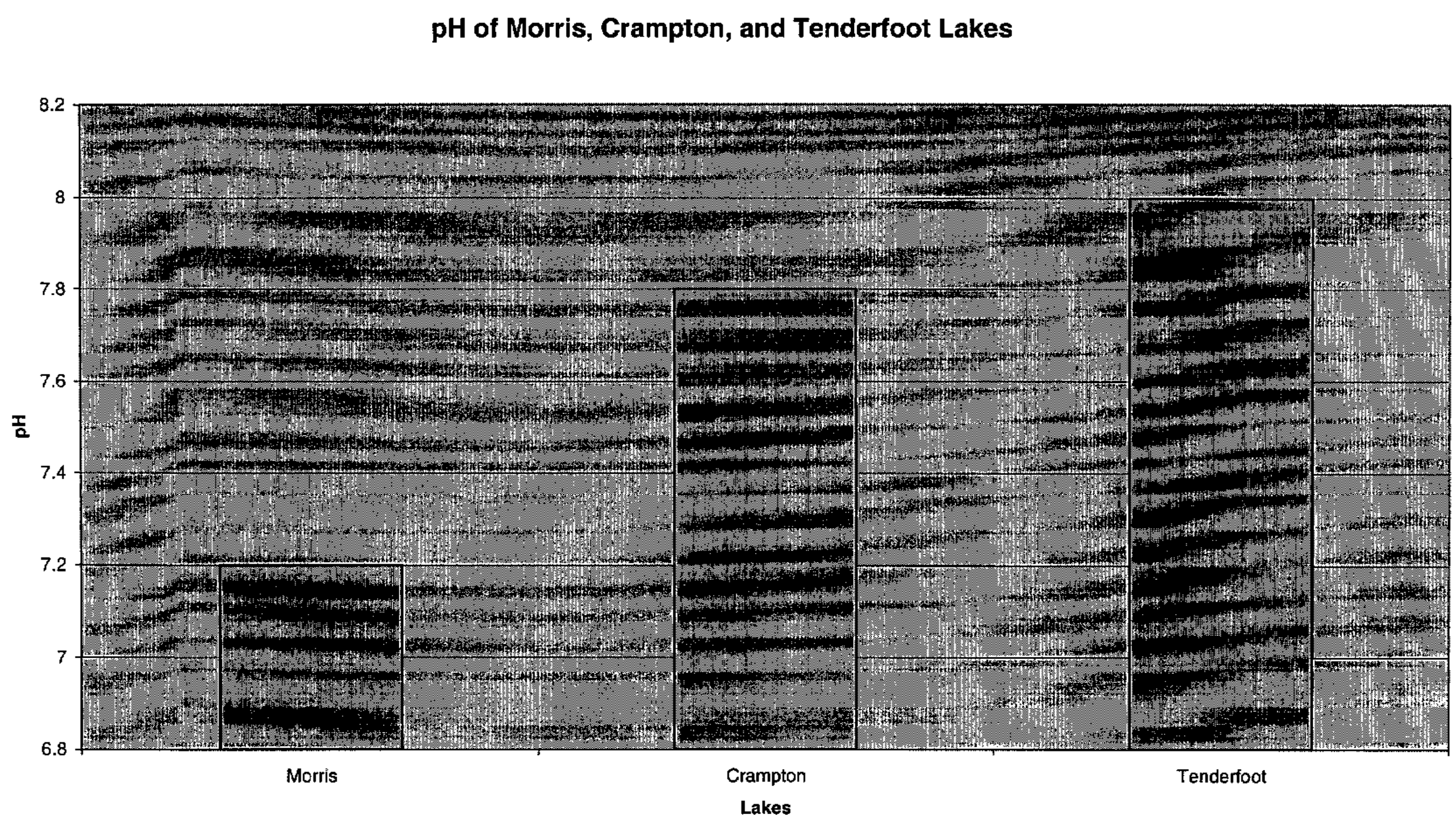


Graph 8: pH of Morris, Crampton, and Tenderfoot Lakes. pH was taken at the surface of the water in the middle of the lake. All measurements were made using a hand-held pH meter.

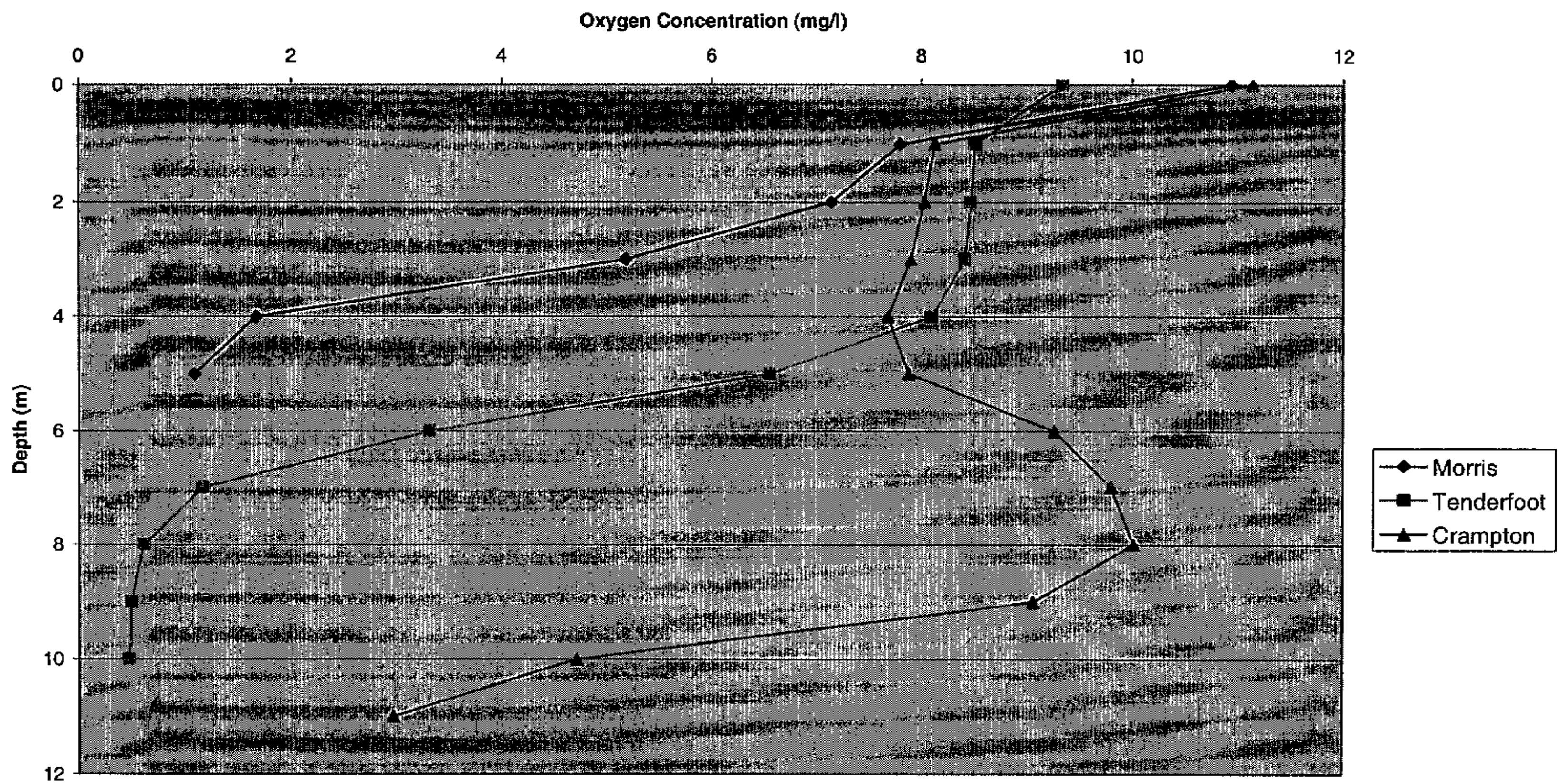
2a. **Oxygen Concentration (mg/l)**			
Depth (m)	Morris Lake	Tenderfoot Lake	Crampton Lake
0	10.94	9.34	11.14
1	7.8	8.51	8.13
2	7.14	8.47	8.03
3	5.18	8.41	7.9
4	1.66	8.1	7.68
5	1.08	6.55	7.88
6		3.31	9.26
7		1.15	9.8
8		0.6	10.01
9		0.49	9.06
10		0.47	4.71
11			2.96

2b. **% Oxygen**			
Depth (m)	Morris Lake	Tenderfoot Lake	Crampton Lake
0	100	100	100
1	92	98	95
2	76	96.5	94
3	31.4	95.2	91
4	15.6	88	90.5
5	9.7	45	92.6
6		23	96.5
7		9	93.4
8		5.7	89.3
9		4.9	68
10		4.5	27.7
11			19.9

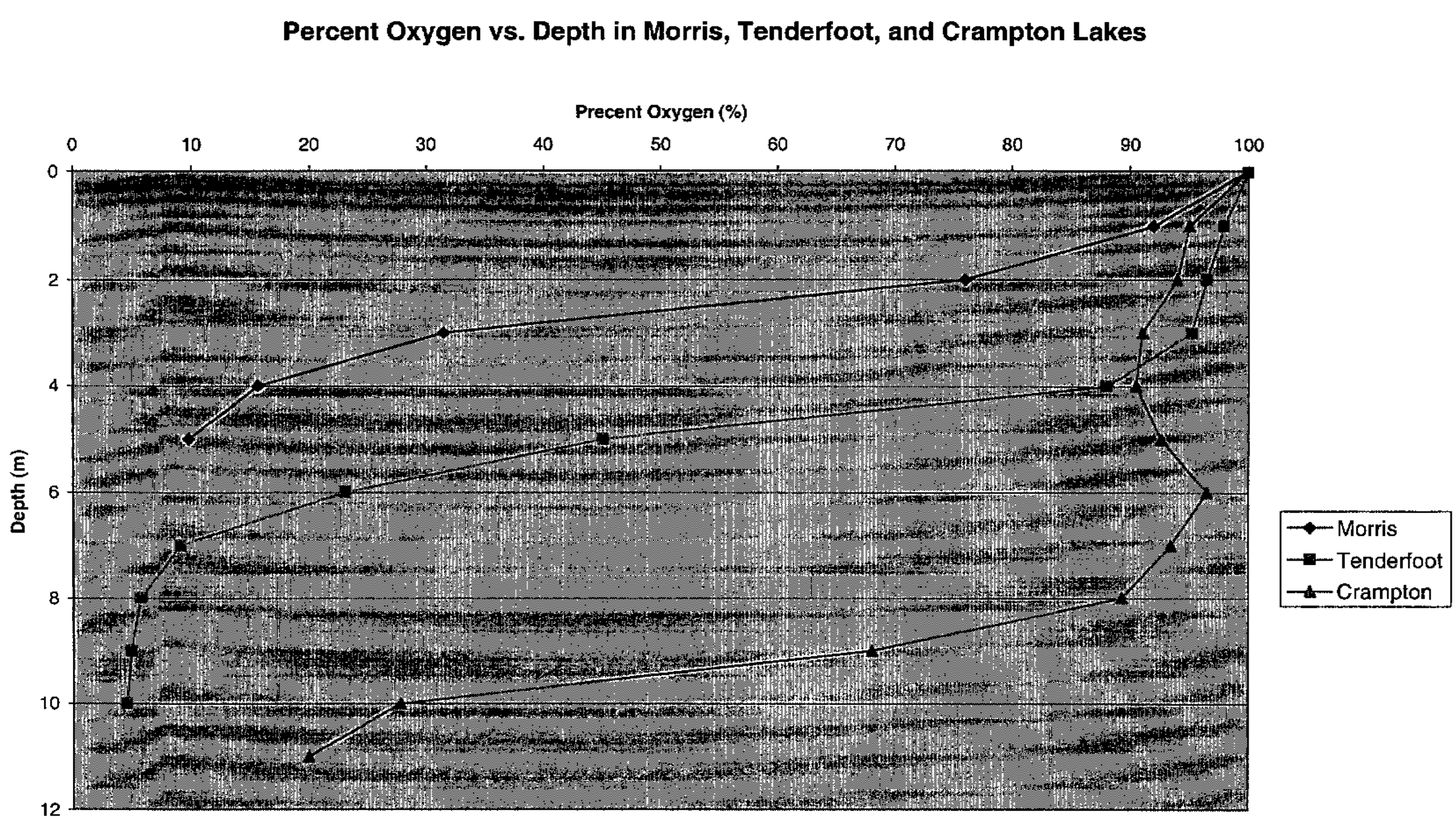
2c. **Temperature (°C)**			
Depth (m)	Morris Lake	Tenderfoot Lake	Crampton Lake
0	24	23.5	23.1
1	24	22.6	23.7
2	20.5	22.2	23.5
3	14.6	22	23.4
4	12.4	21.5	22.8
5	12.1	19.5	20.7
6		17	16
7		15.6	11.2
8		16	10.6
9		14.4	8
10		13.7	6.8
11			7.2

Figure 2: Oxygen and Temperature Data with Varying Depths. The concentration of oxygen (mg/l) is shown in 2a. In 2b, the % oxygen is shown. The temperature of the water is shown in 2c. See graphs 9-11.

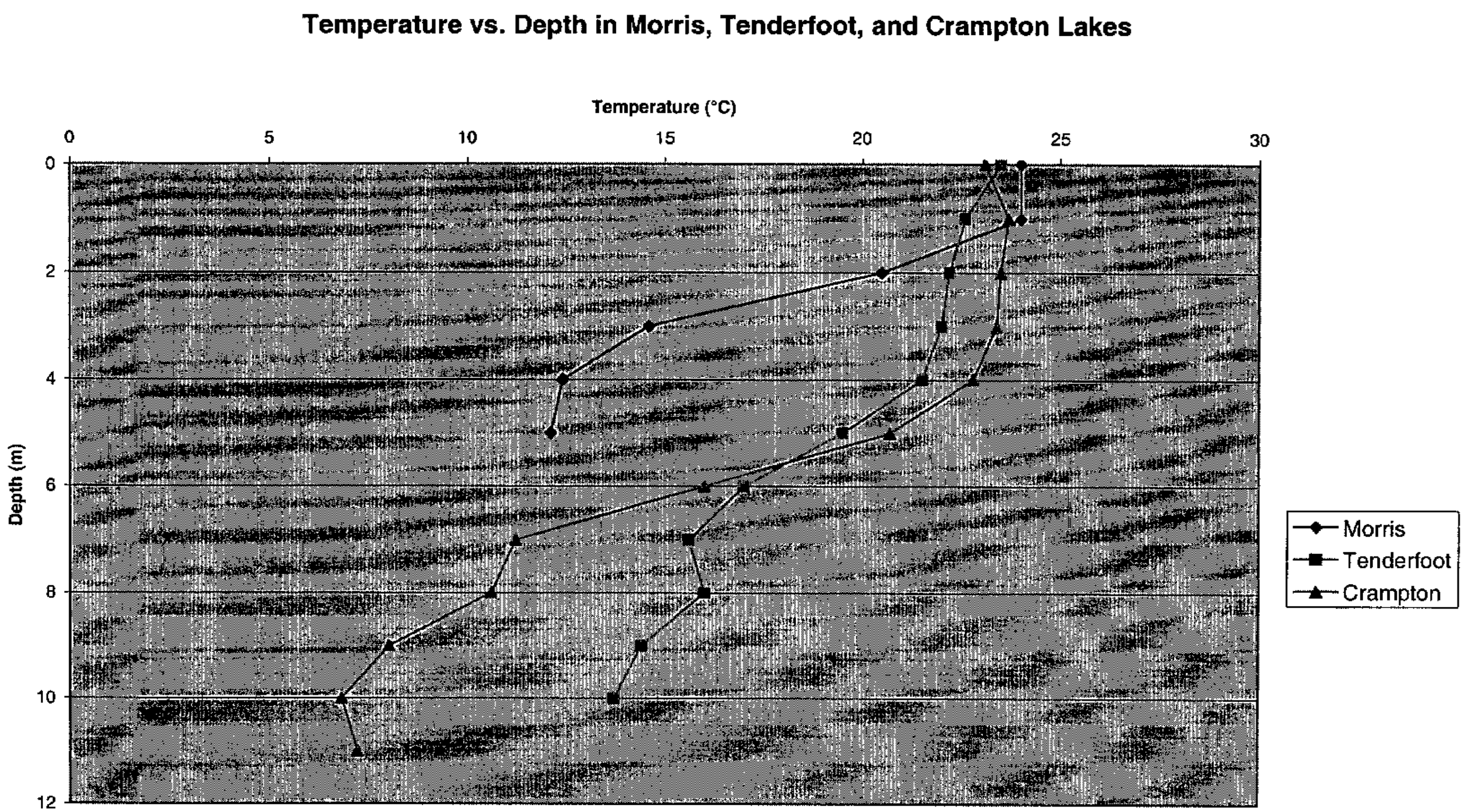
Oxygen Concentration vs. Depth in Morris, Tenderfoot, and Crampton Lakes



Graph 9: Oxygen Concentration vs. Depth in Morris, Tenderfoot, and Crampton Lakes. All measurements were taken using an oxygen meter with a cord marked in meter increments.



Graph 10: Percent Oxygen vs. Depth in Morris, Tenderfoot, and Crampton Lakes. All measurements were taken using an oxygen meter with a cord marked in meter increments.



Graph 11: Temperature vs. Depth in Morris, Tenderfoot, and Crampton Lakes. All measurements were taken using an oxygen meter with a cord marked in meter increments.

Morris Lake 6/12/01 and 7/12/01	
Scientific Name	**Common Name**
Acer rubrum	Red Maple
Alnus incana	Speckled Alder
Arethusa bulbosa	Swamp Pink / Dragon's Mouth
Asclepias incarnata	Swamp Milkweed
Brasenia schreberi	Water Shield
Calla palustris	Water Arum
Carex stricta	Sedge
Chamaedaphne calyculata	Leatherleaf
Cornus canadensis	Bunchberry
Equisetum fluviatile	Water-horsetail
Galium triflorum	Sweet-scented Bedstraw
Ilex verticillata	Winterberry
Iris versicolor	Blue Flag Iris
Kalmia polifolia	Bog-laurel
Larix laricina	Tamarack
Lemna minor	Lesser Duckweed
Lycopodium inundatum	Northern Bog Clubmoss
Najas flexilis	Northern Water-nymph
Nuphar variegatum	Yellow Water Lily
Nymphaea odorata	White Water Lily
Onoclea sensibilis	Sensitive Fern
Pontederia cordata	Pickerelweed
Potamogeton amplifolius	Large-leaved Pondweed
Potentilla palustris	Marsh-cinquefoil
Rubus pubescens	Dwarf Raspberry
Scirpus americanus	Threesquare Bulrush
Sphagnum spp.	Sphagnum Moss
Thelypteris palustris	Marsh Fern
Typha latifolia	Common Cattail
Vaccinium oxycoccos	Small Cranberry

Figure 3: Identified Plants in Morris Lake. Plant samples were collected on June 12th, 2001 and again on July 12th to assure blooming and mature growth of the plants making identification more complete and easier. Plants were taken from the margins of the lake including semi-terrestrial, emergent, and submerged plants. Submerged plants farther from the margins were not collected due to the depth of the lake and the difficulty in both seeing those plants through the colored water and reaching the plants.

Crampton Lake 6/13/01 and 7/12/01	
Scientific Name	**Common Name**
Acer rubrum	Red Maple
Alnus incana	Speckled Alder
Andromeda glaucophylla	Bog-rosemary
Bacopa rotundifolia	Water-hyssop
Brasenia schreberi	Water Shield
Calla palustris	Water Arum
Ceratophyllum demersum	Common Hornwort
Chamaedaphne calyculata	Leatherleaf
Cornus canadensis	Bunchberry
Drosera rotundifolia	Round-leaved Sundew
Galium tinctorium	Southern Three-lobed Bedstraw
Iris versicolor	Blue Flag Iris
Juncus effusus	Soft Rush
Ledum groenlandicum	Labrador Tea
Nuphar variegatum	Yellow Water Lily
Nyphaea odorata	White Water Lily
Onoclea sensibilis	Sensitive Fern
Pontederia cordata	Pickerelweed
Potamogeton amplifolius	Large-leaved Pondweed
Potentilla palustris	Marsh-cinquefoil
Sagittaria latifolia	Arrowhead
Scirpus americanus	Threesquare Bulrush
Scutellaria galericulata	Marsh Skullcap
Sparganium fluctuans	Burreed
Sphagnum spp.	Sphagnum Moss
Thelypteris palustris	Marsh Fern
Typha latifolia	Common Cattail
Vaccinium macrocarpon	Cranberry
Vaccinium oxycoccos	Small Cranberry
Vallisneria americana	Wild Celery

Figure 4: Identified Plants in Crampton Lake. Plant samples were collected on June 13th, 2001 and again on July 12th, 2001 to obtain optimal blooms and plant growth making identification easier. Semi-terrestrial, emergent, and submerged plants were taken from the margins of the lakes, but submerged plants near the farther toward the middle of the lake were not collected due to the depth of the lake and the difficulty of obtaining those plants.

Tenderfoot Lake 6/26/01	
Scientific Name	**Common Name**
Asclepias incarnata	Swamp Milkweed
Calla palustris	Water Arum
Ceratophyllum demersum	Common Hornwort
Chamaedaphne calyculata	Leatherleaf
Elodea canadensis	Common Waterweed
Equisetum arvense	Common Horsetail
Iris versicolor	Blue Flag Iris
Lemna minor	Lesser Duckweed
Lythrum salicaria	Purple Loosestrife
Myosotis scorpioides	Forget-me-not
Myriophyllum sibricum	Common Water-milfoil
Nuphar variegatum	Yellow Water Lily
Nymphaea odorata	White Water Lily
Osmunda regalis	Royal Fern
Pontederia cordata	Pickerelweed
Potamogeton amplifolius	Large-leaved Pondweed
Potamogeton illinoensis	Illinois Pondweed
Sagittaria latifolia	Common Arrowhead
Solanum dulcamara	Bittersweet Nightshade
Thelypteris palustris	Marsh Fern
Typha latifolia	Common Cattail
Vallisneria americana	Wild Celery

Figure 5: Identified Plants in Tenderfoot Lake. Plant samples were collected on June 26th, 2001. Samples were only taken once because at this time, most plants were blooming and identifiable. Plant samples were taken from the margins of the lake including semi-terrestrial, emergent, and submerged. Submerged plants away from the margins of the lake were not collected due to the depth of the lake and therefore the difficulty involved in seeing them on the bottom and reaching them.

Discussion

The water chemistry data gathered could indicate much about the variety and abundance of plants that can be found in the specific lake tested. The size, water clarity, pH, and shape can also affect plant types and amounts. The data collected from the three lakes show limited differences that could explain the differences in plants found in the lakes. When discussing water chemistry, only the data from shallow water is referenced because very few, if any, plants were taken from deep waters. The data for deep water, however, are shown in the graphs as compared to shallow waters.

Morris Lake

Morris Lake is the smallest of the three lakes surveyed. It has a surface area of approximately 12 acres, and it is a shallow lake ("University of Notre Dame Environmental Research Center"). The water is quite colored and dark. Our secchi disk depth was 1.375 m suggesting little light penetration. This would affect the number of plants growing near the bottom of the lake. There are most likely few plants living deep in the water where little light is able to penetrate. However, we were not able to test this hypothesis as we were unable to collect plants at the bottom of the lake.

Oxygen and temperature gradients were found to be similar to expected results. The amount of oxygen and the temperature decreased with increasing depth. These characteristics cause fewer plants to grow in greater depths, as they have to exist in colder and conditions and complete needed processes using less oxygen.

In the shallow water, pH was found to be 7.2, and the alkalinity measured 100 mg/l $CaCO_3$. The pH value corresponds well with a value of 7.5 found in previous research ("University of Notre Dame Environmental Research Center"). The levels of phosphorus among the three lakes were quite similar. The value for Morris Lake was 0.01 mg/l PO_4^{-3} PV. The similarities in the values of the three lakes suggest that phosphorus limitation is not causing differences in plant abundance or species among the lakes. The sulfide level in Morris Lake was the highest of the three at 0.008 mg/l S_2^-. Sulfide is rarely a limiting factor in plant growth, so this value does not clearly explain differences in plant growth. Nitrate (0.6 mg/l NO3- NMR) and nitrogen (0.87 mg/l NH3-Ness) were highest in Morris Lake than the other two lakes sampled. This number may suggest that more plants are able to grow in this lake. Nitrogen is sometimes found to be a limiting nutrient (though less often than phosphorus), so a greater abundance of nitrogen would allow more plants to grow. Iron concentrations in all three lakes were very low, and in Morris Lake, the recorded value was 0.0 mg/l Fe^{2+}. It is improbable then that iron has a great effect on plant growth in the lakes.

Some of the plants found in Morris Lake that were not found in the other two lakes sampled included *Kalmia polifolia*, *Rubus pubescens*, *Lemna minor*, *Arethusa bulbosa*, *Galium triflorum*, and *Ilex verticillata*. Many of these species, especially *Kalmia polifolia* and *Arethusa bulbosa* were found in the marshy areas surrounding the lake. In these areas, *Sphagnum* mosses were also found, suggesting that these areas may have been more acidic and bog-like than the main waters of the lake. Some of the plants found here are characteristic of the acidic, nutrient-poor environments of bogs, and these plants can signal changes in water qualities.

Crampton Lake

Crampton Lake is somewhat bigger than Morris Lake with 72 acres of surface area ("University of Notre Dame Environmental Research Center"). The water of this lake is somewhat clearer (we found a secchi disk depth of 2.25 m), and this allows more light to penetrate to deeper depths, supporting the growth of plants in deeper water. The lake is fairly deep in areas, and has an island in the middle from which plant samples were also taken for this survey.

The oxygen and temperature gradients again reflected what was expected. Deeper water contained less oxygen and was colder. This environment would support fewer plants than the warmer, more oxygen-rich shallow waters. This could not be tested, as we could not collect plants from the bottom or deep waters of this lake.

The pH of Crampton Lake was measured at 7.8, but previous literature states that the pH is approximately 6.0 ("University of Notre Dame Environmental Research Center"). The alkalinity that we measured was 40 mg/l $CaCO_3$. This number more closely corresponds to the alkalinity in the literature, so it is possible that our measurement is inaccurate. The lower pH can also be reflected in the plants found in the lake. As stated before, phosphorus was not significantly different from the other two lakes with a measurement of 0.01 mg/l PO_4^{-3} PV. Sulfide was lower than Morris Lake at 0.002 mg/l S_2^-, but this nutrient does not seem to have a significant effect on plant populations. Nitrate and nitrogen were lower than Morris Lake with values of 0.1 mg/l NO_3^- NMR and 0.21 mg/l NH_3^- Ness, respectively. These lower values may have had some limiting effect on the plant abundance and variety compared to Morris Lake, but approximately the same numbers of species were collected from these two lakes. Iron was measured at 0.0 mg/l Fe^{2+} suggesting again that iron does not have a significant effect on plant growth or limitation.

Plant species found in Crampton Lake but not found in the other sampled lakes included *Andromeda glaucophylla*, *Ledum groenlandicum*, and *Drosera rotundifolia*. These species are characteristic of bog-like conditions in which nutrient levels are low and the pH is also low. *Andromeda glaucophylla* and *Ledum groenlandicum* are commonly found in bogs and are adapted to survive in acidic and nutrient-poor environments. *Drosera rotundifolia* is a sundew, an insectivorous plant. It traps insects on sticky hairs, breaks them down, and uses their nutrients for life processes. These plants are very common in conditions lacking nutrients, and they have adopted this insect-trapping mechanism to supplement their nutrients.

Tenderfoot Lake

Tenderfoot Lake is the largest lake on the property with a surface area of 442 acres, and it is quite deep ("University of Notre Dame Environmental Research Center"). The water is very extremely clear, and we found a secchi disk depth of 4.5 m. The clear water allows much light to penetrate to deeper waters, allowing more plants to grow at greater depths in this lake than darker lakes, such as Morris Lake.

Oxygen and temperature gradients were similar to the other lakes with the temperature and oxygen concentrations declining with increasing depth. Because this was the deepest lake of the three, the temperature got quite cold near the bottom reaching only 7°C. With little oxygen and cold temperatures such as these at great depths, plant growth would be limited.

The pH of Tenderfoot Lake was higher than the other lakes at 8.0. The alkalinity was 80 mg/l $CaCO_3$. The more basic pH and relatively high alkalinity suggests that plants such as those found in Crampton Lake would not be found here. Phosphorus concentration was similar to those of the first two lakes with a value of 0.02 mg/l PO_4^{-3} PV. The sulfide level was the same as that of Crampton Lake at 0.002 mg/l S_2^-. Nitrate and nitrogen measurements were 0.2 mg/l NO_3^- NMR and 0.07 mg/l NH_3^- Ness, respectively. While nitrate levels were close to those of Crampton Lake, the nitrogen concentration was considerably lower than the other two lakes. This may suggest smaller numbers of plants in Tenderfoot Lake if nitrogen is a limiting factor. Iron concentrations were very low with a value of 0.01 mg/l Fe^{2+}, again suggesting that iron has a small effect on plant growth.

There were fewer plants overall collected from Tenderfoot Lake suggesting that productivity of this lake is lower than the other lakes. The size of the lake, however, may have affected this number as it was harder to cover the entire margin of the lake and collect the greatest number of species possible. The plants found only at this site were mostly semi-terrestrial plants found at the margins of the lake. Tenderfoot Lake had a very clear shoreline in comparison to the other lakes in which the margins were somewhat marshy and undefined. The species unique to Tenderfoot included *Solanum dulcamara*, *Myosotis scorpioides*, and *Osmunda regalis*. These plants were found at the edges of the water, sometimes with stems or branches immersed in water. The chemistry of the water most likely had less to do with the presence of these plants than the topography and physical characteristics of the lake.

Conclusion

This study was done to determine the characteristics and chemistry of three lakes to determine the reasons for differences in plant communities, if any. Water chemistry was similar among the three lakes, with the exceptions of pH and nitrogen concentrations. Lakes with a lower pH had distinct plant species that could adapt to those conditions, while lakes with higher concentrations of nitrogen seemed to support more plants. The topography of the lakes seemed to affect plant growth as well. On Tenderfoot Lake, where there was a distinct shoreline, more semi-aquatic plants were found than in the other lakes were the shoreline merged into a marshy area. Overall, there were not extremely large differences in the three lakes on the UNDERC property. Many of the same plants were found in all three lakes. To find significant differences, lakes in more diverse environments must be studied. Also, more diversity would be found in a study between different wetlands such as a bog and a stream.

Acknowledgements

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