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MOUNT DESERT ISLAND LAKE STUDY

Summer 1975

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College of the Atlantic

Bar Harbor, Maine

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INTRODUCTION

The lakes of Maine are one of the state's most valuable recreational assets. Furthermore, the water supplies serving almost one-half the state's population derived from lakes. Increasing pollution in recent years due to domestic and industrial wastes, however, has brought about a severe reduction in usefulness of many Maine lakes, either as a recreational resource or as a source of high quality water. These lakes have largely been victims of cultural eutrophication or over-fertilization, which results from increased input of compounds of phosphorus and nitrogen. Without a doubt, the largest controllable source of these nutrients is domestic and industrial wastewater. Several contemporary factors have tended to intensify this problem on Maine lakes. Lake shore development combined with the practice of using septic tank drainfield systems to dispose of wastewater, and the extended use of phosphorus compounds in synthetic detergents have resulted in ever-increasing quantities of nutrient-rich wastewater being discharged into surface waters since the nutrients contained in septic tank leachate enter the surrounding soil and may then be carried into lakes by subsurface drainage(15). Eutrophication, in the absence of human influence, is a natural process by which a lake reaches old age. The youngest stage in the life of a lake is characterized by low concentrations of plant nutrients and little biological productivity. Such a lake is termed oligotrophic. As time passes, however, additional nutrients enter the lake and biological productivity is increased. This process of nutrient enrichment continues, until eventually the lake becomes eutrophic or highly productive. The productivity of a lake is measured in terms of the amount of aquatic plant life, particularly algae, that can be supported. As a consequence of nutrient enrichment, aquatic plants grow abundantly and upon their death add to the ever-increasing lake sediments. The lake gradually fills in, becoming shallower by the accumulation of dead plant materials and inorganic sediments, and smaller by the

encroachment of shoreline vegetation. Eventually the lake disappears, and a
marsh results, followed later by dry land (15). The principal features
contrasting oligotrophic and eutrophic lakes are given in Table 1.

Eutrophication, independent of human activity, may require thousands of
years for completion. However, it has become increasingly obvious that the
natural rate of aging of lakes can be greatly increased by human activities,
especially those which increase the amount of available nutrients which control
algal growth. The minimal essential nutrient requirements for algae are not
well-defined, but it is generally held that compounds of nitrogen and phosphor-
us are chiefly responsible for the enrichment of surface waters. Thus, most
efforts at slowing the eutrophication process have been aimed at controlling
input of these two nutrients.

Aside from the long-term effects of algal growth on aging of lakes, there
are a number of immediate practical consequences of eutrophication. When well-
balanced, lake enrichment results in accelerated seasonal growth of algae,
especially bluegreens. These "algal blooms" result in diminution of water clar-
ity and upon their death their decay results in serious oxygen depletion.
Hypoxia, in turn, limits the lake to those fish capable of withstanding
periods of oxygen stress and excludes those, such as salmon and trout, which have
a relatively high dissolved oxygen requirement. Putrid masses of these bluegreens
accumulate in the shallows and along beaches, where they are often unsightly
and impart a noxious odor and taste to the water. These conditions, either from
a recreational or water supply standpoint, are undesirable, yet are unavoid-
able consequences of eutrophication.

Until recently, no base-line studies of Maine Lakes other than for fishery
management classification have been done, with the result that problems of
eutrophication have gone unnoticed until well advanced. Some examples of Maine
lakes which have experienced serious problems of nutrient enrichment are Sebasti-
an, Sabbathus, Annabessacook and Cobbossee (15). In addition, many others

Table 1. Features contrasting eutrophic and oligotrophic lakes.*

Oligotrophic	Eutrophic
Deep and steep banked	Relatively shallow, shelving off gradually
Oxygen abundant at all depths all times.	Oxygen depleted at lower depths in summer.
High transparency	Limited transparency
Water poor in plant nutrients	Plant nutrients are abundant
Sediments low in organic matter	Organic matter high
Algae quantitatively poor	Abundant algae
Water blooms of bluegreens common	Water blooms common
Deep basin bottom fauna tolerant of low oxygen levels.	Deep basin bottom fauna survive low oxygen
Diaptomus-type midge larvae present in deep basin; Chironomus usually lacking	Chironomus and Chaoborus larvae typical of deep basin bottom fauna
Support water salmon and trout	Bass, pickerel, and perch principal fish species

Modified from Cole (12).

r to be endangered (4, 22). Recognition of the state-wide threat of eutrophication has resulted in a three-year water quality study of 43 Maine lakes by the Maine Department of Environmental Protection (26). Of the lakes to be studied, only six are in Hancock county and none of these are on Mount Desert Island, in spite of the fact that the Island's lakes experience considerable recreational usage and several serve as municipal water supplies.

The purpose of the Mount Desert Island lake study was to gather baseline data on the water quality of Echo Lake and Long Pond since both lakes possess considerable recreational value and are the most intensively developed lakes on the island. Long Pond, furthermore, serves as the water supply for the town of West Harbor. Another objective of the study was to inform shoreline property owners and local officials of the nature of the eutrophication process and how they might help impede its development. The economic implications of the study are manifest since protection of the excellent water quality of these lakes will continue to insure high lakefront property values, productive trout and salmon fisheries, excellent bathing conditions, and a potable water supply for both lake residents and the surrounding towns.

A preliminary study of the water quality of Echo Lake and Long Pond was carried out in the spring of 1975 by a group of six students from College of the Atlantic. The present study, conducted by two COA students in the summer of 1975, was a continuation of the spring project and included certain activities which best lent themselves to summer work--a sanitary survey of all lake residences and organization of a water quality workshop for lake residents. In addition, the following water quality parameters were assessed: temperature, dissolved oxygen, transparency, alkalinity, pH, nutrients (N and P), algal population, benthic macroinvertebrate population, and bacterial population.

METHODS AND MATERIALS

The lake study was divided into four distinct phases. The

Student interns spent the first several weeks engaged in background work such as drawing property maps, compiling mailing lists, contacting resource personnel, sending out letters to lake residents, acquiring materials, and reinforcing their own background knowledge.

The second and main phase was the sanitary survey. The interns visited lake shore residences, conducted interviews, and eye-tested sewage systems. They also attempted to answer questions regarding lake eutrophication and alternative waste disposal systems. The sanitary survey was not completed as time was short, but approximately seventy percent of the lake residents were interviewed.

The third phase of the study consisted of measuring those water quality parameters which serve as useful indicators of eutrophication and comparing the results with other Maine lakes which are known to be eutrophic.

The results of the lake study were presented to the public in the final phase of the program. A meeting was held at College of the Atlantic in late August to which lake residents and interested public officials were invited. Presentation of findings was followed by discussion of their implications, after which Patricia Stimets, Executive Director of the Congress of Lake Associations, spoke on how lake residents can help solve lake problems. During the last week of the study, the student interns met a number of lake residents on Long Pond where they conducted demonstration workshop on water sampling and testing techniques.

Sanitary Survey

The sanitary survey was an attempt to determine to what extent

in what manner lake shore residents were contributing to the nutrient enrichment of the lakes under study. The survey procedures were based upon those used by the Cobbossee Watershed District, Winthrop, Maine.

A student intern engaged in the lake study spent three days working with Cobbossee Watershed District personnel familiarizing himself with their survey techniques. A list of lake shore property owners was then compiled and property maps traced from the tax records in the town offices of Mt. Desert and Southwest Harbor. A letter (see Appendix) was sent out to all lake residents informing them of the objectives of the study and advising them that the student team wished to conduct an on-site visit of their properties. In the meantime, local plumbing inspectors were contacted and information obtained regarding the current condition of the lake residents' sewage disposal systems. Most properties had been inspected within the past two years and violations had been remedied. However, even though the plumbing inspectors were skilled and experienced men, they were of necessity more concerned with meeting the plumbing code standards than with preserving lake water quality. Thus, it was felt that the information obtained by the survey would complement, rather than duplicate, what had already been done. The plumbing inspectors of the towns of Mt. Desert and Southwest Harbor agreed to support the student team should any violations of the plumbing code be uncovered. The field work required the following equipment: 100 ft. tape for measuring the distance of sewage disposal systems from shore and property boundaries; Abney level for determining elevation and slope; fluorescein dye in tablet form, dissolved in water in small vials prior to going into the field, which

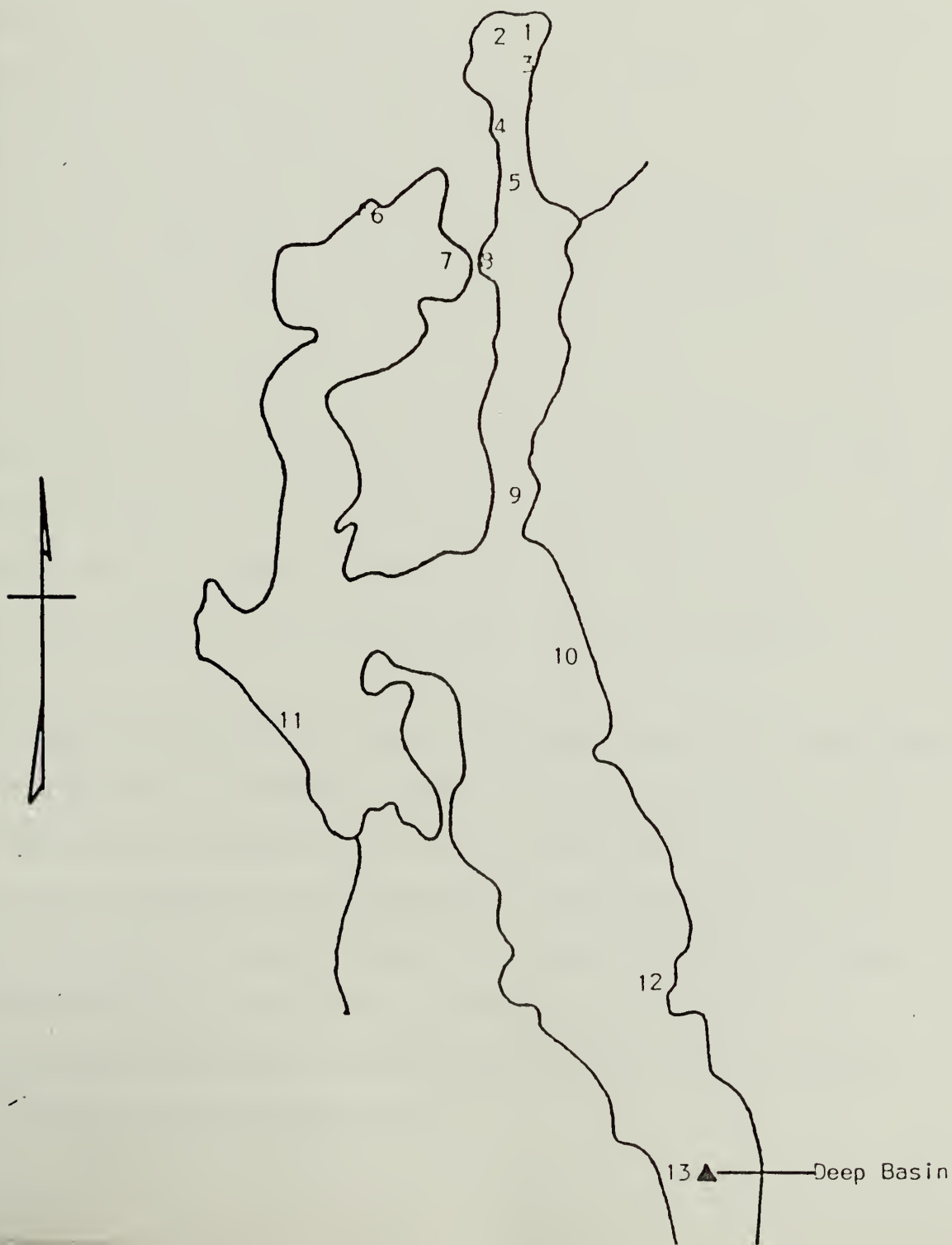
used for dye-testing sewage disposal systems; and chlorine bleach and paper toweling used for cleaning up dye spills. In addition, standard data forms (see Appendix) were taken along and used to record the following for each property inspected: location, township, map and lot numbers, house description, owner's name and addresses, name of person interviewed, months of use per year, average number of occupants, source of drinking water, type of sewage disposal system, plumbing fixtures, date of sewer system installation, date of last pump-out, type of detergent used, distances of buildings and disposal system from lake, elevation of leach field above lake, slope of lot, vegetation, and a site diagram. A space for tabulation of results and results of dye-testing were also included.

A typical interview with a cottage owner would proceed in the following manner. The survey team would approach a cottage and introduce themselves. They explained their mission and referred to the letters which had been sent out. After a few minutes, permission was asked to flush a dye sample down the toilet (sink, etc.) following which one team member would ask questions and fill out the data form while the other member took physical measurements of the property. This entire procedure took about twenty minutes. Usually, however, this was a confidence-building period and would lead into a more lengthy and less formal conversation. At the conclusion of the visit the grounds and lake shore were inspected for any sign of appearance of the dye.

A booklet, "Cleaning Up the Water, Private Sewage Disposal in Maine" (7), and a mimeographed information sheet (see Appendix) with an explanation of the lake study on one side and lake-



Map of Long Pond showing location of water sampling stations (2).



ater and the Secchi disc observed through the tube. Using
Secchi disc viewer" was found to reduce reading irregular-
due to variable lake surface conditions and light reflection.

inity, pH, and Nutrients. After the water temperatures
een recorded, it was possible to distinguish zones of thermal
ification. Water samples were then taken using a van Dorn
er from five depths: surface, bottom of epilimnion, center
talimnion, top of hypolimnion, and one meter off the bottom.
samples were used to determine pH, total alkalinity, ni-
nitrogen, and total and ortho-phosphates.

Total alkalinity and pH were determined simultaneously using
ning Model 7 pH meter. Since the alkalinity values were
low, a special procedure for potentiometric determination of
lkalinity was used (28).

Nitrate nitrogen was determined using the phenoldisulfonic
method (21). Samples were not corrected for chloride ion,
loride concentrations in both lakes had previously been
mined to be well below 10 ppm. A Bausch and Lomb Spectronic
lorimeter with a 2.5 cm light path was used to measure
bance.

Total and ortho-phosphate were determined using an isobutanol
ction technique followed by colorimetric determination of
olybdenum blue complex (27). Previous attempts to measure
-phosphate indicated that phosphate concentrations in both
were less than 10 ppb; hence, the above method was chosen
ts high sensitivity at low phosphate concentrations. As
e foregoing procedure, a Spectronic 20 with a 2.5 cm light
was used to measure absorbance.

al Population. The phytoplankton were sampled using a 10-meter
tion of Tygon plastic tubing (6mm inside diameter). The tubing
weighted at one end and lowered slowly into the water such
t the sample taken represented a 10-meter vertical core. Five
es were combined per sample and fixed to 5% formalin. Sample
lection, preservation, and analysis were according to the pro-
ure outlined by the Maine Department of Environmental Protection
.

thic Macroinvertebrate Population. The benthos was sampled using
5 X 15 cm Ekman dredge. Three samples were taken from the
pest part of the profundal zone of each lake during the winter
gnation period since lack of time prevented summer sampling.
procedure for collection, preservation, and analysis of samples
that outlined by the Maine Department of Environmental Pro-
tion (8) using the sucrose floatation method of Lind (18).

terial Population. Total coliform, fecal coliform, and fecal
eptococci bacteria were tested for using the membrane filter
hnique (3,6,28). The recipes for the preparation of media were
se indicated on the labels of the dehydrated media jars. In
ition to the ingredients listed, 1.5g of Difco agar were added
each 100 ml of media in lieu of using absorbant pads. All media
plates were prepared before going into the field, the number
plates having been determined in advance according to the num-
of water samples to be tested. For each test, each sample
allowed four plates, a control plate and three plates for each
three sample dilutions.

Before going into the field, glass-stoppered BOD bottles were
irilized for 20 minutes at 15 lb. pressure. In the field, samples
e taken over the side of a boat five to ten meters offshore with

entire bottle and cap immersed. Bottles were immediately
led on crushed ice and kept from direct sunlight. Upon return
the laboratory, samples were refrigerated until used. Samples
e considered good only if used before six hours had elapsed
n the time of sampling (6).

RESULTS AND DISCUSSION

Sanitary Survey

The sanitary survey met with an overall favorable response. However, property owners were apprehensive that septic system problems would be uncovered and that they would be reported to local plumbing inspectors, but no real problems were found that the inspectors were not already aware of and no formal complaints were filed. The student interns spent more of their time talking to the residents about water quality and lake problems than they did about the sanitary survey. The lakeshore residents were very interested in their lakes, and it was felt that a heightened sense of awareness of lake problems was achieved through these interviews aside from the information collected.

The results of the Echo Lake sanitary survey are summarized as follows:

Systems surveyed: 29
Average months per year occupancy: 4 1/2
Lot size: 20 adequate, 9 inadequate
Sewage disposal system:
 Septic tanks -- 15 Privies -- 4
 Cesspools -- 8 Other -- 1
System more than 100' from the lake: 14
System less than 100' from the lake: 15
Slope of lot less than 15%: 17
Slope of lot greater than 15%: 12
Maintenance: 19 good, 10 bad
Adequate rating: 15
Inadequate rating: 14

The average figures for occupancy do not include the three

ge recreational facilities on the lake--Acadia National Park
ch, Appalachian Mountain Club camp, and Camp Beech Cliff for
s. The Park beach has an annual visitation of approximately
000 persons. It has a very adequate and well-maintained pumped-
septic system, and according to park officials, receives only
ht usage, using "only one fifth of the amount of paper per
ll than the other comfort stations in the Park". This system
tabulated as adequate. The Appalachian Mountain Club camp has
average occupancy of 100 during 10 weeks of the year. They
e four separate disposal systems, two of which are relatively
v and were deemed adequate, and two of which are old cesspools
d were deemed inadequate. The overall situation here is very
ubtful because of the heavy usage all systems receive. Camp
ech Cliff refused to cooperate with the survey; thus, nothing
known about the adequacy of the sewage disposal system. The
rge numbers of people bathing in Echo Lake and using the three
ove facilities can be expected to contribute to the nutrient
ad on the lake. This is borne out by the bacterial sampling,
ere the only high concentration of total coliforms (150/100 ml)
s found where the Park beach and the Appalachian Mountain Club
mp adjoin.

Of the 14 private disposal systems judged inadequate, eight
re cesspools and six were septic tanks. All the cesspools on
no Lake were thought likely to cause problems for reasons of
e and distance from the lake--the median age was 20-25 years and
e average distance 55-60 feet from the lake. The six poor septic
stems are all located in a small, swampy area near the lake
tlet. Local and state officials, and the property owners are
are of the problem and construction to remedy these systems

s scheduled to begin in September 1975.

A summary of results of the sanitary survey conducted on Long Pond is as follows:

Systems surveyed: 74
Year around residences: no data
Average months per year occupancy: 2 1/2
Average number of occupants: 3
Lot size: 64 adequate, 10 inadequate
Sewage disposal system:
 Septic tanks -- 56 Privies -- 7
 Cesspools -- 10 Other -- 1
System more than 100' from lake: 52
System less than 100' from lake: 22
Slope of lot less than 15%: 45
Slope of lot greater than 15%: 29
Maintainance: 62 good, 12 bad
Adequate rating: 62
Inadequate rating: 12

Although Long Pond has had in the past a large chicken farm, restaurant, a dance hall, and a bottle (private drinking) club on its shores, there are now nothing but private camps. There are no large beaches or commercial camps as on Echo Lake.

Of the 12 sewage systems deemed inadequate, seven were cesspools, four were septic systems, and one was a recirculating chemical toilet. The cesspools, here as on Echo Lake, were located and close to the lake. One of the septic systems was only 10 feet from the lake. The other three were new, pumped-up systems. Two of these were adjacent to one another and the fields located at the top of a steep bank. There was a surface leakthrough from both fields. The other field was in an area of springs and flowing surface water and also had a surface breakthrough. The recirculating toilet was ten feet from a stream running into the lake, and, although there was a 1000-gallon holding-tank nearby, this tank had not yet been installed or placed in operation.

Quality Parameters

temperature and Dissolved Oxygen. When a lake is very unproductive or oligotrophic, the oxygen concentration in the upper layers (epilimnion) decreases as summer stratification develops, while in the lower cool waters (hypolimnion) the oxygen remains near 100% saturation. This ideal situation is found only in a few extremely unproductive lakes or in moderately oligotrophic lakes during the very early stages of summer stratification. Oxidative decay processes occur constantly in the hypolimnion, their intensity reflected by the amount of organic material reaching the lower cool layers from the warm, well-lit upper layers. The oxygen content of the lower waters of very productive or eutrophic lakes is depleted rapidly by the process of decomposition. The resulting dissolved oxygen deficit, in which the hypolimnion is anerobic, is typical of eutrophic lakes (29).

Temperature and dissolved oxygen profiles for Long Pond and Echo Lake are shown in Figures 3 and 4. For purposes of comparison, a temperature-dissolved oxygen profile for Lake Umbagog, a eutrophic lake located in Unity, Maine, is presented in Figure 5. Examination of Figure 3 reveals that cool, well-oxygenated water exists below 17 meters in Long Pond indicating that no oxygen deficit is likely to occur during the period of maximum thermal stratification and that a considerable volume of the lake is suitable as trout and salmon habitat even in late summer. In contrast, the dissolved oxygen-temperature profile of Echo Lake, shown in Figure 4, indicates warmer temperatures and lower oxygen levels below 12 meters than are found in Long Pond. In fact,

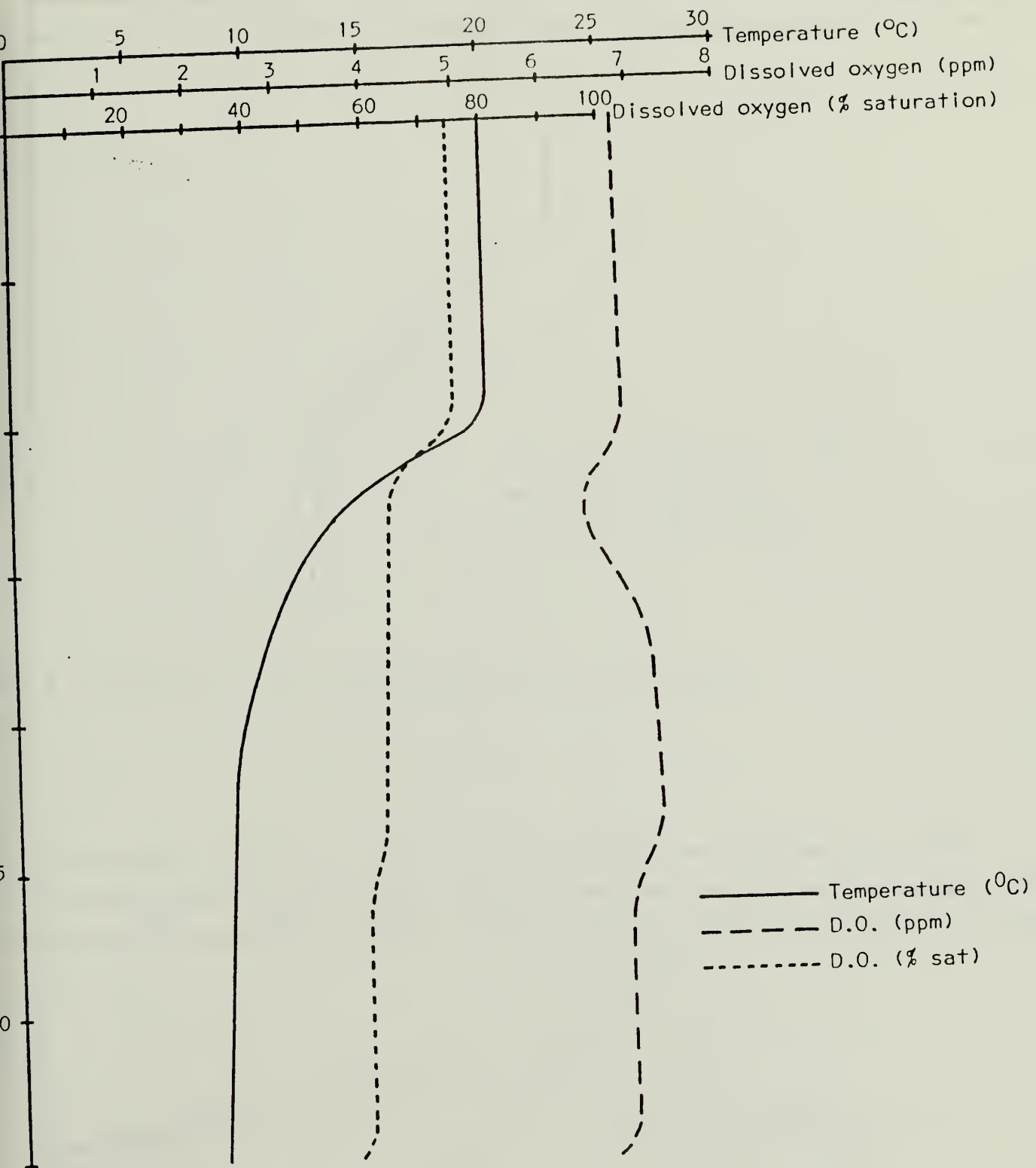


Figure 3. Temperature - dissolved oxygen profile for Long Pond.

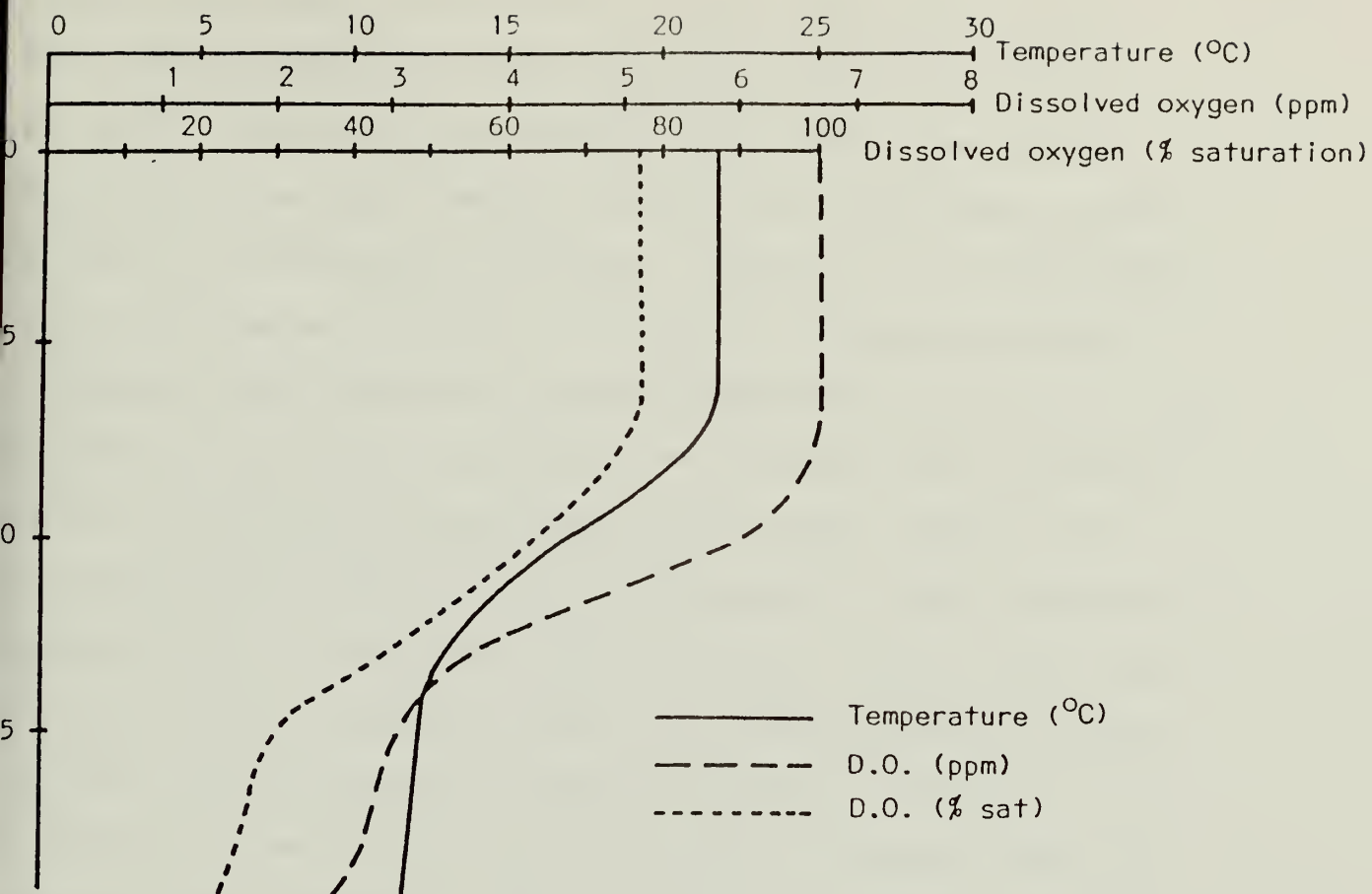


Figure 4. Temperature - dissolved oxygen profile for Echo Lake.

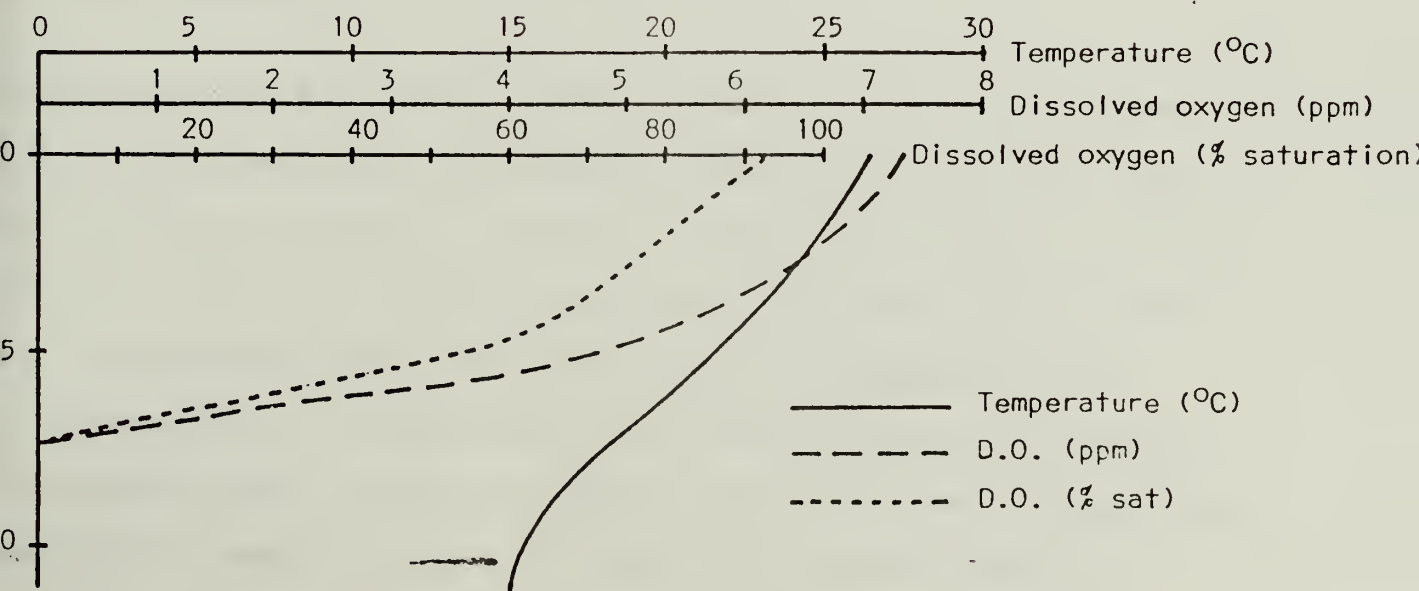


Figure 5. Temperature - dissolved oxygen profile for Lake Winnecook.

dissolved oxygen concentration in the cooler bottom waters of Echo Lake is about half that found in Long Pond. These observations, taken together with the fact that Echo Lake is much shallower and has a smaller volume than Long Pond, suggest that, with the development of summer stagnation, the hypolimnion has the potential of becoming quite poor in dissolved oxygen.

Comparing the dissolved oxygen-temperature profiles of Long Pond and Echo Lake with the profile of eutrophic Lake Winnecook (Figure 5), the most striking difference is the complete absence of dissolved oxygen in the hypolimnion of Lake Winnecook. Oxygen depletion in the deep water indicates exceptionally high bacterial activity associated with the decomposition of organic matter and reflects the much higher biological productivity of Lake Winnecook compared with the MDI lakes. Average values for temperature and dissolved oxygen in the hypolimnion of Long Pond, Echo Lake, and Lake Winnecook are given in Table 2. These data exemplify the differences in trophic status of each lake, with trophic conditions increasing in the order: Long Pond, Echo Lake, Lake Winnecook.

Transparency, pH, Alkalinity, and Nutrients. Secchi disc transparency, pH, alkalinity, and nutrient levels for the lakes under study are given in Table 3. Since no consistent changes in alkalinity were noted with depth, the values given are profile averages. Included are data from Lake Winnecook for comparison.

Differences in transparency are indicative of the abundance of suspended matter including plankton organisms, and transparency values may be used to assess the degree of eutrophication of a lake when considered with other water quality data (26). The

e 2. Comparison of average temperature and dissolved oxygen values in the hypolimnion of three Maine Lakes.

	Long Pond	Echo Lake	Lake Winnecook
h to hypolimnion (m)	17	12	7
erature (°C)	9.2	12.8	16.0
olved oxygen (ppm)	5.9	3.0	0.0

3. Comparison of physical and chemical water quality parameters for three Maine lakes.

Parameter	Long Pond*	Echo Lake	Lake Winnecook
Transparency (m)	10.5	11.0	2.0
	6.5 ^s 6.0 ^b	6.6 ^s 6.0 ^b	6.5 ^s 6.4 ^b
Hardness (ppm CaCO ₃)	2.5	4.8	12.9
Aluminum (ppb)	50 ^s	50 ^s	280 ^{3m}
Lead (ppb)	...	...	21 ^{3m}

Sampling dates for Long Pond and Echo Lake, August 18 through 23, 1975; sampling dates for Lake Winnecook, August 8 through 13, 1973 (23).

Samples taken one meter below the surface and one meter off the bottom, respectively.

Samples taken at 3 meters.

tively high transparencies of Long Pond and Echo Lake compared Lake Winnecook indicate far less suspended matter in the MDI s suggesting less eutrophic conditions than in Lake Winnecook. interpretation is supported by the much higher algal densities observed in Lake Winnecook (see Table 4).

Changes in pH and alkalinity with depth, considered together, be used as an index of biological activity in a lake. At the nt of summer stagnation, pH would be expected to increase in surface layers because of photosynthesis, whereas alkalinity decline because of the precipitation of calcium carbonate. e hypolimnion, conditions would be the reverse, with pH low alkalinity high (17). Changes in alkalinity with depth were gible in Long Pond and Echo Lake, while it increased slight- om 12ppm to 14 ppm in Lake Winnecook, as might be expected more eutrophic conditions.

The lower alkalinities of Long Pond and Echo Lake also suggest levels of certain dissolved nutrients in the MDI lakes com- with Lake Winnecook. Alkalinity, although a measure of lved carbonate and bicarbonate, is indirectly a measure of um and magnesium, both of which play important physiological in aquatic organisms, especially algae, and are required air growth. Carbonate and bicarbonate are also forms of dioxide, the raw material of photosynthesis, and could be ed to increase primary production if no other factors were ng.

s previously noted, nitrates and phosphates are extremely ant nutrients required for the growth of aquatic plants, ularly algae. Although there appears to be little agree- s to the range of concentrations of these nutrients which

e eutrophic conditions, examination of Table 3 reveals far
r levels of $\text{NO}_3\text{-N}$ in eutrophic Lake Winnecook compared with
Pond and Echo Lake. Unfortunately, levels of $\text{PO}_4\text{-P}$ for the
akes could not be determined because of the very low con-
ations present and the resultant difficulties encountered
the phosphate analysis. However, the results of the nitrate
mination, considered together with alkalinity, suggest that
Pond and Echo Lake are poorer in total dissolved nutrients
ence, less eutrophic than Lake Winnecook.

Population. Direct measurement of algal density provides
strongest evidence of eutrophication since numbers of algae
direct manifestation of the biological productivity of a

Furthermore, certain groups of freshwater algae, notably
bluegreens, come to predominate the phytoplankton during
ds of peak growth which result in "water blooms".

A comparison of the algal populations of the MDI lakes and
Winnecook during the period of summer stagnation is pre-
d in Table 4. The differences in algal populations between

DI lakes and Lake Winnecook are striking. Not only are algal
ties in late summer in the MDI lakes much smaller than in
Winnecook, but members of the bluegreen algae, whose pre-

in large numbers is indicative of highly eutrophic con-
ns, predominate in Lake Winnecook. The algal density in
Winnecook is 87 times greater than that of Long Pond and

times greater than that of Echo Lake. Furthermore, 85% of
total algal population in Lake Winnecook consists of bluegreens,
red with Long Pond and Echo Lake in which the bluegreens
up 2% and 15% of the total population respectively.

4. Comparison of algal populations for three Maine lakes.

on	Genus	Number of organisms/ml of water		
		Long* Pond	Echo Lake	Lake Winnecook
PHYTA				
	<u>Ulothrix</u>	12	4	...
	<u>Ankistrodesmus</u>	1	...	...
	<u>Staurastrum</u>	8	...	...
	<u>Arthrodesmus</u>	...	...	1
	<u>Sphaerocystis</u>	...	...	428
PHYTA				
	<u>Asterionella</u>	8	7	8
	<u>Chrysosphaerella</u>	3	...	...
	<u>Diatoma</u>	...	2	...
	<u>Dinobryon</u>	3	1	...
	<u>Mallomonas</u>	1	...	...
	<u>Navicula</u>	...	1	...
	<u>Tabellaria</u>	7	6	22
	<u>Melosira</u>	...	...	32
	<u>Cyclotella</u>	...	...	13
	<u>Fragillaria</u>	...	...	267
PHYTA				
	<u>Anabaena</u>	...	1	1670
	<u>Polycystis</u>	1	3	...
	<u>Microcystis</u>	...	...	1659
	<u>Gomphosphaera</u>	...	...	208
	<u>Chroococcus</u>	...	...	18
	<u>Agmenellum</u>	...	...	656
PHYTA				
	<u>Glenodinium</u>	8	1	...
	<u>Peridinium</u>	5	...	...

Sampling dates for Long Pond and Echo Lake, August 20, 1975;
Sampling date for Lake Winnecook, September 1, 1973 (23).

Cystis and Anabaena, which dominate the bluegreens in Lake
Winnecook, are the characteristic "water bloom" organisms (12).
Observations provide the strongest evidence that Long Pond
and Echo Lake are relatively nutrient-poor and far less eutrophic
than Lake Winnecook.

Macroinvertebrate Population. There are striking
differences in the benthic macroinvertebrate fauna of the Mount
Island lakes and Lake Winnecook as shown in Table 5. Most
of the differences are the dominance of the bottom fauna of Long Pond and
Echo Lake by the dipteran genera Chaoborus, Chironomus, and
Tubifex. In contrast, smaller numbers of dipteran larvae
dominated by the genera Chaoborus, Cryptochironomus, and
Limnodrilus are found in the bottom sediments of Lake Winnecook.
An important dissimilarity between the lakes is the presence
of tube-dwelling worms of the genera Tubifex and Limnodrilus in Lake
Winnecook and their complete absence from Long Pond and Echo Lake.
Although the genera Chaoborus and Chironomus are often
associated with eutrophic conditions (12), their appearance in
small numbers in the MDI lakes compared with Lake Winnecook comes
as a surprise. One might normally expect the opposite situation.
The presence of these organisms in the relatively nutrient-poor,
oxygenated waters of Long Pond and Echo Lake might be
explained for by the fact that members of these genera can tolerate
a wide range of dissolved oxygen conditions. Chironomus, for
example, has been collected from habitats in which the dissolved
oxygen concentration has ranged from 1-14 ppm (25). The Chir-
onidae, including the genera Chironomus, Tanytarsus, Crypto-
chironomus, and Brillia, are the most ubiquitous aquatic insects (25),

le 5. Comparison of benthic macroinvertebrate populations
for three Maine Lakes.

Lum	Class	Genus	Number of organisms/square meter of bottom		
			Long Pond*	Echo Lake	Lake Winnecook
TROPODA					
	Insecta				
		<u>Chaoborus</u>	11873	9727	2013
		<u>Chironomus</u>	286	1859	...
		<u>Tanytus</u>	143	286	...
		<u>Cryptochironomus</u>	...	...	133
		<u>Brillia</u>	...	...	143
	Arachnida				
		<u>Neumania</u>	...	286	...
ELIDA					
	Oligochaeta				
		<u>Tubifex</u>	...	...	198
		<u>Limnodrilus</u>	...	...	209

Sampling dates for Long Pond and Echo Lake, April 21-22, 1975; sampling date for Lake Winnecook, April 21, 1974 (23).

their presence per se, in the absence of supporting evidence, not be a reliable index of the trophic status of a lake.

More explainable is the presence of the worm genera Tubifex and Limnodrilus in the bottom sediments of Lake Winnecook and their absence from Long Pond and Echo Lake. Both genera are highly resistant to oxygen stress, and, although present in "clean" environments, may come to dominate the bottom fauna under anoxic conditions (11). Their absence from Long Pond and Echo Lake is an indication of lower levels of organic matter composition in the bottom sediments of the MDI lakes suggesting less eutrophic conditions than prevail in Lake Winnecook.

Bacterial Population. Natural waters contain many types of bacteria, some of which have their origin in the excremental waste of warm-blooded animals, including humans. Although not commonly used as an index of eutrophication, levels of such bacteria may be indicative of sewage discharge into lake waters, and indirectly, nutrient input.

A group of easily cultivated bacteria is used to indicate the presence of fecal contamination of surface waters. These indicator organisms include total coliforms, fecal coliforms, and fecal streptococci.

Total coliform counts have been the most widely employed method of estimating fecal pollution since the total coliform density is roughly proportional to the amount of excremental waste present (6). Total coliform population limits have been set by federal and state health services, these limits varying with the designated use of the water supply. For example, the Maine Department of Health and Welfare designates 1 coliform

colony per 100 ml as the upper limit for drinking water requiring no disinfection, higher values indicating unsatisfactory conditions requiring sterilization if the water is to be used for drinking or cooking purposes (10). The Maine Department of Environmental Protection, in its classification of fresh surface waters, designates that those of highest quality (Class A) shall contain not more than 100 colonies per 100 ml, and that such waters can be used for recreational purposes, including bathing, and for public water supplies after disinfection (5). With certain exceptions, high total coliform counts are suggestive of significant contamination by excrement of warm-blooded animals, but high coliform levels must be interpreted with caution since (a) they may have their origin in the feces of birds and wild mammals, in addition to humans, and (b) certain members of this group are also present in soils and in vegetation (10).

Fecal coliform counts are becoming more commonly employed as pollution indices because of their relatively infrequent occurrence except in association with fecal pollution. Moreover, when accompanied by fecal streptococci counts, fecal coliform values may aid in the differentiation of animal from human waste (6). Because survival of the fecal coliform group is shorter in fresh surface waters than for the coliform group as a whole, high fecal coliform levels also indicate relatively recent pollution (6).

Since fecal streptococci do not occur and cannot reproduce except in the intestinal tracts of warm-blooded animals, their presence in surface waters indicates the existence of fecal pollution by warm-blooded animals. Furthermore, when

accompanied by fecal coliform studies, fecal streptococci determinations serve as a valuable tool in differentiating animal from human wastes. In intestinal wastes of human origin, the ratio of fecal coliforms to fecal streptococci tends to be greater than four. In comparison, when such ratios are determined for intestinal wastes from non-human sources, the values tend to be markedly less than 0.7 (6).

In this study an attempt was made to determine total coliforms, fecal coliforms, and fecal streptococci. The fecal coliform counts were deemed invalid because of technical difficulties encountered in keeping the plates uniformly incubated and free of water. The total coliform and fecal streptococci counts for Long Pond and Echo Lake are given in Table 6 along with total coliform counts from Lake Winnecook. Station locations are given in the Appendix and are shown on the maps in Figures 1 and 2.

The data in Table 6 indicate that higher levels of total coliform bacteria are found in Lake Winnecook than in Long Pond and Echo Lake, and, of the MDI lakes, Long Pond has a lower average total coliform count than Echo Lake. These results suggest that lower levels of fecal pollution exist in the MDI lakes and that the levels of nutrient input from human sources might also be lower. The highest value for total coliforms was 50 colonies per 100 ml, which was found at the Acadia National Park beach on Echo Lake and which probably was derived from the large concentration of bathers in the area. The values observed for fecal streptococci are of interest since a number of locations were free of these bacteria, indicating that a large fraction of the total coliforms may have been derived from other

Echo Lake is about one-half that of Long Pond, then nutrient loading (due to human contributions of all types) can be expected to be far greater in Echo Lake than in Long Pond. This suggests that Echo Lake is much more predisposed to cultural eutrophication than is Long Pond. Since 50% of the private sewage disposal systems surveyed on Echo Lake were deemed inadequate compared with only 16% on Long Pond, it is apparent, in light of the preceding discussion, that a more vigorous effort is required by Echo Lake residents in preventing or intercepting nutrient flow to the lake.

Due to the location and topography of both Echo Lake and Long Pond, there is little probability that lakeshore residences will be connected to a municipal sewerage system in the foreseeable future. Thus, careful planning and use of individual systems will continue to be a common practice. Septic systems are of limited lifespan since they involve percolation of effluent

Lake Winnecook		Station	Total Coliforms (cells/100 ml)
co-	cells/100 ml)		
A	18		
B	34		
C	0		
D	>800		
E	40		
L	68		
137			
75; sampling date for Lake Winne-			

serious problem, compared with the disposal of excremental wastes. However, "grey water" contains a large fraction of the plant nutrients, especially phosphates, which enter disposal systems. Thus, the least expensive and most convenient solution to preventing nutrient enrichment of lake waters is for lake residents to refrain from using phosphate-containing detergents. A list of recommended phosphate-free detergents is given in the Appendix.

A summary of water quality parameters which illustrate the important differences between the MDI lakes and Lake Winnecook is given in Table 7. The shallow depth, absence of dissolved oxygen in the hypolimnion, elevated bottom temperature, limited transparency, high levels of dissolved nutrients, high algal densities, predominance of bluegreen algae, and the presence of mudworms in the deep basin sediments of Lake Winnecook definitely characterize the lake as eutrophic (compare these with the lake features in Table 1). In contrast, the MDI lakes are deeper, possess higher levels of dissolved oxygen in the hypolimnion, have cooler bottom waters, far greater transparency, lower levels of nutrients, much lower algal densities, and do not have mudworms in the deep basin sediments. Thus, the MDI lakes are far less eutrophic than Lake Winnecook.

Comparing the MDI lakes with each other, as brought out in the previous discussion, Echo Lake is more predisposed to cultural eutrophication due to the threat of nutrient loading than is Long Pond. Furthermore, the water quality data presented in table 7 suggest that Echo Lake is more eutrophic than Long Pond. This may be inferred from Echo Lake's shallower

Table 7. A summary of water quality parameters comparing three Maine lakes.

	Long Pond	Echo Lake	Lake Winnecook
Maximum depth* (m)	14.0	8.5	5.3
Dissolved oxygen in epilimnion (mean saturation)	51	28	0
Epilimnion temperature (mean °C)	9.2	12.8	16.0
Transparency (m)	10.5	11.0	2.0
NO ₃ -N (ppm)	50	50	280
Alkalinity (ppm CaCO ₃)	2.5	4.8	12.9
Algal population (organisms/ml)	57	26	4982 ^{bg}
Tube worms in bottom sediments (organisms/m ²)	0	0	407 ^{tl}

Estimated by summing the values of the depth soundings on the Maine Department of Inland Fisheries and Game maps (1,2) and dividing by the number of soundings.

Algal population of Lake Winnecook dominated by blue-green algae.

Sum of Tubifex and Limnodrilus spp.

depth, greater oxygen depletion in the hypolimnion, and warmer bottom temperatures. On the other hand, the transparency of Echo Lake is similar to that of Long Pond, while Echo Lake's algal density is lower than that of Long Pond. Since the algal counts were based upon a single sampling of each lake, these differences in algal densities are probably more apparent than real.

ECONOMIC IMPACT

A study such as this should not be expected to have any immediate economic impact, except, perhaps, by encouraging a higher level of maintenance of present sewage disposal systems or installation of new ones. In contrast, the long-range economic implications are profound. Even if the simple measure of dispensing with phosphorus-containing detergents is followed by lake shore residents, the rate of cultural eutrophication will be slowed considerably. This means that high lakefront property values, productive trout and salmon fisheries, excellent swimming conditions, and a potable water supply will be protected to be enjoyed for many more years to come.

RECOMMENDATIONS FOR THE FUTURE

The results of this study, especially the water quality work, are based upon a minimum number of observations. This precluded an understanding of seasonal fluctuations in water quality; for example, if an algal bloom had occurred on Echo Lake two weeks prior to sampling, it simply would have passed unnoticed. Furthermore, difficulties encountered with the phosphate analysis

prevented a more detailed assessment of dissolved nutrients available for algal growth. It also became apparent that some water quality parameters were more useful than others in establishing the trophic status of a lake; for example, measurement of algal populations was more meaningful than examining benthic macroinvertebrate populations.

With the above limitations to the present investigation in mind, it is proposed that the eutrophication study of Long Pond and Echo Lake be continued for another year, with the emphasis placed upon gathering water quality data over a 12-month period at weekly or biweekly time intervals, depending on the season. The water quality parameters to be measured should include: transparency, temperature, dissolved oxygen, conductivity, and algal population. The first four measurements can be carried out rapidly in the field, while assessment of the algal population would involve more extensive laboratory evaluation. The advantage of such an approach, compared with one-time sampling, would be to give a much more accurate picture of the biological productivity of the MDI lakes on an annual basis. With these base-line data available, when the lakes are examined at some future date to determine what changes in water quality have occurred, a much more precise assessment of the changes will be possible.

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APPENDIX

n-phosphate cleansing agents recommended for use by lake residents*

Bar Soaps

Ivory
Irish Spring
Palmolive
Safeguard
Cashmere Bouquet

Laundry Soap Powders

Arm & Hammer
Ivory Snow
Ivory Flakes
Instant Fels
Purex

Liquid Dishwashing Detergents

Staff Lime, Lemon, Pink Lustre
Lemon Chiffon
Palmolive
Joy
Ivory Liquid
Thrill
Dove
Lux
Ajax
Octagon

Liquid Laundry Detergents

Era
Dynamo
All

Liquid Fabric Softeners

Rain Barrel
NuSoft
Staff Soft Fabric Rinse

If in doubt, check container labeling; most products specify if phosphates are present or not, and if they are, the percentage by weight of phosphorus.

Location of bacterial sampling stations, Mount Desert Island
lake study, summer 1975.

Long Pond

Station	Location
1	Boat ramp
2	Kane/Shaw
3	Kelmenson/Cote
4	Armstrong/Ross
5	Haraden
6	Contrini
7	Van Allen
8	Causeway
9	Hinckley
10	Poulton
11	West Arm Beach
12	Sellers
13	Deep Basin
14	Tyson

Echo Lake

Station	Location
1	Russell
2	Fuerst
3	Pfeiffer
4	Camp Beach Cliff
5	Deep basin
6	ANP beach



College of the Atlantic

Bar Harbor, Maine

June 23, 1975

Dear

This summer a small group from the College of the Atlantic is conducting a program of sewage system testing around Echo Lake and Long Pond. The purpose of this survey is to gather background information for a long range study of the water quality of the lakes of MDI and to provide landowners with information about private sewage disposal and lakeshore ecology.

The testing will be done with a harmless bright red dye which will be flushed down toilets and placed in drains. The survey personnel will also ask several questions about your sewage system (when it was installed, what size, etc.), take a small soil sample, and make several measurements on your property.

The survey personnel have been trained in water quality testing techniques and environmental law, and will help you with any questions or problems you might have with the State Plumbing Code, the Great Ponds Act, or municipal shoreland zoning. They will be carrying informative material relating to these environmental laws; we hope you will make use of this information as needed.

The survey will take place during July. If you will be at your cottage only on certain days or weekends of the summer, we would appreciate it if you could call or write us, so that we may schedule you for that time. We believe that this survey will be helpful to you in improving your property and maintaining the water quality of the lake. Also, if you have any questions about our survey or about any environmental problems that you are concerned with, please contact us at the college. Our telephone number is 288-5015. We are here to help and we look forward to meeting you this summer.

In August we plan to conduct a workshop and field trip in order to inform lakeshore residents of the results of the study and to train interested persons in basic water sampling and monitoring techniques. Further information on the workshop and field training session will be forthcoming.

Sincerely,

A handwritten signature in cursive script, reading "Fred C. Olday".

Fred C. Olday, Ph.D.
Director
Lake Study Program

MOUNT DESERT ISLAND LAKE STUDY

The unsurpassed natural beauty of Mount Desert Island annually draws millions of visitors from other parts of the United States. An important feature of the scenic landscape and a natural resource of high recreational value are the Island's lakes. In addition to their use as vacation home sites and for fishing, swimming and boating activities, a number of these lakes also serve as municipal reservoirs.

To date, no thorough scientific study of the water quality of the lakes has been done. The Mount Desert Island Lake Study is a five-year program conceived and directed by Dr. Fred Olday, faculty member in biology at the College of the Atlantic, to gather baseline, physical, chemical, biological, and cultural data. In addition, the lake study hopes to inform the local users of the lakes about the results of the study, to create public awareness of the problems of lake pollution, and to train students, local residents and local officials in techniques of water quality monitoring. Endorsement of the study is given by Acadia National Park, the Park Coordination Commission and the Echo Lake Association.

Work began this spring, when a group of six students from COA began the mapping, sampling, and analysis of Echo Lake and Long Pond. The study is continuing this summer and will include an aquatic vegetation survey, a sanitary survey of all lake shore residences, and organization of water quality workshops for lake residents. In addition, the following physical, chemical and biological parameters of water quality will be assessed during the summer stagnation period: temperature profile, dissolved oxygen profile, nutrients (N and P), bacterial population, algal population, color, transparency and conductivity.

HOW YOU CAN HELP THE LAKE

- Do not fertilize lawns and gardens near the lake.
- Do not disturb the natural shoreline vegetation, rocks, and soil; maintain a buffer strip of natural vegetation between gardens, camps, and the waterline.
- Try to keep or plant trees between the lake and your septic tank leaching field.
- Use low or no-phosphate detergents.
- Limit washing machine use and use local laundromats.
- Do not bathe or shampoo in the lake.
- Do not put cooking oils and grease in your toilet.
- Adjust toilet to use less water; put a brick in the toilet tank if necessary to reduce water volume.
- Cut down on shower time and water use throughout the house.
- Encourage and use rowboats and canoes.
- Have your septic tank cleaned and pumped frequently. The following is a list of septic tank pumpers that service your area:

Robinson Hardware and Sheet Metal Co. Main Street, Southwest Harbor	244-3200
Trenton Plumbing and Heating Trenton	667-5135
Ray Plumbing and Heating High Street, Ellsworth	667-5536 (local) 800 432-7826 (tollfree)
off hours (private) Donald Sullivan, Jr. Northeast Harbor	244-3275

If you have any questions or suspect problems with the water quality of your lake, contact your local town office and if you wish to help with this study, telephone or come to the College of the Atlantic in Bar Harbor (288-5015) and ask for the summer lake study interns.

August 1976

Dear Lakeshore Resident,

On Saturday morning, August 23rd, the College of the Atlantic Lake Study Group will hold a workshop in the auditorium at the College campus on Eden Street in Bar Harbor.

The purpose of the workshop is to inform interested persons of the goals of the Lake Study and to present the results of this summer's work. In addition, we will present a speaker from the Congress of Lake Associations and a discussion of the possibility of forming a Long Pond Watershed Association. Finally, a time will be arranged for interested persons to participate in a field session dealing with water monitoring techniques.

WATER QUALITY WORKSHOP
Saturday morning, August 23, 1975
COLLEGE OF THE ATLANTIC AUDITORIUM

8:30 - 9:00	Coffee and doughnuts
9:00	Introduction and Explanation of the Goals of the MDI Lake Study Dr. Fred Olday, Director
9:30	Results of this Summer's Sanitary Survey of Echo Lake and Long Pond Karen Roy, Student Intern
10:00	Results of this Summer's Water Quality Analysis of Echo Lake and Long Pond Bruce Bender, Student Intern
10:30	Concluding Remarks. Organization of a field trip to demonstrate water quality monitoring techniques.
10:45	Break -- Refreshments
11:15	"Maine Lakes and Lake Problems" Patricia Stimets, Executive Director, Congress of Lake Associations of Maine
12:00	Discussion-- Formation of a Long Pond Watershed Association -- Representatives of the Long Pond Ripples Camp Association

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