates that the HCO_3^- concentration is relatively high below the thermocline. The concentration of calcium ions was about 25 mg/L for both the epilmnion and the hypolimnion. The magnesium ion concentration was 15mg/L in the epilimnion and 7mg/L in the hypolmnion. W. Ohle, a German limnologist proposed that a calcium ion concentration between 10 and 25 mg/L was a "medium" concentration.[1] The acidity of the lake seems to have caused the formation of a "medium" amount of calcium by dissolving limestone that must he in the area. Although Northern Wisconsin isn't an area that is known to be high in calcium carbonate, there must be some in the vicinity of Hummingbird Lake.

The results for Roach Lake didn't follow the trend of a greater acidity causing a greater degree of hardness. Roach's acidity was much higher than Hummingbird's. For the epilimnion the acidity was 150 mg/L and for the hypolimnion, it was 220mg/L The hardness was 10mg/L for both layers. There was equal amounts of calcium and magnesium ions. A possible explanation for the low hardness with the high acidity is, it may be that in the region of Roach Lake, there simply is no limestone for the carbonic acid to dissolve.

One similarity in the two lake's acidity is that the hypolimnion is higher than the epilimnion in both cases. According to G. Reid and R. Wood,

> "In these lakes lakes exhibiting two circulation periods the carbon dioxide and carbonate concentrations show a general inverse relationship to the oxygen; that is, the concentration of carbon dioxide and bicarbonate increases slightly with depth."[2]

This statement corresponds with our higher hypolimnion acidity because a higher acidity means a greater concentration of bicarbonate.

The pH is the concentration of hydrogen ions. Many factors can contribute to the pH of a lake. The carbonic acid is one source and the sources of carbonic acid are numerous and already discussed. All oxidation reactions are acid forming. Thus, the combined respiration of aquatic animals and microorganisms, besides increasing the carbon dioxide concentration, also decreases the pH.[3] Acid rain is another source. Northern Wisconsin is susceptible to pollutants from the more southern cities. Some of these pollutants, like SO_3 and NO_3 react with rain water to form sulfuric acid and nitric acid. An important source of hydrogen ions in bogs comes from a characteristic of the Sphagnum moss present. Sphagnum moss can absorb cations such as magnesium and calcium ions and in exchange, release hydrogen ions - thus increasing the acidity.[4]

The pH in the UNDERC Lakes was measured using pH paper. This method is often difficult to perform accurately since it is based on the reader's judgment of the colors, alone. For Hummingbird, 4.5 was the pH of the epilimnion and 4.7 was the pH for the hypolimnion. This lake is therefore highly acid.

For Roach, the pH paper was judged at a pH of 6.0 but there must have been an error in the judgement because, the alkalinity was zero. The alkalinity is the ability of a solution to donate hydrogen ions. Our test for alkalinity involved a pH change between 5 and 4.5 and the sample, upon the addition of the methyl orange indicator, just barely changed to the more acidic color without the addition of any sulfuric acid. According to this observation, the pH of Roach is closer to 5.0 than 6.0. Sources of hydrogen ions in this lake wouldn't include ion exchange through Sphagnum because there is no Sphagnum.

The nutrients, nitrates and sulfates were also measured in the lakes. Hummingbird had less nitrate and sulfate than Roach(See Table 1) The nitrates in Hummingbird were 0.2 and 0.3mg/L for the epilimnion and the hypolimnion respectively. In Roach, however the nitrates were 0.4 and 0.6mg/L for the two respective layers. For sulfates, in Hummingbird the epilimnion and the hypolimnion had 7,5 and 90 mg/L respectively, while in Roach, the sulfate figures were 29 and 140mg/L.

Since Hummingbird doesn't turnover as readily as Roach, its nutrients already have a chance to be established into the sediment. With Roach though, each time it turnsover, the nutients are mixed throughout the water again, ready to be used by any organism that needs them.

> "Sulfate is ecologically important in natural waters in several ways. It is necessary for plant growth; short supply of the material can inhibit the development of phytoplankton populations, and thereby reduce production. Sulfur is important in protein metabolism and is supplied to the organism originally as sulfate."[5]

In both Hummingbird and Roach, the two nutrients were more highly concentrated in the hypolimnion than in the epilimnion. This may be because there is more life in the epilimnion and all these aerobic organisms use up the nutrients. In Hummingbird, the hypolimnion sample had a distinct "sulfur" odor. This shows that some of the sulfate in the hypolimnion had been reduced to hydrogen sulfide by anaerobic sulfur bacteria.

A plankton tow was preformed in each lake on the day of the water sampling. Each plankton tow was conducted using a tow net with an opening of about 0.4 meter diameter. This net was towed at a speed that ensured that the net was just below the surface for 4 minutes. The net was then rinsed into a 250 mL jar, fixed with formalin (so that the sample was 10%) and stained with 6 drops of ~~Lucus~~ Lugol's stain. Tables 2 and 3 describe the plankton counts. These results show that Roach is a more productive lake than Hummingbird. There are 4.6 times as many Rotifers in Roach as in Hummingbird and 3 times as many Copepoda. In the samples, no phytoplankton or protozoa could be detected in Hummingbird, while only 8 specimens per mililiter of sample was found in Roach. Another striking difference was the number of Nauplius larvae. In Roach

you can't compare these unless the sampling was identical in both lakes there were 92.8 larvae per milliliter. There were no larvae found in Hummingbird. The cladocera, however were more productive in Hummingbird. There were 48.8 cladocera per milliliter in Hummingbird while only 8 per milliliter in Roach.

Roach is a more productive lake for a number of reasons which all interrelate. Roach is more like a eutrophic lake than Hummingbird. This shows up in the steepness of the oxygen depth curve. A eutrophic lake has a very steep curve and therefore a high epilimnion to hypolimnion ratio. This ratio for Roach Lake is 1.25 while for Hummingbird it is .286. Besides high productivity, another characteristic of eutrophic lakes is, most are shallow. Although Roach, with a depth of 9 meters, is deeper than Hummingbird (5.5 meters), Roach has nearly 40 times the surface area of Hummingbird. Therefore, Roach is exposed to 40 times the sunlight and wind energy that Hummingbird is. All this sunlight can be used in the lake for photosynthesis and the wind energy will stir up the nutrients so they can be used in the epilimnion by the aerobic organisms. Thus, more production is possible in Roach. Roach isn't nearly as productive as a true eutrophic lake, it is just closer to a eutrophic stage than Hummingbird.

The small concentration of phytoplasm and protozoa in both lakes is probably due to the level of the plankton net. In Roach the phytoplankton – Macrophytes bloom (the bulge in the graph in figure 2)was at a depth of 5 meters. There was no bloom of phytoplasm in Hummingbird. Any phytoplasm in this smaller lake must be dispersed through the epilimnion, but very few in number.

The larger cladocera concentration in Hummingbird is possibly due to a larger fish concentration in Roach. Cladocera are easily visible in the water and Roach Lake has many fish that feed on smaller crustaceans. The lake has yellow perch, largemouth and smallmouth bass, pumpkinseed, and muskellunge. The young of the largemouth and smallmouth bass and the muskellunge subsist on small crustaceans. Yellow perch and pumpkinseed also feed on small crustaceans and a wide variety of other organisms.[6] In Hummingbird the only fish are some stunted yellow perch. Since yellow perch have such a diverse diet, ranging from insect larvae to snails to small fish, small crustaceans aren't their staple food and therefore won't disappear as quickly as a direct result of the fish.

In both lakes, the plankton are the most important living organisms. The larger plankton like the cladocera and the copepods feed on nannoplankton (like bacteria) and rotifers. Every other living organism in the lake ultimately depends upon these plankton. A fish that eats only insect larvae is eating organisms that survive on plankton. In Hummingbird, the yellow perch are stunted, probably because of a short food supply, which stems from a small concentration of plankton.

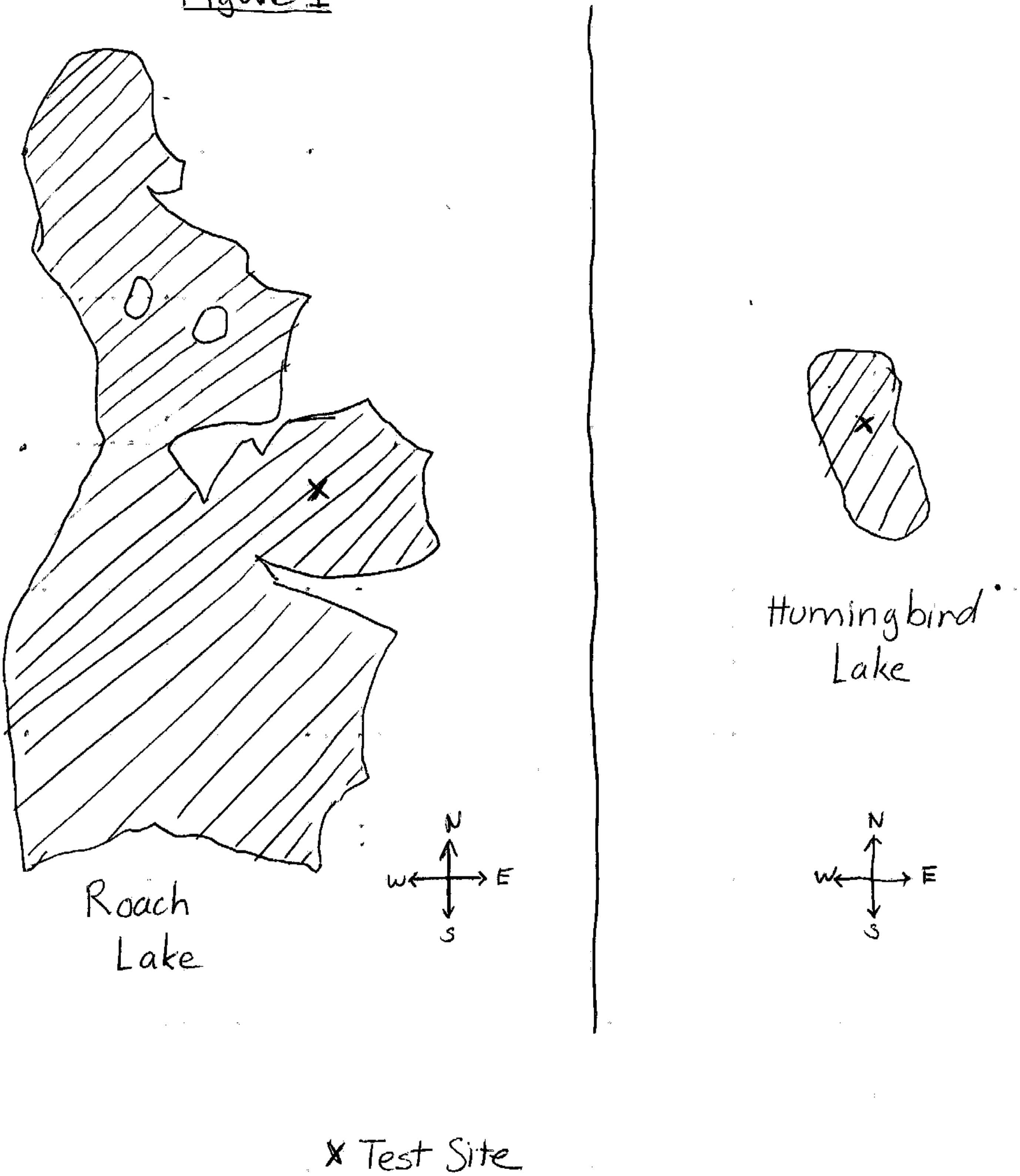
Hummingbird and Roach Lakes are good illustrations of infinite aspects of nature all fitting together is some way to form a living community. Everything formed by nature, from the tiniest piece of seta on the second antennae of a cladoceran to the spots on a fawn's back, has a reason for existence. That little seta fits into the complex, living organism of the cladocera, which fits into the complex, living community of the lake, which fits into the complex, living environment of the region, which fits into the natural world. Often it may seem as though certain organisms are just pests that don't help out the community in any way. For example, ticks, at first glance, it seems like they are just useless parasites that possibly spread disease, then drop off and reproduce. A tick, though, can be of absolute importance in the continuation of species if, for example, a location was extremely overcrowded with a certain kind of mammal. One tick could initiate the spread of a disease that wiped the whole population of this mammal in that area, thereby allowing the mammal's depleted food supply to replenish.

Eventually both lakes will cease to exist. With Roach, it is questionable whether the succession process will go by bog or by marsh. Hummingbird, though is definitely turning into a bog. Some may call it a bog at present. The <u>Sphagnum</u> moss will slowly, but steadily fill in the lake from the edges inward (See figure 4). Bogs are very acidic (because of ion exchange through <u>Sphagnum</u>) and well stratified, both are characteristics of Hummingbird.

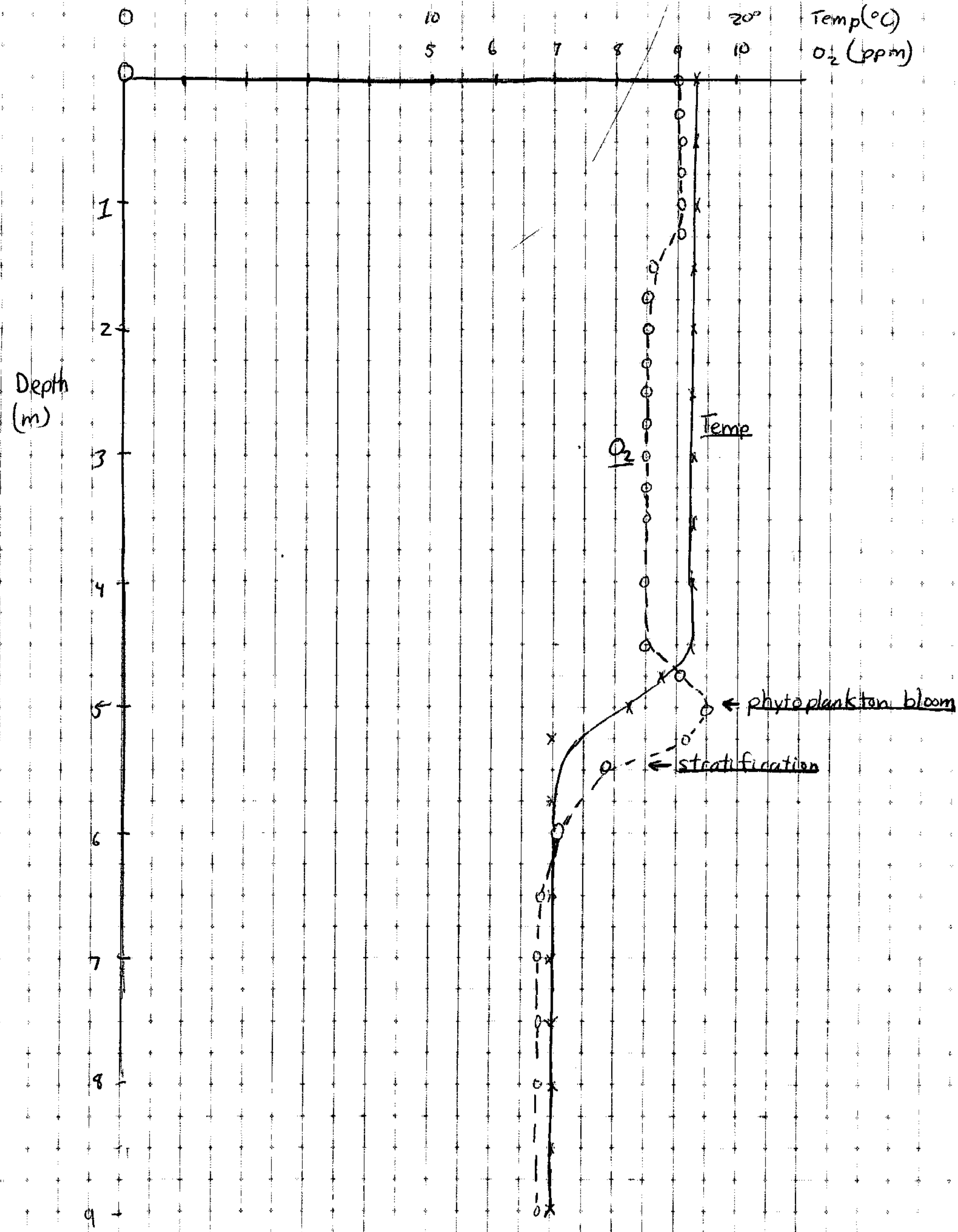
When these lakes fill in, it is almost as if a huge living organism, after performing its function in the community, dies off, leaving some of its nutrients in the form of peat. The vegetation that grows in the peat (black spruce, cotton weed) recycles the nutrients back into the food chain while the nutrients in the sediment remain there in storage until some natural phenomenum brings them back up.

A lake can be thought of as a giant soup bowl which contains all the elements necessary for life. It stores and distributes the life-fiving nutrients, it captures the necessary dissolved gases, it allows in sunlight for photosynthesis, and, of course, is made up of the chemical which, besides being essential to life, enables the mobility of all aquatic creatures; water.

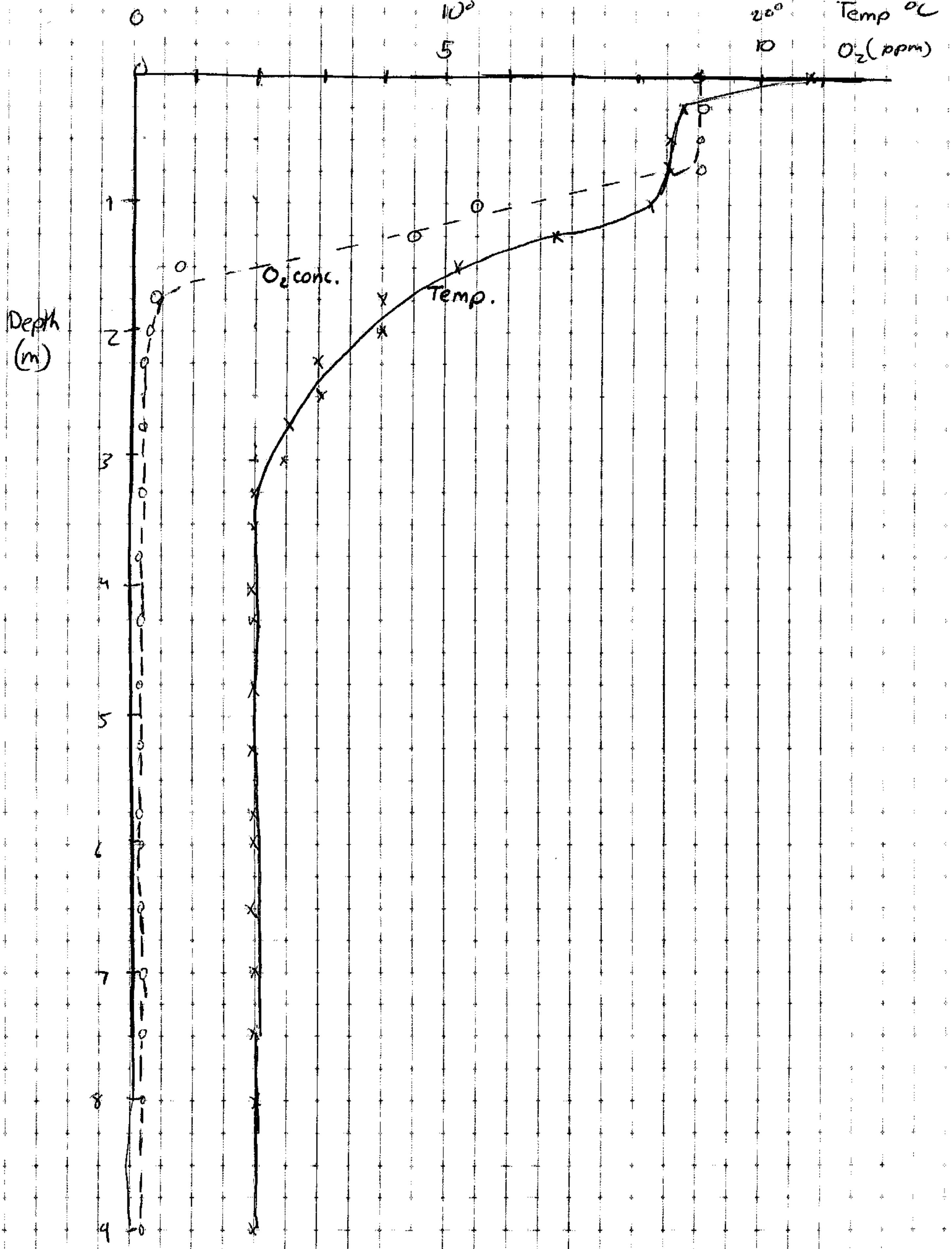
Figure 1



ROACH LAKE Figure 2



HUMINGBIRD LAKE **Figure 3**



Succession from a Lake to a Bog • Figure 4

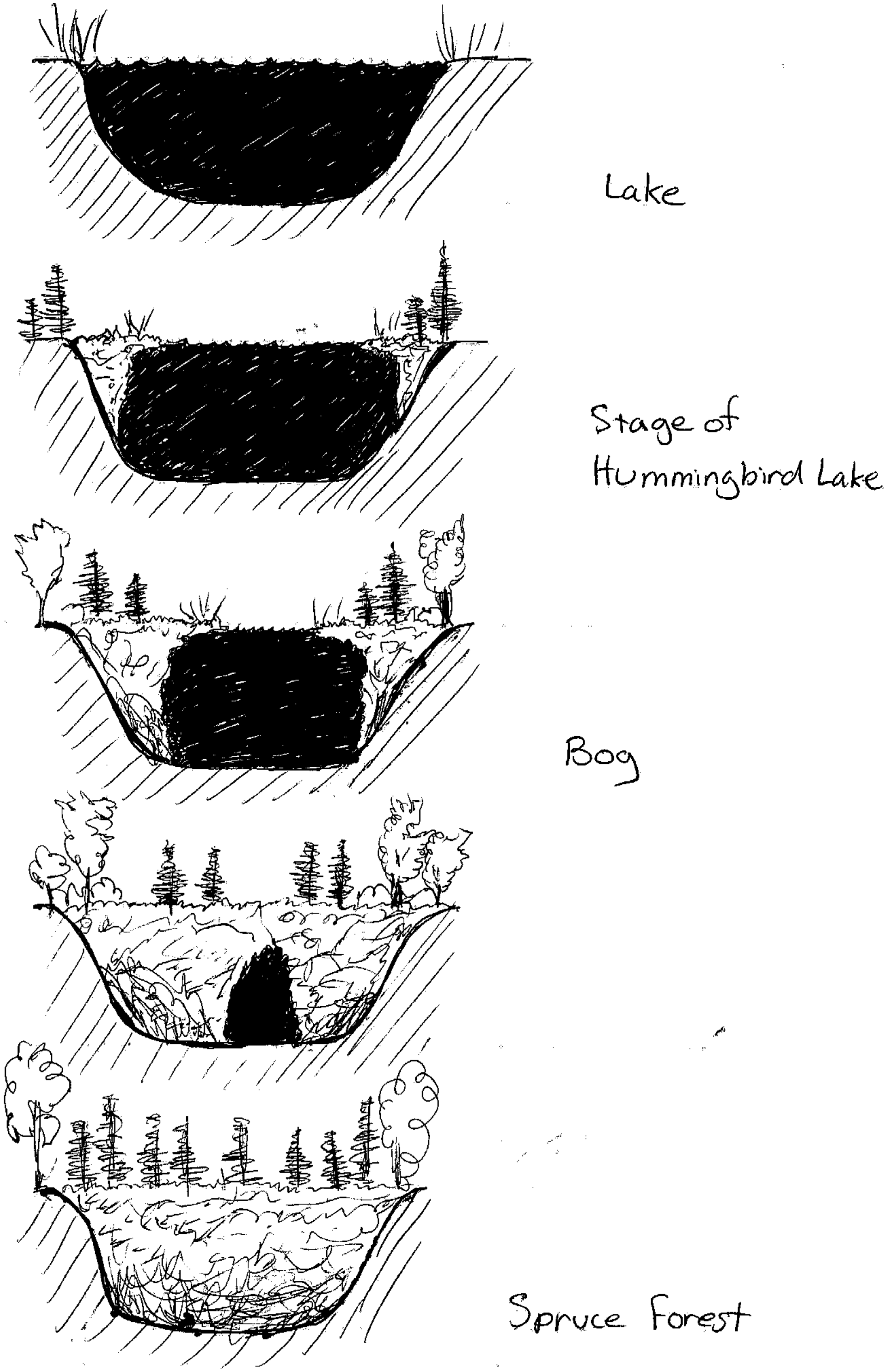


Table 1

ROACH LAKE-Data

	EPILIMNION	HYPOLIMNION
Color-true	1 unit	0 units
-apparent	0 units	5 units
Acidity(mg/L)	150	220
Alkalinity(mg/L)	0	0
pH	6.0	6.0
Hardness (mg/L)	10	10
Ca^{++}	5	5
mg^{++}	5	5
Conductivity	85	280
Nitrates(mg/L)	.4	.6
Sulfates (mg/L)	29	140

HUMMINGBIRD LAKE-Data

Color-true	150 units	160 units
-apparent	150	175
Acidity(mg/L)	35	90
Alkalinity(mg/L)	0	0
pH	4.5	4.7
Hardness(mg/L)	40	34
Ca^{++}	25	27
Mg^{++}	15	7
Conductivity	25	25
Nitrates(mg/L)	.2	.3
Sulfates(mg/L)	7.5	90

Table 2
ROACH LAKE-PLANKTON

ROTIFERS (Counts per ml.)

Karatella cochlearis	46.4
Karatella taurocephala	43.2
Conochiloides sp.	51.2
Conochilus sp.	12.8
Sinantherina sp.	51.2
Trichocera sp.	8.0
Asplancha sp.	6.4
Total--	219.2

CLADOCERA

Bosmina coregoni	4.8
Holopedium gibberum	3.2
Total--	8.0

COPEPODA

Paracyclops fimbriatus	9.6
Limnocalanus sp.	32.0
Total--	41.6

PHYTOPLAKTON AND PROTOZOA

Asterionella sp.	4.8
Dinobryon sp.	1.6
Gomphosphaeria sp.	1.6
Total--	8.0
NAUPLIUS LARVAE	92.8

Table 3

HUMMINGBIRD LAKE-PLANKTON

ROTIFERS (Counts per ml.)	
Asplancha sp.	1.6
Keratella sp.	40.0
Kellacottia sp.	2.4
Polyarthra sp.	3.2
Total-	47.2
CLADOCERA	
Daphnia sp.	3.2
Bosmina sp.	12.8
Holopedium sp.	36.8
Total-	48.8
COPEPODS	
Cyclops sp.	14.4

FOOTNOTES

[1] Reid,g. and Wood, R. Ecology of Inland Waters and Estuarys. D. Van Nostrand Company, N.Y., N.Y. 1979 pp206.

[2] ibid., p215.

[3] Spotte, Stephen H. Fish and Invertefrate Culture. John Wiley & Sons, Inc. N.Y., N.Y. 1970 p260.

[4] Moss, Brian. Ecology of Fresh Waters. John Wiley & Sons, Inc. Blackwell Scientific Publications, Great Britain, 1980. p363.

[5] ibid. p359.

[6] Lagler, Karl F. Fish and Fishing in Michigan. Follett's Bookstore, Ann Arbor, Michigan. 1949. pp. 15, 16,20,28.

BIBLIOGRAPHY

1. Buchsbaum, Ralph. *Animals Without Backbones*. The University of Chicaga Press. Chicago, Ill., 1948
2. Greene, Richard W. *A Guide to UNDERC*. The University of Notre Dame, Notre Dame, IN
3. Lagler, Karl F. *Fish and Fishing in Michigan*. Follett's Bookstore, Ann Arbor, Michigan. 1949
4. Macon, T.T. *Ponds and Lakes*. George Allen & Unwin, Ltd. London, England. 1973
5. Moss, Brian. *Ecology of Fresh Waters*. John Wiley & Sons. Blackwell Scientific Publictions, Great Britain, 1980
6. Reid, G. and Wood,R. *Ecolology of Inland Waters and Estuarys*, 2nd Ed. D. Van Nostrand Company, N.Y., N.Y. 1979
7. Spotte, Stephen H. *Fish and Invertebrate Culture*. John Wiley & Sons, Inc. N.Y.,N.Y. 1970