Bay Lake & Bolger Bog
"a comparison and contrast"

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References

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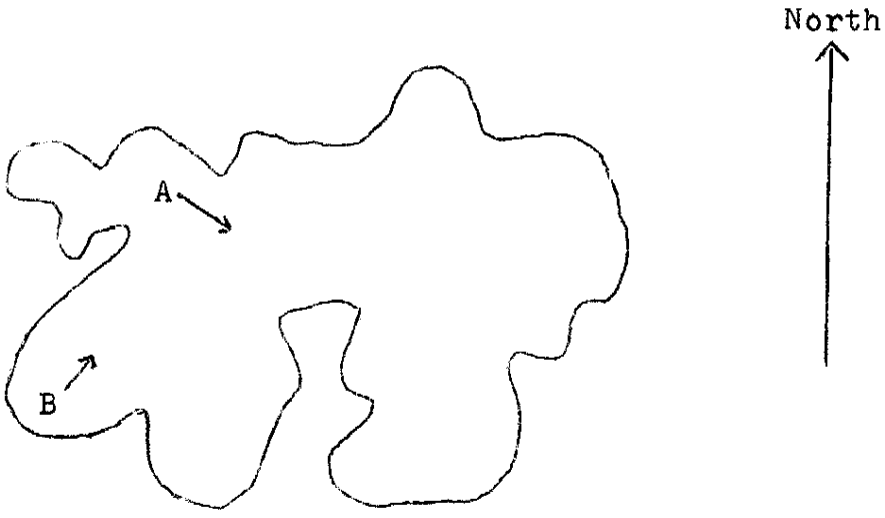
The University of Notre Dame Environmental Research Center is located on the state line between Gogebic County, Michigan and Vilas County, Wisconsin. This region of the United States was once covered entirely by glaciers, the last of which rededed about 12,000 years ago. As a result, the topography is marked with many small lakes. Bay Lake and Bolger Bog are both the result of the glacial action and yet contrast in many ways.

Bay Lake is one of the larger lakes on the UNDERC property and one of its four arms has public access. Water flowing into Bay Lake comes from Tuesday and Hummingbird Lakes. From Bay, this water flows into Emiline (not on UNDERC property) to Kickapoo Lake, and then into Brown Creek. Brown Creek finally empties into Palmer Lake.

Sampling of Bay Lake was done in two places; Site A and Site B.



Bay Lake

⟶ plankton tow direction

The shoreline of Bay Lake is closely lined with large trees. Spruce, pine, maple and birch are common. Many of the birch trees had been blown down, apparently the result of a recent tornado or strong storm. Site A was very open and unprotected, thus the wind was very strong. Site B was much more closed in and protected, therefore it was also much calmer. The wind did not affect our sampling. Site B was also very shallow (about 2 m) compared to Site A (about 10 m). Because of the lake's large size, it is very open and is easily stirred up by winds from almost any direction.

Fish populations in Bay Lake include walleye, northern pike, yellow perch, large and smallmouth bass. However, I also caught many bluegill and pumpkinseed as well.

Walleye ----------*Stizostedion vitreum*

Northern Pike ---------*Esox lucius*

Yellow Perch ----------*Perca flavescens*

Largemouth Bass -------*Micropterus salmoides*

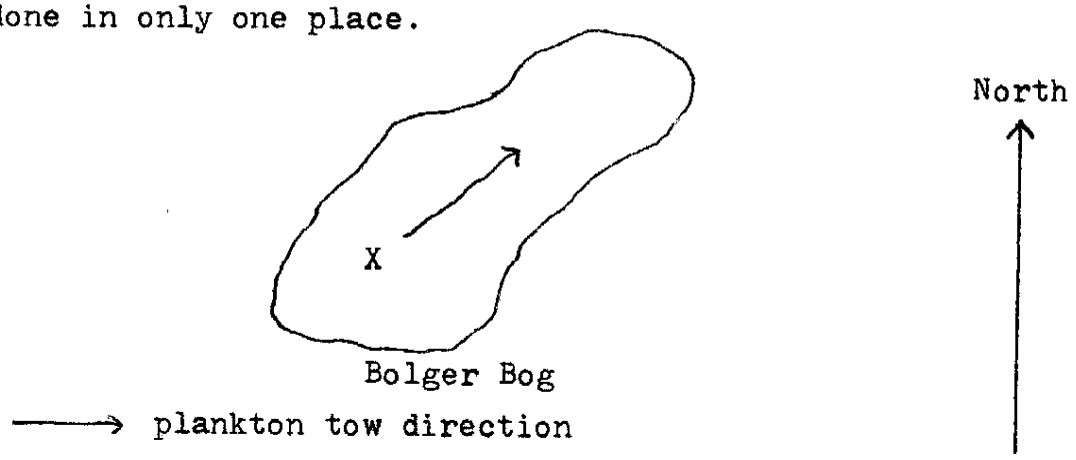
Smallmouth Bass -------*Micropterus dolomieu*

Bluegill ----------*Lepomis macrochirus*

Pumpkinseed ----------*Lepomis gibbosus*

Bolger Bog is located approximately one mile directly south of Bay Lake. It is a large kettle bog, however its size is very small in comparison with Bay Lake. Bolger is said to be a seepage lake, that is, it has no significant drainage except that which percolates through the surrounding mat. Since the basin of Bolger is entirely sealed off from the surrounding groundwater, the influence

of outside water is minimized. Sampling of Bolger Bog was done in only one place.



The shoreline of Bolger Bog is marked by a thick Sphagnum mat which extends from three to six meters from the shore. Other plants found in the immediate vicinity include pitcher plants, sundew, Labrador tea, leather leaf, bog cranberry, and tamarack. Farther out from the Sphagnum mat, conifers such as white cedar and black spruce are present, and even further back, many hardwoods can be found. Bolger affords a good example of a "quaking bog" since the entire bog mat quakes when one walks on it. Caution must be taken when nearing the edge of the mat since it is easy to fall thru as I unfortunately discovered.

The vegetation and sloping surroundings of Bolger protect it from almost all winds. Its small size and remoteness help to keep it undisturbed and usually very calm. Unlike Bay Lake, Bolger is very closed in and quiet.

The only large fish in Bolger are suckers and shiners. Several small species of fish that live under and around the mat include mud minnows, bluntnose minnows, northern red belly dace, and brook stickleback.

Suckers ----------Catostomidae

Shiners ----------Cyprinidae

Mudminnow ----------Umbra limi

Northern Red-Bellied Dace -----Chrosomus eos

Brook Stickleback ----------Eucalia inconstans

WATER CHEMISTRY ANALYSIS

One major difference between the two lakes is their temperature and oxygen stratification. Each year, the water undergoes seasonal changes in temperature. In the spring, the ice melts and the surface water is warmed. As it reaches $4^{o}C$, it becomes more dense, and some stratification begins. This sets up convection currents that along with the strong spring winds, mix the water in the lake until it is at a uniform $4^{o}C$ temperature. Nutrients from the bottom and oxygen from the top are uniformly distributed throughout the lake. This phenomenon is called spring turnover. As the warmth of spring continues, the surface water temperature climbs and temperature stratification develops. This forms three distinct layers in the lake. The warm surface water is called the epilimnion which is followed by the metalimnion and then the bottom layer called the hypolimnion. The metalimnion is characterized by a rapid decline in temperature and the hypolimnion is usually very cold with little temperature change.

YSI recordings in each lake were taken at various depths and this data was used to construct temperature and oxgen profiles. It is obvious that Bay Lake has already

turned over, however, Bolger Bog has not. Bay has significant oxygen levels present even at the bottom of the lake, and the temperatures indicate clearly the three stratified layers. Bolger has very little oxygen near the bottom even though the lake is only about three meters deep. The presence of hydrogen sulfide confirms the lack of oxygen in Bolger. Hydrogen sulfide (H_2S) is an indicator of low oxygen levels since it can only form when oxygen is absent. There was no detectable H_2S in Bay and this was expected since Bay had significant oxygen levels near its bottom. The temperature profile of Bolger shows a gradual decline in temperature rather than the distinct stratified layers of a lake that had turned over.

The obvious reason to explain why Bay Lake turned over and Bolger Bog did not deals with each lakes watershed. Bay Lake, being large and open, is very much affected by winds. These winds help mix the lake up and turn over the oxygen and nutrients. Bolger, on the other hand, is protected from the winds mixing energy by its small size and sheltered surroundings. It has not yet turned over and most likely will not. One must also consider that Bolger is a seepage lake and remains undisturbed while Bay is a drainage lake which has both water inputs and outputs to aid the turnover.

Another observation of the temperature and oxygen profiles is that in both lakes an oxygen bulge occurred. Bay Lake (Site A) had two bulges, one at 1.75 meters and one at 2.75 meters. Bolger Bog had just one bulge that occurred at 0.25 meters. These oxygen bulges can be attributed

to the photosynthesis activity of phytoplankton that are at the depth of the bulge. During photosynthesis, the phytoplankton release oxygen and this accounts for the increase in oxygen at the depth of the bulge. Since the YSI readings were taken at 11:00 AM, the photosynthesis activity was probably at its peak since photosynthesis is greatest during midday. The phytoplankton that could be found at various depths will probably not all be the same since the light wavelengths that penetrate to the different depths depend on not only the depth of the water, but also the color of the water itself. Different phytoplankton have different light preferences.

Acidity, the ability of the water to donate H^+ ions, was one of the major differences between the two lakes. Bolger Bog has a higher acidity than Bay Lake. This is mostly due to the abundance of the Sphagnum mat found at Bolger. Sphagnum has the ability to absorb ions out of nutrient-poor water by exchanging hydrogen ions in its tissues for various cations that are in the water. This process, which results in an increase in hydrogen ions in the water, increases the acidity of the lake. This increase in acidity decreases the rate of decomposition and thereby increases the net accumulation of organic matter. Calcium ions absorbed by the Sphagnum create a shortage of calcium ions for microbial activity. Colder temperatures, a result of no turnover of the warm water on the surface with the colder water near the bottom, can also limit the decomposition process. Organic matter cannot be broken down because

decomposer organisms cannot survive the acidic, nutrient deficient, cold conditions. Eventually the buildup of organic material will continue until the lake fills itself in.

Sphagnum is not the only source of the high acidity. H^+ ions are generated merely by the reaction of water and carbon dioxide. $H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + {}^-HCO_3$. A shift of this equation to the right increases the hydrogen ion concentration and thus increases the acidity. This occurs in both Bolger and Bay. Acid rain and the action of decaying process on the bottom of the lakes also contribute to high acidity levels.

Bolger Bog also has a higher alkalinity than Bay Lake. This indicates that Bolger has a higher buffering capacity than Bay. This could be caused by a number of factors. One explanation relates to the reaction of water and carbon dioxide. ${}^-HCO_3$ is known as carbonate ion and serves as an excellent buffer. The pH of Bolger was slightly lower than the pH of Bay.

The color tests; Bolger had higher color readings, and the secchi disc readings; Bay had higher secchi disc readings, both confirm the fact that the water of Bolger is darker than the water of Bay. This darker water in Bolger limits the light penetration to the depths of the bog. This limits the photosynthetic activity of phytoplankton as well as most other activity that is dependent upon light. The difference between the true color and the apparent color readings in Bolger are probably due to plankton or small particles that were in the water. These were

removed upon centrifuging to give the more accurate true color readings.

Specific conductance indicates the amount of inorganic ion concentration in the water. Bolger has a higher specific conductance than Bay and therefore its water contains more inorganic ions. This also corresponds to the fact that Bolger has higher hardness readings. Both calcium, magnesium, and total hardness levels were higher in Bolger than they were in Bay. These high hardness levels may account for the high conductivity. Although it is not essential for high hardness to accompany high conductance readings, the two are related. The high alkalinity of Bolger also fits in with the high hardness levels and the high conductance.

Unfortunately, we were unable to complete the phosphate tests on the water samples. Phosphates are usually the most limiting of all the nutrients in a water system and thereby would tell us the most about the nutrient levels. Bay Lake does have higher level of both sulfates and nitrates in the water and from this we might tend to believe that it might be more productive because it has more nutrients. However, few conclusions can be drawn without more data.

Water Chemistry Data

Bay Lake Site A 6/5/81 11:00 AM

Tim Cogan Greg Liebscher

Test	Epilimnion	Bulge (1.75m)	Hypolimnion
Acidity methyl orange	---	---	---
phonolphthalein	20	30	30
Alkalinity	trace	trace	trace
Apparent Color	25	25	25
True Color	25	25	25
Calcium Hardness	5	5	5
Magnesium Hardness	0	0	0
Total Hardness	5	5	5
Nitrates	1.3	1.9	1.8
Phosphates	na	na	na
pH	5.5	5.5	5.5
Sulfates	70	15	22
Specific Conductance	62	18	18
Secchi Disc	2.3 m when sunny		
H_2S	---	---	---

na - test equipment was not available

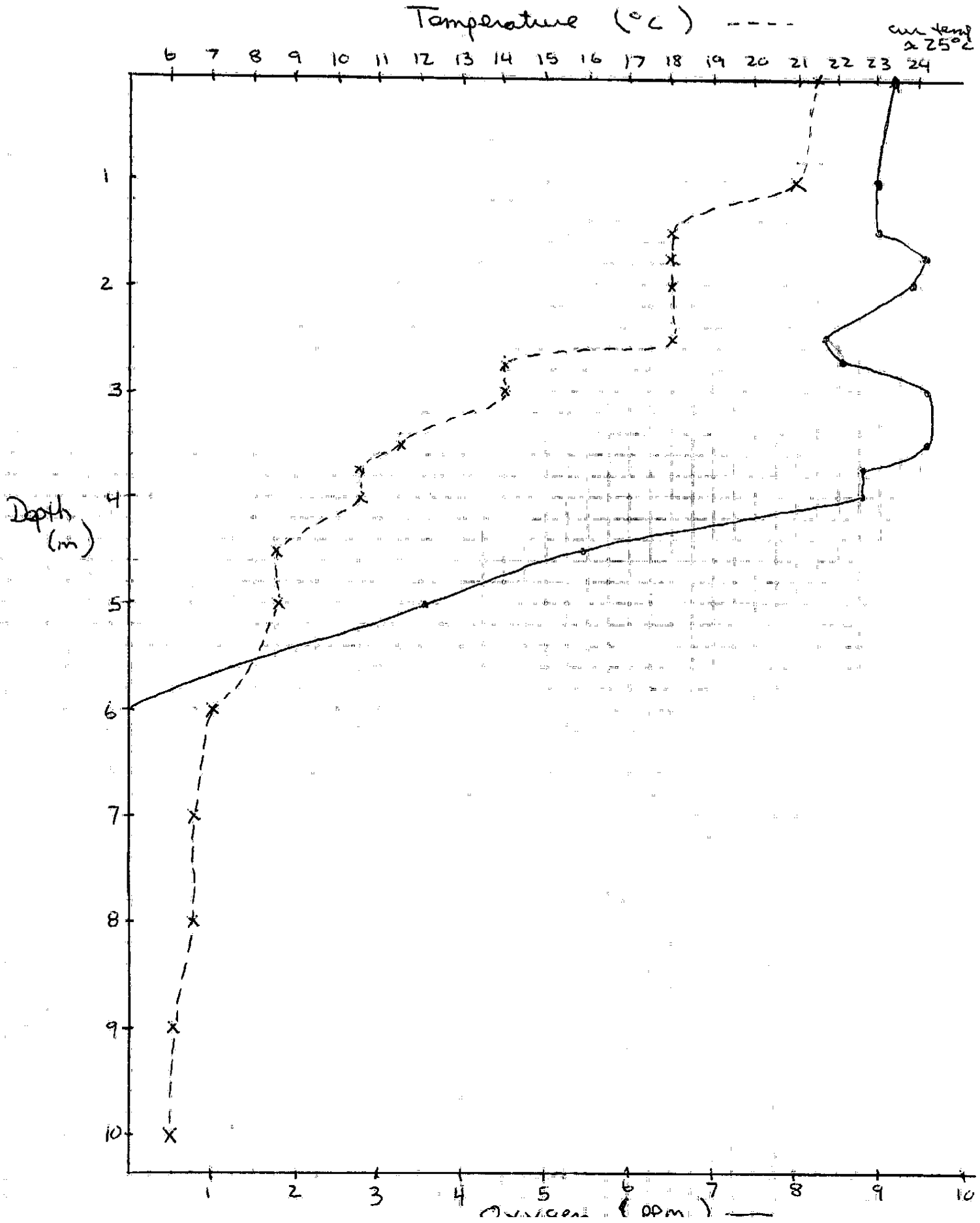
All tests were done using Hach water chemistry kits.

Temperature and Oxygen Data
Bay Lake Site A 6/5/81 11:00 AM
Tim Cogan Greg Liebscher

Depth (m)	Oxygen (ppm)	Temperature (°C)
air	---	25.0
surface	9.2	21.5
1.0	9.0	21.0
1.5	9.0	18.0
1.75	9.6	18.0
2.0	9.4	18.0
2.5	8.3	18.0
2.75	8.6	14.0
3.0	9.6	14.0
3.5	9.6	11.5
3.75	8.8	10.5
4.0	8.8	10.5
4.5	5.4	8.5
5.0	3.6	8.5
6.0	---	7.0
* 7.0	---	6.5
* 8.0	---	6.5
* 9.0	---	6.0
* 10.0	---	6.0

*-These recordings may actually be from the bottom of the lake since it was difficult to determine when the YSI probe was actually on the bottom.

Bay Lake
Site A



Water Chemistry Data

Bay Lake Site B 6/5/81 11:00 AM

Tim Cogan Greg Liebscher

Test	Epilimnion	Hypolimnion
Acidity		
methyl orange	---	---
phenolphthalein	20	30
Alkalinity	trace	trace
Apparent Color	25	25
True Color	25	25
Calcium Hardness	5	5
Magnesium Hardness	0	0
Total Hardness	5	5
Nitrates	1.8	1.2
Phosphates	na	na
pH	5.5	5.5
Sulfates	30	15
Specific Conductance	18	19
Secchi Disc	2m (bottom)	
H_2S	---	---

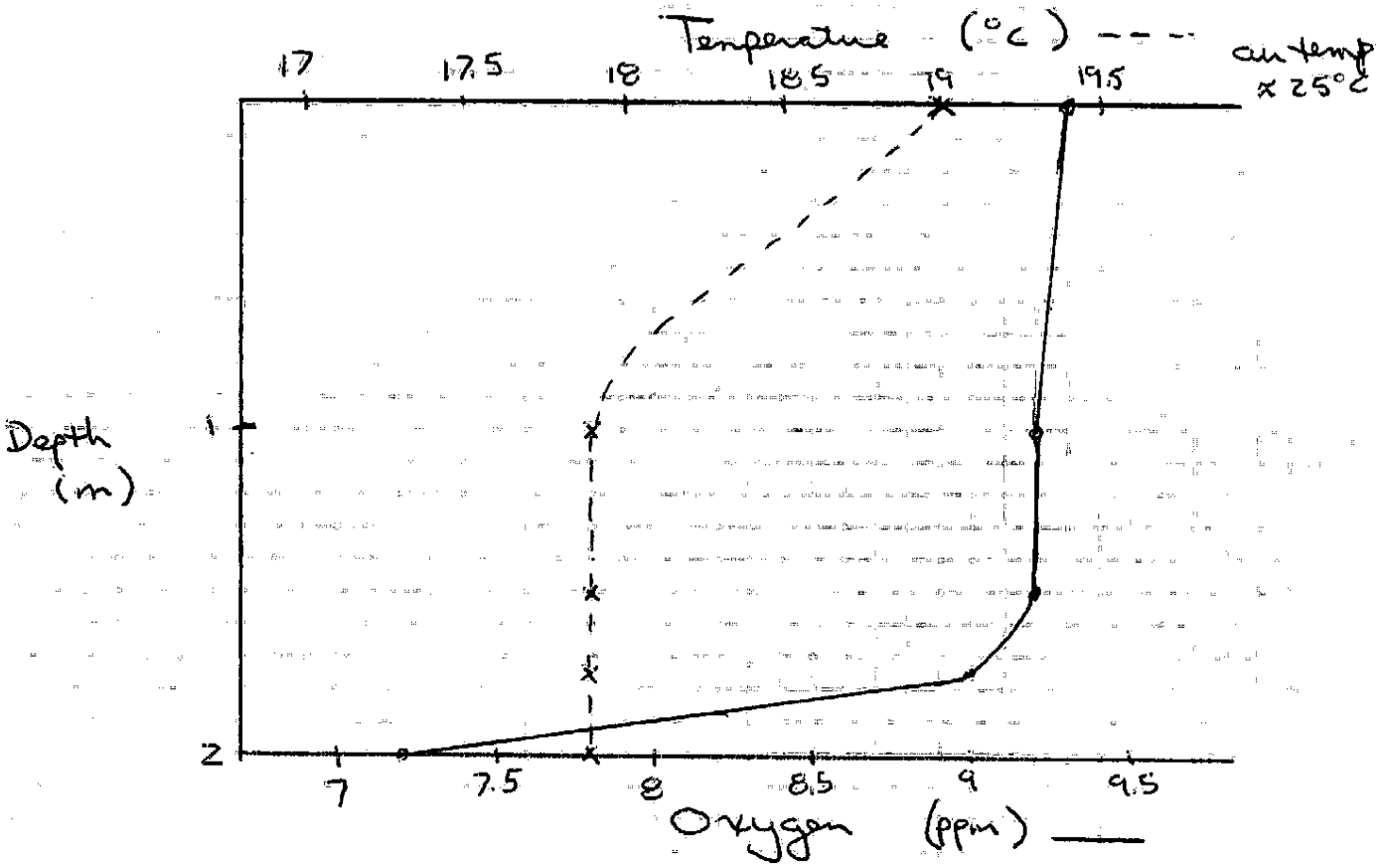
na - test equipment was not available

All tests were done using Hach water chemistry kits.

Temperature and Oxygen Data
Bay Lake Site B 6/5/81 11:00 AM
Tim Cogan Greg Liebscher

Depth (m)	Oxygen (ppm)	Temperature (°C)
air	---	25.0
surface	9.3	19.0
1.0	9.2	18.0
1.5	9.2	18.0
1.75	9.0	18.0
2.0	7.2	18.0

Bay Lake
Site B



Water Chemistry Data

Bolger Bog 6/3/81 11:00 AM

Tim Cogan Greg Liebscher

Test	Epilimnion	Bulge (.5m)	Hypolimnion
Acidity			
methyl orange	---	---	---
phenolphthalein	45	45	40
Alkalinity	25	20	20
Apparent Color	110	75	110
True Color	80	75	80
Calcium Hardness	15	12	15
Magnesium Hardness	20	18	25
Total Hardness	35	30	40
Nitrates	0.1	0.0	0.0
Phosphates	na	na	na
pH	5	5	5
Sulfates	0.0	0.0	0.0
Specific Conductance	45	45	70
Secchi Disc	1m when sunny	.8m when cloudy	
H_2S	---	---	present by smell

na - test equipment was not available

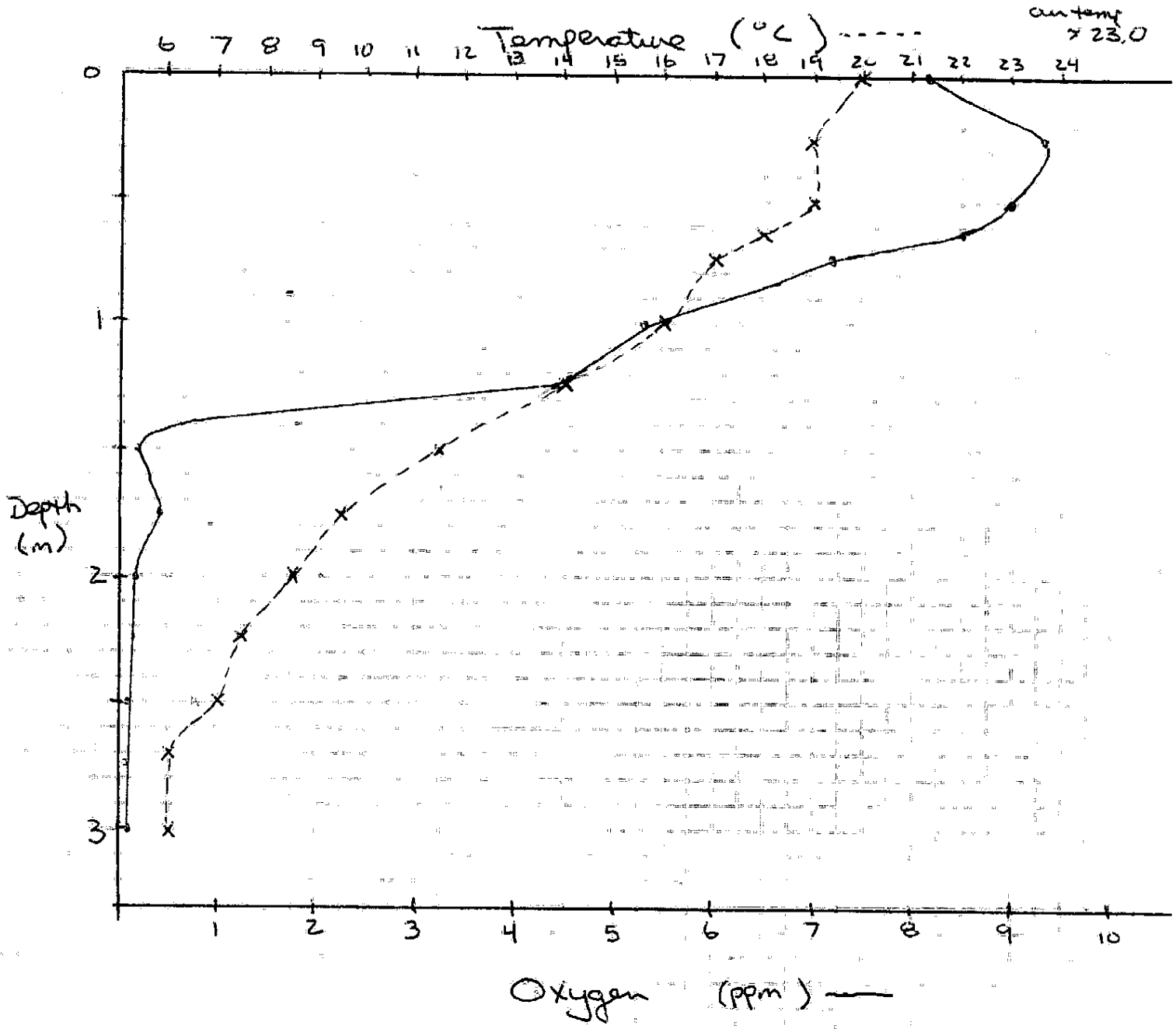
All tests were done using Hach water chemistry kits.

Temperature and Oxygen YSI Data
Bolger Bog 6/3/81 11:00 AM
Tim Cogan Greg Liebscher

Depth (m)	Oxygen (ppm)	Temperature (°C)
air	---	23.0
surface	8.2	20.0
.25	9.3	19.0
.50	9.0	19.0
.625	8.5	18.0
.75	7.2	17.0
1.0	5.3	16.0
1.25	4.4	14.0
1.5	0.2	11.5
1.75	0.4	9.5
2.0	0.2	8.5
2.25	0.2	7.5
2.5	0.15	7.0
* 2.75	0.15	6.0
* 3.0	0.15	6.0

*-These recordings may actually be from the bottom of the bog since it was difficult to determine when the YSI probe was actually on the bottom.

Bolger Bog


air temp
x 23.0
6 7 8 9 10 11 12 Temperature (°C) ----- 13 14 15 16 17 18 19 20 21 22 23 24
0
1
2
3
Depth (m)
1 2 3 4 5 6 7 8 9 10
Oxygen (ppm) ——

PLANKTON ANALYSIS

Plankton are small drifting organisms in the water which, even if motile, cannot swim against the current. In order to collect these organisms, we used standard plankton tows and then estimated a count of the organisms using a Sedgwick-Rafter Cell. A Sedgwick-Rafter Cell is a chamber with dimensions 50mm x 20mm x 1mm and contains exactly 1ml of water. This method can tell what organisms are found in the water sample and their relative numbers. In 1ml of a plankton tow from Bolger Bog, I observed approximately: (Zooplankton)

Kelicottia ----------393.3
Keratella ----------280
Cyclops ----------130
Chaoboridae larvae ----------50
Canthocamptus ----------30
Asplanchna ----------13.3

In 1ml of a plankton tow from Bay Lake, I observed approximately: (Zooplankton)

Colonial Rotifers ----------423.3
Daphnia ----------240
Keratella ----------143.3
Bosmina ----------40
Diaptomus ----------36.6

One must always keep in mind that these are only approximations. It is possible that other organisms may be present in the lakes since 1ml is only a small fraction of the total sample size and the sample was only a small

fraction of the total amount of water in the lake.

Conditions at the time of sampling can also affect the plankton. The sample at Bolger Bog was from a night time plankton tow. Plankton often vertically migrate to the surface after the sun goes down. Thus the night sample was much richer than the day sample at Bolger and I used it to obtain the Sedgwick-Rafter counts.

Wind and currents can also affect the plankton counts. In Bay Lake, Site A was used to count plankton because the plankton tow was much richer there than at Site B. Plankton cannot swim against currents and thus they are at the mercy of the winds. Very possibly, the plankton at the Site B vicinity were blown clear across the lake to the Site A vicinity thereby making the tow at Site A more plentiful.

Other variables that may affect plankton counts include plankton tow times, plankton netting size used, the speed of the tow, the location of the tow, the weather conditions, and possibly even the identification skill of the plankton counter.

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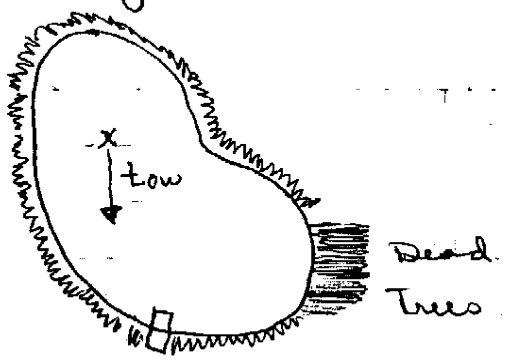
no phytoplankton at all?
no discussion of same,
if true

DISCUSSION

Many of the contrasts and comparisons have already been mentioned so this will be brief. Bolger Bog and Bay Lake seem to contain two entirely different ecosystems. Plankton analysis showed that the plankton, usually at the bottom of the food chain, found in each lake are different. Thus other organisms found in each lake are expected to differ because many of the larger organisms depend on plankton for their food source. Species of fish found in each lake are different and the vegetation surrounding the lakes are different. Water chemistry analysis shows many contrasts between the two bodies of water. Even the watershed of each lake was different. And yet, the two lakes are less than a mile apart. Even though each lake was formed during the same period of time, as a result of the glaciers, each lake seems to be moving toward a different end. Bolger is definitely on its way to reaching the late stages of a bog and Bay is still strongly surviving as a lake. The most obvious note about each lake is that all of the aspects of the lakes that we analyzed are interrelated. The watershed affects not only the vegetation, but also the water chemistry, the fish populations, the plankton populations... No one factor is independent of any other. It is therefore important that when examining a lake, or any ecosystem, as many factors as possible should be considered.

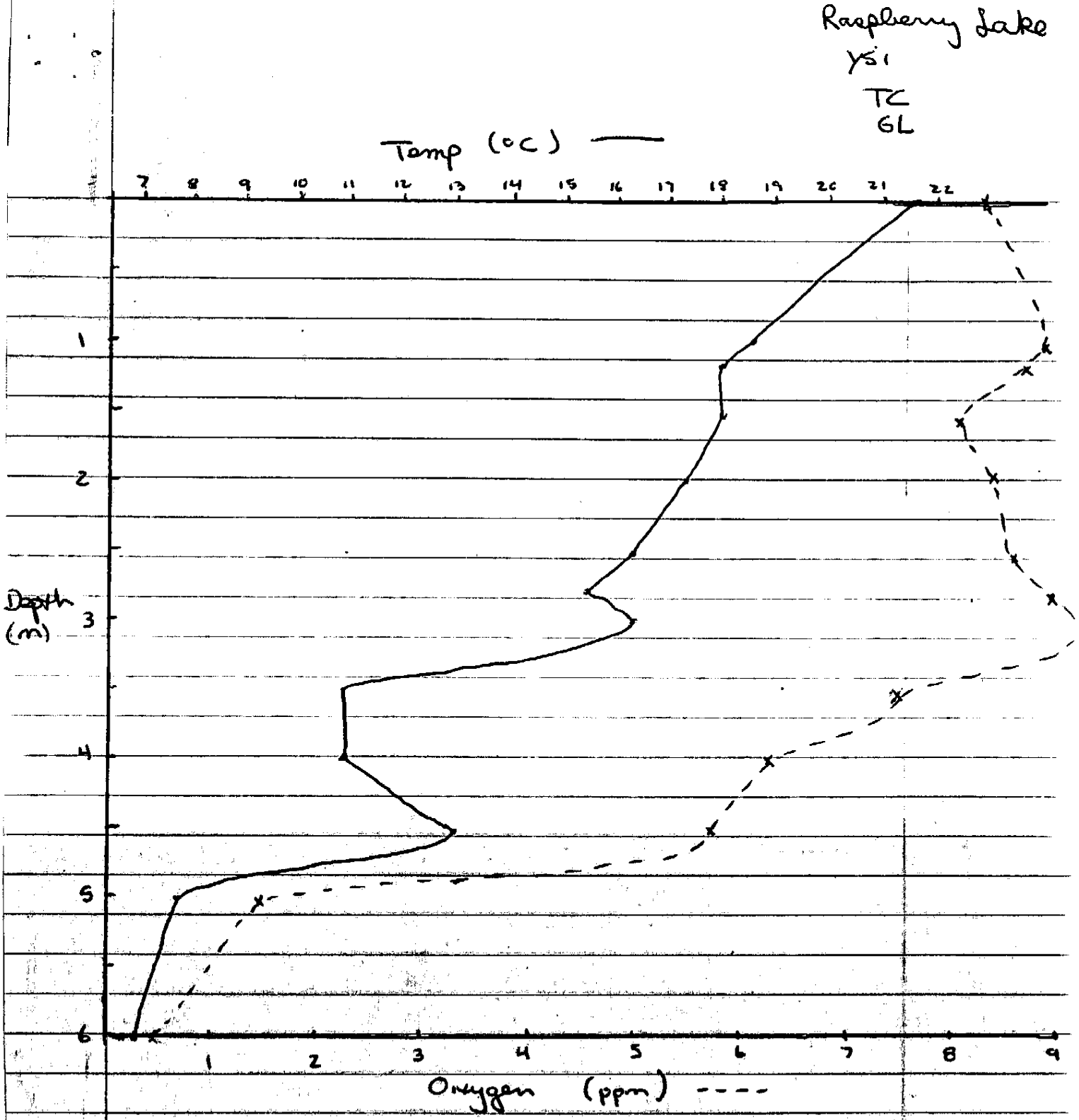
Raspberry Lake

6/2/81
~ 9:00 AM



Weather: mostly sunny, gentle but steady breeze
Surroundings: Sphagnum, Tamaracks, black spruce
hardwoods further back

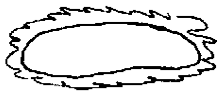
H_2O Chemistry	Epilimnion	Hypolimnion
Acidity		
methyl orange	—	—
phenolphthalein	90	90
Alkalinity	—	—
Apparent Color	5	25
True color	1	10
Calcium Hardness	10	10
Mg Hardness	—	—
Total Hardness	10	10
Nitrates	.2	.2
Phosphates (ortho)	.1	.1
Total Phosphates	.13	.13
pH	5	5
Specific Conductance	15.3	16.8
Sulfates	1.0	1.0
Secchi disc	4 m	
plankton tow	very rich	
H_2S	—	—


Raspberry Lake
YSI
TC
GL
Temp (°C) ——
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Depth (m)
1
2
3
4
5
6
1 2 3 4 5 6 7 8 9
Oxygen (ppm) ----

Tim Cogan
Greg Hielscher

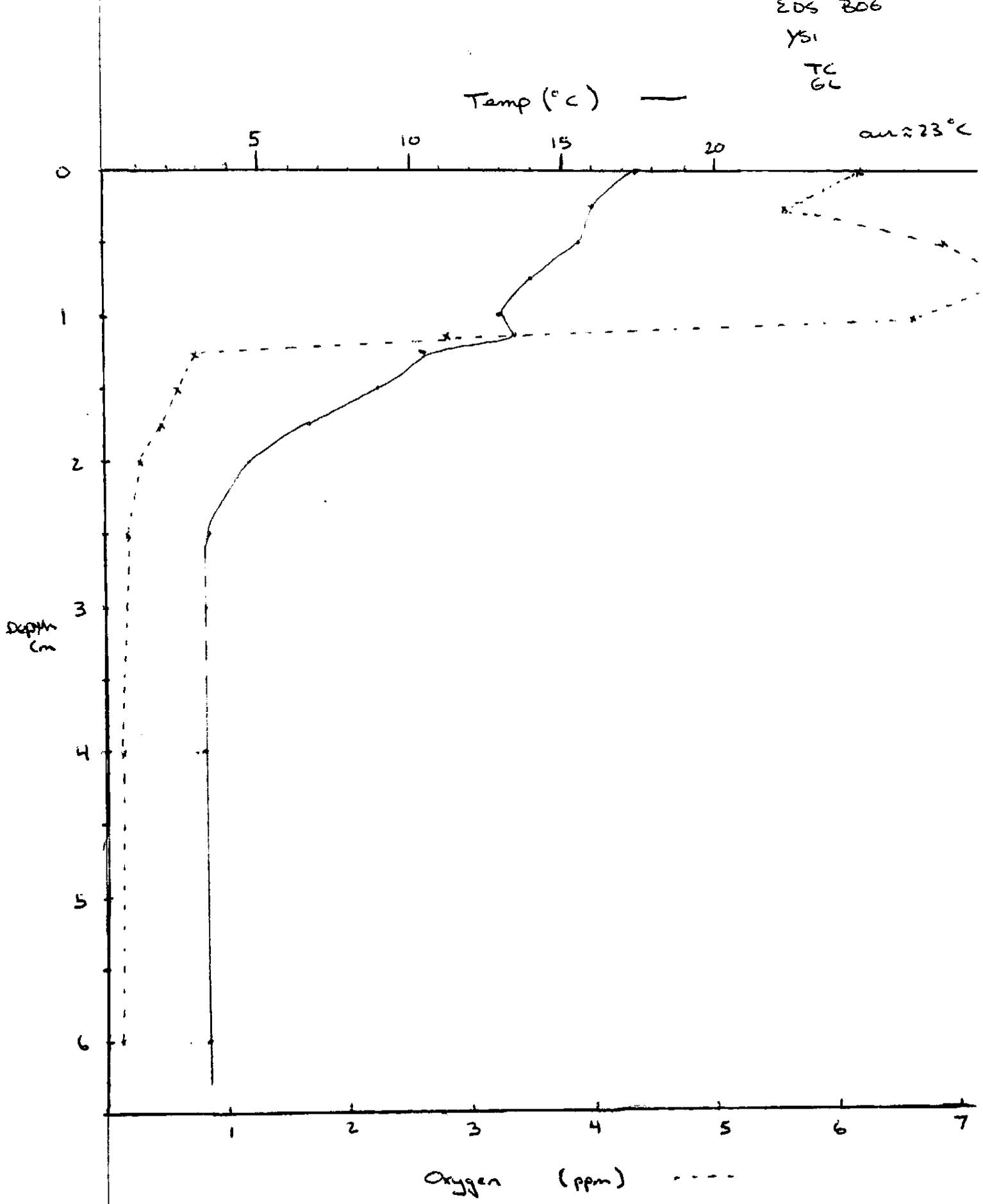
Ed's Bog

6/4/81
~ 9:00 am



Weather: bright sunshine, very calm
Surroundings: sphagnum, leatherleaf, tamaracks, black spruce, balsam fir. Very protected. Well developed, classic bog.

H_2O chemistry	Epilimnion	Bulge (3/4 m)	Hypolimnic
Acidity			
methyl orange	5	5	5
phenolphthalein	70	73	65
X Alkalinity	0	0	0
Apparent Color	10	20	20
True Color	5	10	10
X Calcium Hardness	8	8	8
X Mg Hardness	—	—	—
X Total Hardness	8	8	8
Nitrates	—	—	—
phosphates	NA	NA	NA
Specific Conductance	21	18	21
Sulfates	4	1	0
pH	5	5	5
secchi disc	1.3 m		
H_2S	—	—	present

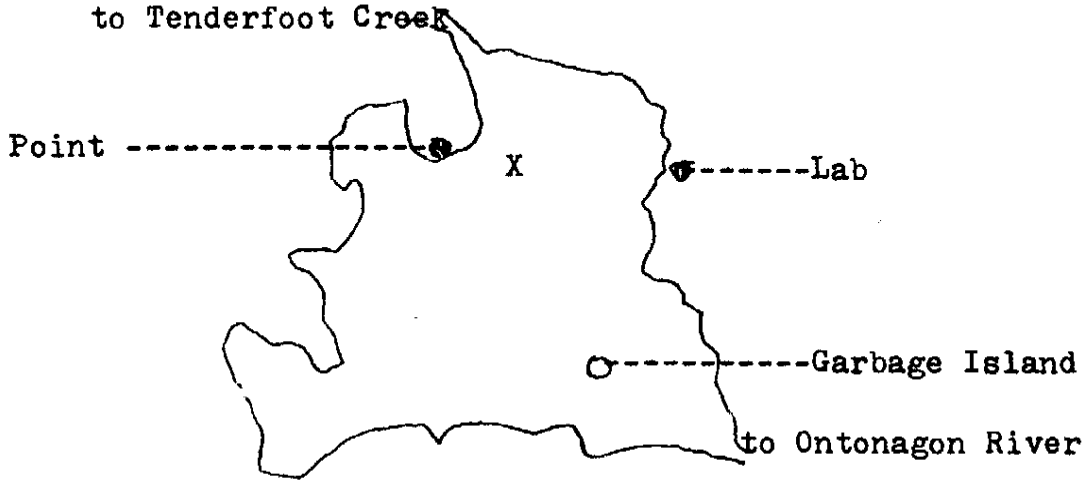

EOS 806
YSI
TC
GL
Temp (°C) ——
air ≈ 23°C
5
10
15
20
0
1
2
3
4
5
6
Depth cm
1
2
3
4
5
6
7
Oxygen (ppm) ----

Temperature and Oxygen YSI Data

Tenderfoot Lake 6/4/81 2:00 PM

Tim Cogan Greg Liebscher

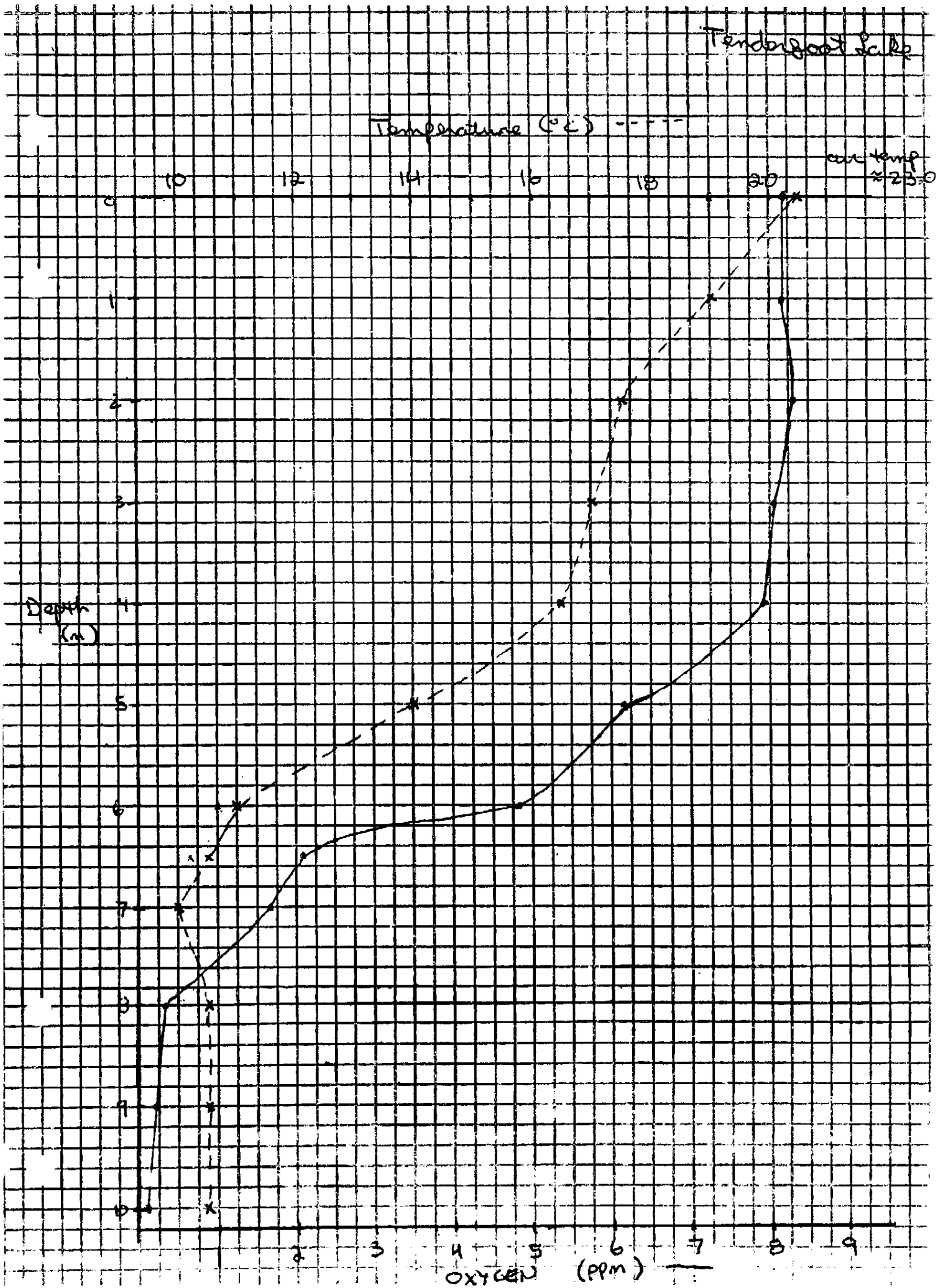
Depth (m)	Oxygen (ppm)	Temperature (^{o}C)
air	---	23.0
surface	8.2	20.5
1.0	8.2	19.0
2.0	8.3	17.5
3.0	8.1	17.0
4.0	7.9	16.5
5.0	6.2	14.0
6.0	4.8	11.0
6.5	2.1	10.5
7.0	1.7	10.0
*8.0	0.3	10.5
*9.0	0.2	10.5
*10.0	0.15	10.5



*-These recordings may actually be from the bottom of the lake since it was difficult to determine when the YSI probe was actually on the bottom.

Weather - sunny and not very windy.

X - recording site


Tenderfoot Lake
Temperature (°C)
10
12
14
16
18
20
air temp ≈ 23.0
0
1
2
3
4
5
6
7
8
9
Depth (m)
2
3
4
5
6
7
8
9
OXYGEN (ppm)