AN ANALYSIS OF TUESDAY LAKE AND ROACH LAKE.

by

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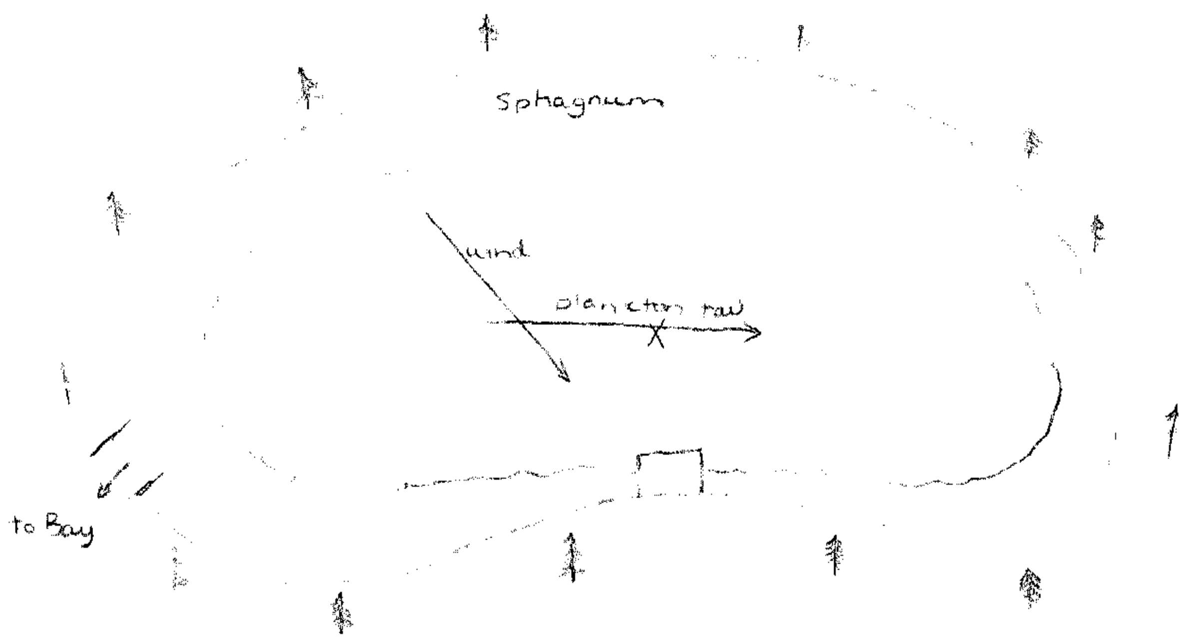
References?

The University of Notre Dame Environmental Research Center (UNDERC), located 20 miles from Land O'Lakes, Wisconsin, in Gogebic County, Michigan, consists of 7,500 acres (16 square miles) of wilderness containing numerous aquatic habitats. UNDERC's lakes, bogs, and marshes vary in every possible way: size, shape, animal and plankton content, water chemistry, border trees, and bottom consistency. The lakes and bogs all supply an excallant site for the analysis of an aquatic environment. This report will discuss and then compare an analysis of two lakes, Tuesday and Roach, that was conducted by Sally Georgen, Barbara Jacobs, and Karen Olson during the week of June 1, 1981.

TUESDAY LAKE

Tuesday Lake, located in the southeast cornr T:45 N; R:42 W, is one of the smallest lakes on the property (recorded surface area = 1.2 ha.), Because it is a glacial bogpot it is very deep (greatest depth recorded at 20 meters) and, therefore, a low surface to volume ratio. The lake is completely surrounded by a thick Sphagnum mat, which provides homes for many animals such as, the common garter snake (*Thamnophis serialis serialis*), and various species of frogs (*Rana clamitans* and *Rana pipiens*); it is also an excellant rooting ground for various plants such as, the endangered "pitcher plant", the woody-stemmed "labrador tea", and tamarack. The mat does not form a firm foundation, but rather it has a "waterbed" effect when walked on. Following the thick bog mat is a layer of dead trees and shrubs. The dead trees indicate the Sphagnum's ability to hold water thus drowning the surrounding tree roots. A layer of hardwoods and conifers (black and white spruce, and balsam are very abundant here) complete the surrounding shoreline. This mixed hardwood-conifer forest forms a protective layer. The breakdown of vegetable matter, such as cellulose and lignin, produces a brown or black substance called humus. Once oxidized in water humic acid is easily detectable by the tea-color it gives the water. The presence of humic acid was detected in Tuesday by this brownish stain which is caused mainly by the conifers that regularly drop their needles. The lake floor, a very murky mud, also indicates the decay of a large quantity of organic material. Besides the small amount of vegatation in the shallow areas, Tuesday does not have an extensive macrophyte population. Rain water appears to be the major water source for this glacial pothole. Water exits Tuesday via the northwest corner into Bay Lake where it will eventually flow into Palmer Lake. Tuesday has no record of fish populations and none were observed during the water collection period. Overall Tuesday is a small, deep, well protected lake surrounded by a bog mat that has neither a percievable current nor a large macrophyte population and appears to be undergoing active decomposition along the shoreline as well as beneath the surface. Tuesday is a classic example of bog development.



Tuesday's map shows the locations for a plankton tow (described later) and water collections.Tuesday's great depth and adequate protection from the wind allowed a thermocline and an oxygen bulge to form, thus permitting a single collection site for gathering the samples: an epilimnion sample taken at one meter, a sample from the bulge taken at one and three-quarters meter, and a hypolimnion sample taken at 4.5 meters. A series of chemical tests will be performed on these samples. The depth at this site is 12 meters.

Besides the chemical tests, an oxygen-temperature profile was conducted at this site. Using a YSI meter the amount of dissolved oxygen per quarter meter at certain temperatures was obtained. A secchi disc was used to measure the amount of light penetration at this site. A Kemmerer was used to collect water at the desired depths from which a pH was measured. The remaining water was transfered to the appropriate collection bottles for further chemical testing, as described in the Hach kit for the study of water chemistry, in the laboratory.

	Epilimnion	O_2 Bulge	Hypolimnion
acidity	75 mg/l	120 mg/l	85 mg/l
alkalinity	—	—	—
Color true	55	55	50
app	60	60	65
Hardness tot	20 mg/l	25 mg/l	25 mg/l
Ca^{2+}	11 mg/l	5 mg/l	12 mg/l
Hg^{2+}	9 mg/l	20 mg/l	13 mg/l
Nitrates	1.2 mg/l	1.2 mg/l	0.8 mg/l
pH	5.0	5.0	5.3
phosphate ortho	0.15	0.18	0.15
tot	0.04	1.3	0.03
Conductance	15 mmhos	15 mmhos	25 mmhos
Sulfates	3 mg/l	8 mg/l	6 mg/l
H_2S	—	—	Yes

TUESDAY LAKE

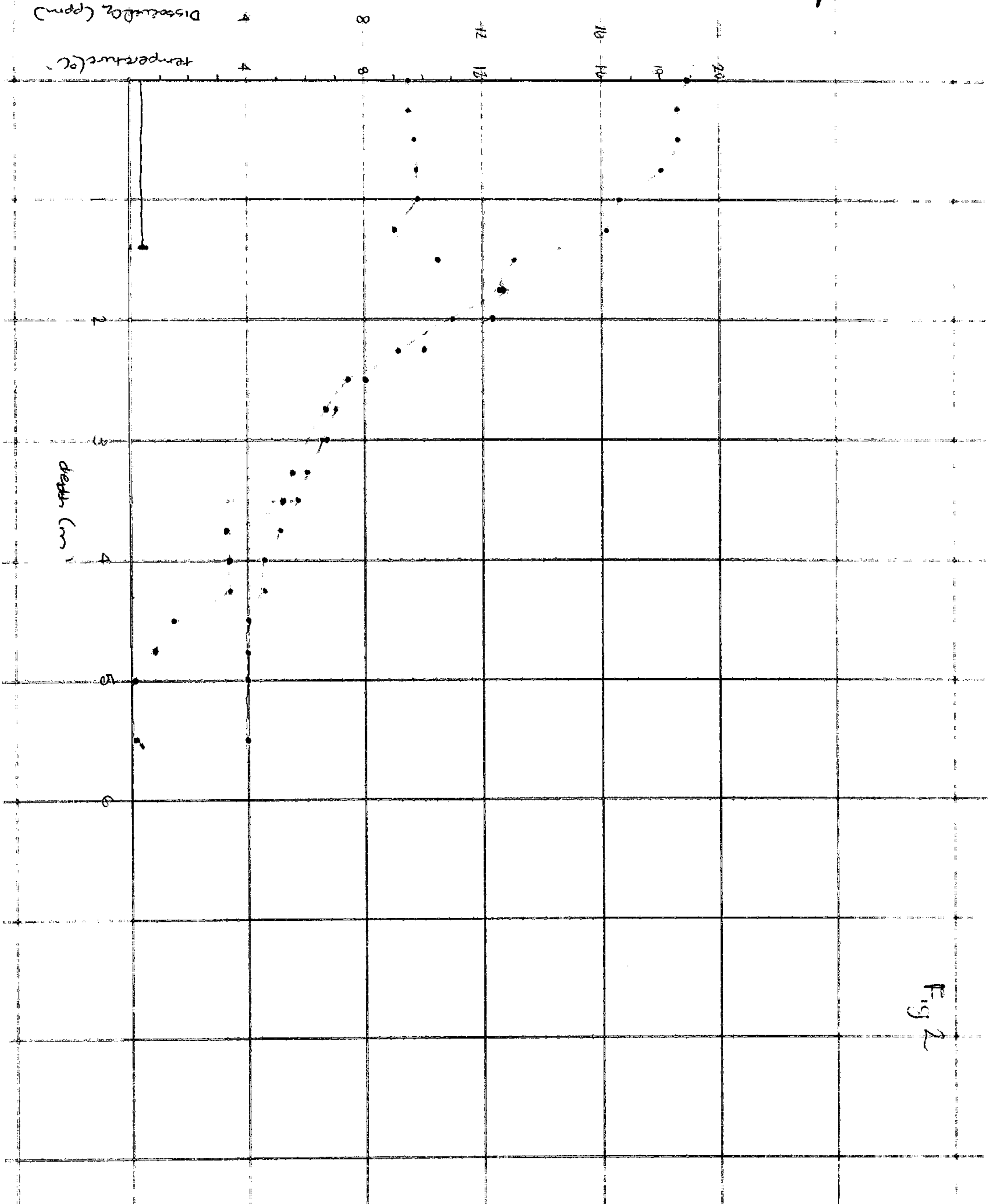


Fig 2

Refer to the graph (fig. 2) and the chart (table 1) for the following section.

According to the graph a shallow thermocline formed as well as an oxygen bulge. The thermocline is the direct result of the winds inability to penetrate the dense forest to mix the water. The low surface to volume ratio also inhibits the small winds that do penetrate the forest to turn the lake over. Without a current or continual water input from another lake, the water stagnates and the conditions become favorable for the formation of Sphagnum. The oxygen bulge appeared at 1.5 meters approximately the same depth where the secchi disc disappeared. This supersaturated oxygen region comes either from the surface or as the result of oxygen releasing microorganisms that prefer dim light or that may be trapped because of the temperature difference. The air temperature was 23.5° C and higher than the temperature of the epilimnion which was recorded on the YSI at 19°. The temperature of the hypolimnion was 4° and very little oxygen was present in this region also. (Occaisional drifting of the boat may have had an effect on the exact position of the hypolimnion and oxygen bulge.)

The secchi disc is a circular disc suspended from a segmented rope in the water. The loss in visibility of the secchi disc indicates the depth at which light penetration is drastically reduced. The secchi disc reading at this location occured at 1.4 meters. The weather conditions were significant enough in allowing the lake to appear clear. ?

The pH of both the epilimnion and hypolimnion measured 5.0 on the pH scale, indicating that they are both acidic. The oxygen bulge also measures acidic, although at 5.3. This difference can be considered negligable until the acidity data is considered.

$$H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons 2H^+ + CO_3^=$$

This reaction is a summary of what occurs between carbon dioxide and water in the lake which results in the natural formation of bicarbonates, carbonates, and hydronium ions. The acidity and alkalinity are inversely proportional to the product being used up. This explanation for normal acidity and alkalinity is consistant with the results from Tuesday. A higher acidity reading in the bulge region may be the result of an alternate source of the highly electronegative hydronium ion normally associated with the *Sphagnum* concentrates in the bulge region where photosynthesis produces a continual surplus of negatively charged ions. Because of the abundance of hydronium ions, all of the buffer is quickly used up leaving a surplus of hydronium ions in solution. The presence of phytoplankton in the bulge region may have an effect on these readings. In photosynthesis these phytoplankton utilize the carbon dioxide that would normally form carbonates and bicarbonates, thus lowering the amount of buffer present. Acid rain, the result of the condensation of chemicals and pollutants in the air, supplies most of the water to Tuesday and may contribute additional hydronium ions to this system. The hypolimnion has a higher level of hydronium ions than the epilimnion. This may be the result of the macrophyte population which at this depth is recieving enough light to undergo photosynthesis. Another explanation is that a build-up of acidic material may have occured in the hypolimnion as a result of the acid rain.

Two types of water color are possible in the lakes: apparent and true. Apparent water color is an unchanged water sample from the source under investigation. True color is water from the same source that has been centrifuged in order to remove any plankton or the other forms of turbidity from the same sample. When measured in a spectophotometer the true color is expected to have a lower absorbancy since everything that would absorb the light is removed during centrifuging. There is a consistant difference between the true and apparent colors in the epilimnion and the oxygen bulge regions. The difference between true and apparent colors in the epilimnion may be the result of small seperable debris ? and not plankton. The large difference in the hypolimnion's true and apparent colors may be due to a sample containing sediment that was stirred-up during the water collection. Despite the differences, the data is feasible.

Water hardness is the result of certain dissolved substances, usually some form of lime such as Mg^{++} and Ca^{++}, in the water. Because the values were so low, the concentrations of all the chemicals were doubled to produce the same low results. The total hardness is fairly consistant within the different regions. A notable difference occurs between the amounts of calcium and magnesium present within the different regions which may be due to the fact that there ? are mollusks or other organism concentrated in the bulge that require Ca^{++}. Low hardness is also a result of low alkalinity; the Ca^{++} and Mg^{++} would usually react with HCO_3^- to form $CaCO_3$ or $MgCO_3$ which would have alternate effects on the acidity, etc. of the lake. A source of -COOH (in this form or as a phosphoric or fatty acid) may be present in the lake which contributes its H^+ to the *Sphagnum* mat and the Ca^{++} quickly attaches to the COO^-, removing most of the Ca^{++} in solution.

Specific conductivity, measured in mmhos/cm, is the ability for water to conduct electricity. The higher the ion concentration the more electricity that can be conducted through the solution. The specific conductance data, although low, is consistant in the epilimnion and bulge regions. A slight increase in the hypolimnion suggests a higher concentration of ions possibly the result of unused nutrients or dead phytoplankton that have dropped to the bottom. Seasonal turning over of the lake would permit a circulation of these nutrients to the areas where they would be utilized but because of Tuesday's depth and bog-like conditions these nutrients become entangled in the sediments. Seepage of stored water and ions would account for an excess of ions. Because the phytoplankton utilize these nutrients,it would make sense that a higher specific conductance would occur in the bulge also. One explanation might be that the water collection stradled the epilimnion and bulge regions with most of the water coming from the epilimnion. This would account for the similarities in color between these two regions <u>etc</u>. and explain smaller differences in nutrient levels, <u>etc</u>. Experimental error would also account for the similarity.

Phosphate, an essential compound for organisms in natural water, exists naturally in several forms, but for a quantitative analysis the phosphate must be converted to the only form that the Hach kit can measure- orthophosphate. The spectophotometer indicated the absorbance readings which were then converted to concentrations of phosphate for the treated water samples. Variation occurs between the three regions with the bulge containing the most phosphate. Plankton require phosphates, therefore, if the plankton which contain the phosphate occur in that region then an increase is acceptable. A smaller difference may be attributed to many factors: the water collected contained a large amount of water from the epilimnion; the Kemmerer may have collected water that was close to shore where plankton are less abundant; the phosphates may not have been completely converted; or possibly the plankton may have moved to a more stationary area because of the great disturbance during the collections. Asimilar difference appeared in the total phosphate test, although the difference in the bulge was more defined. This test may have been more sensitive to the conditions of the lake. The fact that this data is consistant and explainable give evidence that it is probably correct.

"Nitrate represents the most completely oxidized state of nitrogen commonly found in water." Formed by microorganisms which act on organic nitrogenous compounds, nitrates are used to give an indication of the lakes total nitrogen concentration. High levels of nitrate in natural waters indicate biological waste in the final stage of stablization. Nitrate levels in the epilimnion and bulge regions are identical, again , suggesting an error in the water collection. This data may also suggest that utilization of nitrogen is going on in both these regions by small populations of plankton. The relatively low amount of nitrate suggests that Tuesday does not have a large amount of this type of biological waste. This point is reflected in a lake that appears to be almost devoid of all life, but is increasing in its bog-like character.

Sulfate, like nitrate is a good indicator of the lakes sulfur concentration. High levels of sulfate also indicates large amounts of biological wastes. The sulfate data is low indicative of a small microorganism population. As expected, sulfate is more common in the plankton-contained, bulge regionand was succeeded by the hypolimnion which acts as a receptical for unused biproducts etc. Tuesday appears to have no excessive biological wastes. This is expected as the conditions are becoming more bog-like and, therefore, increasingly difficult to support life.

Sulfide is the poisonous biproduct of anaerobic decomposition of organic matter, therefore, sulfide's presence indicates that oxygen is not available for bacterial decomposition. Oxygen's absence from the hypolimnion indicates that the lake does not turn over; the presence of hydrogen sulfide (H_2S), a dissolved form of sulfide, reveals the absence of oxygen from the hypolimnion and, consequently, the lakes inability to turn over. Sulfides presence is easily recognized by it's pungent oder. In Tuesday this recognizable "rotten egg" smell was evident in the hypolimnion. This is substatiated by the graph which shows a thermocline which must be present for H_2S to develop. The data on the graph and the presence of H_2S prove that Tuesday does not turn over and that it is stagnating.

ROACH LAKE

Roach is a very large lake (recorded surface area= 38.4ha.) and lies in Gogebic County, Michigan (T:44 N; R:42 W sw cor. sec.3 and nw cor. sec.10) as well as extending into Vilas County, Wisc.. Roach is most popular because the clearness of it's water makes it an ideal swimming hole (even at night). The forest that surrounds Roach is composed ~~of~~ almost entirely of hardwoods such as, birch, and maple which grow in a clay-like soil. This hardwood forest is important for several reasons: it provides additive protection from the wind because the trees grow right to the waters edge; and without conifers, to contribute the bulk of materialused in humic acid production, the water doesn't have a tea color to it. Although there are a few fallen, dead trees, there is no Sphagnum mat along the waters edge. Dense, nonemergent vegetation (not to be confused ~~with seaweed~~) covers parts of the lake floor. The composition of the lake bottom is unique; it is made of very soft mud in most areas of the lake floor except close to the shoreline where the bottom was covered with small pebbles and a firmer material. Roach's fish include yellow perch, large and small mouth bass, pumpkin seed, muskellunge, and two Notre Dame graduate students. Because Roach is a seepage lake, most of its water enters by means of the rain, the soil bottom and clay borders, small streams and rivulets (neither of which appeared in the area examined), and exits via the soil and evaporation.

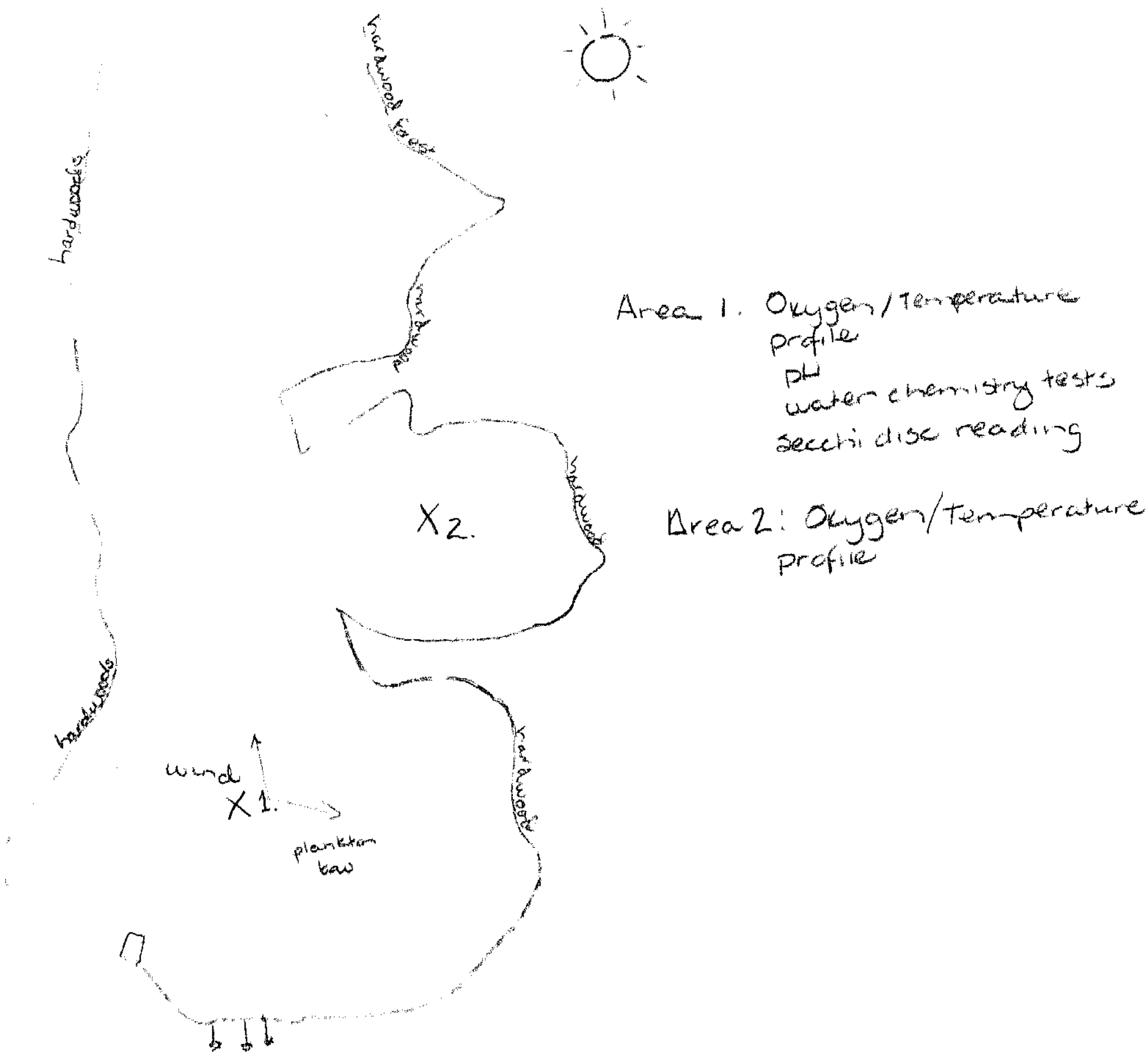


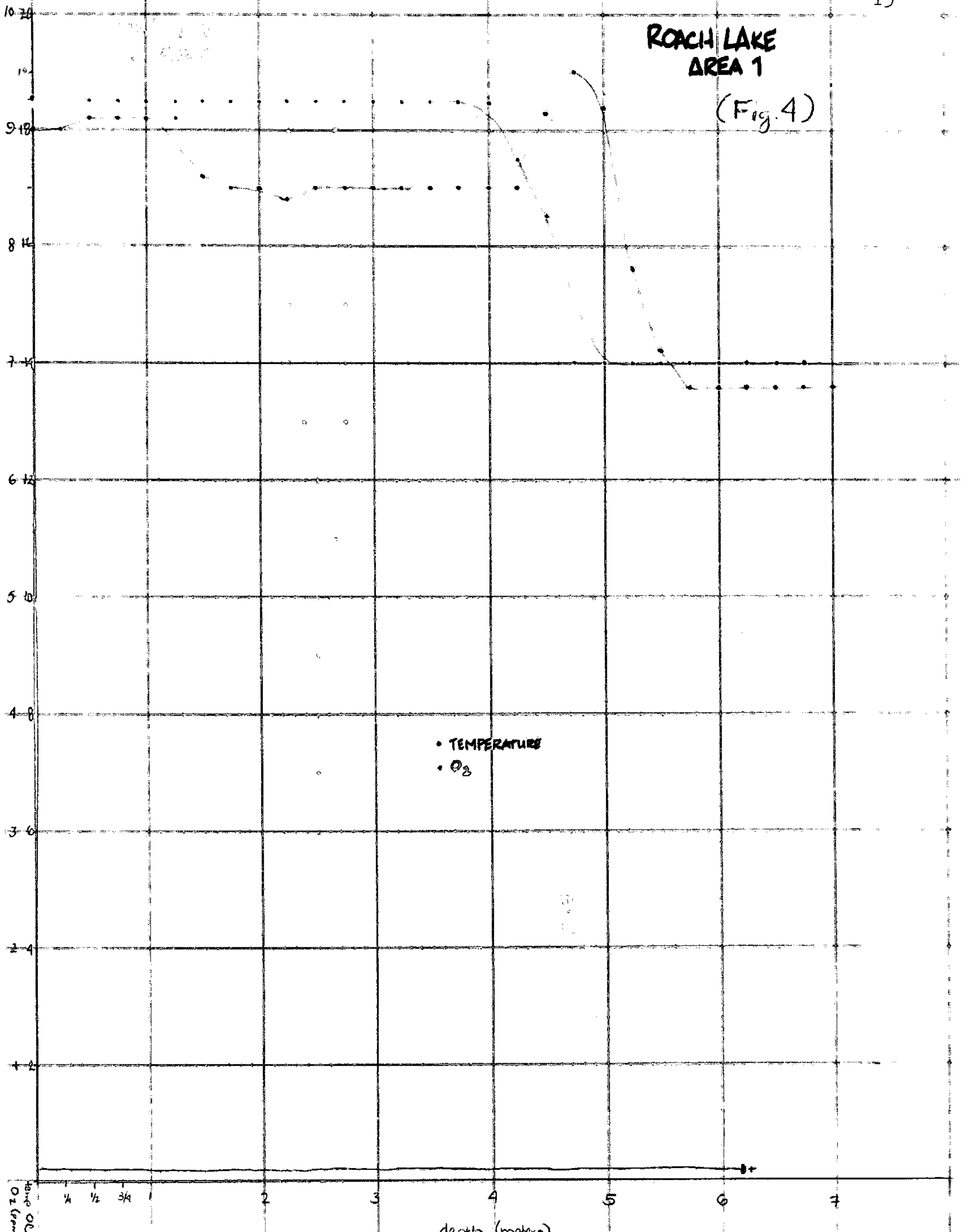
Fig. 3

Roach's map shows the location for the two collection sites (only an oxygen-temperature profile was conducted at site 2). Site 1, located approxmately in the center of the first bay and accessible from the dock, has a depth of 2 meters. Site 2, located approximately in the center of the second bay (accessible only through the first bay) had a depth of of 6 meters. It also shows the location for a plankton tow and the direction of the wind. Roach's great depth and adequate protection allowed a thermocline to form, thus permitting a single collection site for gathering the samples. The second site was used to test for a similar thermocline formation. The epilimnion sample was taken at 1 meter while the hypolimnion was taken at $4\frac{3}{4}$ (4.75) meters.

Roach's samples from the epilimnion and hypolimnion were analysed with the same technique that was used for the analysis of Tuesday Lake.

Table 2

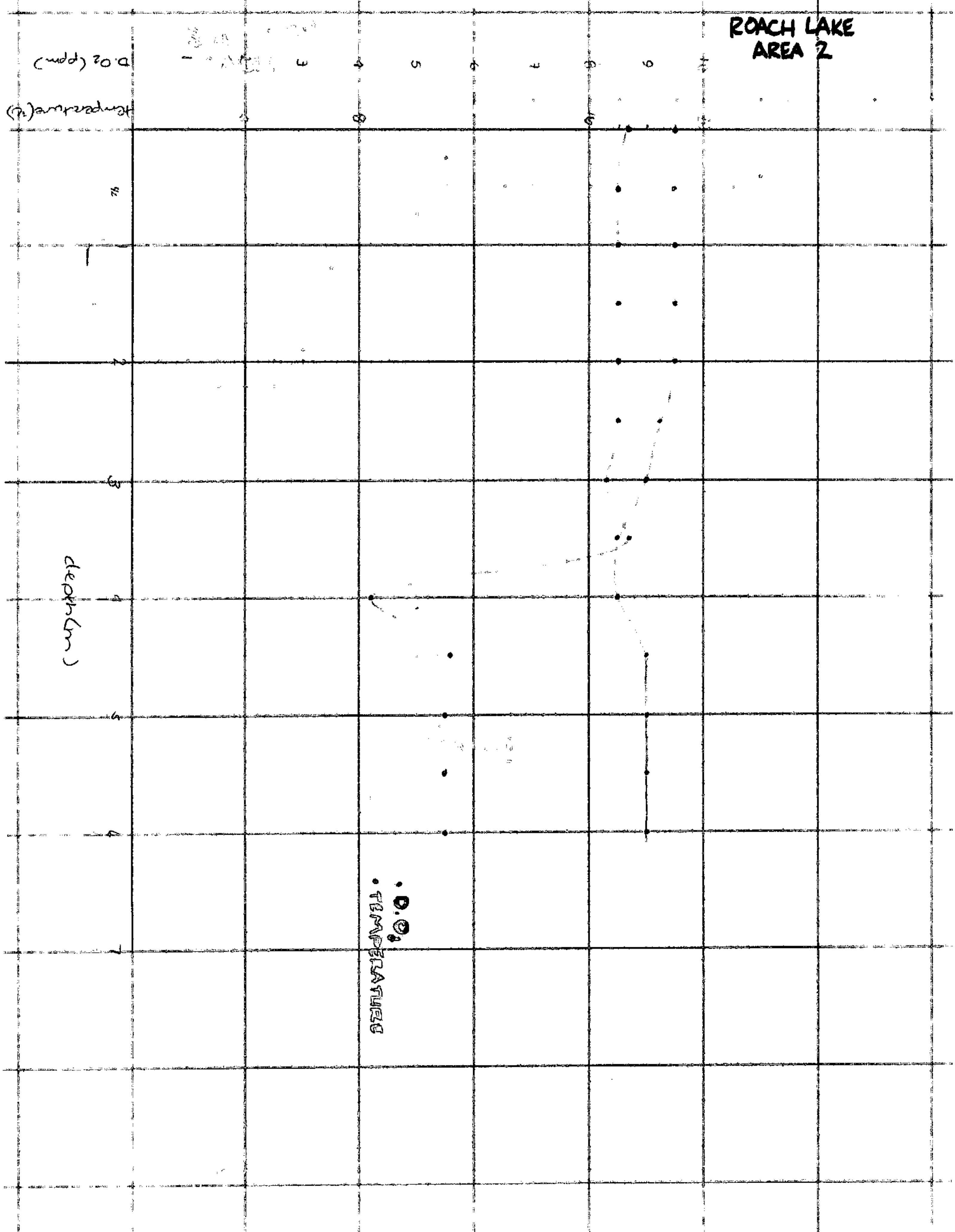
	Epilimnion	Hypolimnion
acidity	30/50 mg/l (methyl orange / phenylphthaline)	30/220
allcalinity	—	—
Color true	1	-2
app	0	5
Hardness tot.	10 mg/l	10 mg/l
Ca^{2+}	5 mg/l	5 mg/l
Mg^{2+}	5 mg/l	5 mg/l
Nitrates	4	6
pH	6	6
phosphates	not done on this lake because of a shortage of mat'ls.	
Conductance	85 mmhos/cm	280 mmhos/cm
Sulfates	29 mg/l	140 mg/l
H_2S	—	—


ROACH LAKE
AREA 1
(Fig. 4)
• TEMPERATURE
• O2
depth (meters)
temp °C
O2 (ppm)

The following section will refer to the data shown in table 2 and the graph (fig. 4).

According to the graph a thermocline formed as a result of some protection from the wind. Although winds do penetrate the forest the lake may be too large and too deep in certain areas to mix. The absence of Sphagnum indicates that there is turning over or that an adequate current keeps this lake from stagnating. At site 1 and oxygen bulge appeared in the hypolimnion indicating oxygen is present for turning over. This bulge may be present in the hypolimnion because at this depth there is very little light penetration and a more suitable climate for these oxygen releasing organisms. The temperature of Roach, also a glacial lake,reaches 14°C. Even though it is a glacial lake, Roach's depth and incredivle light penetration has prevented it from reaching the lower temperatures expected of a glacial lake. The higher temperature may keep this lake from transforming into a bog. A similar thermocline formed at site 2, but besides the presence of on oxygen bulge, a depression occured. Such a curve, in theory, would indicate the presence of an aerobic organism, such as zooplankton, but because it appears before the oxygen bulge (where phytoplankton are located) this explanation is rejected. Such a depression may be the result of error. The temperature in area 2 does not drop very low which indicates that this condition may be similar throughout the lake.

The secchi disc at site 1 was still clearly visible at the end of the rope (6 meters). The weather conditions were significant in allowing the lake to appear very clear; sunny, cloudless, and a low but forceful wind. The tea colored water that appeared in Tuesday was not present in Roach. This may be due chiefly to the relatively few conifers on the shoreline which produce humic acid in the water. Because this stain did not interrupt the


ROACH LAKE
AREA 2
D.O.2 (ppm)
temperature (°C)
depth (m)
• D.O.2
• TEMPERATURE

water's natural color an incredible light penetration was recorded (it may be possibe that the light penetration exceeded the depth).

A pH of 6 was common to both regions. Such a pH is reasonable since humic acids are absent end, therefore, not contributing to the acidity. Because Roach is a seepage lake, most of the intake of water comes from the rain or water stored in the soil. As a result, the acidic pH is caused by acid rains, and humus or erosion in the soil. Because of its size and depth it may be hard to keep the acid from collecting.

The acidity level is low and constant for the two samples using the methyl orange test described in the Hach kit and it corresponds with the slightly acidic pH. Using the phenylpthaline test, described by the Hach kit for pH within this range, a drastic difference occured between the epilimnion and the hypolimnion. Several explanations can be offered for this difference: the pH was originally incorrect and, therefore, this test is more indicative of the actual acidity; a build up of material in the hypolimnion due to seepage may have caused it; CO_2 and H_2O bonding as the result of phytoplankton in the hypolimnion; or as a result of dirty dishware or experimental error.

An alkalinity reading of 0 favors the low pH theory. An abundance of macrophyes or phytoplankton in this region may use the CO_2 in photosynthesis that would normally form carbonates and bicarbonates, thus lowering the alkalinity. If some compound contains surplus hydronium ions (other than those formed when CO_2 and H_2O bond in photosynthesis) and at the same time masks the hydronium ion from the pH reading, but dissociates during the acidity test, than a high pH, high acidity, and low alkalinity is feasible.

The low hardness of Roach Lake also appears to follow the low pH, high acidity theory. In Roach the amount of Ca^{++} and Mg^{++} were constant for both regions indicating a small amount of life that occupy these regions. Because of the tremendous light penetration, this is very likely.

The specific conductance data is incredulously high even compared to Tuesday which had more ions in solution. There is probably some conductance, although it may have been exaggerated by the Hach kit apparatus. A higher conductivity in the hypolimnion would again suggest a higher concentration of ions due to a plankton population or unused nutrients which have settled to the bottom. Because the Ca^{2+} and Mg^{2+} hardness is consistent in both regions, the higher conductivity in the bulge could not have been caused by either of these ions. Because of the depth and the presence of a thermocline, the nutrients that fall to the bottom will become tied up in the sediment and increasingly difficult to redistribute.

The color data shows inconsistancy as well as unbelievability. Low readins for true and apparent color were expected because of the water's clearness. It is impossible for a sample to have a negative true color. Also is it unlikely that centrifuging should add to the apparent color. No explanations can explain this data except the possibility of experimental or mechanical error dirty dishes.

The nitrate concentrations were low with a small difference occuring between the two regions. A higher nitrate level in the hypolimnion may be the result of plankton and macrophytes consentrated in that region. The low nitrate concentration in the lake, again, indicates the clearness of the water because it is low in biological wastes.

Sulfates are abundant in Roach with a large amount occuring in the hypolimnion. This indicates that microorganisms in the hypolimnion prefer sulfur to the other nutrients. Such a large number of sulfates indicate a large amount of biological wastes which is concentrated in the sediment and possibly the cause of the soft, slimy mud found in the deeper regions. The large number of sulfates recorded may also be the result of experimental error, as it appears that Roach does not support enough life to produce this amount of only one product.

Hydrogen sulfide was not found in Roach, therefore, the lake's surface area and hardwood forest must allow sufficient wind through to turn over the water. The temperature curve showed that a thermocline was present yet the absence of H_2S proves that Roach turns over.

TUESDAY LAKE AND ROACH LAKE PLANKTON STUDY

Plankton are drifting organisms which, even if mobile, cannot swim against the current. Plankton, because of its small size, forms the beginning of the aquatic food web. In fact, without plankton all life may be impossible, unless an alternate food source was developed, plankton are divided up into two groups: phytoplankton and zooplankton. The phytoplankton starts the food web by autotrophically making its nutrients. Phytoplankton require sunlight for photosynthesis, thus phytoplankton must live at a depth where light is available. Since they are photoinhibited, phytoplankton tend to live below the surface during the day, however, at night they move closer to the surface. The movement of the phytoplankton is followed by the movement of the zooplankton and other organisms that feed on the phytoplankton. Plankton require certain nutrients such as carbon, phosphorus, and nitrogen of which phosphorous is usually the limiting factor in fresh water. Temperature, nutrient availability, and the water's chemistry can have a drastic effect on any plankton population and thus the entire aquatic ecosystem.

On the days that the water chemistry samples were collected for Tuesday and Roach, a plankton tow was conducted. The plankton tow involved towing of a standard plankton net for four minutes at a depth of one meter, four meters behind a rowboat. The contents of the net were then rinsed into a bottle and preserved for identification. The following table includes the types of net planktons that were collected in the morning tows for both lakes and the approximate quantities of each type.

Table 3

	Tuesday	Roach
Asplanchna	*	*
Bosmina	very few	*
Conochiloides	—	few
Conochilus	—	very few
Cyclops	few	—
Daphnia	few	—
Eucyclops	*	—
Holopedium	*	*
Keratella	abundant	abundant
Limnocalanus	—	few
Nauplius	—	many
Pericyclops	—	very few
Polyarthra	very few	very few
Sinantherina	—	few
Trichocerca	—	

* less than 5 per .1 ml

Not much zooplankton was collected in either lake. It is hard to say this was the result of the time of day or because the nature of the lakes is conducive to supporting life. The fish population in Roach may have had an effect on the zooplankton count. Fish feed on a variety of smaller organisms including, insect larvae,and zooplankton. At the greater depths and when conditions are less favorable for the fish than they may feed more on zooplankton. Because of the acidic conditions of both the lakes, especially Tuesday, it may be increasingly difficult for these zooplankton to survive. Also, because of the depths of these lakes, nutrients that fall to the bottom become tied up in the sediments until the lake turns over (Tuesday does not turn over, therefore, these nutrients remain in the sediments). Zooplankton can not submerge to these levels where no oxygen and low temperatures exist.

Keratella appears to be the most abundant zooplankton in both bodies of waters. In general, the rotifers appear to be the better represented class of zooplankton in both lakes. This may reflect unusual feeding habits and lifestyles which permit them to live in conditions that are unfavorable to other zooplankton. Because they are filter feeders, they have a better chance of obtaining supersaturated nutrients from the water. Their ability to leave the water and crawl into the mud etc. may be an advantage to their survival. Nauplii are also very abundant in Roach and not Tuesday. only copepods! This may be the result of newly hatched arthropods which have not yet been effected by the less severe conditions of Roach. These larva may also be unfit for fish consumption, or because they are arthropods and, therefore, more phylogenetically advanced, they may be better adapted to this environment. The bright sunlight and wind as well as the small numbers collected may have had an effect on the plankton data. Therefore, it is difficult to deduce very much from the plankton data.

SUMMARY

Tuesday Lake is tending toward total bog formation and Roach Lake is tending more toward oligotrophism, however, a comparison of both reveals that Tuesday and Roach are not very different. Both Tuesday and Roach are glacial lakes, although their surface to volume ratios are very different. The pH, acidity, and alkalinity for both lakes are the same, withTuesday's being a little more severe. The oxygen-temperature profiles show the same type of stratification but one is more indicative of it's surroundings. The secchi disc readings differed, also as a result of the surrounding foliage. Both sets of data resemble the data from other bogs on the property.

An oligotrophic lake is a body of water with insufficient nutrition. Other characteristics of an oligotrophic lake include a bowl-shaped bottom (usually the result of a glacier), a low ratio of water between the epilimnion and the hypolimnion, and low water hardness, specific conductivity, and alkalinity readings. According to this information, Roach Lake qualifies as an oligotrophic lake. Because of the high acidity as well as the fact that it is very difficult to turn over, Roach has bog potential. Research is now being conducted on Roach to see if the future of the lake can be predicted. If the conditions below the surface increase in the same direction, then nothing can prohibit the formation of a Sphagnum, the bog mat.

The two lakes are seperate and independent of each other, yet all of the lakes at UNDERC have the soil under them, therefore, they are bound to have similar chemical aspects (this is seen in the formation of many bogs). The total ecosystem productivity is the proper comparison. Because of the bowl shape, neither Tuesday or Roach prohibiting full utilization of the lake bottom. Much of their nutrients get locked up in the hypolimnion, thus lowering productivity further. The productivity concept leads us back to the conclusion that Tuesday, probably oligotrophic at one time, is becoming a bog while Roach still remains oligotrophic.