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0.5

An Ecological Analysis
of
Inkpot Lake and Forest Service Bog
at the
University of Notre Dame
Environmental Research Center

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Biology 569
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INTRODUCTION

The following environmental study was performed at the University of Notre Dame Environmental Research Center. This property is located at 46°N latitude, 89°30'W longitude, in both Gogebic County, Michigan and Vilas County, Wisconsin. The 7000 acres maintain over twenty glacial-formed lakes. These kettle lakes are in the Great Lakes drainage basin, thus their water eventually flows north. "Climatological maps classify the region as humid microthermal—that is, no dry season, with cold winter and cool, long summer."¹ The temperature range is; winter (-20 to -10 °C), summer (16 to 21 °C). Precipitation averages between 50 and 100 centimeters per year. Flora and fauna are diverse and abundant.

In this analysis two water bodies, Inkpot lake and Forest Service Bog, are investigated. Water chemistry, plankton, and successional trends are examined in order to understand the waters' related yet different ecosystems.

GENERAL PARAMETERS - INKPOT LAKE

Water Chemistry

The following data was collected Tuesday morning, 30 May 1978. The skies were overcast, the temperature was 20°C, and a substantial wind was present. Sampling was done with the aid of a temperature and oxygen probe, secchi disc, and a kemmerer sampler. Testing was done with a Hach kit.

Data

Time - Tuesday AM

Setting - overcast, windy, water murky, trees and brush surrounding lake

Water Profile

<u>Depth (meters)</u>	<u>Dissolved Oxygen (ppm)</u>	<u>Temperature °C</u>
surface	7.4	21
1	7.1	20
2	7.1	17
3	6.1	11
4	3.5	10
5	1.1	8
6	1.0	8

pH surface-6.6 3 meter-6.6 4 meter-6.6

Secchi disc 1.6 meters

	<u>1 METER</u>	<u>4 METER</u>
Nitrate Nitrogen	.4 mg/l	.35 mg/l
Specific Conductance	86 micromhos/cm	75 micromhos/cm
Alkalinity		
phenol	no reaction	no reaction
Brom Cresol Green	20 mg/l	30 mg/l
Acidity		
methyl orange	0	0
phenolphthalein	0.8 mg/l	0.75 mg/l

	<u>1 METER</u>	<u>4 METER</u>
Hardness		
Total (Ca ⁺⁺ &Mg ⁺⁺)	40 mg/l	50 mg/l
Calcium (Ca ⁺⁺)	35 mg/l	40 mg/l
Magnesium (Mg ⁺⁺)	5 mg/l	10 mg/l
Color	60 units	50 units
Phosphate total	.29 mg/l	.20 mg/l

From the preceding data it could be implied that a distinct thermocline was present between 1 and 3 meters. The water sampling was taken in the center of the lake, an area with a depth of 5.5 to 6.0 meters.

Plankton

The following list were organisms present in both AM and PM plankton net sampling on 30 May 1978. The samples were collected in plankton nets with fine bolting cloth which were dragged behind a boat. A sample was a time interval of two minutes.

<u>AM</u>	<u>PM</u>
<u>Keratella</u> sp.	Copepods <u>Senecella</u> <u>Culonoides</u>
<u>Asterionella</u> sp.	<u>Dinobryon</u> sp.
<u>Dinobryon</u> sp.	<u>Keratella</u> sp.
<u>Anabaena</u> sp.	<u>Microspora</u> sp.
<u>Melosira</u> sp.	<u>Polycystis</u> sp.
<u>Senecella</u> <u>Calonoides</u> (Copepod)	<u>Anabaena</u> sp.
<u>Microspora</u> sp.	<u>Asterionella</u> sp.
<u>Eudorina</u> sp.	<u>Gloetrichia</u> sp.
<u>Gloetrichia</u> sp.	<u>Microspora</u> sp.
<u>Polycystis</u> sp.	
<u>Daphnia</u> sp. (Cladoceran)	numerous <u>Chaoboridae</u>
<u>Bosmina</u> sp. (Cladoceran)	
<u>Holopedium</u> sp. (Cladoceran)	
Nauplius	
<u>Kellecotia</u> <u>longespina</u>	

The following data indicates the relative frequency of the present species:

List of AM and PM Samples with Relative Amounts/cm

<u>AM Sample</u>	<u># in Sample</u>	<u>#/ml</u>
<u>Dinobryon</u> sp.	424	4494
<u>Keratella</u> sp.	108	1357
<u>Asterionella</u> sp.	104	1102
<u>Anabaena</u> sp.	44	466
<u>Microspora</u> sp.	19	201
cyclomophic daphnia (Cladoceran)	17	180
<u>Eudorina</u> sp.	16	170
<u>Polyartha</u> sp.	6	63
Calanoid Copepod	6	63
<u>Asplankna</u> sp.	5	53
Nauplius	4	42
<u>Kellicottia Longespina</u>	2	21
<u>PM Sample</u>	<u># in Sample</u>	<u>#/ml</u>
<u>Dinobryon</u> sp.	449	4759
<u>Keratella</u> sp.	153	1622
<u>Asterionella</u> sp.	101	1071
Cyclomorphic daphnia (Cladoceran)	36	382
Calanoid Copepod	21	223
Nauplius	17	180
<u>Microspora</u> sp.	11	117
<u>Kellicoltia Longespina</u>	10	106
<u>Anabaena</u> sp.	9	95
<u>Ceratium</u> sp.	1	11
<u>Polyartha Trigla</u>	1	11

Macro Flora and Fauna

The surface area of Inkpot Lake is 7.6 hectares. The area's drainage system consists of Moccasin Lake draining into Inkpot, water from Inkpot flowing into Plum Lake, and then into Kickapoo Lake. The trees present along shore reflected the generally steep sides of the shore bank. Trembling Aspen (Populus Tremuloides), Red Pine (Pinus Resinosa), White Pine (Pinus Strobus), White Birch (Betula Papyrifera), and Red Maple (Acer Rubrum) were found. These trees are usually found in dry (well-drained) habitats, as was the area. At the water's margin equisetum and clusters of cattails (Typha sp.) were common along with decaying fallen timber. The littoral zone contained numerous different species of macrophytes, among these were; Waterweed (Elodea sp.), Waterlilly (Nymphaena sp.), and Duckweed (Lem na sp.).

Macro aquatic invertebrates found included; fingernail clams (Sphaerium sp.), freshwater shrimp (Hyallela sp.), snails (Helisoma sp.), (Stagnicola sp.), (Gyraulus sp.), and (Physa sp.) and leeches of the genus Placodella. Northern pike, yellow perch, and muskellunge are fish present in the lake.

GENERAL PARAMETERS - FOREST SERVICE BOG

Water Chemistry

The following data was collected on the morning of June 1, 1978. It was a clear, calm day; the temperature was 21°C.

Data

Time - Thursday AM

Setting - calm, clear, sphagnum bogmat, stunted pines and tamaracks

Water Profile

<u>Depth (meters)</u>	<u>Dissolved Oxygen (ppm)</u>	<u>Temperature °C</u>
surface	6.4	19.0
1	6.3	19.0
1.5	5.5	16.0
2	4.1	13.0
3	1.4	8.5
4	1.1	8.5

pH 4.6

Secchi disc 2.5 meters

	<u>1 METER</u>	<u>3 METER</u>
Nitrate Nitrogen	.10 mg/l	.10 mg/l
Specific Conductance	10.5 micromhos/cm	9.5 micromhos/cm
Alkalinity		
phenol	no reaction	no reaction
Brom Cresol Green	no reaction	no reaction
Acidity		
methyl orange	0	0
phenolphthalein	105 mg/l	110 mg/l
Hardness		
Total (Ca ⁺⁺ &Mg ⁺⁺)	5 mg/l	5 mg/l
Calcium (Ca ⁺⁺)	.05 ml/drop	.05 ml/drop
Magnesium (Mg ⁺⁺)	fraction/drop	fraction/drop
Color	20 units	60 units
Phosphates	.25 mg/l	.25 mg/l

Plankton

The following is a list of plankton found in a plankton net on 1 June 1978.

<u>AM</u>	<u>PM</u>
<u>Dinobryon</u> sp.	<u>Dinobryon</u> sp.
<u>Keratella</u> sp.	<u>Asterionella</u> sp.
<u>Conochilus</u> sp. (Rotifer)	<u>Keratella</u> sp.
<u>Microspora</u> sp.	<u>Staurastruni</u> sp.
<u>Senecella Calanoides</u>	<u>Conochilus</u> sp. (Rotifer)
Cladoceran	<u>Diatoma</u> sp.
Nauplius	Cladoceran
<u>Mongeotia</u> sp.	Copepodes <u>Calanoid</u>
<u>Polyartha</u> sp.	<u>Tabellaria</u> sp.
<u>Ankistrodesmus</u> sp.	<u>Ankistrodesmus</u> sp.
<u>Staurastrum</u> sp.	<u>Ulothrix</u> sp.
<u>Anabaena</u> sp.	<u>Polyartha</u> sp.
<u>Asterionella</u> sp.	
<u>Dactylococcus Infusionum</u>	
<u>Gloctrichia</u> sp.	
<u>Tabellaria</u> sp.	
<u>Ulothrix</u> sp.	

The following is an indication of the relative frequency of which the organisms occurred.

List of AM and PM Samples with Relative Amounts/cm

<u>AM Sample</u>	<u># in Sample</u>	<u>#/ml</u>
<u>Conochilus</u> sp. (Rotifer)	247	4940
<u>Keratella</u> sp.	42	840
<u>Dinobryon</u> sp.	35	700
Nauplius	9	180
<u>Cyclomorphic Daphnia</u> (Cladoceran)	8	160

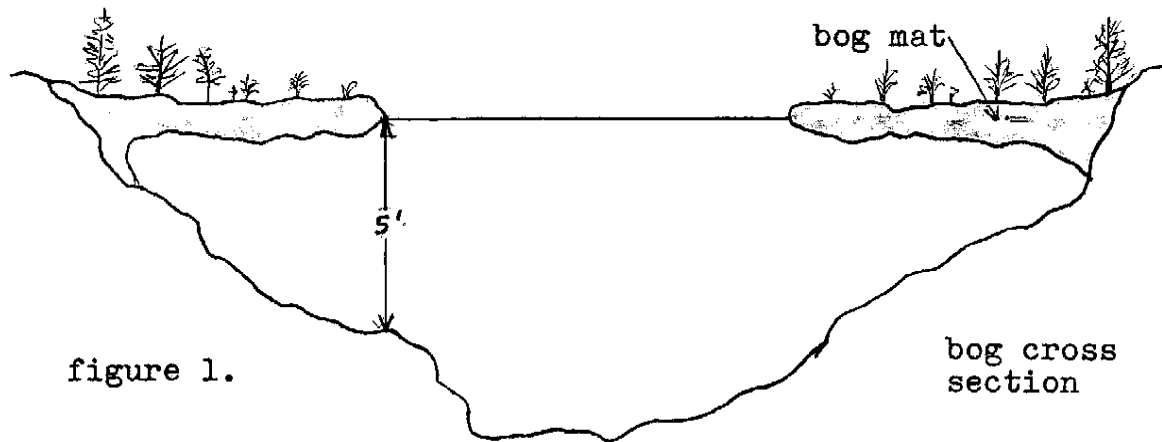
<u>AM Sample</u>	<u># in Sample</u>	<u>#/ml</u>
<u>Microspora</u> sp.	5	100
<u>Dactylococcus Infusionum</u>	4	80
<u>Mongeotia</u> sp.	4	80
<u>Polyartha</u> sp.	4	80
<u>Ankistrodesmus</u> sp.	3	60
<u>Asterionella</u> sp.	3	60
<u>Staurastrum</u> sp.	2	40
Calanoid Copepod	1	20
<u>Anabaena</u> sp.	1	20

<u>PM Sample</u>	<u># in Sample</u>	<u>#/ml</u>
<u>Conochilus</u> sp.(Rotifer)	167	3340
<u>Dinobryon</u> sp.	43	860
<u>Keratella</u> sp.	9	180
<u>Asterionella</u> sp.	9	180
Calanoid Copepod	7	140
Nauplius	5	100
<u>Polyartha</u> sp.	3	60
<u>Staurastrum</u> sp.	2	40
<u>Ulothrix</u> sp.	2	40
<u>Tabellaria</u> sp.	1	20
<u>Ankistrodesmus</u> sp.	1	20

Macro Flora and Fauna

The plant community of Forest Service Bog conspicuously contrasted that of Inkpot Lake. The low area surrounding the bog was comprised primarily of moss (Sphagnum). The trees present were; Tamarask (Larix Larcina) and Black Spruce (Picia Mariana) close to the edges of the bog with Jack Pine (Pinus Banksiana) on firmer ground. These trees are characteristically found in wet habitats. Also located on the quaking bog mat were numerous other flora characteristic of the low pH

environment. Among these were Bog Rosemary (Andromeda Glaucophylla), pitcher plants (Sarracenia Purpurea), Leatherleaf (Chamaedaphne Calyculata), and Sundew (Drosera Rotundifolia). A limited littoral zone was present as the bog mat extended over the water surface. At the edge of the bog mat the water was already 5.0 to 6.0 feet deep.



Insect populations were constantly high with many caddis flies, dragonflies, and damsel flies. The small island present was also surrounded by Sphagnum sp. The bogs' surface area was estimated at less than one hectare. No direct drainage to or from another body of water was present, only slight seepage can be assumed to occur. "For bogs to form, the basin must be sealed off from the surrounding groundwater so that influence from outside water is minimized."²

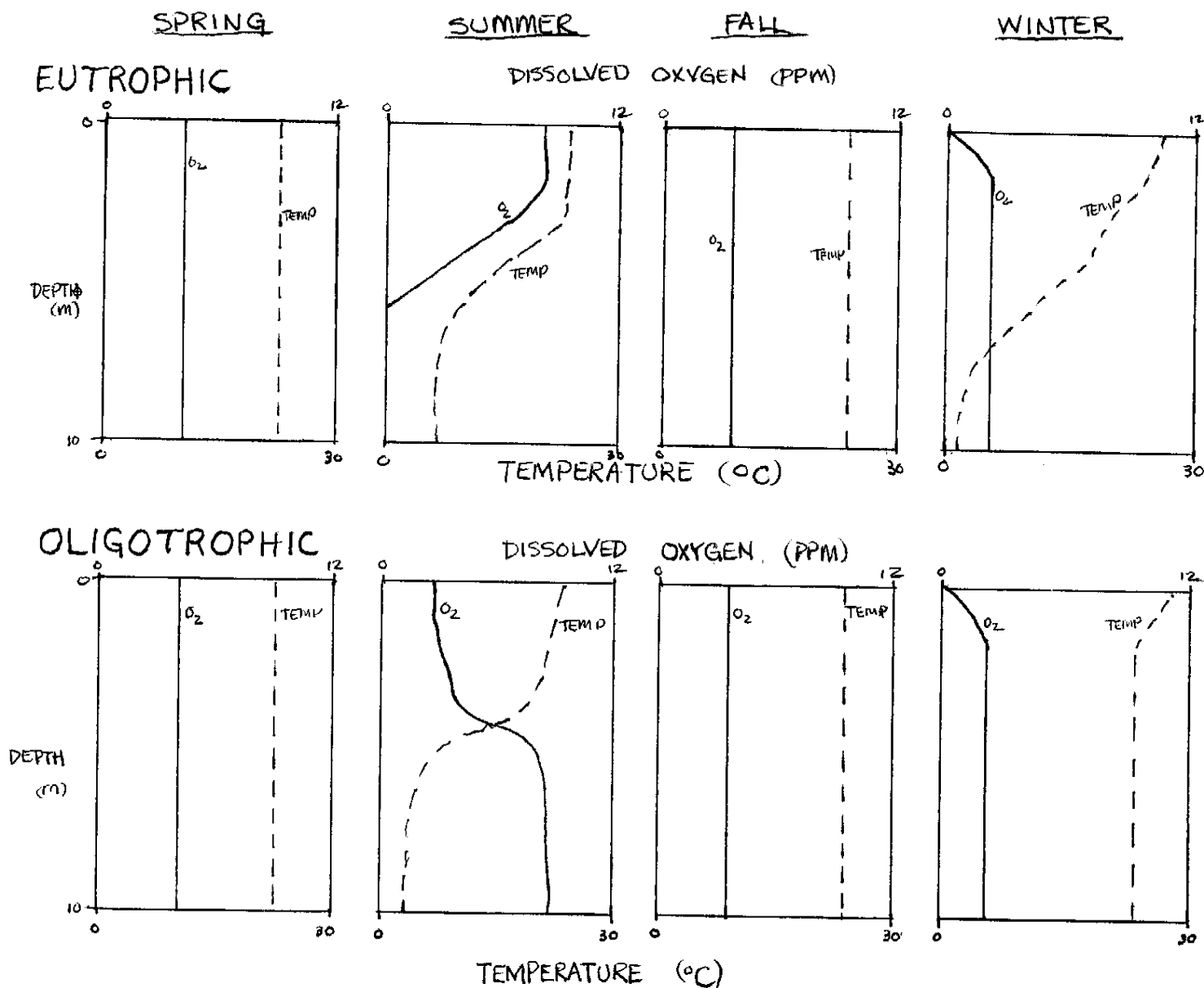
GENERAL CHEMISTRY

Dissolved oxygen is probably the single most indicative factor of a lake. Although these readings are dependent on several factors, the most important are temperature and atmospheric pressure. At a high temperature, water has a restricted ability to hold dissolved oxygen. This is due to the higher kinetic energy in this water. At a low temperature kinetic energy is also lower, thus water is capable of keeping higher concentrations of oxygen dissolved. Since atmospheric pressure is lowest at high elevations, water bodies found in mountainous areas have less pressure exerted from the atmosphere, which would tend to force oxygen out of the water. Lakes at or below sea level have substantially more pressure and hence are restricted somewhat by the atmospheric pressure. These previous statements do not necessary say that lakes at sea level hold less oxygen than those in mountainous areas. The overall ability to hold oxygen is dependent on numerous additional conditions, including salinity, specific gas characteristics, and biological activity.

The main sources of dissolved oxygen in lakes are plants both microphytes and macrophytes and the atmosphere. The amount of aquatic vegetation in a lake (dependent on the extent of littoral zone for macrophytes) greatly influences the oxygen level. Wave action besides increasing surface area for atmospheric absorption, can also increase oxygen uptake through physical turbulence.

An annual oxygen/temperature profile would differ for a

typical Eutrophic lake (Figure 2) and also an Oligotrophic lake (Figure 3).



Eutrophic lakes have a clinograde oxygen curve in summer, in contrast to the orthograde curve in Oligotrophic lakes. The lack of oxygen below the thermocline in an Eutrophic lake during summer is due to rapid use of available oxygen in the hypolimnion. This is accomplished through the decomposition of dead and settling plankton from the epilimnion. In contrast, oxygen remains in the hypolimnion of a low productive lake

(Oligotrophic). This is a direct result of low quantities of both nutrients and plankton.

The region of the lake where light reaches, and thus photosynthesis occurs is the euphotic zone. Below this is the compensation level where the rate of decomposition and respiration consume oxygen at the same rate at which photosynthesis occurs. Below is the aphotic zone where respiration and decomposition tax the available oxygen supply. After summer stratification, this region loses its supply of oxygen. This can be indicated by the presence of hydrogen sulfide H_2S a decomposition by-product which can be toxic to organisms. The water in this case would remain anaerobic until fall turnover.

Besides seasonal changes in oxygen levels, daily fluctuations occur. This has been termed the oxygen pulse. "Maximum oxygen production usually occurs immediately after dawn."³ This erratic production coupled with night-time respiration by plants cause oxygen levels to fluctuate substantially daily. On sunny days, it is possible for the water to become super-saturated with oxygen. As stated earlier, respiration and decomposition account for the major portions of oxygen loss, however, chemical reactions to ions in the water and ultra violet light can also utilize portions of the dissolved oxygen present.

One can observe from the preceding graphs that thermal transfer occurs at the atmosphere-water interface. There is little difference in temperature trends between Oligotrophic and Eutrophic lakes. The most striking characteristic

is the great disparity in temperature between the hypolimnion and epilimnion during summer stratification. If an ice cover is present during winter the coldest part of the lake would be the surface.

Specific conductivity is the measure of electrical conductance of a solution which indicates the relative amount of ionized materials in water. This parameter may be correlated with salinity. By definition, "conductance is the reciprocal of the resistance measured between two platinum electrodes one centimeter apart and having a surface area of one centimeter squared each, units are in micromhos/cm."⁴

The only source of nutritionally important ions for phytoplankton must be found in the water in which it exists. The lack of some ions and the abundance of others can regulate the variation and quantity of phytoplankton present. Animals may also be directly affected as in the case of carbonaceous-shelled animals. In waters with low dissolved ion concentrations, these animals may bear abnormally thin shells or even not appear at all.

Water hardness is a measure of cations in water. This parameter can be divided into three categories calcium, magnesium, and total hardness. Procedure in this study dealt with the testing for calcium and total, while subtraction of calcium from total yielded magnesium. Both of these elements are capable of limiting biological processes in lakes. Magnesium is necessary in the formation of chlorophyll molecules while calcium is vital for proper skeletal and shell formation.

It has been shown that soft water lakes usually contain less living matter per unit area than hard water lakes. "The total estimated biomass of plant substance in certain medium lakes of Wisconsin was found to be three to five times that of poor lakes, while the animal mass, not counting fish, was as much as triple that of poor lakes."⁵ Although hard lakes may hold a greater biomass per unit area, medium lakes tend to show a greater specie variation. A reasonable hardness scale shows:

Soft water lake $>$ 20 mg/l

Medium water lake = 20 to 60 mg/l

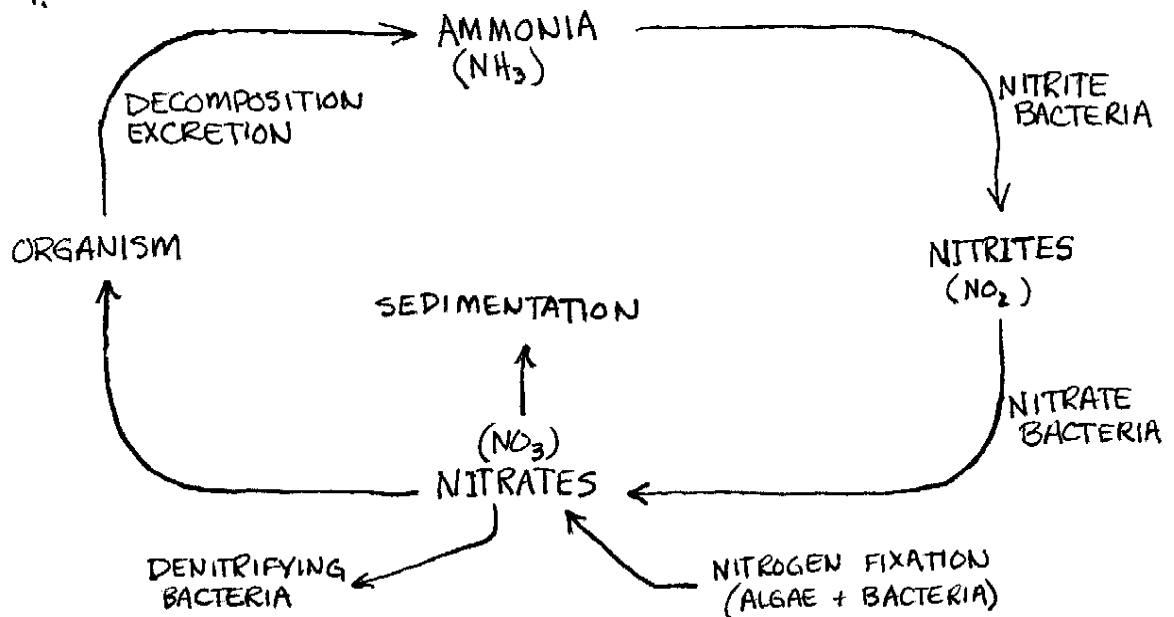
Hard water lake $<$ 60 mg/l

The color parameter investigated in this study was apparent color, that is the interplay of light on unfiltered water. This would include plankton, detritus and other colloidal substances. These suspended materials of varying size yield the apparent color of a water body when compiled together. When a particular group of seston predominates, water color can be altered substantially. Blooms of Cyanophyta render water a dark greenish color. Chrysophyta in high concentrations produce a yellow-green color, while zooplankton may tint the water red. Bog water with high levels of humic acid often turn water to a tea color. The intensity of this coloration regulates the depth of the trophogenic zone.

The nitrogen parameter studied was the relative quantity of nitrate (NO_3) present. This is the form which is most easily taken up by plants. Nitrogen can enter the body of water through the atmosphere-water interface, run off, and

bacterial production (autochthonous). It is an essential element to all ecosystems because of its role in the synthesis and maintenance of protein. The following illustration shows the nitrogen cycle (Figure 4). Since nitrogen is a vital nutrient, its presence indicates the possibility for normal production, not automatic high production in a lake.

FIGURE 4.



Phosphorus is an important nutrient because it is vital in the operation of energy transfer systems of the cell. It is also the limiting nutrient in most freshwater lakes. This means that the amount of phosphorus is an important indicator for the overall production of a lake. A low phosphorus average would tend to keep phytoplankton at low levels, and hence limit fish populations.

The pH of the water determines to a great extent how phosphorus is present. Under circumneutral and moderately alkaline conditions calcium phosphate is probably prevalent. In high alkaline water sodium phosphate predominates.

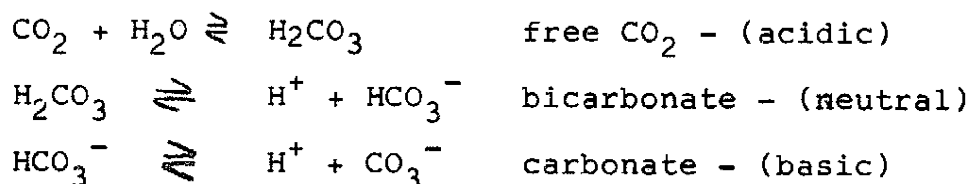
In acidic water ferric phosphate and aluminum phosphate predominate.

The pH is the logarithm of the reciprocal of the hydronium ion, where H^+ is the amount of hydrogen ions in a solution in moles per liter. In water, a neutral solution of 7, there

$$pH = \log \left(\frac{1}{H^+} \right)$$

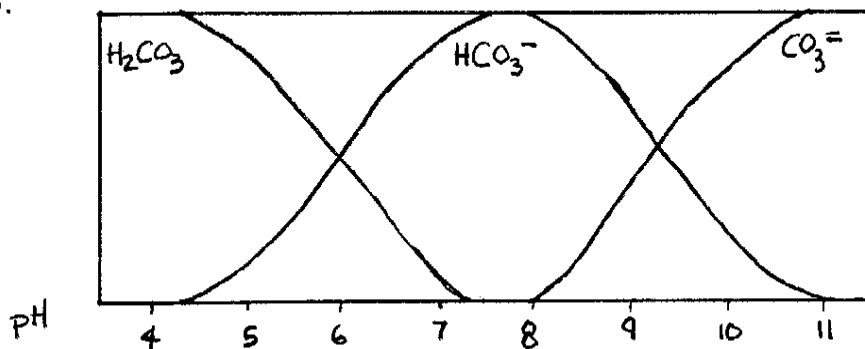
is an equal amount of hydronium ions and hydroxide ions (OH^-). An increase of H^+ lowers the pH, while an increase of OH^- results in a higher pH value. Correspondingly, a value below 7 is considered acidic and values above are basic.

Hydrogen ion concentration (pH) is related to the occurrence of three forms of carbon dioxide in water.



In Figure 5 (below), one may visualize this important balance of ions. From this one may conclude that in Forest Service the almost exclusive form of CO_2 is H_2CO_3 . This contrasts to Inkpot's dominate HCO_3^- concentration. This basic difference contributes to the effect that the whole ecosystem with regards to species present.

FIGURE 5.



Alkalinity refers to the quality and quantity of compounds which bring about a shift in the pH of the solution towards the alkaline side of the pH range.⁶ This often reflects the activity of calcium carbonate (CaCO_3). This parameter does not coincide with pH. It is possible that water with a higher alkaline pH, has a lower alkalinity than another sample that may be pH neutral. Alkalinity and acidity are relative buffering capacities in a water sample.

Secchi discs are used to determine the degree of transparency of a water body. The depth at which it disappears is approximately the region of 5% sunlight transmission. It presents a clear indication of the extent of the trophogenic zone. A problem encountered with the device is the fluctuation of readings with respect to sunlight present.

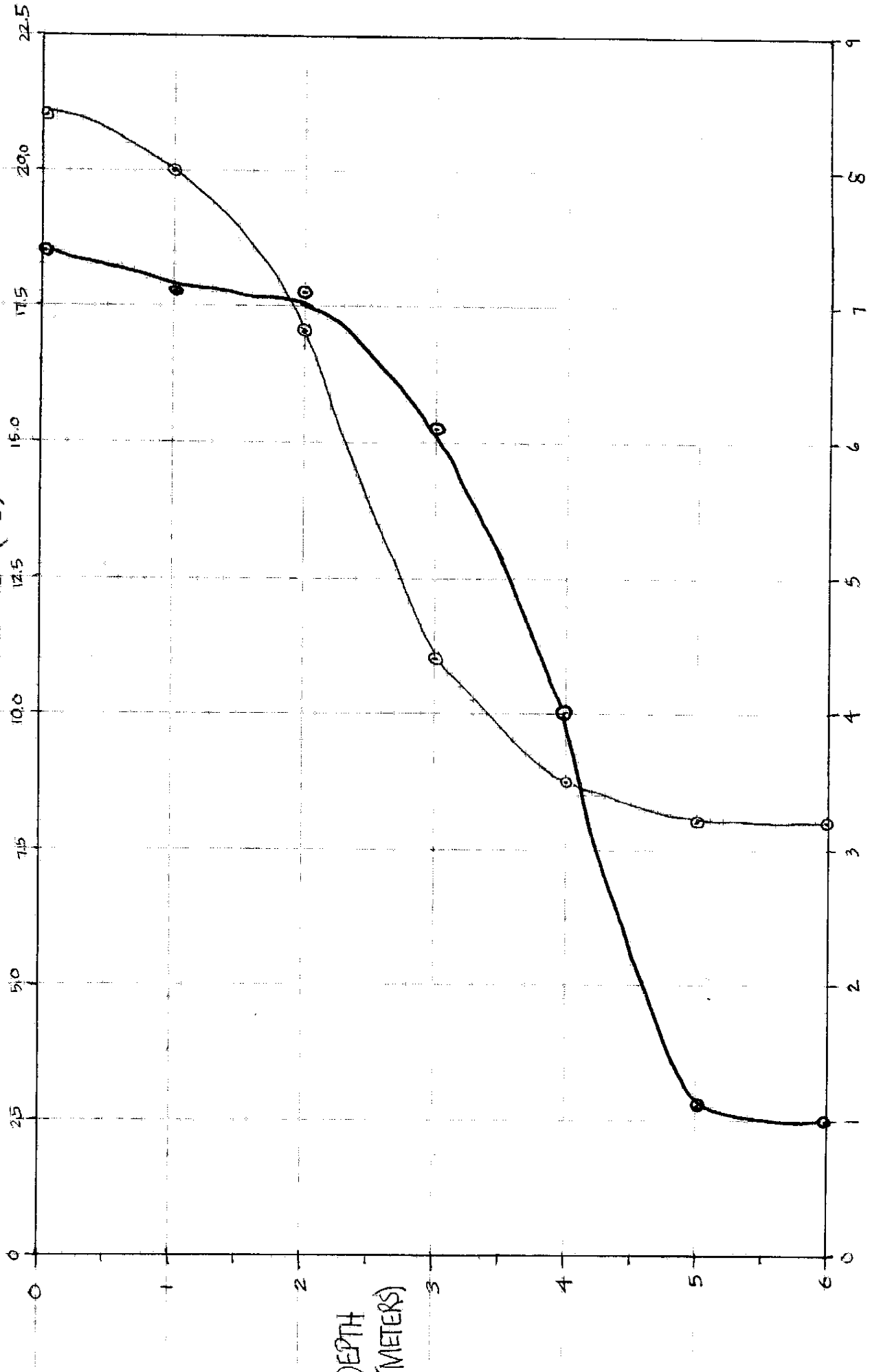
OXYGEN / TEMPERATURE PROFILE — INKPOT LAKE

TAKEN : 30 MAY 1978 - AM

—○— OXYGEN
—○— TEMPERATURE

TEMPERATURE (°C)

DISSOLVED OXYGEN (PPM)

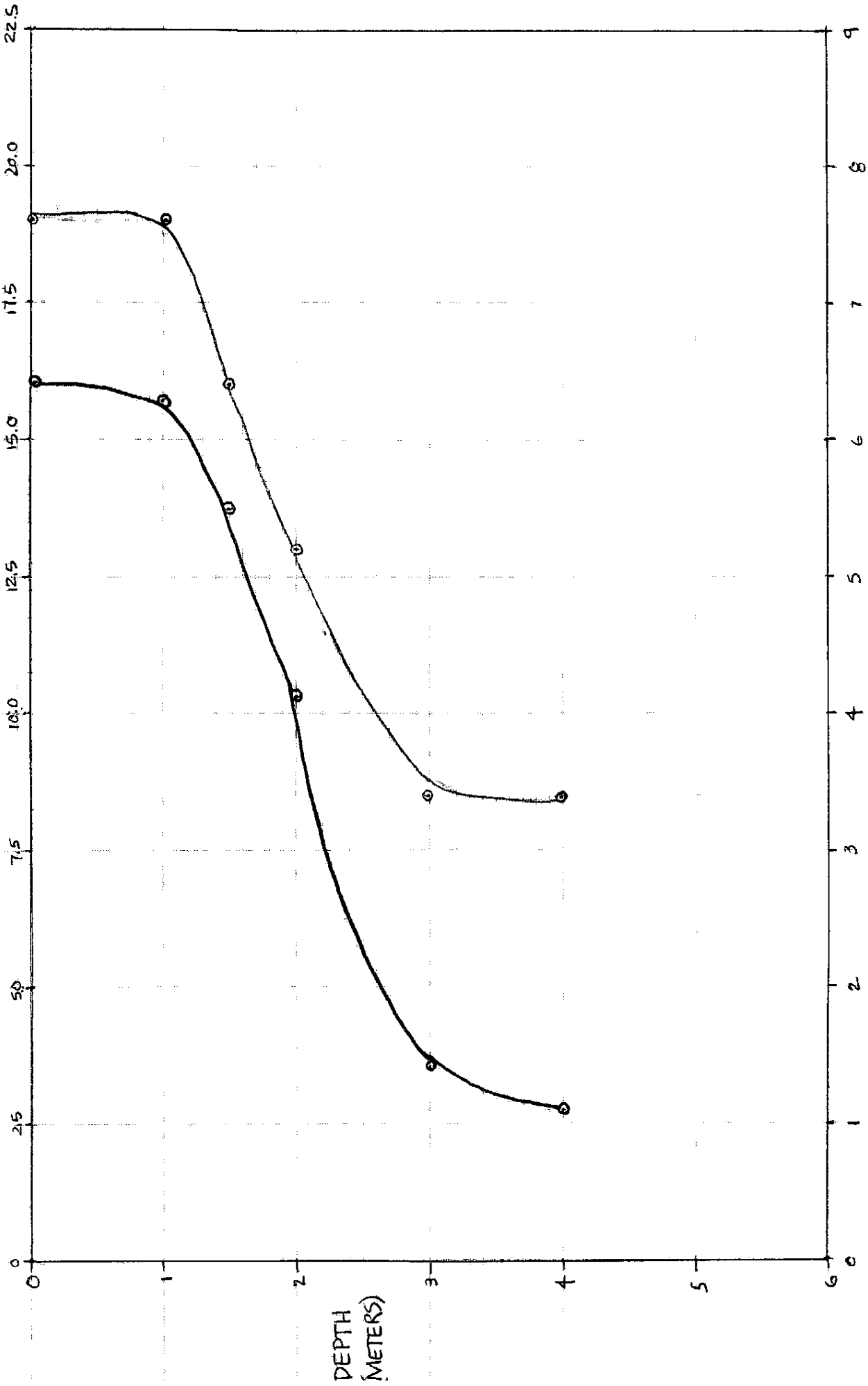


OXYGEN/TEMPERATURE PROFILE - FOREST SERVICE BOG

TAKEN : 1 JUNE 1978 - AM

—○— OXYGEN
—○— TEMPERATURE

TEMPERATURE (°C)



DISSOLVED OXYGEN (PPM)

WATER BODY ANALYSIS - INKPOT LAKE

Inkpot lake is a dimictic lake found in temperate North America. At the time of investigation, the lake was undergoing summer stratification. If one observes the oxygen/temperature profile (Graph I) one can deduce that the thermocline indicates that although it is definitely present, it has not had enough time to develop a distinct thin interim layer between the epilimnion and hypolimnion. One can assume that within a few weeks the thermocline will taper down to perhaps a one meter width, causing the distinct non-mixing bilayer system. Another indication of the recent but yet uncompleted stratification is the presence of a substantial quantity of dissolved oxygen below the thermocline. This can be attributed to the low quantity of decomposing plankton which is settling from the epilimnion. As the summer progresses, the oxygen present will be utilized in decomposition of the phytoplankton and zooplankton. Because of lake stratification, dissolved oxygen will not be replaced until fall turnover. Thus, an anaerobic condition will occur, and hydrogen sulfide will become present.

Although the sampling day was overcast, the lake's secchi disc transparency was low at 1.6 meters. Along with a significant color index, it can be presumed that substantial suspended matter was present. Northern Wisconsin is on the Canadian Shield composed mainly of granite, a hard, low water soluble rock as compared to limestone. This results in lakes with medium to low levels of hardness. Inkpot falls into

the medium category. Calcium ions were in higher concentration than magnesium as is the case for most lakes in the area. This concentration was ample to produce carbonaceous animals.

Inkpot's pH reading was 6.6, down from an 8.4 reading in 1976. Nevertheless, this can be accounted to many factors such as time of year, interim time between sampling and testing or even faulty equipment or human error.

Nutrient concentrations were slightly higher in the epilimnion than the hypolimnion. Since Inkpot is an eutrophic lake it is reasonable that both nitrogen and phosphorous were present in significant quantities. A contributing factor to this concentration is the relatively steep sided shore areas. This along with the dense tree cover allows more allothanos materials to enter the lake.

The alkalinity readings show a substantial amount at both depth readings, indicating the presence of materials that shift the pH toward the alkaline side. In comparison, acidity readings were low under 1 mg/l at both depths. Since the pH of this lake probably did not change 2 units in 2 years, I believe my pH value for the lake may be low. The high alkalinity indicated the presence of high buffering capacity. If a bog were to begin draining into the lake slowly, the pH would not shift quickly. If this drainage pattern was reversed and the bog possessed low acidity, its pH could rise quickly, endangering species present. If this drainage continued to occur the bog may even halt its succession.

PLANKTON ANALYSIS - INKPOT LAKE

Before analyzing the plankton data, one should recognize the data's limitations. It would be erroneous to assume that these plankton samples were very accurate. Although they were timed two minute samples, towing rates were different for each one. If the tow was moving too slow the net would submerge to a lower water strata. This would yield different results than a surface tow. If the net was towed too quickly negative pressure would appear in front of the net. This would cause potential sample water to be "repelled" from the net, reducing the yield. This error could alter population analysis substantially. Another factor that detracts credibility from our study would be the size of the bolting cloth. In order to reduce the amount of back pressure a wider bolting cloth weave was used. Using this weave, however, we were unable to contain small plankton (Nannoplankton) and bacteria which can be up to 60% of the living matter in a sample.

Although our data is far from being precise, some generalizations can be deduced. Seasonal variation is known to affect phytoplankton populations. In early spring Chrysophytes (Diatoms especially) are recorded in large numbers. As the weather warms, greens become more common. During the hot summer, (Cyanophytes) blue greens capitalize on their maximum conditions and out compete other algae, often causing blooms. When fall arrives, temperatures decline and Diatoms become more prevalent.

Sampling analysis was done by investigating a one milliliter sample in a Sedgewick-Rafter counting cell. At the

time of sampling, Inkpot's algae progression was probably in the state of a declining diatom population with blue green algae increasing. Large populations of Chrysophytes such as Asterionella indicate that they were the dominate algae in the lake at that time. By the end of July, it could be assumed that Cyanophytes such as Anabaena would be the dominate algae present. Characteristically, blue greens do not need high levels of nutrients (as diatoms do), thus after much of the nutrients settle out of the epilimnion, diatoms can no longer compete. Few organisms prey on blue greens, and some blue greens are capable of secreting toxins to inhibit diatoms.

Plankton do not uniformly inhabit lakes. Phytoplankton are limited to the trophogenic zone of a lake in order to photosynthesize. Since zooplankton are dependent directly or indirectly on the phytoplankton, they are usually found above the compensation level. Nevertheless, since these animals can migrate some species may be more abundant in the tropholytic zone during the day while migrating vertically at night to feed. Since excessive light can limit photosynthesis, phytoplankton often are not found in surface waters on sunny days. The depth to which they descend in the water column depends on water transparency, light, temperature, and nutrients.

Although it appears that the count for phytoplankton is lower in the AM than PM, the difference is not significant enough to warrant a conclusion. On the other hand, there appears to be a substantial increase in the number of both copepods and cladocerans in the PM sample. From the Sedgewick-

Rafter counting cell, it was determined that 63 copepods and 180 cladocerans were found in one milliliter in the AM sample. The PM sample indicated 223 copepodes and 382 cladocerans per milliliter. Perhaps this is due to nocturnal feeding on phytoplankton. It appears that zooplankton live in lower water strata during the day. Perhaps this is done to stay out of strongly illuminated surface waters to avoid predation by fish and other nekton. At night, they expend energy since they are negatively buoyant and feed near the surface.

Another difference between the AM and PM samples was the appearance of chaoborus (Dipteran larvae) in the PM sample, but not in the AM sample. Although they were too large for the Sedgewick-Rafter counting cells, over 100 were collected in the PM sample. "Some species of chaoborus inhabit the bottom during the day and migrate to the lake's surface at night."⁷ This migration can be rapid (20 m/hr). Once at the surface, these predatious larvae feed on migrating zooplankton.

WATER BODY ANALYSIS - FOREST SERVICE BOG

Forest Service Bog is an excellent example of a well progressed bog community. Associated with this progression are various chemical parameters which are characteristic of this unique ecosystem. One such parameter is the low levels of nutrients. Both nitrogen and phosphorous were found in similar concentrations above and below the thermocline. The nitrogen concentration, however, was recorded at .10 mg/l, substantially lower than phosphorous. This would indicate that nitrogen could be the limiting nutrient in the bog. If this is correct it would be an unusual incident for a freshwater ecosystem.

Another characteristic of bog water is its low pH, alkalinity and corresponding high acidity. The bog had a pH of 4.6 (acidic), down slightly from 4.85 recorded in 1976. This range of fluctuation could not be considered significant. Along with the low pH was the absence of compounds that would bring about a pH shift towards the alkaline range. Using phenolphthalein as the indicator, the acidity reading corresponded with a high reading (over 100 mg/l). This indicates the stability of the acidic condition in the bog.

The thermocline in Forest Service Bog was located between the one and three meter depths. Again the large width would taper as the summer progressed. Although there was little dissolved oxygen below the thermocline, the duration of its presence could quite possibly be longer than that in Inkpot's hypolimnion. This would be due to the lower rate of production

and finally decomposition due to the scarcity of nutrients.

Bog water is typically soft, and the concentrations of cations in Forest Service was very low. Total hardness was 5 mg/l. This low value made it difficult to determine the relative amounts of calcium and magnesium ions present. Due to the problems of using fractions of a drop of indicator, our results show the hardness is calcium. This would probably be the dominant of the two cations. Species such as finger-nail clams would be thin shelled if they could survive at all under these circumstances. If fish were present they would stand a good chance of having soft skeletal structure.

A heavy concentration of humic acids from sphagnum moss resulted in a high apparent color. The sample was comparable in color to "weak tea". The apparent color at three meters was 60 units, following centrifugation the true color was 50 units. This indicates that only 10 units of color could be attributed to suspended materials. This low amount of seston is due to the lack of nutrients to support large populations of plankton. In lakes, one would be more likely to find a lower true color in comparison to the apparent color.

The bog had a secchi disc transparency of 2.5 meters, unusually high for bogs. This along with the condition that surface of the bog was lower in apparent color is unexplainable. The specific conductance was also low, homogeneous in the lake at 10 micromhos/cm. This is another characteristic of a bog's ecosystem.

PLANKTON ANALYSIS - FOREST SERVICE BOG

Forest Service Bog had noticeably less phytoplankton than Inkpot Lake. This scarcity of phytoplankton was most apparent in quantitative results in comparison to specie variation. The only group of plankton found in substantial quantities were Rotifers. In the sample 76% of the organisms counted were Rotifer, chiefly Conochilus and Keratella. Rotifers are small zooplankton, omnivorous in eating habits and found at the base of the zooplankton group.

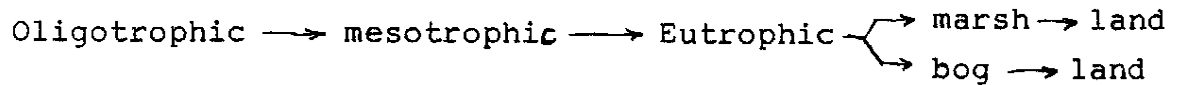
There's an accuracy problem in calculating the quantity of a species per unit volume. When analyzing a small portion of a milliliter there is a high risk of error. If only one individual of a species is identified in a sample, the relative frequency of this species may be misunderstood. In our data only one Anabaena was present in the AM sample, however, because of the large conversion factor an estimated 20 were found per milliliter. This lone Anabaena may have been substantially rarer or even common. The only solution to this problem would be to analyze an entire milliliter - thereby reducing the chance for substantial error. This procedure, however, would be extremely time consuming. From this limited data analysis, conclusions must therefore be drawn from the species found with a significant population.

The high rotifer population in the sample may be accounted for by the fact that they consume detritus. The rotifer probably out-competed the phytoplankton for the scarce nutrients present. Also found in the PM sample was

a significant population of chaoborus larvae. Once again it appears that these predaceous larvae ascend to the surface for nocturnal feeding on plankton. It is probable that the abundant rotifers comprise the largest part of their diet.

ECOSYSTEM ANALYSIS

From the data it is clear that two very distinct micro-cosms have been investigated. Before one can fully understand their differences, it is essential to know where these water bodies are in successional relation to each other. The succession of lentic water bodies is the following:



In a sense all lakes are born to die as each will eventually progress to become filled-in basins. Oligotrophic lakes are characterized by low: production, nutrients, hardness, and alkalinity. These lakes also tend to be deep with steep sloping shores (limited littoral zones). Mesotrophic lakes are those intermediate lakes progressing to Eutrophic condition. Eutrophic lakes are characterized by high levels of nutrients, conductivity, hardness, and production. Gentle sloping gradients provide for more aquatic macrophytes and general production in these lakes. It is at this point in succession that we find Inkpot Lake. After reaching this state of succession, the water body progresses to either a bog or a marsh. Bogs are easily distinguished by their characteristic flora as listed earlier. It is at this stage in progression that Forest Service bog is at. "Marshes are broad treeless wetland areas, occupied by abundant grasses, rushes and sedges."⁸ Gradually bogs and marshes fill in to form terrestrial environments. At present it would be uncertain to decide if Inkpot will succede to a bog or marsh. The absence of sphagnum does not indicate it

is not heading in the bog direction as of yet. The presence of drainage from Moccasin Lake and the substantial runoff that it receives may prevent a bog succession, thus it will probably progress to becoming a marsh. The only way to be sure would be to wait several hundred years and do another analysis on it.

Ecological succession is the progressive change in communities. It is after generations of this (non-static) communities change that influences change within the community itself. "Both the rate and the direction that evolution takes may be strongly influenced by the physical, chemical, and biological features of the environment acting on one hand to limit species development, or on the other hand, to provide new conditions in which organisms with novel modifications may flourish."⁹

FISH - AN INVESTIGATION OF TENDERFOOT LAKE

To prepare a significant study of Tenderfoot Lake, background research must be done before actual data collection. The research should include investigation into previous work done on: geological history, ecosystem succession, water flow and drainage, and any other source that would aid in understanding this microcosm. This research is important as it not only enhances knowledge of where the lake is in respect to the other lakes, but also it gives you an idea of what to expect in the new lake study.

After preliminaries are completed a data collection schedule and program should be designed. Since the investigation is both qualitative and quantitative, frequent sampling as well as site variation should be done. The way to get a good qualitative data would be to choose sites varying in: water depth, distance from shore, presence of different dominant macrophytes and bottom morphology. This would insure a good cross-section of the lake in which to collect species with differing habitational preferences. In order to get a good quantitative sampling, numerous nets should be used around the basin and should be checked often for fish. A good schedule to follow would be after setting the nets in varied areas to check and remove trapped fish twice a day, once in the morning and once at late dusk. The morning sample would yield nocturnal feeders and the dusk sample the day feeders. This procedure should be carried out every day of the week. The longer the data is collected the more substantial

and useful the data will be.

Since the sampling sites will differ substantially, chemical analysis should be taken at each site. This would indicate the chemical parameters and differences at the sites which would be useful information in determining natural habitation characteristics of the fish.

Various chemical analyses should be performed in order to base your conclusions. Dissolved oxygen and temperature are very important. Areas of the lake which are fit for some fish could be intolerable to other species. Water hardness is an important parameter concerning the possibility of soft-boned fish, a characteristic of fish in some UNDERC lakes. Secchi disc transparency is a vital test used to determine the depth of the trophogenic zone as well as the littoral zone. It is in these water strata that most fish will feed. A qualitative and quantitative study of nutrients, both nitrates and phosphates can be useful in making inferences about the overall productivity of the lake. Determination of the limiting nutrient and how it effects fish populations is important when regarding a lake's ecosystem from a holistic viewpoint. Acidity and alkalinity will yield the buffering capability of the lake. In previous years Tenderfoot has been one of the more alkaline lakes at UNDERC. One may realize the importance of water chemistry data to provide a complete picture of the micro balances in the lake. It is from these interactions that fish species may be under stress or undergoing dynamic growth.

Different types of nets should be employed to assure

a wide variety of fish in the sample. Gill nets should be placed in the center of the basin above and below the thermocline. This would indicate if a species was found predominately at a certain depth or condition. To set these nets weights should be tied on to the ends to hold the net submerged. Buoys at the surface would prevent the nets from sinking and tangling, they are also necessary to keep the net taut so that fish swimming into the nets will be snared. These nets should be of different size mesh panels. This would aid in the collection of fish of differing year groups as well as species. Fyke nets should also be used, primarily in water 3-4 feet deep. These nets must be staked firmly to assure that the currents do not move them. The wing net which extends from the open end of the Fyke net must be taut to be effective. This net works under the principal that fish will encounter the wing and follow it like a guide wall while heading for deeper water. Once they enter the 'basket' they are confused and can not find the way out.

The previous nets are useful in catching larger fish which will be snared in the gill nets or those which can not swim out of or through the Fyke nets. Minnow traps with bread as bait can be used to collect small fish near shore. The smaller nekton populations are important as they serve as a basic diet to many larger fish. Another way of obtaining smaller fish in significant numbers, would be

netting similar to our seine netting attempts at Tender-foot Creek. Two people are needed to hold the net, a third person can help by rounding up the fish towards the net. Once the fish are within the parameter of the net, it is lifted thus trapping the fish.

Once the fish are caught, they should be weighed, measured (both forked length ^{by A} and total), gutted and sexed. Weight and length could give some indication of the biomass, but more important would be used to determine the growth ^(condition factor) ratio. From this ratio one can utilize a reference book such as Curlander's and see if the fish population for a species is showing abnormal (stunted or dynamic) or normal growth. This would be done by the comparison of the acquired ratio to standards for that species in northern Wisconsin. A high or normal result would indicate the presence of sufficient food and other nutrients which support that food chain. A stunted population would indicate overcrowding, a low nutrient lake, or the possibility that the species is being out-competed by other nekton.

A food analysis could be done by observing the contents of fish intestines. This is informative in relating the differences of fish eating habits. Some fish such as perch are predaceous in nature, others may be omnivorous. If a species' favored food is in short supply, it may become stressed and have to prey on another food type or perish.

Another informative parameter is the fish scale analysis. Here fish scales are removed from an area near the posterior of the fish, and observed through a microprojection apparatus. From the number of rings on a scale it is possible to determine the age of most fish species. This data can then be use to determine the age distribution of a particular species after a series of analyses are done. This procedure should be done carefully as error is common due to misinterpretation of the fish rings. A fish under stress can develop an extra ring on it's scales or not even develop one during the year. Credibility is increased when a large number of fish are examined.

After a number of fish are analyzed a population growth chart can be done. This would indicate by year class how fish are doing with respect to growth. This type of data would aid in comparisons of fish populations with other lakes in the area and around the country. It is possible that certain species are below the norm for size, and through this comparisson relative amounts can be known. Another use of this chart would be the revelation of how each yearclass is doing with respect to survival.

Knowledge of the feeding habits of fish can be deduced from the data. Basin location, food preference, time of feeding, are among the characteristics that can be learned if large numbers of fish are analyzed. If this can be done a good survey of Tenderfoot can be completed.

*used to think
was a trout
this*

Footnotes

- 1 Greene, R.W., A Brief Guide to the University of Notre Dame Environmental Center. pg 3.
- 2 Ibid. pg 2.
- 3 Reid, G., and R.D. Wood. Ecology of Inland Waters and Estuaries. pg 197.
- 4 Ibid. pg 226.
- 5 Ibid. pg 229.
- 6 Ibid. pg 206.
- 7 Ibid. pg 385.
- 8 Ibid. pg 31.
- 9 Ibid. pg 421.

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