Tenderfoot Lake & Tender Bog:

Aquatic Biology and Chemistry

(UNDERC'82)

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Introduction

Deep in the North Woods of Michigan and Wisconsin, in a region carved out by glaciers some 12,000 years ago, lies the University of Notre Dame Environmental Research Center (UNDERC). The area is blanketed by a predominantly second-growth forest of Aspen, Birch, Pine, Swamp Conifer, and Red Maple (last heavy logging occured between 1900 and 1902). A great variety of wildlife thrives within this forest, including bears, deer, coyotes, muskrats, mosquitoes, porcupines, beavers, snakes, frogs, eagles, loons, wood ducks, priests, professers, students, a few dusty vans, and an occasional timber wolf. The center of UNDERC lies at 46°13' North by 89°32' East, with an altitude ranging between 536 and 506 m, and an area of about 2833 ha. Twenty-seven lakes on the property account for 150 ha of surface area, with an additional 303ha in the form of three lakes which border the property. Two streams, a few small bogs,,and many vernal ponds are also located throughout the area. Following is a general description, data report(physical/chemical/plankton), and discussion of the limnology of two of these bodies of water: Tenderfoot Lake, a large lake bordering UNDERC; and a neighboring kettle lake known as Tender Bog.

II. Tenderfoot Lake

A. General Description

Tenderfoot Lake is the largest lake on the UNDERC property (surface area: 182 ha). It is a drainage lake with five small bays, two islands, an established inflow (Palmer Lake via the ~~Ontagon~~ River), and an established outflow in the form of Tenderfoot Creek(a wide and fairly sluggish stream, much protected by surrounding trees, it supports a large quantity of aquatic macrophytes). Large weed beds occur throughout the lake, including: water milfoil, waterweed, cattail, duckweed and fragrant waterlily. The surface of the lake generally has a slight chop except in the early morning and at dusk (at which times the water is smooth). Rocks covered with a fine brownish silt are visible on the lake bottom near shore. Tenderfoot Lake is surrounded by a mixture of conifers and hardwoods which grow right to the water's edge. The lake supports a number of fish, including muskellunge, northern pike, walleye, yellow perch, crappie, sunfish, rock bass, large- and smallmouth bass. The depth of the lake exceeds 8 meters in some places, and has a gradual thermocline ranging between 4.5 and 7 meters below the surface. Oxygen drops off sharply below 4.5 meters, and H_2S is absent.

II. Tenderfoot Lake

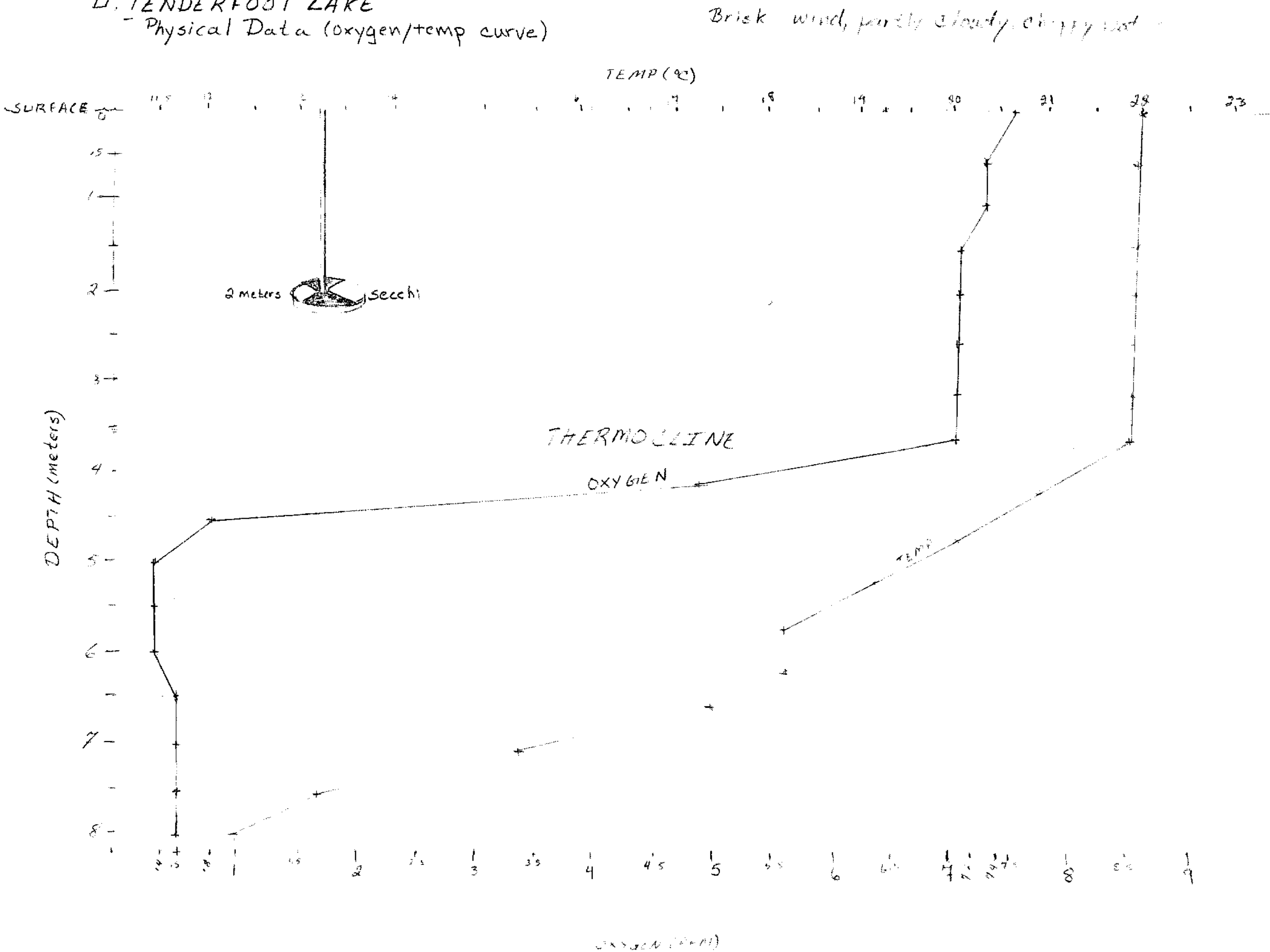
Where A + B located? depth samples taken?

B. Chemical Data

		EPILIMNION	HYPOLIMNION
Acidity:			
Methyl Orange (mg/l)		0	0
Phenolpthalein(mg/l)	A	10	10
	B	10	10
Alkalinity (mg/l):	A	50	40
	B	40	40
Hardness:			
Calcium (mg/l):	A	30	40
	B	30	30
Magnesium (mg/l):	A	30	10
	B	20	20
Total (mg/l):	A	60	50
	B	50	50
Nitrates (mg/l):		0.9	0.8
Total Phosphates (mg/l):	A	0.05	0.05
	B	0.05	0.05
pH:		7.9	7.4
Secchi Disc (meters):		2	
Specific conductance (umhos):		70	72
Sulfate (mg/l):		0	0

II. TENDERFOOT LAKE

- Physical Data (oxygen/temp curve)



II. Tenderfoot Lake

C. Plankton Data

Sedgewick-Rafter Cell contains 1ml water sample. 8.5 fields ≤ the width of the cell. 0.5 of one longitudinal sweep was counted.

	#'s counted
Ceratium hirundinella	187
Volvox (colonies of)	126
Desmidium	108
Dinobryon sertularia (colonies of)	96
Asterionella (colonies of)	67
Fragilaria (colonies of)	43
Keratella cochlearis	43
Anabaena (colonies of)	35
Aphanizomenon (colonies of)	11
Chrysoperlla	8
Daphnia dubia	7
Asplanchnapus	7
Asplanchna	3
Polyarthra	3
Vorticella (colonies of)	3
Cyclops	3
Diaptomous	2
Nauplius	2
Bosmina longirostris	2
Pediastrum duplex	2
Kellicotia longispina	1
Chaetonotus sp.	1

III. Tender Bog

A. General Description

Tender Bog is a small kettle bog in the midst of a thick coniferous forest. An extensive *Sphagnum* mat surrounds an open water surface area of about .96ha. The mat supports a variety of plants, including Indian Pipes, pitcher plants, and dense clusters of bushes (blueberry?). The surface of the water is smooth at all times, and appears black. Tender Bog is between 12 and 15meters deep, and is drained by a narrow rivulet through the southwest corner of the mat. The thermocline is between 1 and 2 meters below the surface, and there is little oxygen below .6 meters. H_2S is present in the hypolimnion. There is no evidence of a fish population in Tender Bog.

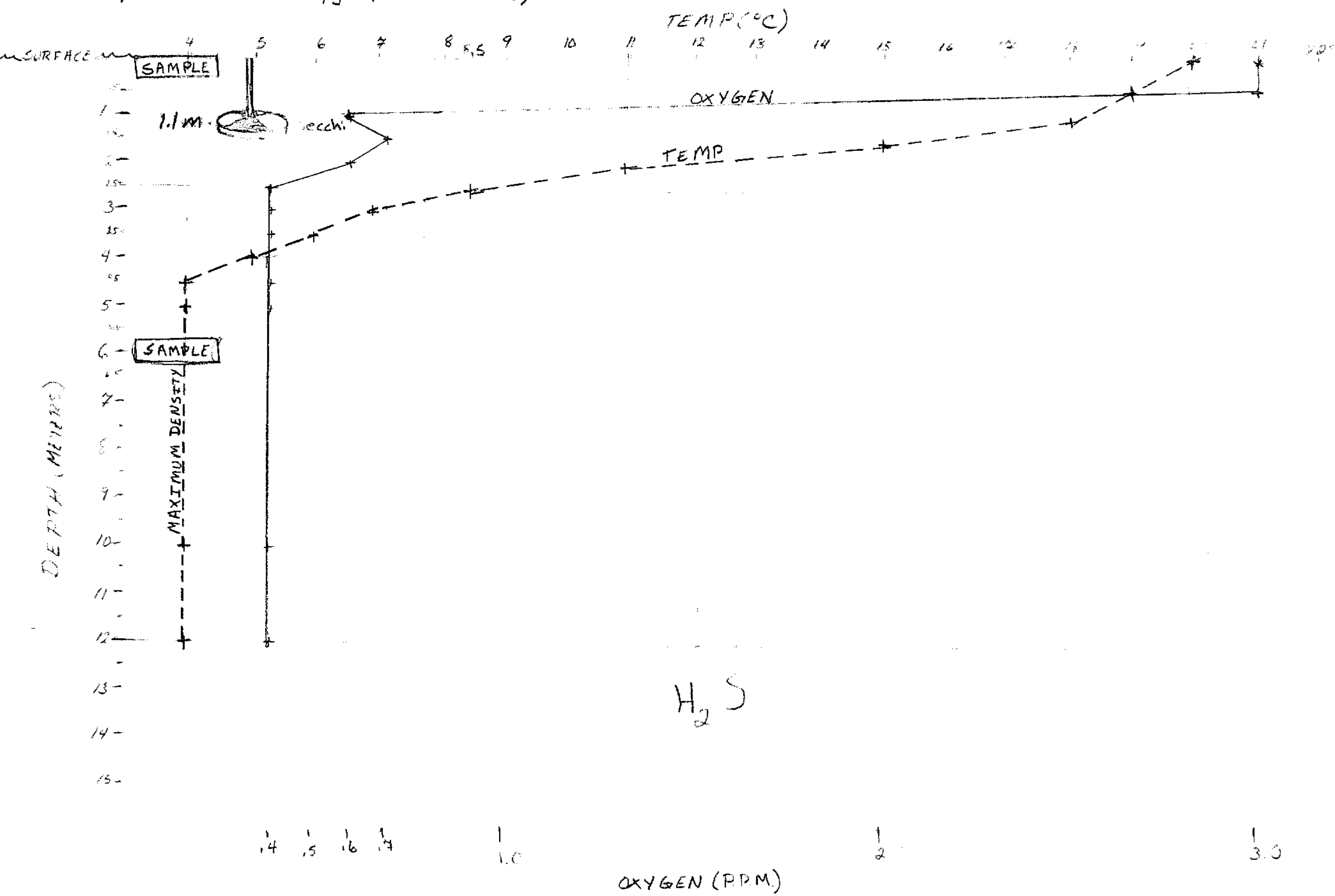
III. Tender Bog

B. Chemical Data

		EPILIMNION	HYPOLIMNION
Acidity:			
Methyl Orange(mg/l):	A	40	30
	B	40	50
Phenolpthalein(mg/l):	A	30	50
	B	30	50
Alkalinity(mg/l):		0	0
Hardness:			
Calcium(mg/l):		6.5	6.5
Magnesium(mg/l):		6.0	2.5
Total(mg/l):		12.5	9
Nitrates(mg/l):		.005	.005
pH:		4.0	4.3
Secchi Disc(meters):		1.1	
Specific Conductance(umhos):		25	27
Sulfate(mg/l):		1.5	1
Total Phosphates(mg/l):		.02	.01

III. TENDER BOG, OVERCAST, RAIN THREATENING.

B. Physical Data (Oxygen/TEMP curves)



III. Tender Bog

C. Plankton Data

Sedgewick-Rafter cell contains 1 ml water sample. 8.5 fields = the width of one cell. 3 longitudinal sweeps were counted.

	#'s counted
Keratella cochlearis	533
Desmidium	122
Bosmina longirostris	48
Peridinium tabulatum	39
Cyclops	8
Staurastrum	4
Pinnularia	2
Aphanizomenon (colonies of)	2
Fragilaria (colonies of)	1

IV. Discussion

A. Chemistry

The seasonal changes in a lake (or lack there of), govern to a large degree the water chemistry of that lake. Temperature stratification, once established, can involve a very abrupt thermocline. The thermocline forms the interface between epilimnion (higher temperature, lower density) and hypolimnion (lower temperature, higher density). Maximum water density occurs at 4 degrees celcius. This stratification effectivly prevents the mixture of upper and lower layers of water, and thus the (EPILIMNION) upper layer (with producing phytoplankton) is cut off from recycled nutrients from the lake bottom, while the (HYPOLIMNION) lower layer (with consuming and decomposing organisms) is cut off from a ready oxygen supply. "Full circulation occurs only at or near the temperature of maximum density, and this occurs only twice a year. (Spring and late Fall)" (Russell-Hunter, 1970, p.129). Seasonal overturn does not occur in bogs, creating a permanantly anoxic hypolimnion and unproductive epilimnion. Formation of H_2S in the waters of the hypolimnion is a positive indication of extremly low oxygen content. H_2S is strongly evident in the hypolimnion of Tender Bog. "In larger lakes which are relatively shallow, or which have their underwater contours interrupted by many islands or submerged banks, temperature stratification is liable to be more transitory." (Russell-Hunter 1970, p.131) Because of this, Tenderfoot Lake lacks H_2S, and has a much less abrupt oxygen curve than Tender Bog.

High levels of acidity are characteristic of bogs, due to Uronic acid produced by the *Sphagnum* mat, and humic acids produced by conifers. "...'humic acid'. The important biological effect of this chemical condition is to reduce the rate of, or even prevent entirely, the process of bacterial breakdown which, in other lakes, result in the return of plant nutrients to the water from dead organic materials on the bottom." (Russell-Hunter 1970) Thus it appears that even if Tender Bog were to turn over, productivity would not be enhanced much due to the highly acidic conditions.

Alkalinity or Buffer capacity of a lake is due to decomposition producing excess calcium. This calcium complexes with CO_2 (excess CO_2

due to low light and therefore low photosynthesis) to produce $CaCO_3$. (Russell-Hunter 1970) Decomposition is almost non-existant in Tender Bog due to the constant thermocline, low oxygen, highly acidic conditions of the water, and is therefore also low in $CaCO_3$. The lack of CaCO3 in any quantities in Tender Bog can also be attributed to ion exchange system of *Sphagnum* moss (uptake of available Calcium ions in exchange for H^+ ions). In Tenderfoot Lake, calcium is released by decomposition to be recycled during Spring and Fall turnovers. "Calcium is a limiting factor for bacterial decomposition, thus reducing nutrient turnover. Because *Sphagnum* ties up available Ca^{++}, decomposing bacteria cannot survive, and organic material piles up on the bog bottom." (Russell-Hunter 1970) OK

The total hardness of Tender Bog is substantially lower than that of Tenderfoot Lake. This is typical. "Generally speaking, extremely humic and most extremely oligatrophic lakes are poor in calcium salts, while many -- though certainly not all -- eutrophic lakes have hard water."(Russell-Hunter 1970) Judging by the much greater total hardness of the water of Tenderfoot, as compared to that of Tender Bog, Tenderfoot could be classified as somewhere between Oligatrophy and Eutrophy.

Lack of magnesium could also be a limiting factor in the productivity of Tender Bog. "Magnesium is required universally by chlorophyllous plants as the magnesium porphyrin component of the chlorophyll molecules, and as a micronutrient in enzymatic transformations of organisms, especially in transphosphorylations of algae, fungi, and bacteria." (Wetzel 1975, p.157)

Nitrogen levels are low in Tender Bog as compared to Tenderfoot Lake. This is probably due to: "Losses of nitrogen occur(ing) by... permanent loss of inorganic and organic nitrogen-containing compounds to the sediments."(Wetzel 1975, p.187)

The relatively lower amounts of phosphates in Tender Bog as compared to Tenderfoot Lake is probably also due to the lack of decomposition and turnover in Tender Bog. Colloids of ferric iron may also contribute to a further reduction of nutrients by "Locking-up" phosphates at the bottom of this dystrophic lake.(Russell-Hunter 1970) The small amounts of phosphorus in comparison to other nutrients in Tenderfoot Lake is compensated for by rapid recycling of this key nutrient. "...phosphorus is least abundant(in comparison to other major nutritional components of biota), and yet most commonly limits biological productivity. ... phosphorus, most of which is within the particulate phase of living biota, primarily algae. ...Losses of colloidal and particulate phosphorus fractions are replaced by regeneration of solubilized phosphorus fractions from decomposition at depth, by release of phosphorus from sediments."(Wetzel 1975).

The Secchi Disc readings for both lakes is rather low. The darkness of the water in Tender Bog is most likely due to tall trees cutting down available sunlight, the overcast sky on the day the reading was taken, and the staining effect of humic acid. Tenderfoot lake has a thriving and large population of phytoplankton, this population effectively obscurs the water, causing low secchi readings.

The color of Tenderfoot Lake is due, once again, to the seasonal turnovers and low acidity that favors decomposing, calcium circulating bacteria. "Calloidal $CaCO_3$ (common to very hardwater lakes), scatters light in the greens and blues and gives these waters a very characteristic color appearance."(Wetzel 1975, p.61) The dark, tea-colored water of Tender Bog , with a greater apparent color at depth owes its hues to the characteristically high acid, undisturbed stratification conditions typical of bogs. "With increasing concentrations of organic matter, especially humic compounds, an increase (of emitted scattered light)in yellows and reds. It is not infrequent for color to rise with depth in strongly stratified lakes due to dissolved organic and ferric compounds near the sediments."(Wetzel 1975, p.61)

IV. Discussion

B. Biology

The number of species, and total biomass of each species of living organisms found within a given lake is dependent on, and reflects, the chemistry of that lake. Photosynthetic (producing) organisms are dependent on light, therefore the transparency of water dictates the maximum depth at which photosynthetic organisms can descend and still produce. "Secchi disk transparency is essentially a function of the reflection of light from its surface, and is therefore influenced by both the absorption characteristics of the water and of its dissolved particulate matter. ...(in a) very generalized way (the Secchi) has been used to estimate the approximate density of phytoplankton populations." (Wetzel 1975, p.63) A 1% incident light allows for photosynthesis. Secchi reading X 2 is the depth of 1% incident light. Therefore, in Tender Bog (Secchi 1.1 meters), photosynthetic organisms cannot produce below the depth of 2.2meters, whereas in Tenderfoot Lake, photosynthesis can occur as deep as 4 meters below the surface.

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{} C_6H_{12}O_6 + 6O_2 + e^-$$

Low productivity leaves oxygen present on the bottom(Wetzel 1975), however, Tender Bog is firmly stratified, thus sealing off oxygen to the hypolimnion. Under these conditions, any productivity at all will eventually lead to anoxic conditions in the bottom of the bog. The highly acidic condition of bog water also plays its part in reducing productivity, either directly, or through resulting lack lack of nutrients(due to absence of decomposing bacteria). "...humic acid waters are essentially infertile, and the faunal productivity of dystrophic lakes is very low."(Russell-Hunter 1970, p. 123)

Temperature stratification, disrupted by seasonal overturn of nutrients is vital to the continuing productivity of a lake. "While the thermocline persists, inorganic nutrients liberated by bacterial action in the bottom waters of the lake cannot become available to the green plants of the...upper layers of the epilimnion. Only the Spring and Autumnal overturns can recirculate nutrients at or near the lake bottom into the water bathing the living primary producers." (Russell-Hunter 1970)

Diatoms are the primary producers in many lakes. Silica is a limiting factor, as is light and nutrient availability. Tenderfoot supports a great variety and abundance of diatoms. The number of diatom species, and particularly the number (biomass) of diatoms, is markedly low in Tender Bog. A photosynthetic organism, Ceratium hirundinella is the most abundant organism in Tenderfoot Lake. In Tender Bog, on the other hand, the most abundant species of plankton is the consumer Keratella cochlearis. The success of Ceratium , along with the high numbers of other producers such as; Volvox, Desmidium, Dinobryon, and Asterionella in Tenderfoot Lake is directly due to the availability of sunlight and nutrients for photosynthetic production. These producers, in turn support a host of primary consumers in more limited quantities(ie - Daphnia dubia, Polyarthra, Diaptomus, Bosmina longirostris, etc.) Tender Bog, with its dark waters, overhanging trees, high acidity, and lack of seasonal overturn, supports a more limited variety and total mass of photosynthetic organisms. The largest producing group, Desmidium, is far out-numbered by the consuming rotifer Keratella cochlearis in Tender Bog. The amount of Desmidium in Tenderfoot Lake is aproximatly six times greater than the amount found in Tender Bog. The fact that Tender Bog supports over twice the number of Keratella cochlearis than does Tenderfoot Lake, is possibly due to a high acid tolerance level built into the physiology of the rotifer, (reducing competition from other species), together with a ready food supply in the form of insect larvae.

Fish are precluded from the acidic water of Tender Bog, with the possible exception of the mud minnow (Umbra limi) which will venture down to anaerobic areas for short periods of time. Tenderfoot Lake in contrast, supports a diverse population of fish including, muskellunge, northern pike, walleye, yellow perch, crappie, sunfish, rock bass, and large- and smallmouth bass. This abundance, and most particularly the wide diversity of species of organisms found in Tenderfoot Lake is characteristic of a trophic level somewhere between Oligatrophy and Eutrophy. "...late meta, early eutrophic lakes have the greatest diversity of organisms, whereas extremely eutrophic lakes have a reduction in diversity, although the numbers are still great..." (Helenthall lecture, UNDERC 1982) In contrast, Tender Bog, with its acid water, low productivity, and Sphagnum mat, is a typical dystrophic lake on its way to becoming part of the forest floor...

...deep in the North Woods of Michigan!!!

Bibliography

Greene, R. W.; Dept of Biology University of Notre Dame, Notre Dame, IN 46556: A Guide to U.N.D.E.R.C. -- University of Notre Dame Environmental Research Center.

Russell — Hunter, W.D.; Aquatic Productivity: an introduction to some basic aspects of biological oceanography and limnology, Syracuse University and the Marine Biological Laboratory, Woods Hole. Collier - Macmillan Canada, Ltd., Toronto, Ontario 1970

Wetzel, R. G.; Professor of Botany, Kellogg Biological Station, Michigan State University; Limnology; W.B. Saunders Co., Philadelphia, London, Toronto 1975