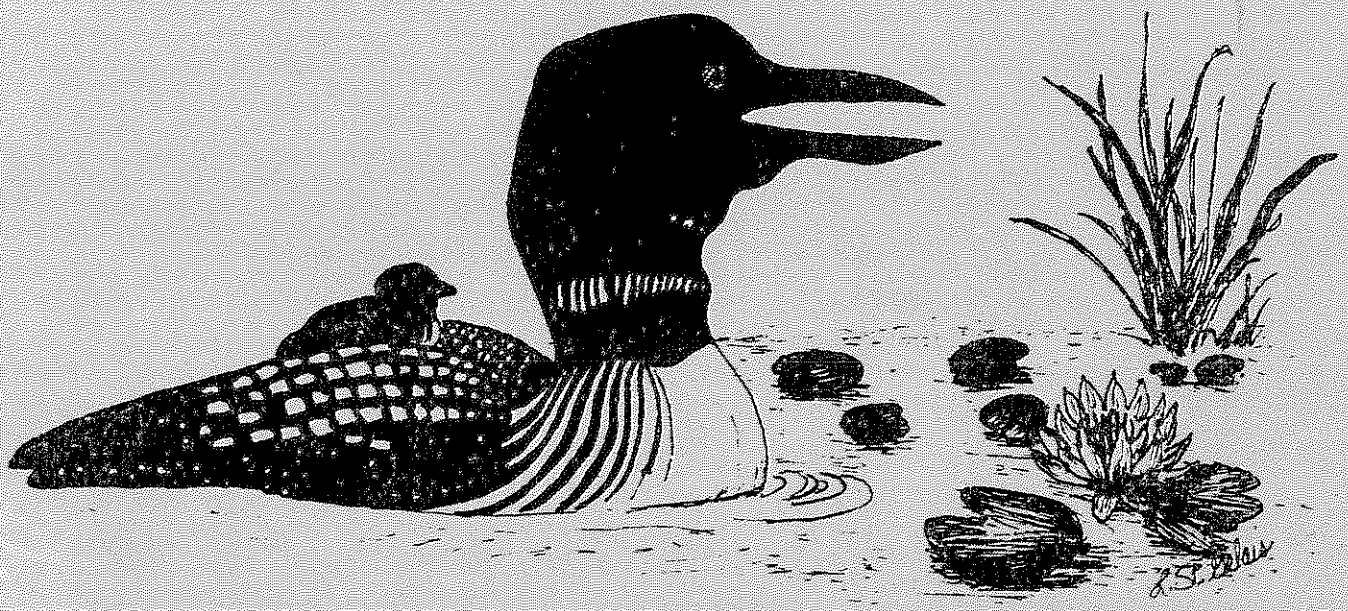
# THE PEMAQUID LAKES
# 1995
## NH LAKES LAY MONITORING PROGRAM

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**University of New Hampshire**

UNIVERSITY OF NEW HAMPSHIRE COOPERATIVE EXTENSION


NEW HAMPSHIRE LAKES LAY MONITORING

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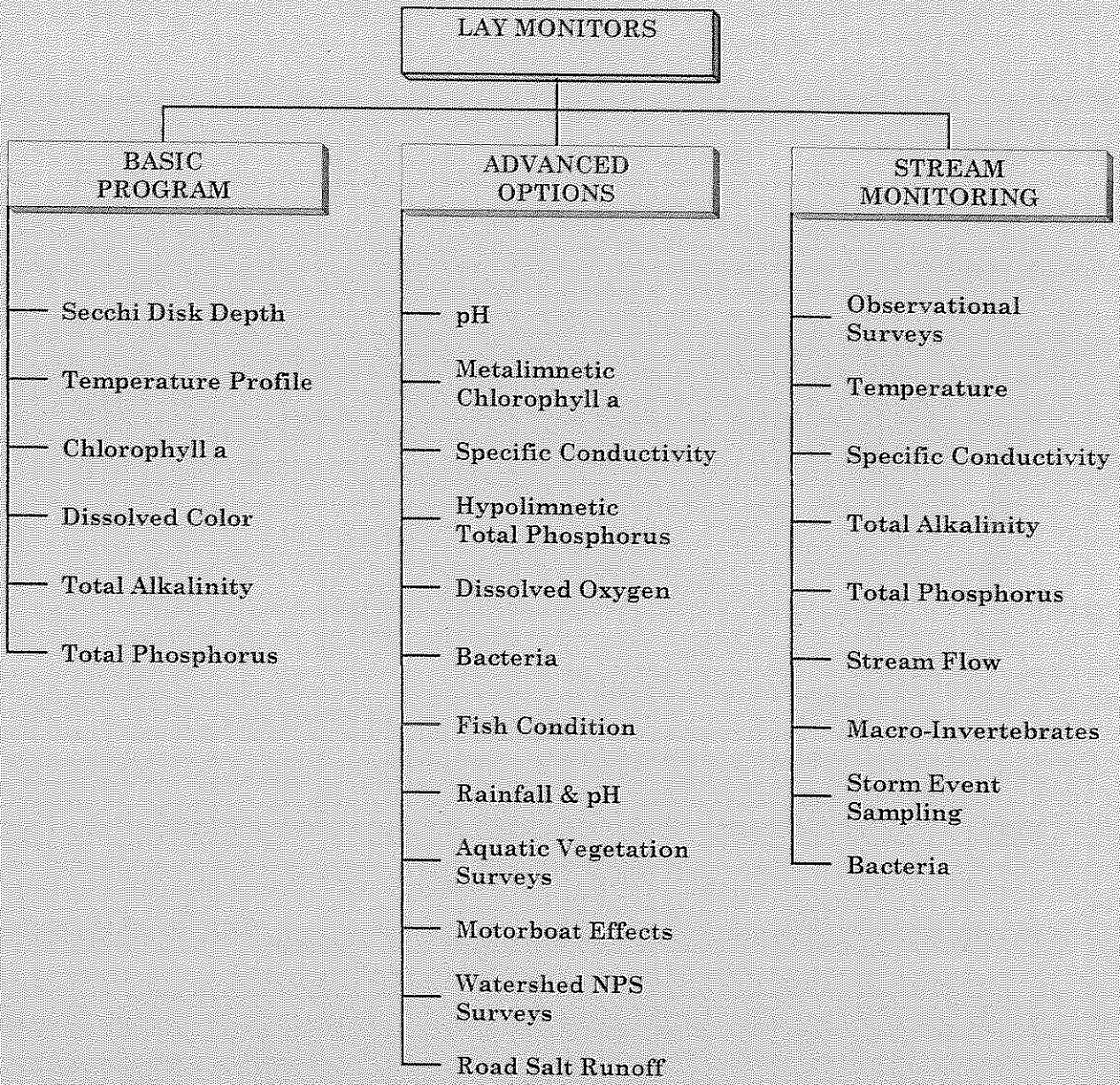
# PARAMETERS SAMPLED

## NH LAKES LAY MONITORING PROGRAM




Freshwater Biology Group (FBG) corroboration with the lay monitor data includes assessment of 1) physical parameters (water transparency, temperature profiles, light transmission profiles and water color); 2) chemical parameters (dissolved oxygen profiles, "free" carbon dioxide, total alkalinity, pH, total phosphorus and specific conductivity profiles); 3) biological parameters (chlorophyll a, phytoplankton community and zooplankton community). Note: in addition to the above parameters, other measurements are often collected at the discretion of the FBG or at the request of the lake association.

# PREFACE

This report contains the findings of a water quality survey of the ponds in the **Pemaquid Watershed Association (PWA)**, towns of Bremen, Bristol, Damariscotta, Nobleboro and Waldoboro, Maine, conducted in the summer of 1995 by the **Freshwater Biology Group (FBG)** of the University of New Hampshire and the **Pemaquid Watershed Association**.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1995 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

# ACKNOWLEDGMENTS

1995 was the eighth year of participation in the **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** for the **Pemaquid Watershed Association** monitors. Peter Fischer again undertook the formidable task of coordinating the multi-lake study and acted as liaison to the **Freshwater Biology Group (FBG)**.

**Table 1. 1995 Pemaquid Watershed Association Volunteer Monitors.**

| Monitor Name | Lake Monitored |
|---|---|
| Scott Giguere | Biscay |
| Peter Fischer | Boyd |
| David Libby | Duckpuddle |
| Albert "Mac" Rogers | McCurdy |
| Steve O'Bryan | Paradise |
| David McLeod | Pemaquid |

**The Freshwater Biology Group** congratulates the Lay Monitors on the quality of their work, and the time and effort put forth. We encourage other interested members of the **Pemaquid Watershed Association** to continue the ongoing water quality monitoring effort in 1996.

Financial support for the volunteer monitoring effort was provided by the towns of Bremen, Bristol, Damariscotta and Nobleboro. Additional support was supplied by the Great Salt Bay Sanitary District, which provided lab space and personnel who performed bacteriological analysis, the Mobile Glass Company of Bristol, which assisted in equipment repair, and Gilliam's Fish Market in Damariscotta, which acted as a collection point for water quality samples. We would also like to acknowledge the past support of the GTE Telephone company (grant for digital thermometers) and the Science Source of Waldoboro (equipment donation) through whose contributions data collection has become more efficient.

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included, Robert Craycraft (laboratory and field team coordinator), Neim Hoang Dang, Tracy Grazia, Sean Proll and John Raifsnider. Other **FBG** staff assisting in the fall included Jessica Chappel and Rick Falzone.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Derry Conservation Commission, Dublin Garden Club, Governor's Island Club Inc., Meredith Bay Rotary Club, Nashua Regional Planning Commission, The New Hampshire Audubon Society, The Pemaquid Watershed Association, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Berry Bay, Bow Lake Camp Owners, Caanan Street, Canobie Lake, Chalk Pond, Chesham Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin

Lake, Glines Island, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pea Porridge Pond, Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Sunset Lake, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

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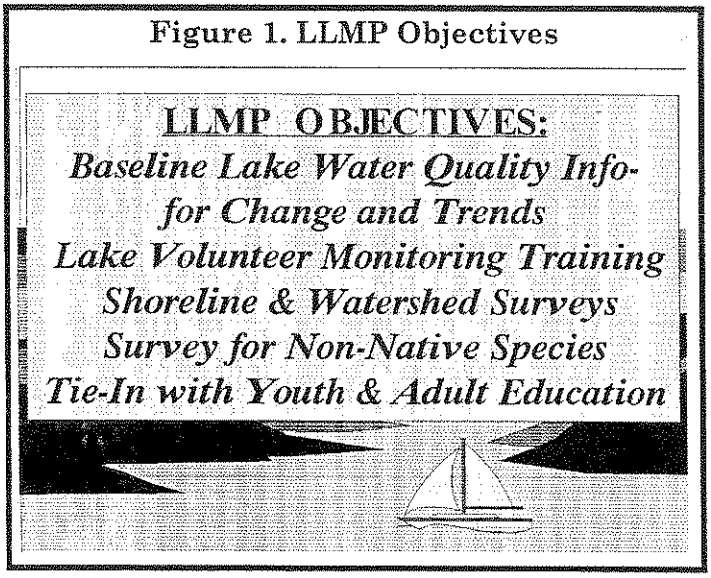
# INTRODUCTION

## The New Hampshire Lakes Lay Monitoring Program

1995 marked the eighteenth year of operation for the **NH Lakes Lay Monitoring Program (LLMP).** The LLMP has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

**Figure 1. LLMP Objectives**




The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative costshare funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

The 1995 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program.** National recognition for the high quality of work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Figure 2).

Our work with volunteer monitor data incorporated into Geographic Information System technology was covered the spring '95 issue of the Volunteer Monitor Newsletter of which we were co-editors. The new Watershed Evaluation System for non-point source pollution (NPS Pollution) was field tested by our Wentworth and Winnipesaukee monitors and has been presented at meetings and conferences across the country. We completed a long-term trend study of selected areas of Lake Winnipesaukee utilizing a decade of data collected by our **NH LLMP** volunteers, for the Lakes Region Planning Commission, which was published as part of the Winnipesaukee Watershed Project. Working with teachers at Salem High School we incorporated

Figure 2. Awards & Recognition

AWARDS

and

1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal
1991- Renew America Success Award
Environmental Success Index
UN Environmental Programme
Soviet Embassy Reception
White House Environment Breifing
1992- EPA Administrators Award
Environmental Exchange Network
1993- NH Lakes Association
1994- Fourth National Citizens' Volunteer Monitoring Conference
EPA Office of Watersheds Award
1995- Co-editors Volunteer Monitor Newsletter (Spring Issue)
Winnipesaukee Watershed Project

students into a watershed protection study of Canobie Lake. The results of this project were quite astounding with students preparing posters and informational materials for their neighbors, for the Salem town meeting and for a special presentation to local officials.

On the local front, the NH Senate Agricultural and Environment committee and the NH House Resource, Recreation and Development Committee were again briefed on **NH LLMP** activities. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America and on the Environmental Network Clearinghouse and were recently acknowledged by the National Awards Council for Environmental Sustainability. To date, the approach and methods of the NH LLMP have been adopted by new or existing programs in twenty two states and ten countries (Figure 3)!

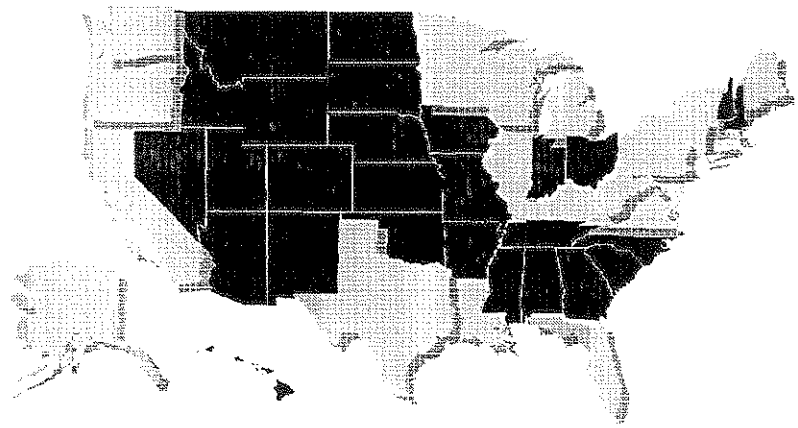
## Importance of Long-term Monitoring

A major goal of a monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For almost two decades, weekly

Figure 3. National LLMP Support to Volunteer Monitoring Programs

**NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 22 States.**



**Light gray shading denotes LLMP assisted states**

data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

Consider the hypothetical data depicted in Figure 4. Sampling only once a year during August from 1988 to 1992 produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" was only manageable through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection in our hypothetical lake.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened,

Figure 4.

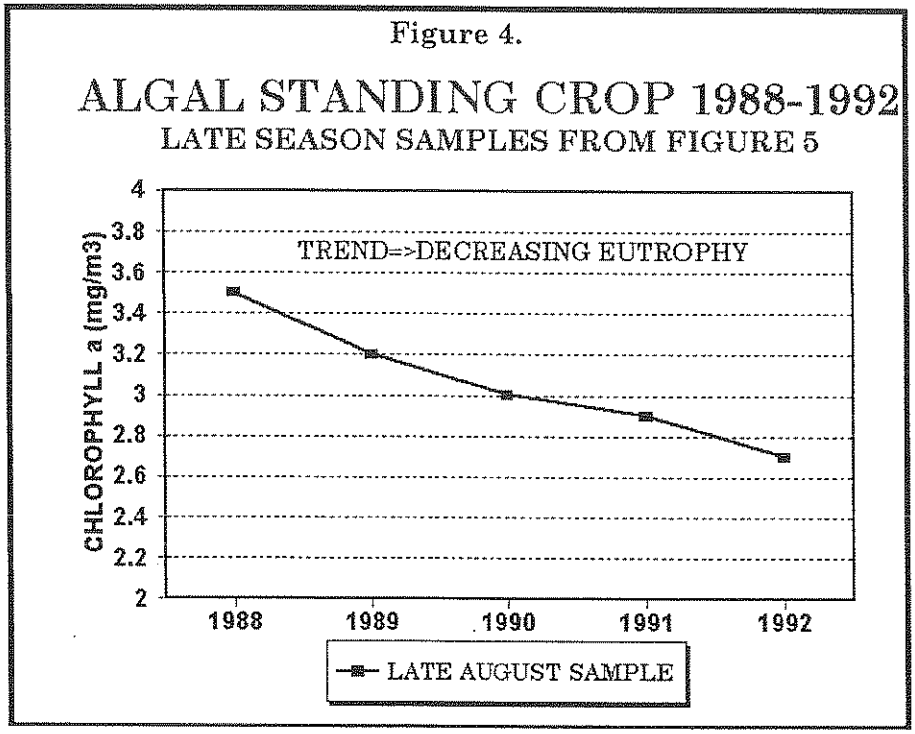



Figure 5.

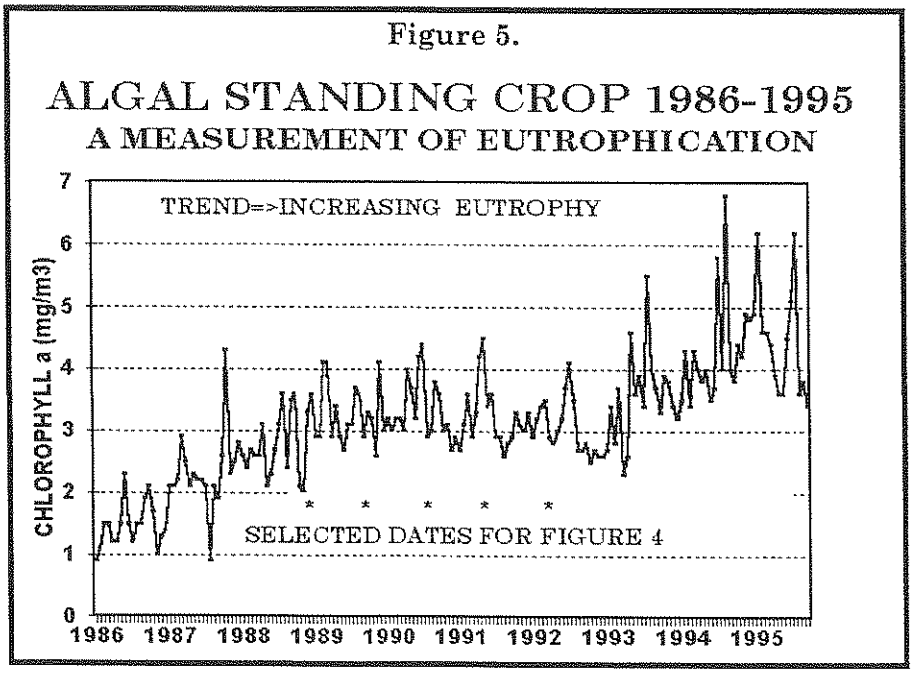


**Figure 6.** Locations of the ponds falling within the Pemaquid Watershed.

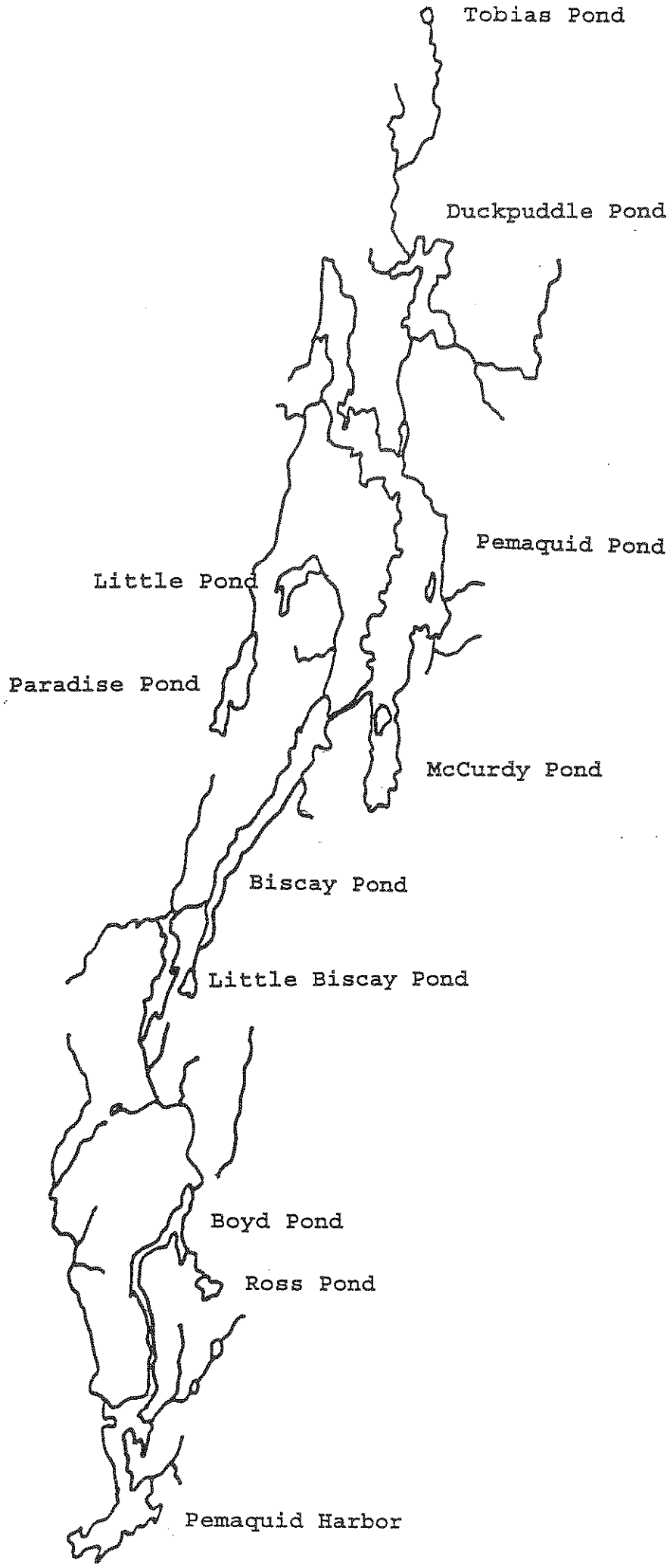

Tobias Pond
Duckpuddle Pond
Pemaquid Pond
Little Pond
Paradise Pond
McCurdy Pond
Biscay Pond
Little Biscay Pond
Boyd Pond
Ross Pond
Pemaquid Harbor

**Figure 7.** Location of the Duckpuddle Pond, Site 1 Basin; and Pemaquid Pond, Sites 1 Basin and 2 Basin; in-lake sampling stations. The location of the Glendon Stream sampling station, which feeds Duckpuddle Pond, is also listed.

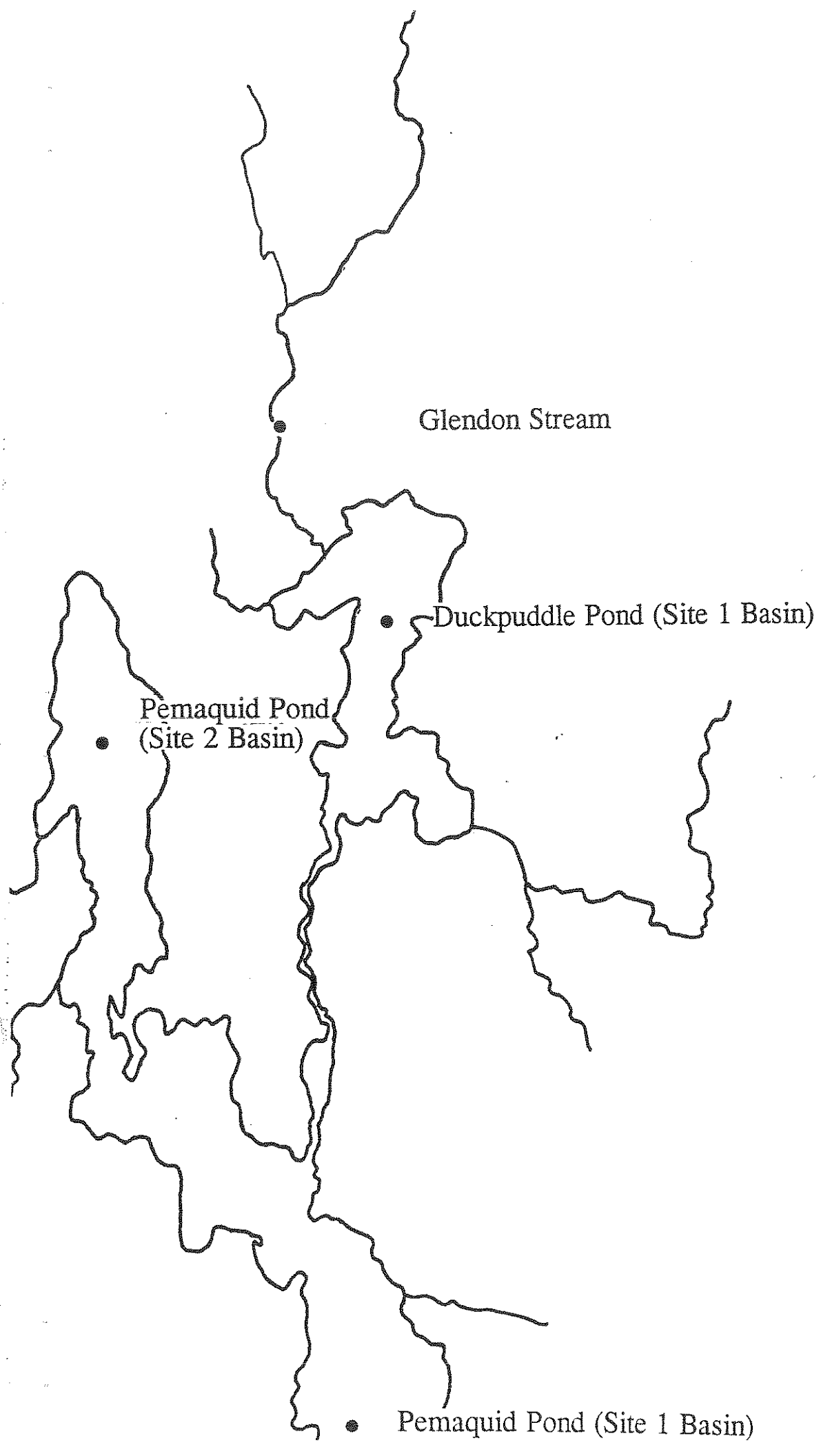

Glendon Stream
Duckpuddle Pond (Site 1 Basin)
Pemaquid Pond
(Site 2 Basin)
Pemaquid Pond (Site 1 Basin)

**Figure 8.** Location of the Biscay Pond, Site 1 North; McCurdy Pond, Site 1 Basin; and Pemaquid Pond, Site 1 Basin; in-lake sampling stations. The location of the Biscay Stream (Site 20 Biscay Road) is also included and functions as both the major outlet of Pemaquid Pond and the major inlet to Biscay Pond.

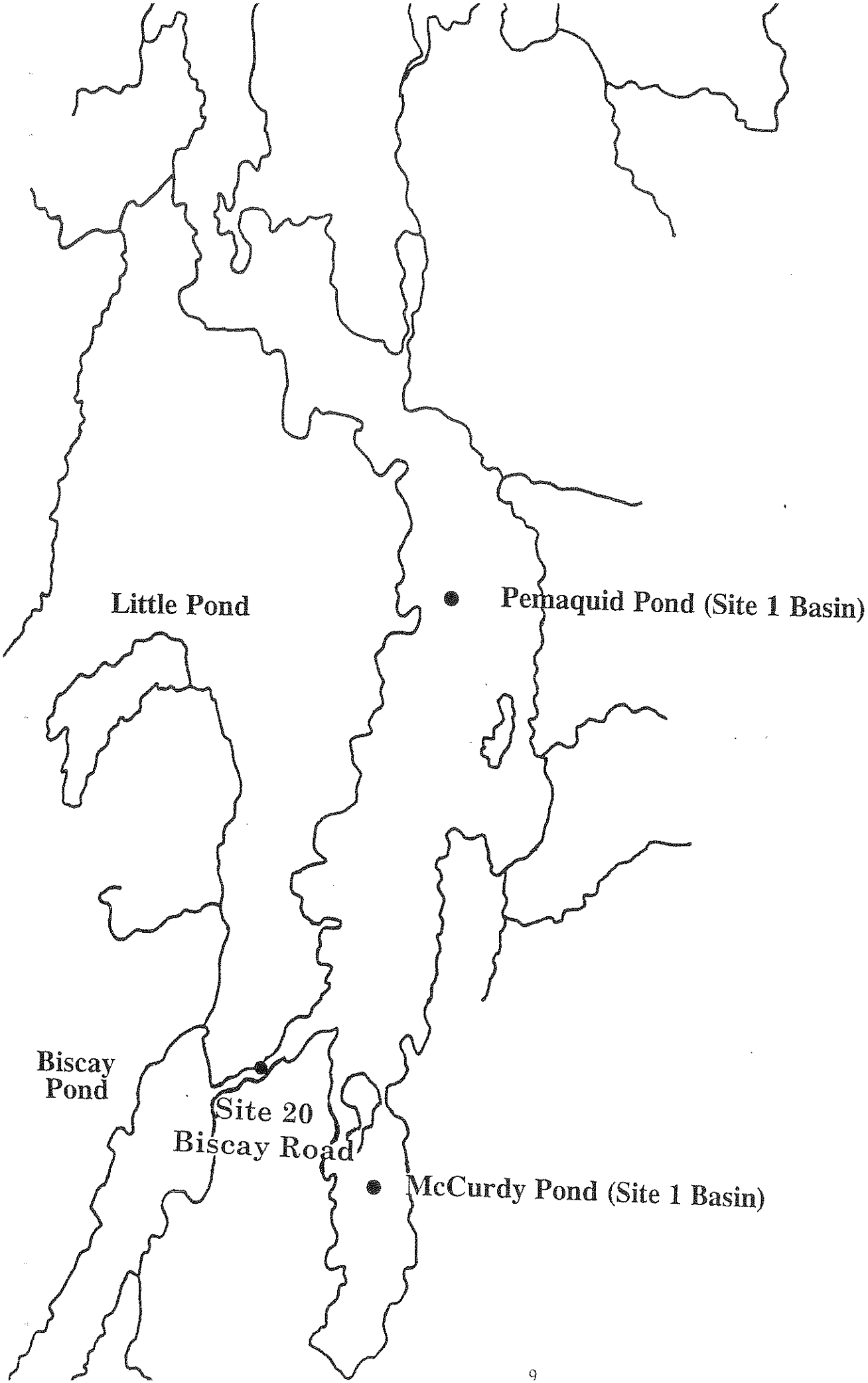

Little Pond
Pemaquid Pond (Site 1 Basin)
Biscay Pond
Site 20
Biscay Road
McCurdy Pond (Site 1 Basin)

**Figure 9.** Location of the Biscay Pond, Site 1 North; McCurdy Pond, Site 1 Basin; and Paradise Pond, Site 2 North; deep in-lake sampling stations. The location of the Pemaquid River (10 Lessner Road) sampling station which functions as the major outlet of Biscay Pond is also included.

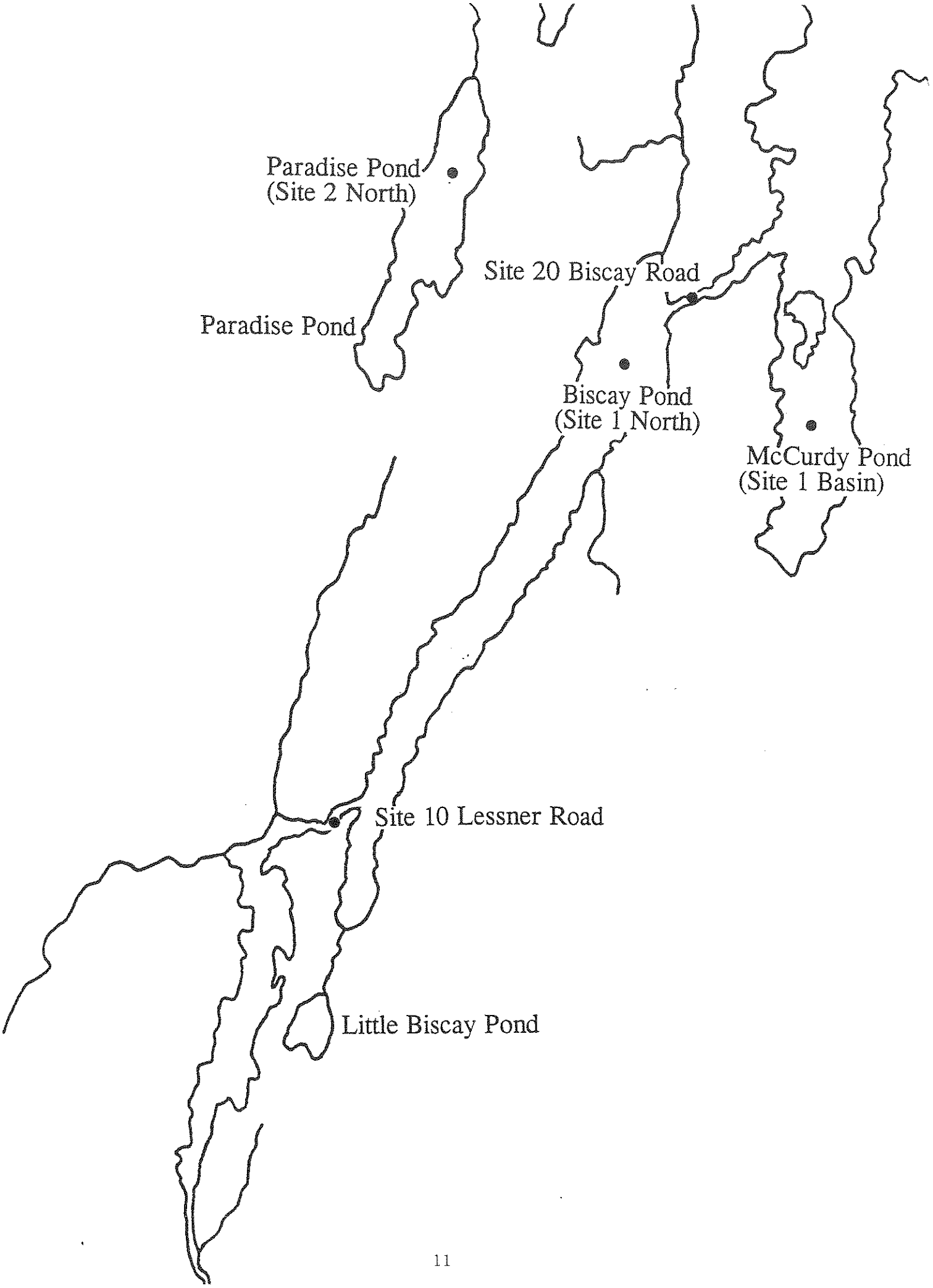
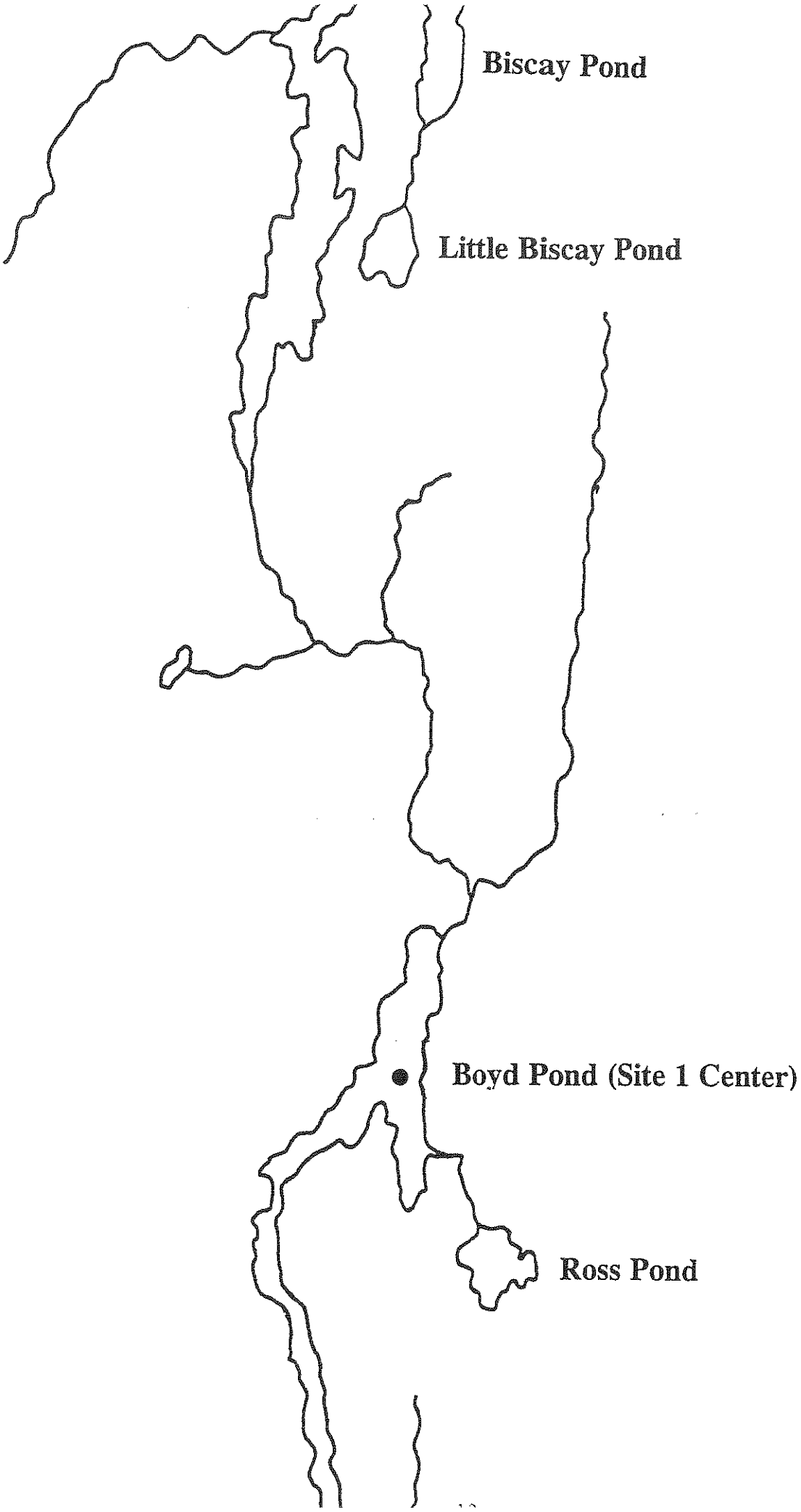

Paradise Pond
(Site 2 North)
Site 20 Biscay Road
Paradise Pond
Biscay Pond
(Site 1 North)
McCurdy Pond
(Site 1 Basin)
Site 10 Lessner Road
Little Biscay Pond

**Figure 10.** Location of the Boyd Pond deep sampling station, Site 1 Center.


Biscay Pond
Little Biscay Pond
Boyd Pond (Site 1 Center)
Ross Pond

improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of the lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a lay monitor in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

## Purpose and Scope of This Study

1995 was the seventh year that monitoring of Boyd Pond and the eighth year that monitoring of Biscay, Duckpuddle, McCurdy, Paradise and Pemaquid Ponds was undertaken by the **Freshwater Biology Group** and the **Pemaquid Watershed Association** (Refer to figures 6 through 10 for site locations). The monitoring program was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on one open water deep station in each pond while additional tributary sampling was undertaken at selected points around the ponds to document potential "hot spots" within the watershed.

The primary purpose of this report is to discuss results of the 1995 monitoring season with emphasis on current conditions of Biscay, Boyd, Duckpuddle, McCurdy, Paradise and Pemaquid Ponds including the extent of eutrophication. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for Maine and New Hampshire lakes that include **Maine DEP** surveys, New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. However, care must be taken when comparing results among the various studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

# The General Scenario - 1995

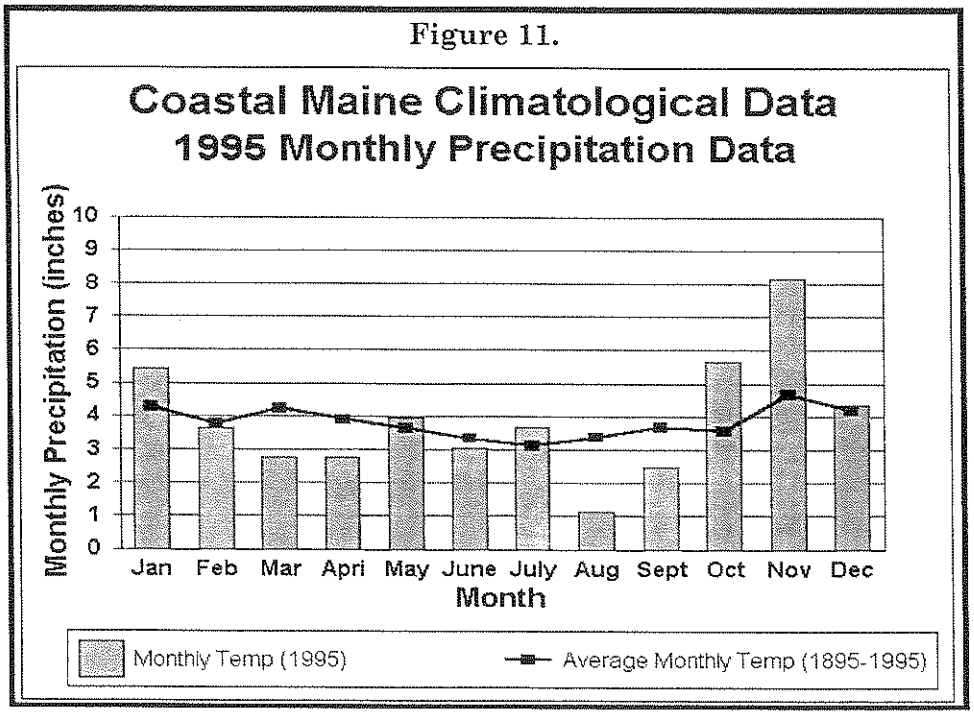
## 1995 Climatic Summary

The winter months of 1994-95 were characterized by above average temperatures and near to below average precipitation levels in coastal Maine. Much of the precipitation was in the form of rainfall early in 1995 which minimized snowpack accumulation. The minimal snowpack accumulation and the below average precipitation levels during the spring months resulted in a relatively dry spring. Conditions such as these typically favor higher alkalinities (buffering capacities) and higher pH levels in the tributary streams and in our northern New England lakes as acidic spring runoff is minimized.

Below average rainfall continued to characterize coastal Maine into the spring months with precipitation levels over one inch below the historical average (1895-1995) during the months of March and April while the month of May was characterized by precipitation levels approximately one quarter inch above normal and June one quarter inch below average (Figure 11). The summer was off to a wet start with 3.6 inches of rainfall during the month of July which exceeded the normal by about one-half inch. However, the months of August and September were again plagued by "drought" conditions with the precipitation levels over one inch below the historical average. The pattern of below average precipitation levels abruptly changed during the fall months of October and November with precipitation levels exceeding the historical monthly average precipitation levels by over two inches. In general, the 1995 coastal Maine precipitation levels (through September) were below normal while short-term wet spells were encountered. Note: While the general precipitation scenario, described above, summarizes the 1995 precipitation data for coastal Maine, the locality of daily precipitation events was highly variable and might not characterize the conditions around the Pemaquid Ponds.

Monthly precipitation levels collected in close proximity to the Pe-

Figure 11.



maquid Ponds (Newcastle and West Rockport climatological data stations) followed the general precipitation trends characteristic of the coastal Maine region although differences were evident (i.e. Wet months and dry months tended to hold true among the different stations although the ambient precipitation levels tended to vary greatly among the climatological sampling stations (Figures 12 and 13).

Figure 12.

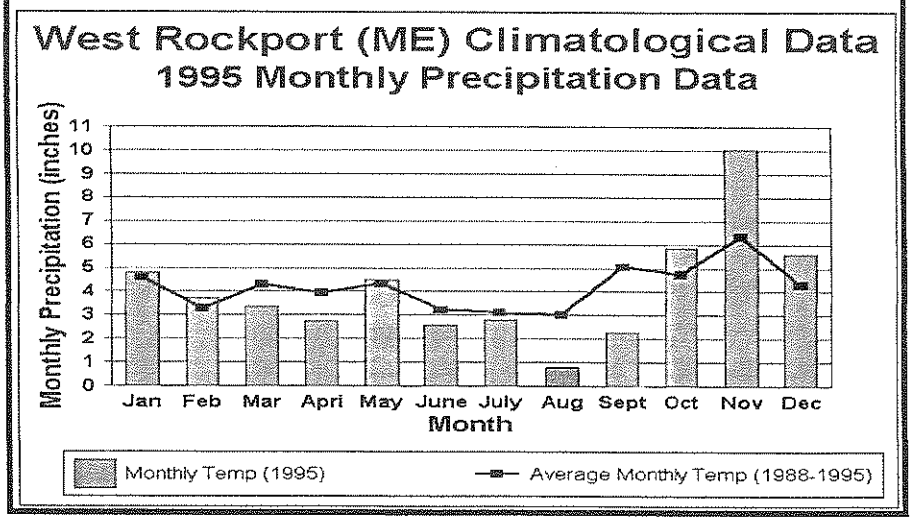
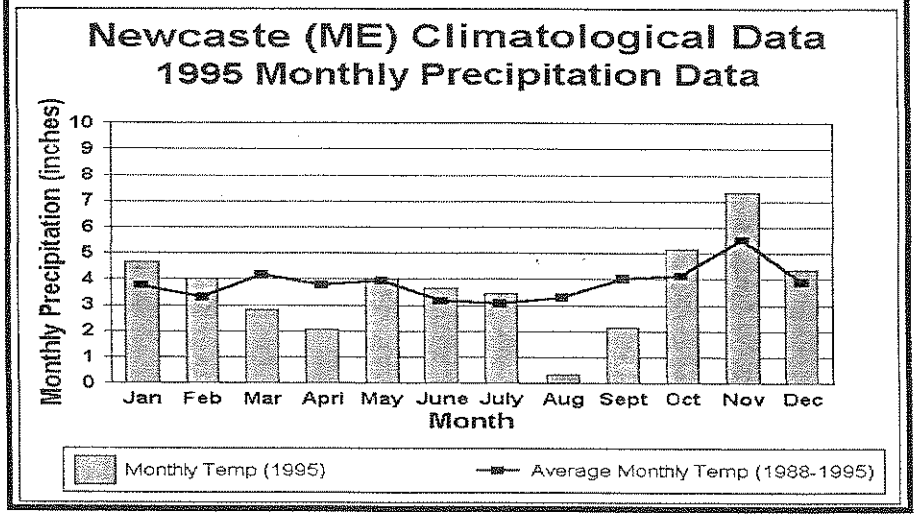


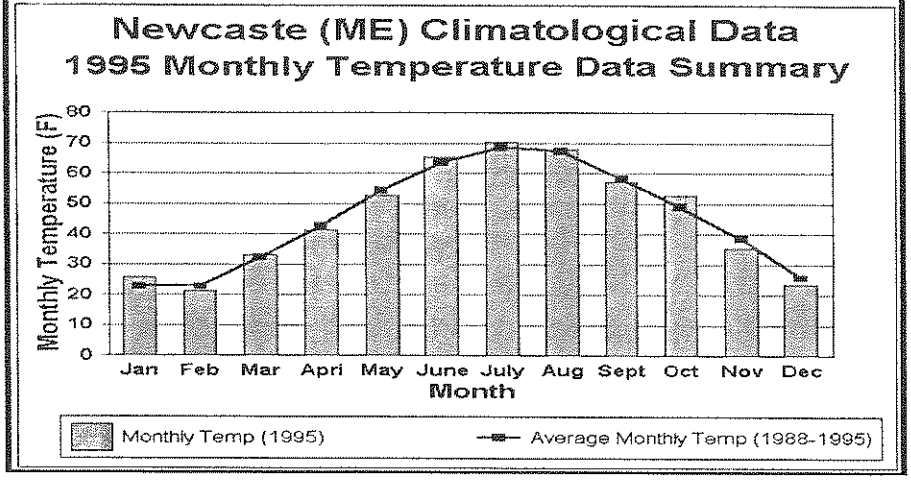

Figure 13




The 1995 temperature patterns also had an effect on water quality. The above average temperatures during much of January, and March minimized snowpack retention and in turn minimized the corresponding spring runoff previously discussed (Figure 14). The temperatures were more characteristic of normal conditions in April and May while the months of June and July were again characterized by above average temperatures. The above average temperatures in June resulted in the rapid surface water (epilimnetic) warming which is conducive to algal, aquatic plant and bacterial growth.

Additional factors favoring localized algal, aquatic plant and bacterial growth included greater sunlight penetration during clear days, lower lake levels during the dry summer months, as well as, the mobilization of deep-water algal populations into the surface waters and increased growth rates during optimal conditions (discussed below). The above average temperatures, conducive to primary productivity, persisted through July but dipped to near average levels in August and resulted in surface water cooling in the Pemaquid Ponds which continued into the fall months.

Figure 14.




## 1995 Water Quality Observations

Higher Secchi Disk transparency readings, relative to 1994, were characteristic of Duckpuddle, McCurdy and Pemaquid Ponds while Secchi Disk transparencies decreased in Biscay and Boyd Ponds during the 1995 sampling season. The Duckpuddle, McCurdy and Pemaquid Pond sampling stations were clearer due to a combination of factors associated with the atypically dry summer months. Less dissolved colored compounds (dissolved organic matter from the breakdown of vegetation and soils) were washed in from surrounding forest and wetland areas. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes.

As with dissolved color, the dry spring reduced the sediment and suspended matter load to many of our lakes and streams during that period while continued dry conditions through most of the summer continued to minimize sediment loading.

If Increased clarity was not the result of less dissolved color or chlorophyll *a* concentrations than it was likely due to less suspended sediment by default. To find out how these water quality indicators inter-relate for your lake, compare the Secchi Disk, chlorophyll *a* and dissolved color graphs enclosed in this report (Figures 15 through 17). Note whether changes in clarity (Secchi Disk depth) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

However, during warm summers such as 1995, microbiological populations can have an increased effect on the water clarity. In general, bacterial populations tend to persist longer and at higher densities as temperatures increase. This occurrence is not necessarily indicative of water quality problems as the majority of these organisms occur naturally and function to recycle materials throughout the lake (heterotrophic bacteria). Many **NH LLMP** volunteer monitors reported longer sample filtration times in 1995 yet no apparent increase in the appearance of algae on their filters. Heterotrophic bacteria were the most likely culprits in these cases. Large concentrations of these minute organisms can have a profound effect on water clarity as they can rapidly absorb and redirect light which will in turn diminish our Secchi Disk readings.

These same climatic conditions, however, also favor the longevity of disease causing pathogenic organisms. If cases of ear infections, stomach problems or other sickness were more prevalent this past summer it would be a good idea to incorporate microbiological (bacteria) testing into future monitoring efforts (see Discussion section).

Most **LLMP** lakes experienced "algal blooms" during the 1995 sampling season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". All types of "algal blooms" were observed in several participating **LLMP** lakes in 1995. The occasional formation of certain "algal blooms" are naturally occurring phenomenon and are not necessarily associated with changes in lake productivity. However, increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms of varied extent typically occur even in our most pristine lakes late in the fall and early in the spring as a result of lake mixing, which resuspends nutrients, at those times.

In most participating **NH LLMP** lakes, particularly during the months of July and August, cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, or a related species were observed. These algal forms often develop within nearshore weed beds where they can be seen along the lakebottom. Sometimes "clouds" are observed drifting freely into shallow areas around the lake. These algae often take advantage of nutrients that leak from particularly active submerged weeds or from bottom areas that have been disturbed by weed removal or other activities.

*Mougeotia* and related algal forms (*Spirogyra* and *Zygenema*) flourished in 1995. The above average temperatures and a number of bright and sunny days during the months of June, July and August stimulated macroscopic plant growth that in turn provided optimal habitat and conditions for the growth of filamentous algal "clouds". While increased growth of *Mougeotia* and the related forms is often perceived as an indication of declining water quality, the 1995 algal populations are more likely attributable to the natural weather conditions that characterized 1995. Elevated macroscopic plant and elevated filamentous algal growth were documented in lakes ranging from unproductive, pristine systems, to those lakes typically considered highly productive and suggest a naturally occurring, short term, climatological impact upon our New Hampshire lakes. If this is true, reduced macroscopic plant and filamentous algal growth should characterize future summers which demonstrate more normal temperature patterns (cooler temperatures and more typical precipitation).

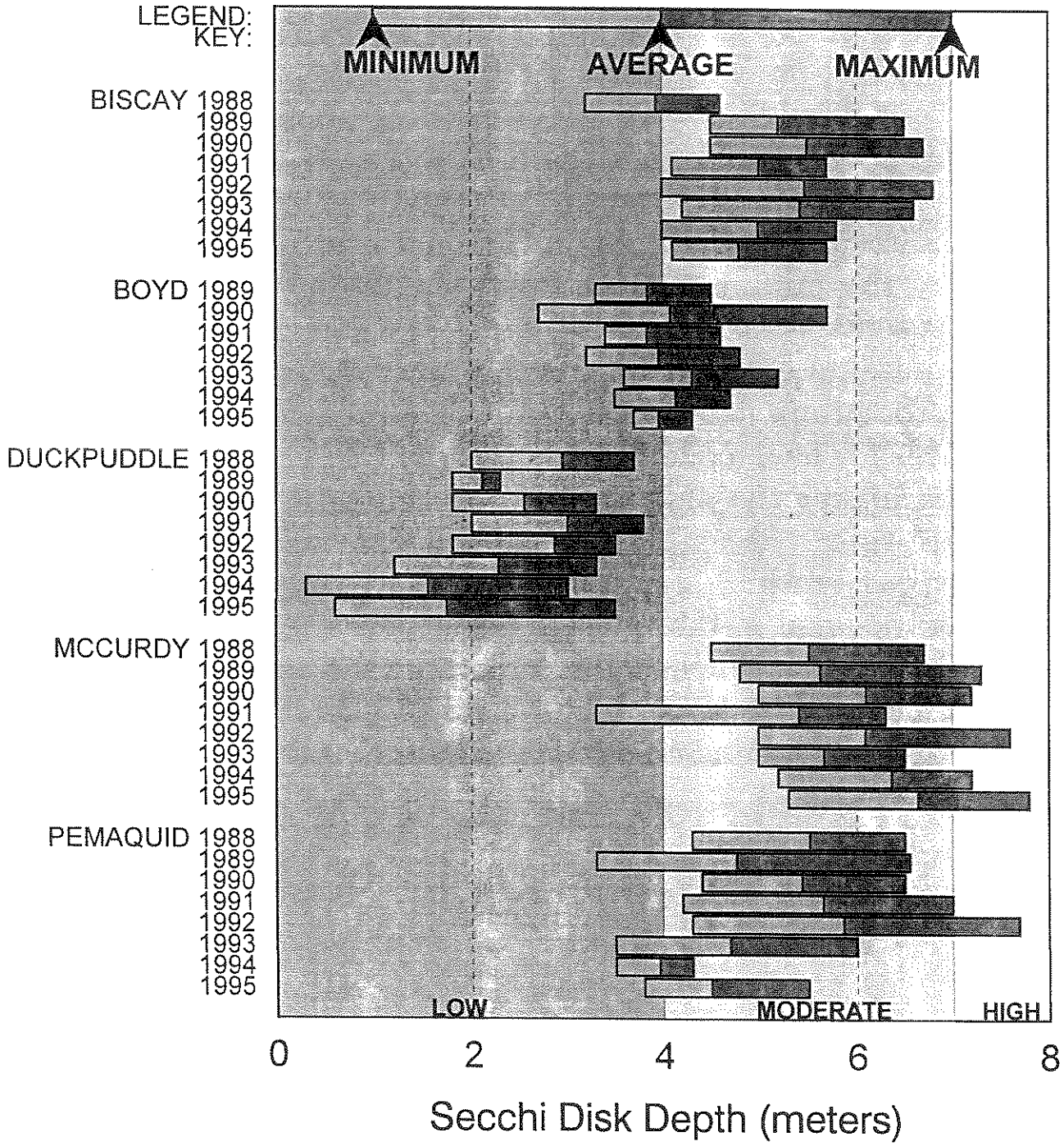
For a limited number of lakes, weather conditions became conducive to the formation of "blooms" of other algae species during the summer months when the water temperatures were above average. Unlike 1993, when the algal blooms were short-term events (spanning less than a week), the blooms persisted for greater than a month in a handful of sampled lakes. In those lakes which experienced long-term algal blooms the types of algae tended to be of the nuisance blue-green bacterial variety (formerly referred to as blue-green algae) and included such nuisance

forms as *Anabaena, Lyngbya, Merismopedia* and *Oscillatoria.*

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication nutrient loading. The **LLMP** will continue to monitor "bloom" phenomenon in 1996 as it can be a sign of the changing land use practices and impacts within the lake watershed that can result in a long-term increase in lake productivity. Future monitoring will continue to monitor the frequency of algal blooms in our New Hampshire lakes' and discern whether or not they are signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the weather conditions of this past summer.

**Figure 15.** Comparison of the 1995 Biscay Pond, Boyd Pond, Duckpuddle Pond, McCurdy Pond and Pemaquid Pond lay monitor Secchi Disk Transparency data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value, the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter. Note: Paradise Ponds is not included in the intercomparison due to the shallowness of the pond (the Secchi Disk reached the lakebottom before disappearing from view).

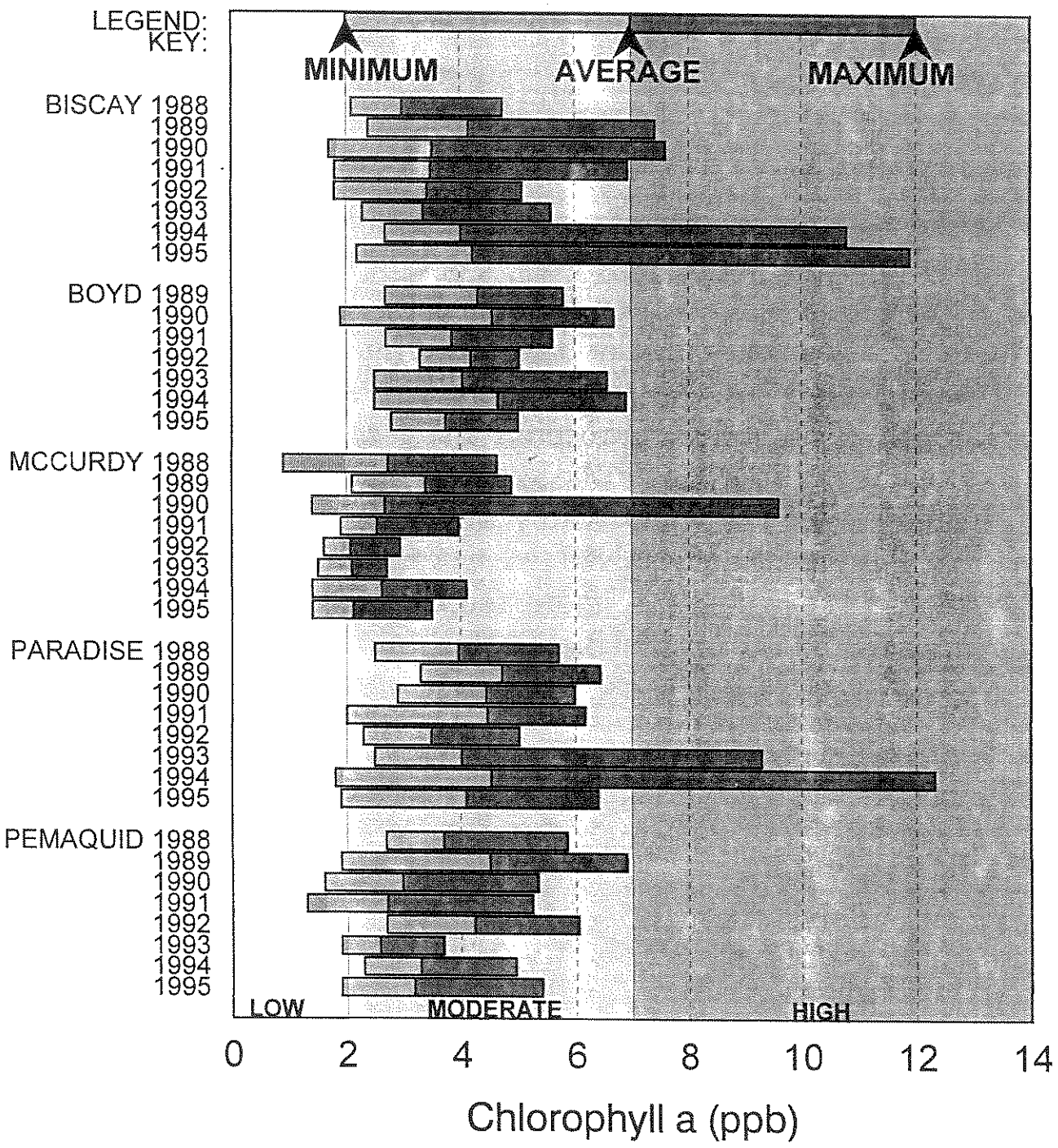
# LAY MONITOR SECCHI DISK DATA
# PEMAQUID PONDS
# YEARLY COMPARISONS (1988-1995)




**The higher value = clearer water**

**Figure 16.** Comparison of the 1995 Biscay Pond, Boyd Pond, McCurdy Pond, Paradise Pond and Pemaquid Pond lay monitor chlorophyll *a* data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and chlorophyll *a* concentrations. The higher the chlorophyll *a* concentration, the greener the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter. Note: Duckpuddle Pond is not included in the intercomparison due to the difference in scale (i.e. much higher chlorophyll *a* concentrations). Refer to figure 32 for a graphic depiction of the historical Duckpuddle Pond chlorophyll *a* data.

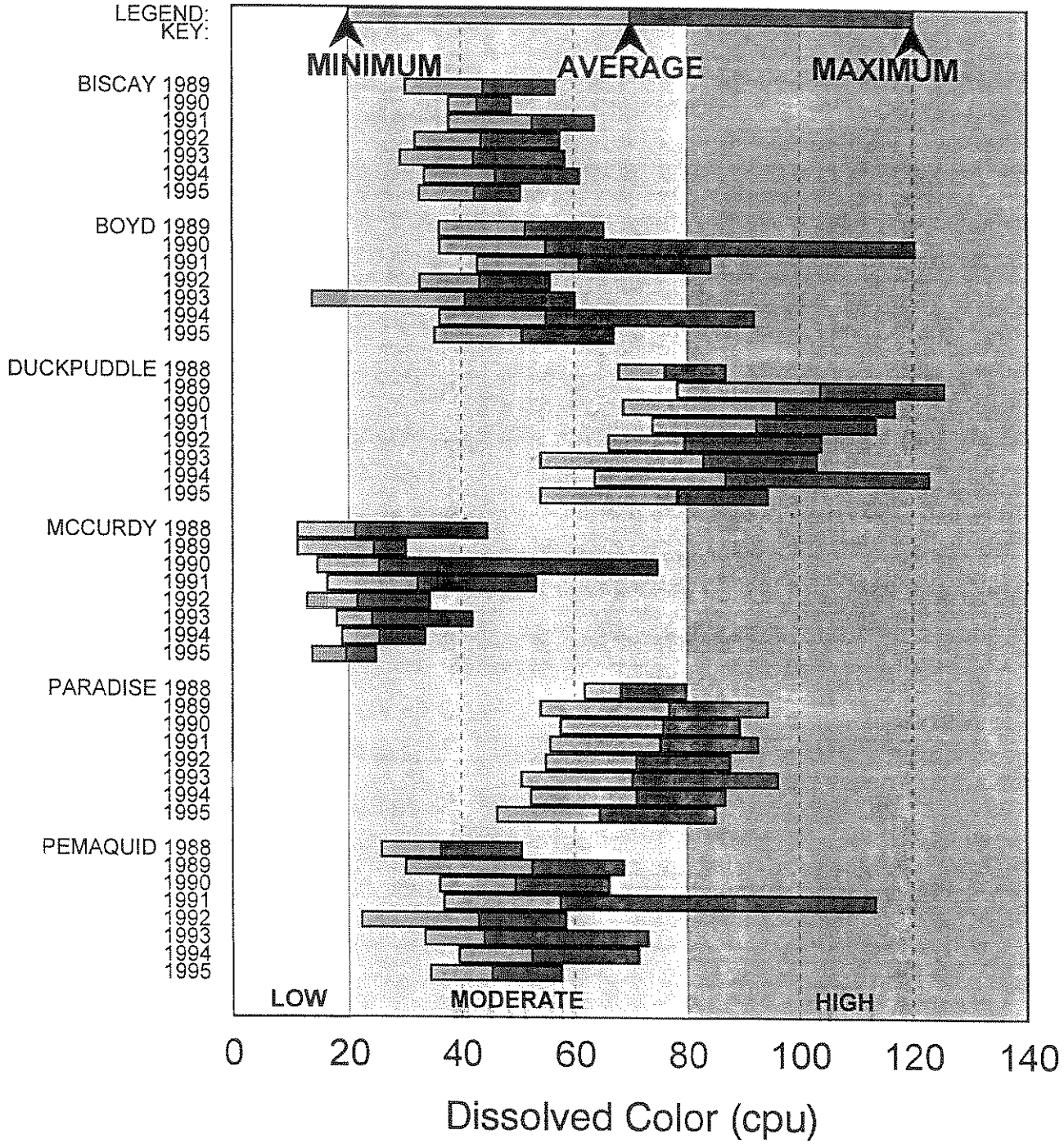
# LAY MONITOR CHLOROPHYLL a DATA
# PEMAQUID PONDS
## YEARLY COMPARISONS (1988-1995)




**The higher value = more algal growth**

**Figure 17.** Comparison of the 1995 Biscay Pond, Boyd Pond, Duckpuddle Pond, McCurdy Pond, Paradise Pond and Pemaquid Pond lay monitor dissolved color data. The patterns of the bars display the minimum, mean and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the ranges characteristic of low, moderately and highly colored waters. The higher the dissolved color concentration the more colored the water (i.e. more tea colored). Color data are expressed as chloroplatinate color units (ptu).

# LAY MONITOR DISSOLVED COLOR DATA
# PEMAQUID PONDS
# YEARLY COMPARISONS (1988-1995)




**The higher value = more "tea" colored water**

# Table 2. Biscay Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Biscay Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 4.8 | (1995: | 12 | values; | 4.1 | - | 5.7 | range) |
| Average chlorophyll: | 4.2 | (1995: | 12 | values; | 2.2 | - | 11.9 | range) |
| Average Lake Phos.: | 9.3 | (1995: | 4 | values; | 7.1 | - | 12.2 | range) |
| Average color, 440: | 42.6 | (1995: | 12 | values; | 32.6 | - | 50.7 | range) |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 North | 05/06/1995 | 4.1 | 3.8 | 12.2 | ---- | ---- | 46.4 |
| 1 North | 05/22/1995 | 4.6 | 3.6 | ---- | ---- | ---- | 45.5 |
| 1 North | 06/08/1995 | 4.6 | 2.8 | ---- | ---- | ---- | 49.0 |
| 1 North | 06/17/1995 | 4.5 | 2.2 | ---- | ---- | ---- | 50.7 |
| 1 North | 07/02/1995 | 5.1 | 2.6 | ---- | ---- | ---- | 44.7 |
| 1 North | 07/15/1995 | 5.7 | 6.4 | ---- | ---- | ---- | 45.5 |
| 1 North | 08/05/1995 | 4.3 | 11.9 | ---- | ---- | ---- | 44.7 |
| 1 North | 08/23/1995 | 5.0 | 2.6 | ---- | ---- | ---- | 40.4 |
| 1 North | 09/01/1995 | 4.8 | 5.0 | ---- | ---- | ---- | 45.5 |
| 1 North | 09/16/1995 | 4.6 | 4.1 | ---- | ---- | ---- | 33.5 |
| 1 North | 09/30/1995 | 5.1 | 2.7 | ---- | ---- | ---- | 32.6 |
| 1 North | 10/14/1995 | 5.1 | 3.0 | ---- | ---- | ---- | 32.6 |
| 1 Surface | 11/18/1995 | ---- | ---- | 9.1 | ---- | ---- | ---- |
| 6 Rt130 | 04/15/1995 | ---- | ---- | 8.6 | ---- | ---- | ---- |
| 10 Lessner | 04/13/1995 | ---- | ---- | 7.1 | ---- | ---- | ---- |

<< End of 1995 listing, 15 records >>

# BISCAY POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the Biscay Pond deep sampling station, Site 1 North, between May 6, 1995 and October 14, 1995 (refer to Table 2 and Figures 18 through 22). Additional early season (April) tributary sampling was undertaken to assess the phosphorus (nutrient) concentrations following spring snowmelt. The following section summarizes the 1995 Biscay Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 Biscay Pond water clarity (Secchi Disk transparency) measurements were representative of a moderately productive lake based on the water quality criteria employed by the **Maine Department of Environmental Protection (DEP)**. The 1995 seasonal water transparency average of 4.8 meters (15.8 feet) decreased for the third consecutive year but remained within the historical range of water transparency readings (Figure 21).

2) The 1995 Biscay Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were moderate to high. The seasonal average chlorophyll *a* concentration (4.2 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a moderately productive lake (Figure 22). The 1995 seasonal average Biscay Pond chlorophyll *a* concentration increased for the second consecutive year and a new chlorophyll *a* maximum of 11.9 mg $m^{-3}$ was documented on August 5 during an algal bloom.

3) The 1995 Biscay Pond seasonal average dissolved lakewater color levels (a measure on naturally occurring "background" color) were moderate (42.6 chloroplatinate color units; cpu) but slightly less than the 1994 Biscay Pond seasonal average dissolved color concentration of 46.2 cpu.

4) The 1995 Biscay Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations, measured in the surface waters, were moderate when collected by the volunteer monitors on May 6, 1995 (12.2 parts per billion; ppb) and again on November 18, 1995 (9.1 ppb). Additional total phosphorus data collected at the Rt. 130 (8.6 ppb) and at the 10 Lessner Brook tributary sites in April were moderate. The 1995 Biscay Pond total phosphorus concentrations are within the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a moderately productive lake.

5) Biscay Pond temperature profiles collected by Scott Giguere indicate the upper mixed layer of water extended to about 5.0 meters during the period of

summer thermal stratification, typical of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP** (1974, 1976, 1981, 1982, 1988 and 1990), indicate reduced dissolved oxygen concentrations in the bottom (hypolimnetic) waters of Biscay Pond during thermal stratification. Lower hypolimnetic dissolved oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic animal and vegetative matter) and external (i.e. leaf litter from watershed runoff) sources. As dissolved oxygen concentrations are reduced below 1 milligram per liter the potential for internal nutrient release (nutrient are resuspended from the sediments) increases significantly.

6) For all measurements considered and averaged for the season, Biscay Pond is classified as a moderately productive, mesotrophic, lake.

7) The primary purpose of the Biscay Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant and algal production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and inter-relationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transparency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or preferably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

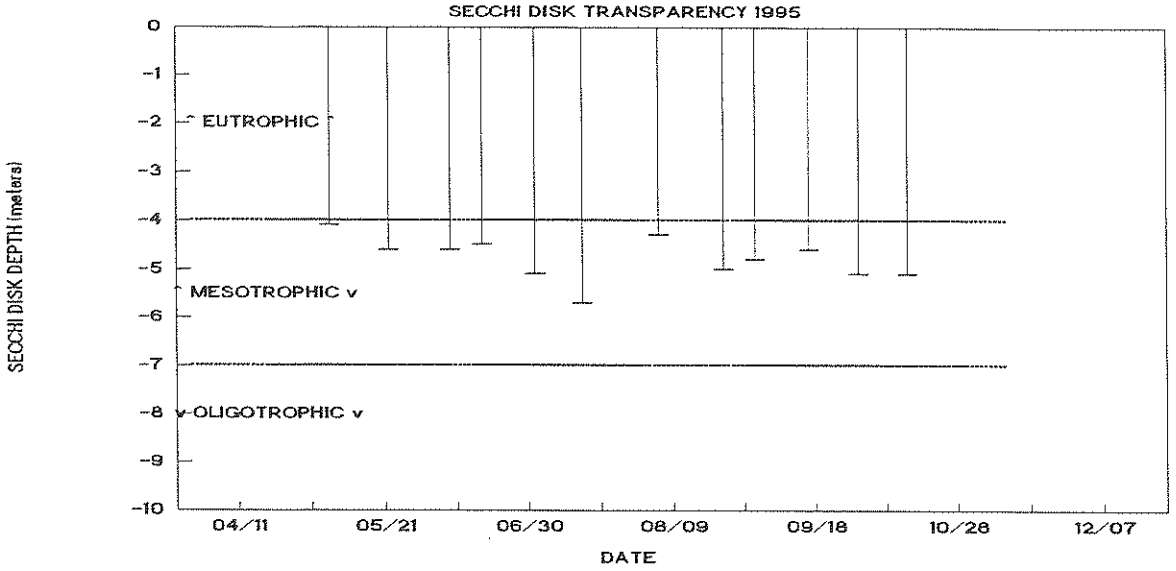
Water quality data collected from the Biscay Pond deep sampling station (representative of the average pond conditions) between 1988 and 1995 indicate variable seasonal average chlorophyll *a* concentrations and Secchi Disk transparencies over the aforementioned time span (Figures 21 and 22). However, the new chlorophyll *a* maximum documented on August 5 could be an early "warning sign" of the pond's response to improper land use practices within the watershed. On the other hand this atypical reading might be the result of variations in precipitation or temperature patterns during that period. If localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

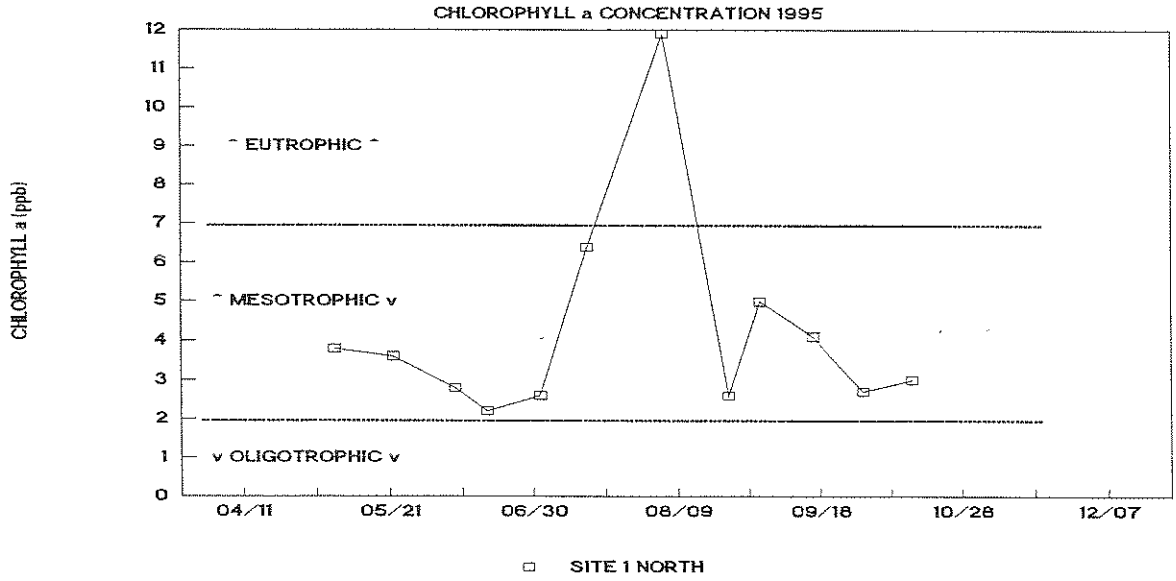
**Figure 18.**Biscay Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 1 North. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 19.**Biscay Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 1 North. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 20.**Biscay Pond, 1995. Seasonal dissolved color trends of lay monitor Site 1 North. The dotted horizontal line represents the dissolved color average for participating Pemaquid Watershed lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# BISCAY POND - SITE 1 NORTH



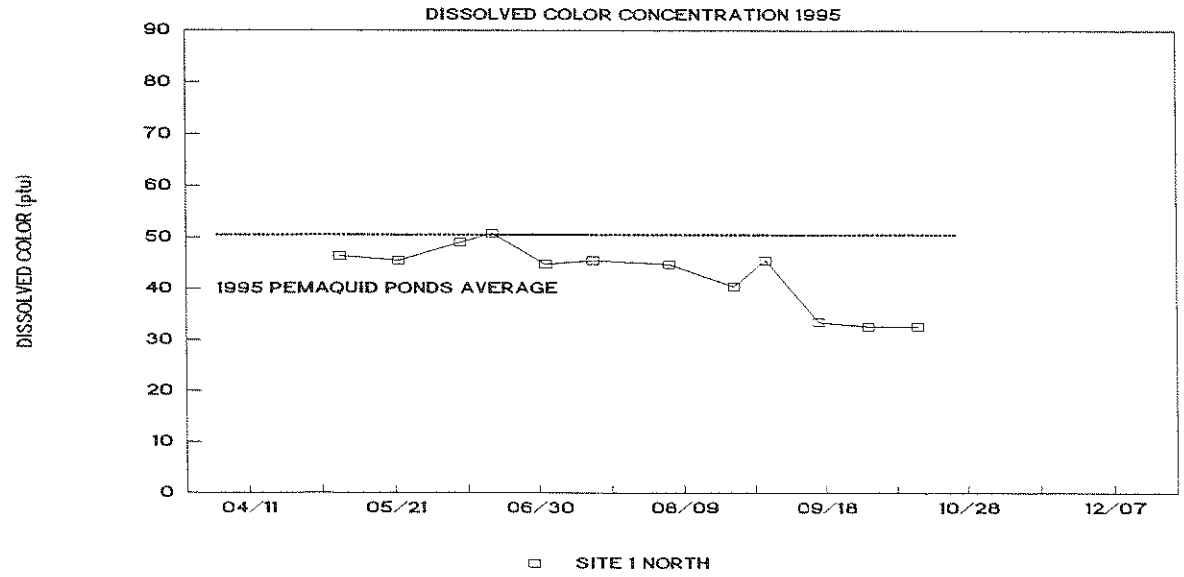
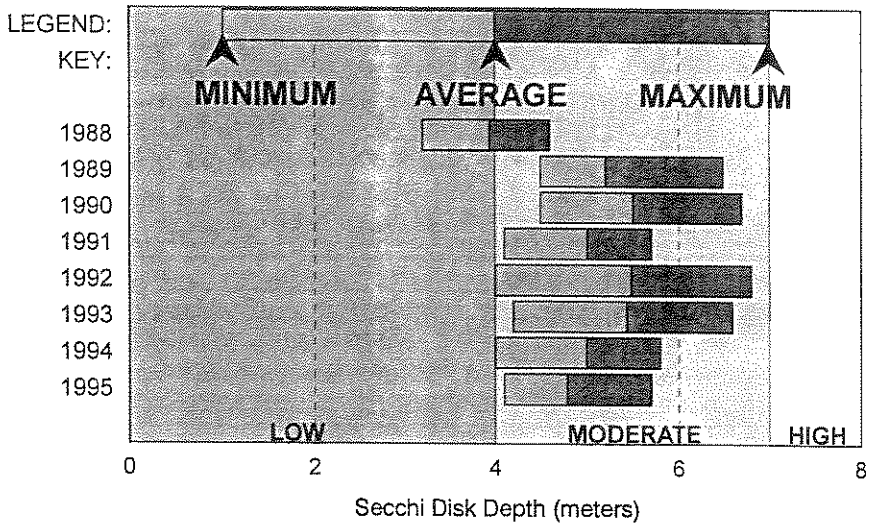



**Figure 21.**Comparison of the 1995 Biscay Pond lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

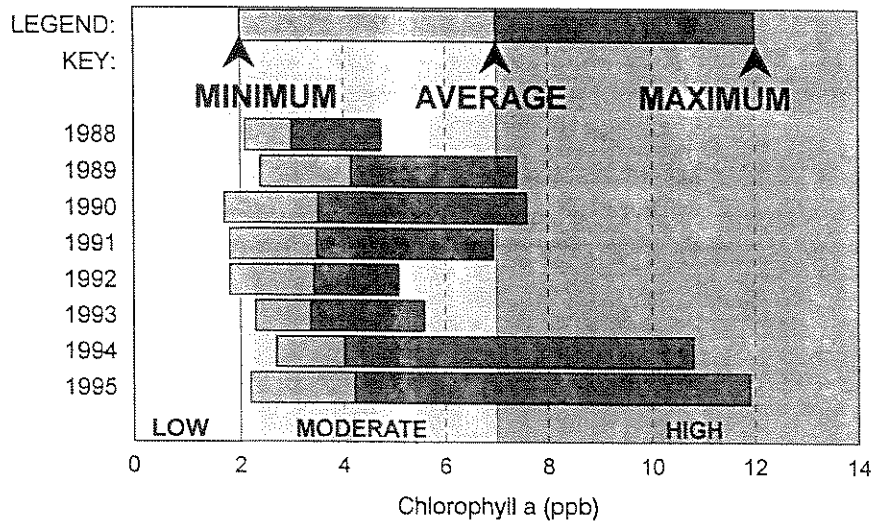
**Figure 22.**Comparison of the 1995 Biscay Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# BISCAY POND - SITE 1 NORTH
# LAY MONITOR SECCHI DISK DATA
## YEARLY COMPARISONS (1988-1995)




The higher value = clearer water

# BISCAY POND - SITE 1 NORTH
# LAY MONITOR CHLOROPHYLL a DATA
## YEARLY COMPARISONS (1988-1995)




The higher value = more algal growth

# Table 3. Boyd Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Boyd Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 4.0 | (1995: | 11 | values; | 3.7 | - | 4.3 | range) |
| Average chlorophyll: | 3.7 | (1995: | 11 | values; | 2.8 | - | 5.0 | range) |
| Average Lake Phos.: | 23.7 | (1995: | 3 | values; | 12.9 | - | 40.3 | range) |
| Average color, 440: | 50.9 | (1995: | 10 | values; | 35.2 | - | 67.0 | range) |

| Site | Date | Trans-parency (m) | Chl a (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 Center | 05/07/1995 | 3.9 | 4.4 | ---- | ---- | ---- | 56.7 |
| 1 Center | 05/21/1995 | 3.9 | 3.4 | ---- | ---- | ---- | 63.6 |
| 1 Center | 06/04/1995 | 3.9 | 4.3 | ---- | ---- | ---- | 67.0 |
| 1 Center | 07/01/1995 | 3.9 | 3.6 | ---- | ---- | ---- | 61.8 |
| 1 Center | 07/16/1995 | 4.0 | 3.6 | ---- | ---- | ---- | 48.1 |
| 1 Center | 07/30/1995 | 4.0 | 5.0 | ---- | ---- | ---- | 43.0 |
| 1 Center | 08/13/1995 | 4.3 | 2.8 | ---- | ---- | ---- | 44.7 |
| 1 Center | 09/03/1995 | 4.2 | 3.5 | ---- | ---- | ---- | 44.7 |
| 1 Center | 09/17/1995 | 3.7 | 3.6 | ---- | ---- | ---- | 43.8 |
| 1 Center | 09/30/1995 | 3.9 | 3.4 | ---- | ---- | ---- | ---- |
| 1 Center | 10/14/1995 | 3.9 | 3.6 | 18.0 | ---- | ---- | 35.2 |
| 1 Hypo | 07/30/1995 | ---- | ---- | 40.3 | ---- | ---- | ---- |
| 9 PemRvr | 04/13/1995 | ---- | ---- | 12.9 | ---- | ---- | ---- |

<< End of 1995 listing, 13 records >>

# BOYD POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the Boyd Pond deep sampling station, Site 1 Center, between May 7, 1995 and October 14, 1995 (refer to Table 3 and Figures 23 through 27). Additional early season (April 13, 1995) tributary sampling was undertaken in the Pemaquid River to assess the phosphorus (nutrient) concentrations following spring snowmelt. The following section summarizes the 1995 Boyd Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 Boyd Pond water clarity (Secchi Disk transparency) measurements are representative of marginally moderately to highly productive lake based on the water quality criteria employed by the **Maine Department of Environmental Protection (DEP)**. The 1995 seasonal water transparency average of 4.0 meters (13.2 feet) decreased for the second consecutive year but remained within the range of historical water transparency readings (Figure 26).

2) The 1995 Boyd Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were moderate. The seasonal average chlorophyll *a* concentration (3.7 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a moderately productive lake (figure 27). The 1995 seasonal average Boyd Pond chlorophyll *a* concentration decreased relative to the 1994 seasonal average chlorophyll *a* concentration and was at the lowest level since monitoring of Boyd Pond was initiated in 1989.

3) The 1995 Boyd Pond seasonal average dissolved lakewater color levels (a measure on naturally occurring "background" color) was moderate (50.9 chloroplatinate color units; cpu) but slightly less than the 1994 seasonal average of 55.1 cpu.

4) A 1995 Boyd Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentration was high in the surface waters and measured 18.0 parts per billion; ppb on August 10, 1995 while an additional bottom water (hypolimnetic) total phosphorus sample measured 40.3 ppb on July 30, 1995 which suggests the accumulation of phosphorus near the lakebottom as the summer progressed. The 1995 total phosphorus concentrations exceed the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a highly productive lake.

5) Boyd Pond temperature profiles collected by Peter Fischer indicate the upper mixed layer of water extended to about 3.0 meters during the period of summer thermal stratification, typical

of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP** (1990 and 1994), indicate reduced dissolved oxygen concentrations in the bottom (hypolimnetic) waters of Boyd Pond during periods of thermal stratification. Lower hypolimnetic dissolved oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic animal and vegetative matter) and external (i.e. leaf litter from watershed runoff) sources. As dissolved oxygen concentrations are reduced below 1 milligram per liter the potential for internal nutrient release (nutrient are resuspended from the sediments) increases significantly and might explain the elevated hypolimnetic total phosphorus concentration documented in Boyd Pond on July 30, 1995.

6) For all measurements considered and averaged for the season, Boyd Pond is classified as a moderately productive, mesotrophic, lake. However, as in 1994, the total phosphorus and Secchi Disk readings border more productive, eutrophic, levels.

7) The primary purpose of the Boyd Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and interrelationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transparency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or pref-

erably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

Water quality data collected from the Boyd Pond deep sampling station (representative of the average pond conditions) between 1989 and 1995 indicate relatively constant seasonal average chlorophyll *a* concentrations and Secchi Disk transparencies over the six year span. While the seasonal average chlorophyll *a* concentrations and Secchi Disk transparencies have fallen into the classification of a moderately productive lake, short term water quality perturbations have been documented. These short term fluctuations might characterize the natural water quality variations for Boyd Pond associated with changing weather patters but might be an early "warning sign" of Boyd Pond's response to improper land use practices within the watershed.

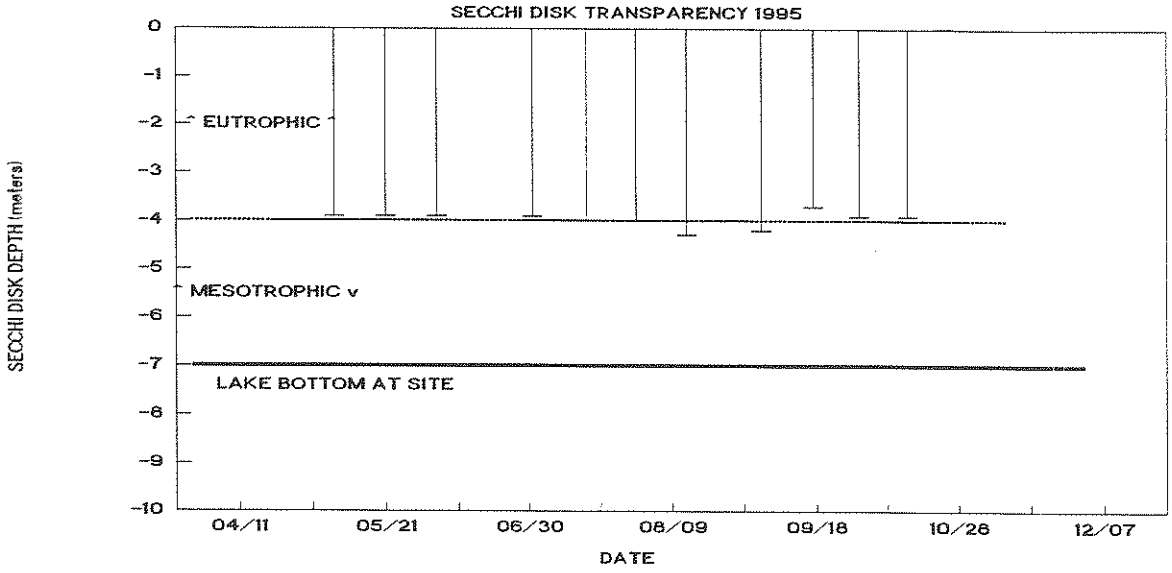
If localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

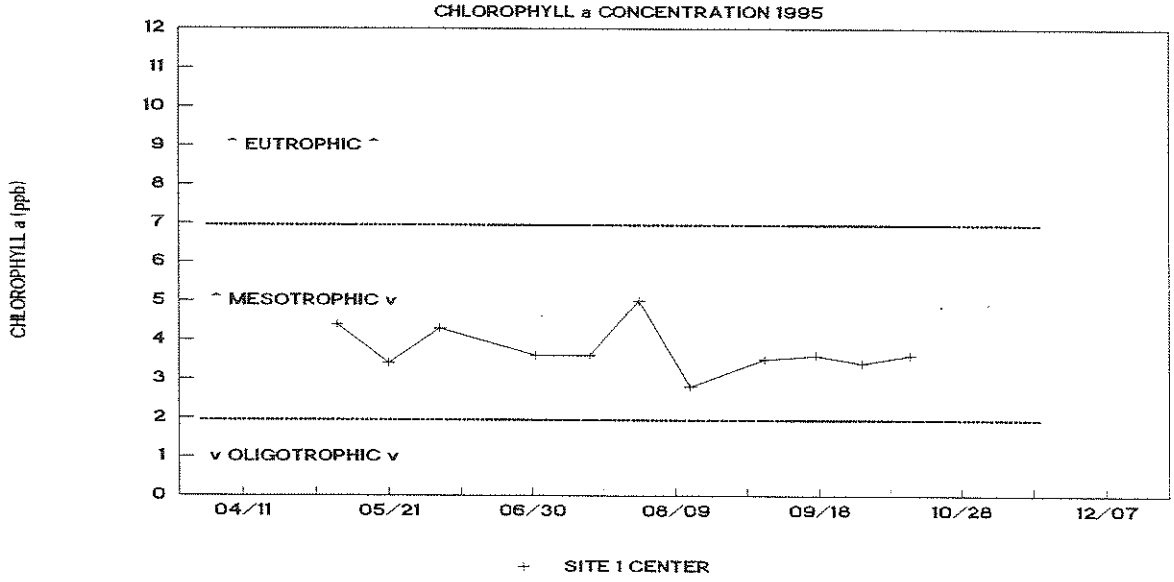
**Figure 23.**Boyd Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 1 Center. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum site depth. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 24.**Boyd Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 1 Center. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 25.**Boyd Pond, 1995. Seasonal dissolved color trends of lay monitor Site 1 Center. The dotted horizontal line represents the dissolved color average for participating **Pemaquid Watershed** lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# BOYD POND – SITE 1 CENTER



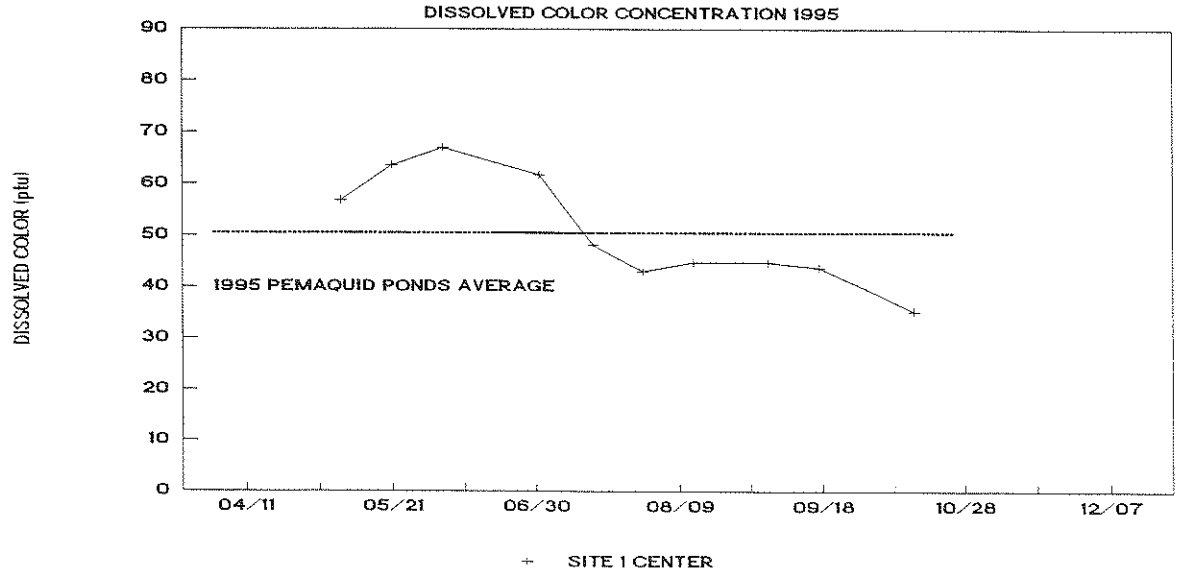
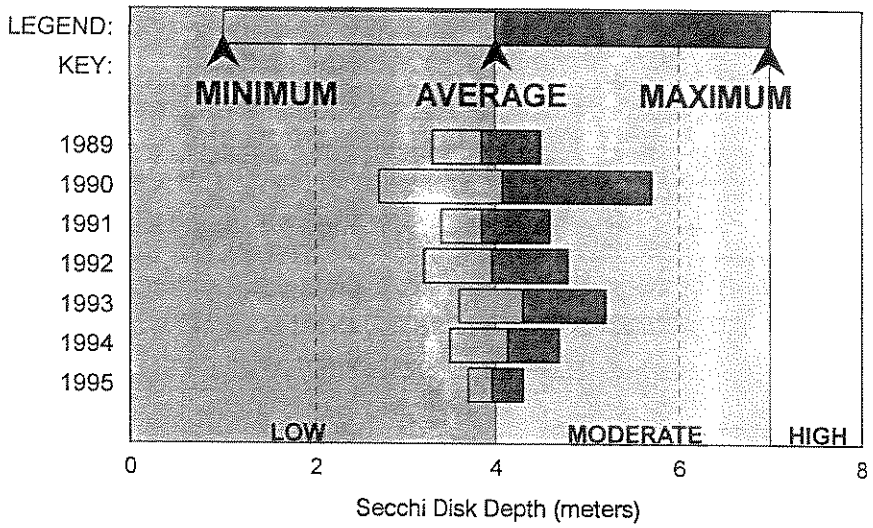



**Figure 26.**Comparison of the 1995 Boyd Pond lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

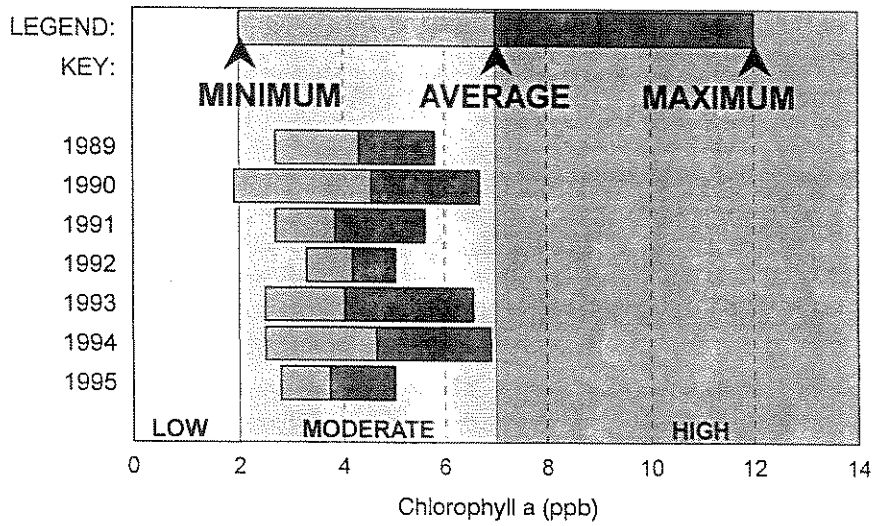
**Figure 27.**Comparison of the 1995 Boyd Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# BOYD POND - SITE 1 CENTER
# LAY MONITOR SECCHI DISK DATA
## YEARLY COMPARISONS (1989-1995)




**The higher value = clearer water**

# BOYD POND - SITE 1 CENTER
# LAY MONITOR CHLOROPHYLL a DATA
## YEARLY COMPARISONS (1989-1995)




**The higher value = more algal growth**

# Table 4. Duckpuddle Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Duckpuddle Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Average transparency: | 1.7 | (1995: | 11 | values; | 0.6 | - 3.5 | range) |
| Average chlorophyll: | 10.0 | (1995: | 11 | values; | 2.3 | - 24.9 | range) |
| Average Lake Phos.: | 24.5 | (1995: | 23 | values; | 13.4 | - 42.1 | range) |
| Average color, 440: | 78.3 | (1995: | 9 | values; | 54.1 | - 94.5 | range) |
| Average Trib. phos: | 29.9 | (1995: | 2 | values; | 20.3 | - 39.5 | range) |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 Basin | 05/09/1995 | 2.9 | 3.0 | 13.4 | ---- | ---- | 78.2 |
| 1 Basin | 05/21/1995 | 3.5 | 2.3 | 16.2 | ---- | ---- | 89.3 |
| 1 Basin | 06/04/1995 | 2.8 | 5.9 | 22.3 | ---- | ---- | 85.9 |
| 1 Basin | 06/19/1995 | 2.2 | 4.9 | 20.3 | ---- | ---- | 91.9 |
| 1 Basin | 07/02/1995 | 1.6 | 12.1 | 24.6 | ---- | ---- | ---- |
| 1 Basin | 07/18/1995 | 0.6 | 24.9 | 21.0 | ---- | ---- | 79.9 |
| 1 Basin | 07/31/1995 | 0.7 | 8.7 | 20.3 | ---- | ---- | 73.9 |
| 1 Basin | 08/13/1995 | 1.6 | 14.2 | 28.9 | ---- | ---- | 54.1 |
| 1 Basin | 08/27/1995 | 1.2 | 11.0 | 35.5 | ---- | ---- | ---- |
| 1 Basin | 09/10/1995 | 1.1 | 9.1 | 28.1 | ---- | ---- | 94.5 |
| 1 Basin | 10/01/1995 | 1.0 | 14.1 | 30.7 | ---- | ---- | 56.7 |
| 1 Bottom | 05/09/1995 | ---- | ---- | 16.7 | ---- | ---- | ---- |
| 1 Bottom | 05/21/1995 | ---- | ---- | 15.7 | ---- | ---- | ---- |
| 1 Bottom | 09/10/1995 | ---- | ---- | 31.2 | ---- | ---- | ---- |
| 1 Bottom | 10/01/1995 | ---- | ---- | 26.9 | ---- | ---- | ---- |
| 1 Meta | 06/04/1995 | ---- | ---- | 19.3 | ---- | ---- | ---- |
| 1 Meta | 07/02/1995 | ---- | ---- | 17.5 | ---- | ---- | ---- |
| 1 Meta | 07/18/1995 | ---- | ---- | 42.1 | ---- | ---- | ---- |
| 1 Meta | 07/31/1995 | ---- | ---- | 31.9 | ---- | ---- | ---- |
| 1 Meta | 08/13/1995 | ---- | ---- | 24.6 | ---- | ---- | ---- |
| 1 Meta | 08/27/1995 | ---- | ---- | 35.5 | ---- | ---- | ---- |
| 1 MidMeta | 07/31/1995 | ---- | ---- | 16.2 | ---- | ---- | ---- |
| 1 MidMeta | 08/27/1995 | ---- | ---- | 25.1 | ---- | ---- | ---- |
| 16 | 04/14/1995 | ---- | ---- | 20.3 | ---- | ---- | ---- |
| 19 Glendon | 04/13/1995 | ---- | ---- | 39.5 | ---- | ---- | ---- |

<< End of 1995 listing, 25 records >>

# DUCKPUDDLE POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the Duckpuddle Pond deep sampling station, Site 1 Basin, between May 9, 1995 and October 1, 1995 (Refer to Table 4 and Figures 28 through 43). Additional early season (April) tributary sampling was undertaken in the Glendon Stream to assess the phosphorus (nutrient) concentrations following spring snowmelt. The following section summarizes the 1995 Duckpuddle Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 Duckpuddle Pond water clarity (Secchi Disk transparency) measurements were representative of highly productive lake based on the water quality criteria employed by the **Maine Department of Environmental Protection (DEP)**. The 1995 seasonal water transparency average of 1.7 meters (5.6 feet) increased slightly relative to the 1994 seasonal average water transparency (1.6 meters) but remained below the seasonal average levels documented between 1988 and 1993 (Figure 31).

2) The 1995 Duckpuddle Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were moderate to high. The seasonal average chlorophyll *a* concentration (10.0 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a highly productive lake (Figure 32). The 1995 seasonal average chlorophyll *a* concentration decreased slightly relative to the 1994 seasonal average chlorophyll *a* concentration but remained well in excess of the seasonal average chlorophyll *a* concentrations documented between 1988 and 1993 (Figure 32).

3) The 1995 Duckpuddle Pond seasonal average dissolved lakewater color level (a measure on naturally occurring "background" color) was high (78.3 chloroplatinate color units; cpu) but slightly less than the 1994 seasonal average dissolved color concentration of 83.3 cpu.

4) The 1995 Duckpuddle Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations, measured in the surface waters, were high when sampled by the lay monitors and ranged form 13.4 to 35.5 parts per billion; ppb. Additional total phosphorus concentrations measured in the bottom waters (metalimnion) included elevated total phosphorus concentrations, relative to the surface total phosphorus concentrations, which suggest internal nutrient loading (nutrient released from the bottom sediments). The 1995 total phosphorus concentrations are high but remain within the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a highly productive lake.

5) Duckpuddle Pond temperature profiles collected by David Libby indicate the upper mixed layer of water extended to about 3.0 meters (9.9 feet) during the period of summer thermal stratification, typical of a northern temperate lake. Dissolved oxygen data, collected by David Libby (May 9 through October 1, 1995), indicate the deeper waters become anoxic following the development of thermal stratification (Figures 33 through 43). By mid July (July 18) the dissolved oxygen concentration was reduced below 3 parts per million (the minimum dissolved oxygen concentration required for the successful growth and reproduction of most warmwater fish) at about 4 meters, which is similar to the 1993 and 1994 data. Furthermore, by July 31 the dissolved oxygen concentrations in the bottom two meters of Duckpuddle pond were reduced below 1 milligram per liter; at which time the potential for internal nutrient loading increases and can favor a buildup of phosphorus in the deeper waters. The dissolved oxygen concentrations remained blow 1 milligram per liter on August 13 in the bottom two meters of in the bottom meter of water on August 27. Subsequent dissolved oxygen sampling indicate Duckpuddle Pond became thermally constant (turned over) by September 10 at which time the dissolved oxygen concentrations increased above 7 milligrams per liter throughout the water column. Lower dissolved oxygen concentrations concentrations near the lakebottom are indicative of accumulating organic matter from both internal (i.e. decaying aquatic animal and vegetative matter) and external (i.e. leaf litter and grass clipping) sources.

6) For all measurements considered and averaged for the season, Duckpuddle Pond is classified as a highly productive, eutrophic, lake based on the classification scheme employed by the **Maine DEP**.

7) The primary purpose of the Duckpuddle Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and interrelationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transpar-

ency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or preferably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

Water quality data collected from the Duckpuddle Pond deep sampling station (representative of the average pond conditions) between 1988 and 1995 indicate variable seasonal average chlorophyll *a* concentrations and Secchi Disk transparencies over the aforementioned time span (Figures 31 and 32). However, the seasonal average Secchi Disk transparencies have illustrated a general trend of decreasing values between 1991 and 1995. In 1994 and 1995 the atypically low seasonal average Secchi Disk transparencies corresponded to atypically high chlorophyll *a* concentrations and included cyanobacterial blooms during the summers months (large concentrations of cyanobacteria" are commonly associated with highly productive waters).

The poor water quality documented in Duckpuddle Pond (particularly over the past two years) is symptomatic of excessive nutrient loading into the Pond. Much of the nutrient load is internal (nutrients released from the sediments) while 1994 data collected in the Glendon Stream indicate a large external (nutrients coming from the watershed) nutrient load as well.

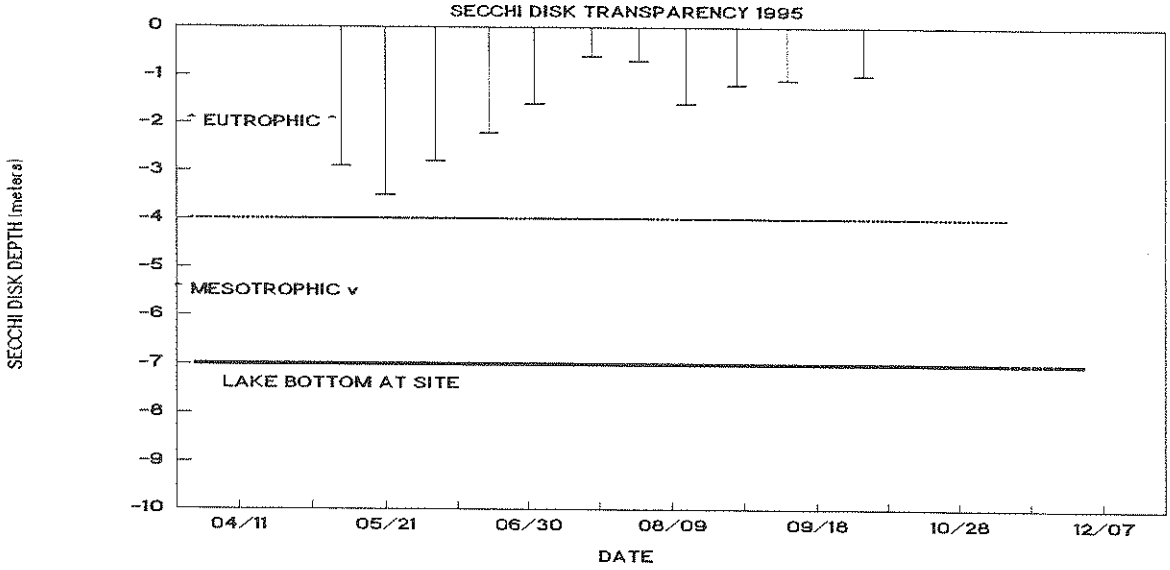
If localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

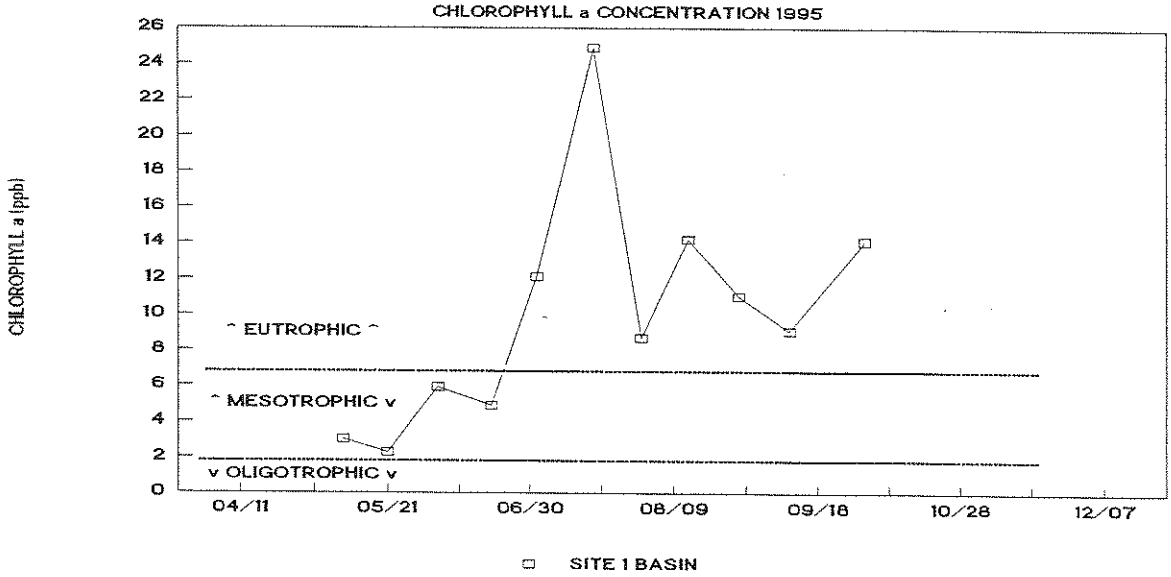
**Figure 28.**Duckpuddle Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes while the double solid horizontal line denotes the maximum site depth. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 29.**Duckpuddle Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 30.**Duckpuddle Pond, 1995. Seasonal dissolved color trends of lay monitor Site 1 Basin. The dotted horizontal line represents the dissolved color average for participating Pemaquid Watershed lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# DUCKPUDDLE POND - SITE 1 BASIN



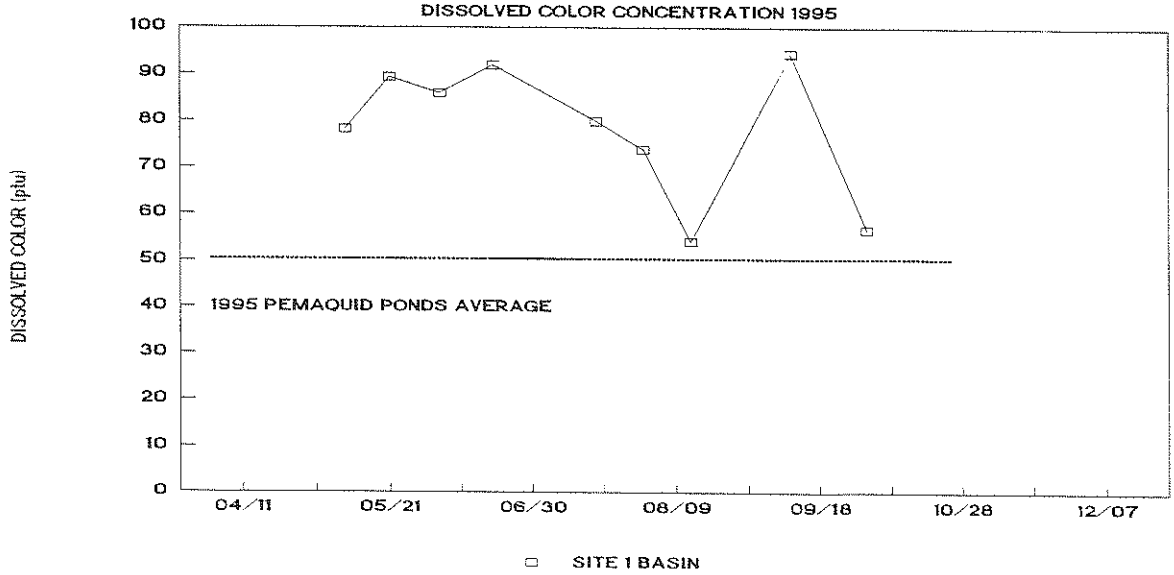
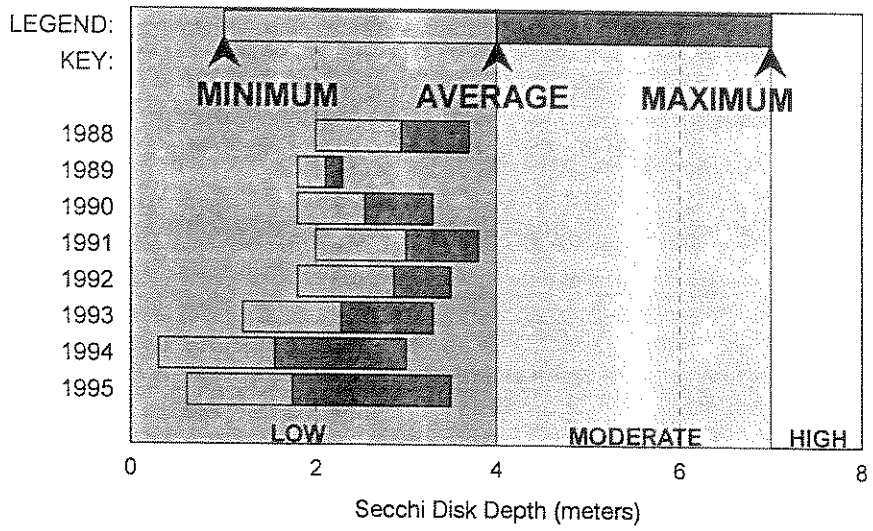



**Figure 31.**Comparison of the 1995 Duckpuddle Pond lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

**Figure 32.**Comparison of the 1995 Duckpuddle Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# DUCKPUDDLE POND - SITE 1 BASIN
# LAY MONITOR SECCHI DISK DATA

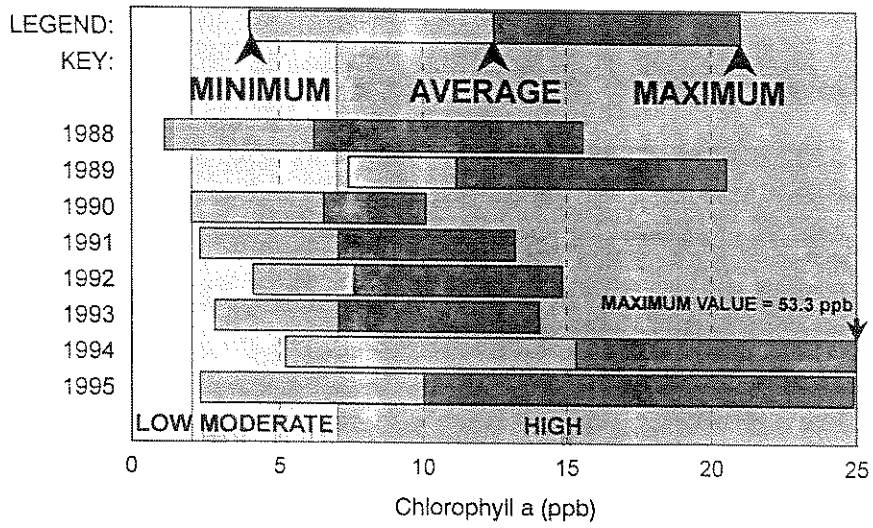
## YEARLY COMPARISONS (1988-1995)




The higher value = clearer water

# DUCKPUDDLE POND - SITE 1 BASIN
# LAY MONITOR CHLOROPHYLL a DATA

## YEARLY COMPARISONS (1988-1995)




The higher value = more algal growth

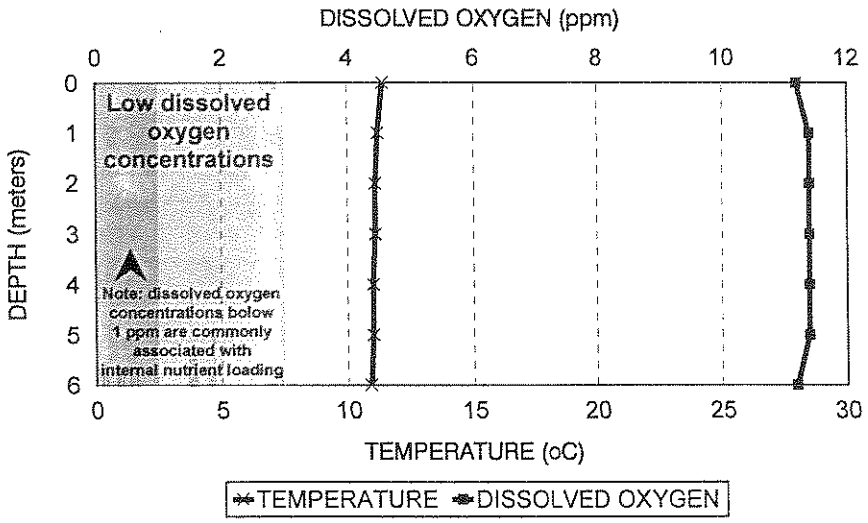
**Figure 33.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on May 9, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

**Figure 34.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on May 21, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### MAY 9, 1996




# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### MAY 21, 1996

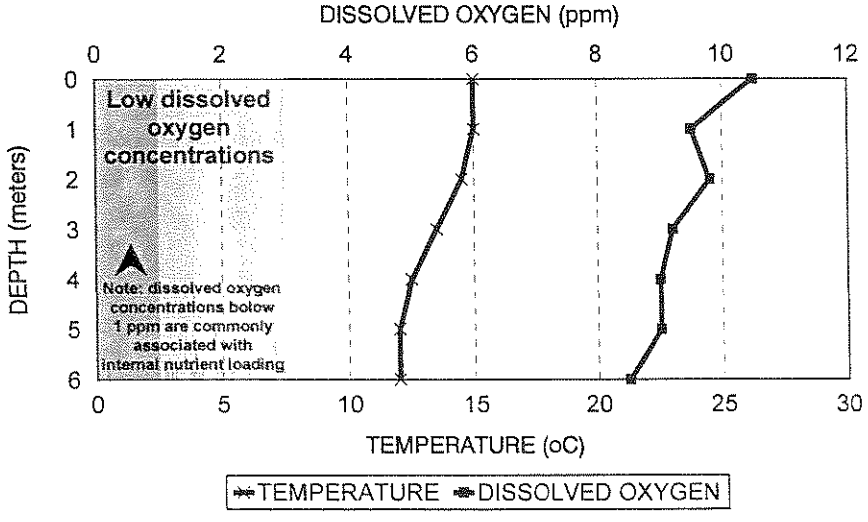


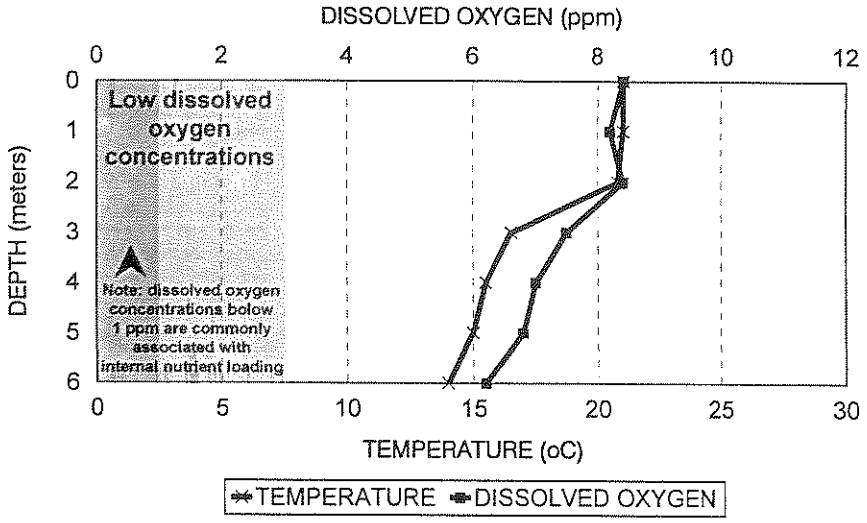
**Figure 35.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on June 4, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

**Figure 36.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on June 19, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### JUNE 4, 1996




# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### JUNE 19, 1996

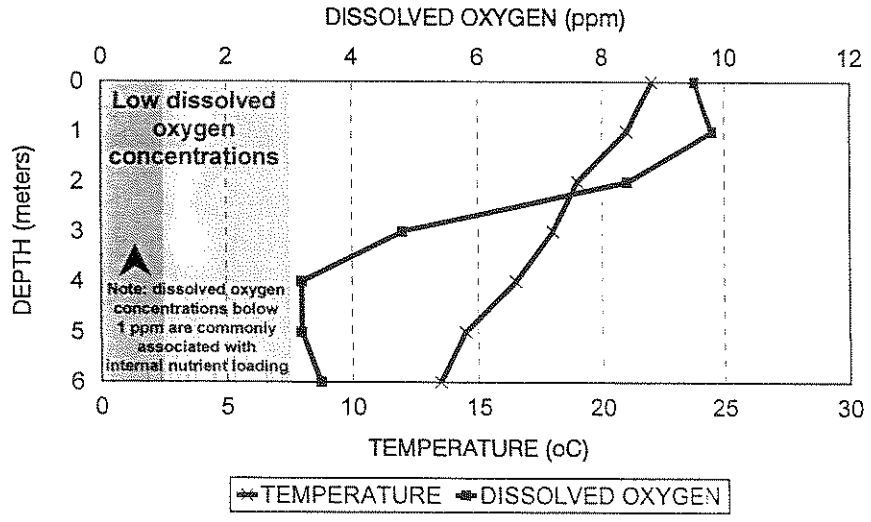


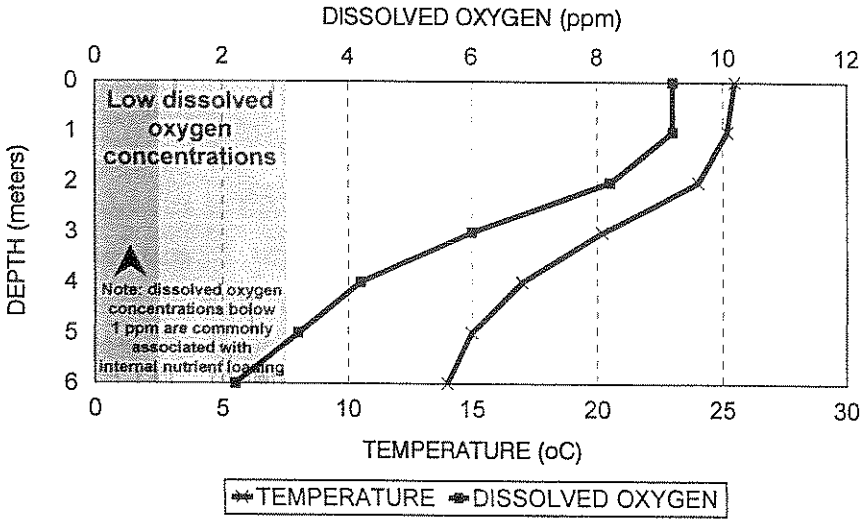
**Figure 37.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on July 2, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

**Figure 38.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on July 18, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### JULY 2, 1996




# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### JULY 18, 1996

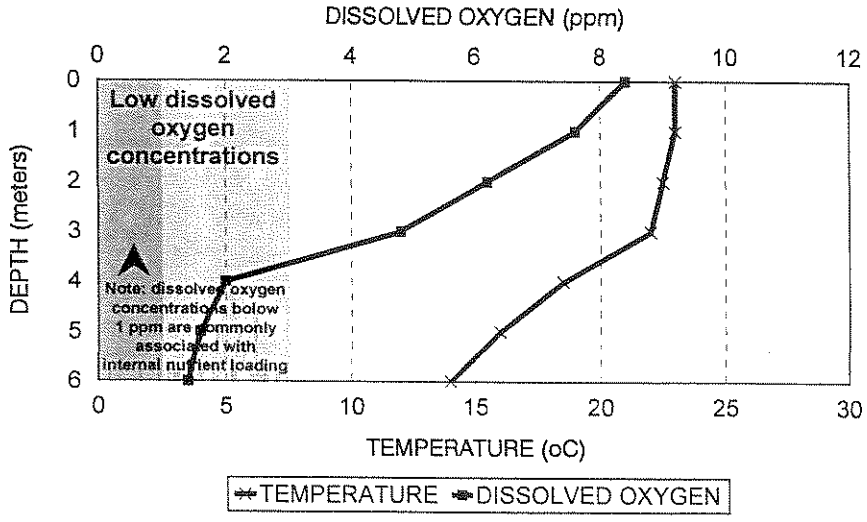


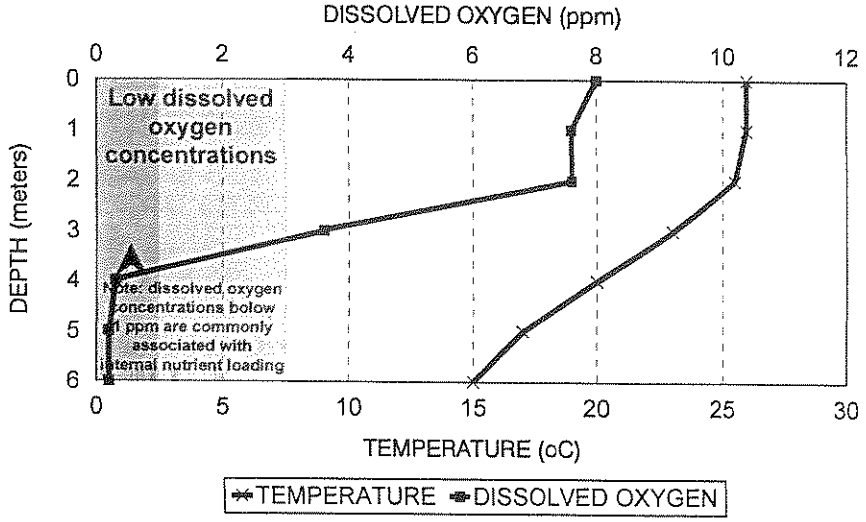
**Figure 39.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on July 31, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

**Figure 40.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on August 13, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### JULY 31, 1995




# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### AUGUST 13, 1996

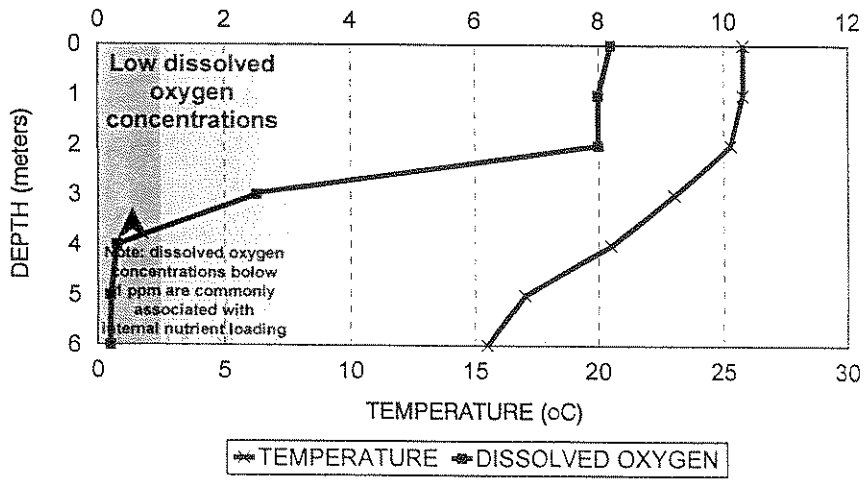


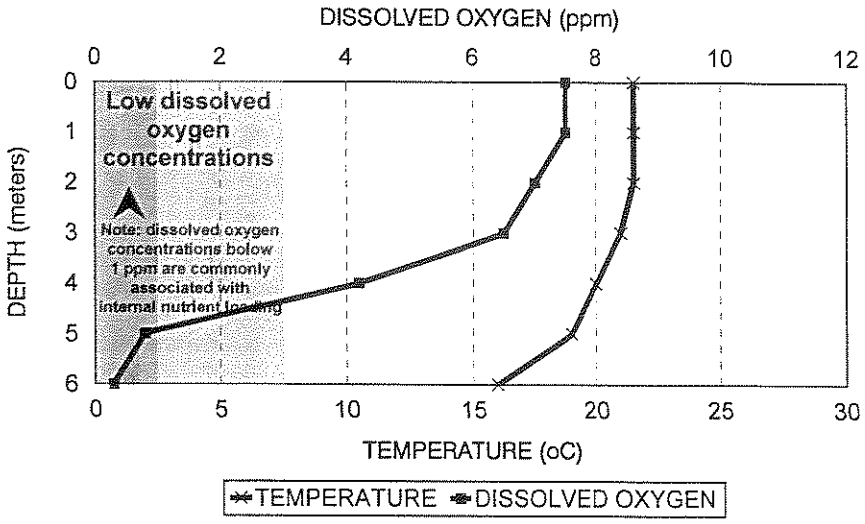
**Figure 41.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on August 27, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

**Figure 42.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on September 10, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### AUGUST 27, 1996




# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

### SEPTEMBER 10, 1996

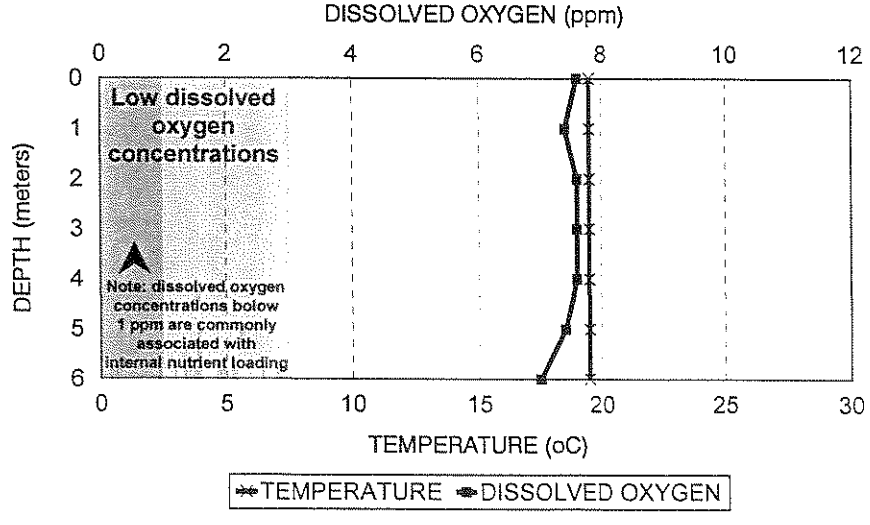
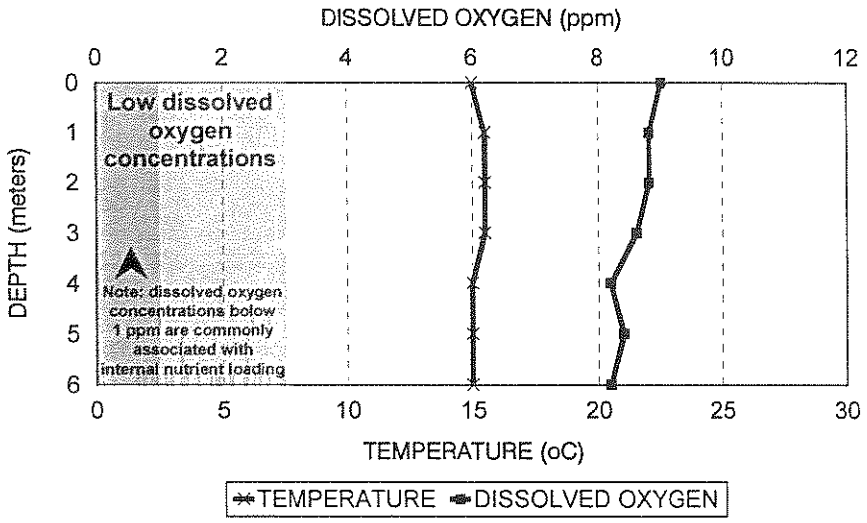


**Figure 43.** Duckpuddle Pond, Site 1 Basin, temperature and dissolved oxygen profiles collected on October 1, 1996. The temperature and dissolved oxygen data were collected at one meter increments and are reported in degrees Centigrade (°C) and in parts per million (ppm), respectively.

# DUCKPUDDLE POND

## TEMPERATURE AND DISSOLVED OXYGEN DATA

## OCTOBER 1, 1996



# Table 5. McCurdy Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

McCurdy Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 6.6 | (1995: | 12 | values; | 5.3 | - | 7.8 | range) |
| Average chlorophyll: | 2.1 | (1995: | 12 | values; | 1.4 | - | 3.5 | range) |
| Average Lake Phos.: | 12.4 | (1995: | 2 | values; | 11.2 | - | 13.7 | range) |
| Average color, 440: | 19.7 | (1995: | 12 | values; | 13.7 | - | 24.9 | range) |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 Basin | 05/09/1995 | 7.0 | 2.4 | 11.2 | ---- | ---- | 23.2 |
| 1 Basin | 05/20/1995 | 6.2 | 3.5 | ---- | ---- | ---- | 24.9 |
| 1 Basin | 06/04/1995 | 5.3 | 1.9 | ---- | ---- | ---- | 24.9 |
| 1 Basin | 06/17/1995 | 6.0 | 3.0 | ---- | ---- | ---- | 24.9 |
| 1 Basin | 07/04/1995 | 6.3 | 2.1 | ---- | ---- | ---- | 20.6 |
| 1 Basin | 07/14/1995 | 7.0 | 2.1 | ---- | ---- | ---- | 18.0 |
| 1 Basin | 07/30/1995 | 6.6 | 2.0 | ---- | ---- | ---- | 18.9 |
| 1 Basin | 08/13/1995 | 6.9 | 1.4 | ---- | ---- | ---- | 19.8 |
| 1 Basin | 08/26/1995 | 7.8 | 1.9 | ---- | ---- | ---- | 17.2 |
| 1 Basin | 09/09/1995 | 6.9 | 2.1 | ---- | ---- | ---- | 15.5 |
| 1 Basin | 09/24/1995 | 6.6 | 1.6 | ---- | ---- | ---- | 14.6 |
| 1 Basin | 10/08/1995 | 7.1 | 1.5 | 13.7 | ---- | ---- | 13.7 |

<< End of 1995 listing, 12 records >>

# MCCURDY POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the McCurdy Pond deep sampling station, Site 1 Basin, between May 9, 1995 and October 8, 1995 (refer to Table 5 and Figures 44 through 48). The following section summarizes the 1995 McCurdy Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 McCurdy Pond water clarity (Secchi Disk transparency) measurements are representative of a moderately productive lake based on the water quality criteria employed by the **Maine Department of Environmental Protection (DEP)**. The 1995 seasonal water transparency average of 6.6 meters (21.8 feet) increased for the second consecutive year and is the highest seasonal average water transparency recorded since participation in the **NH LLMP** was initiated in 1988 (Figure 47).

2) The 1995 McCurdy Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were low to moderate (Figure 45). The seasonal average chlorophyll *a* concentration (2.1 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a marginally unproductive/moderately productive lake (Figure 48). The 1995 seasonal average McCurdy Pond chlorophyll *a* concentration decreased relative to the 1994 seasonal average chlorophyll *a* concentration and was near the historical minimum of 2.0 mg $m^{-3}$ (Figure 48).

3) The 1995 McCurdy Pond seasonal average dissolved lakewater color level (a measure on naturally occurring "background" color) was low to moderate (19.7 chloroplatinate color units; CPU) and at the lowest level since participation in the **NH LLMP** was initiated in 1988.

4) The 1995 McCurdy Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations were moderate to high and measured 11.2 parts per billion; ppb on May 9, 1995 and measured 13.7 ppb on October 8, 1995. The 1995 total phosphorus concentrations exceed the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a moderately to highly productive lake.

5) McCurdy Pond temperature profiles collected by Albert Rogers indicate the upper mixed layer of water extended to about 4.0 meters during the period of summer thermal stratification, typical of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP** (1975 and 1985), indicate reduced dissolved oxygen concentrations in the bottom

(hypolimnetic) waters of McCurdy Pond during periods of thermal stratification. Lower hypolimnetic dissolved oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic animal and vegetative matter) and external (i.e. leaf litter from watershed runoff) sources. As dissolved oxygen concentrations are reduced below 1 milligram per liter the potential for internal nutrient release (nutrient are resuspended from the sediments) increases significantly and might explain the elevated hypolimnetic total phosphorus concentration historically documented in McCurdy Pond.

6) For all measurements considered and averaged for the season, McCurdy Pond is classified as a moderately productive, mesotrophic, lake.

7) The primary purpose of the McCurdy Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and interrelationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transparency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or preferably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

Seasonal average water quality data collected from the McCurdy Pond deep sampling station (representative of

the average pond conditions) between 1988 and 1995 indicate a trend of increasing Secchi Disk transparencies while the chlorophyll *a* data indicate a trend of decreasing chlorophyll *a* concentrations. Based on the current and historical water quality data, McCurdy Pond exhibits the highest water quality of the participating Pemaquid Watershed Association ponds.

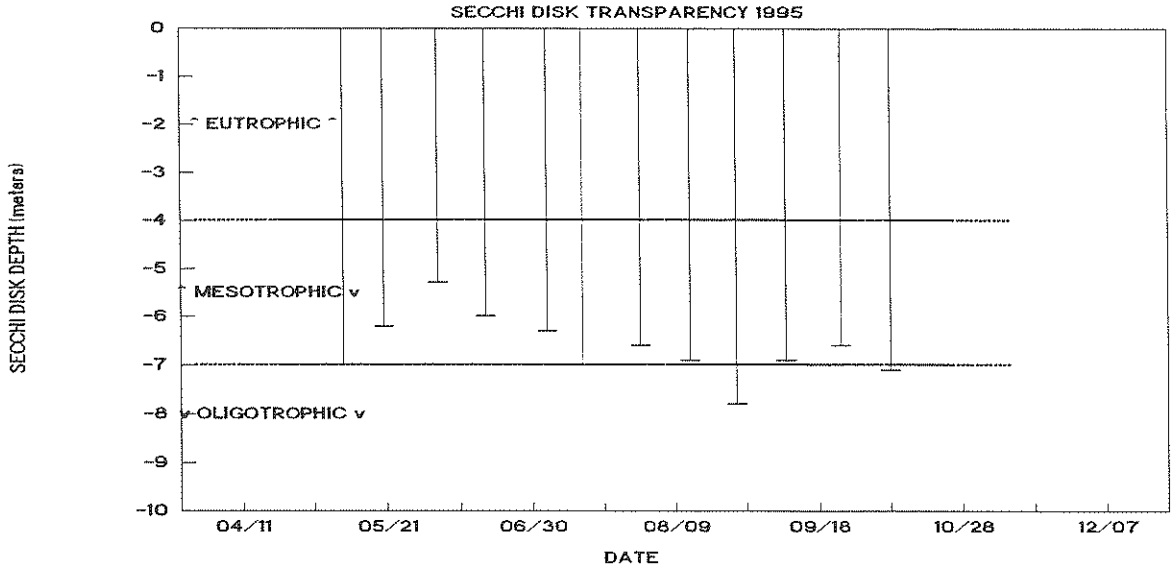
While data collected from the deep sampling station, Site 1 Basin, indicate continued high water quality, more localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) might be overlooked in the shallows and in more embayed areas of McCurdy Pond. If such problem areas are a concern, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

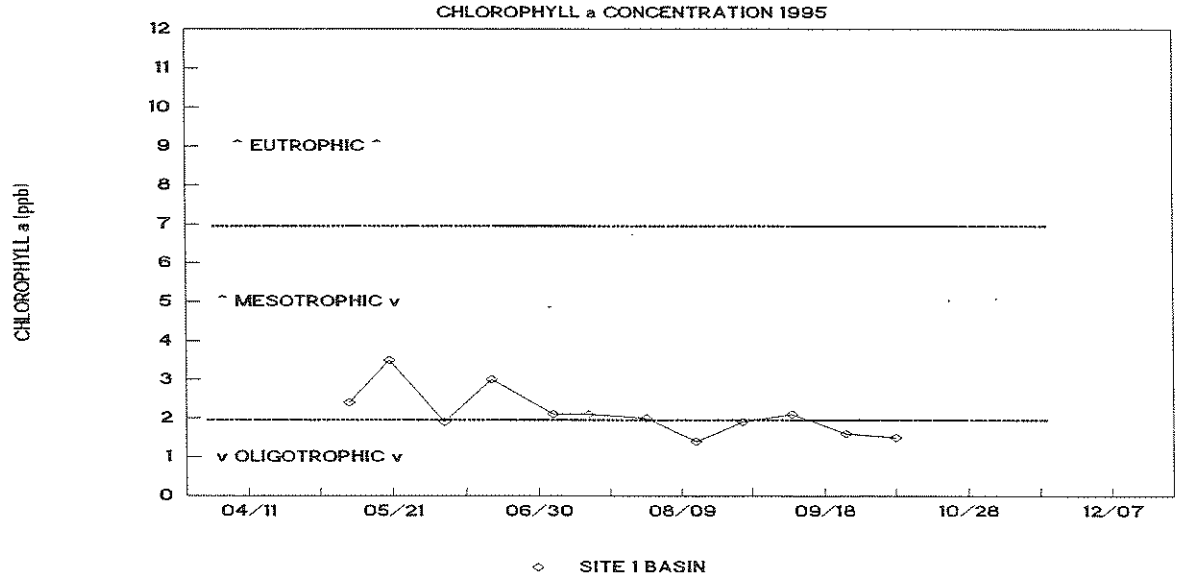
**Figure 44.**McCurdy Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 45.**McCurdy Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 46.**McCurdy Pond, 1995. Seasonal dissolved color trends of lay monitor Site 1 Basin. The dotted horizontal line represents the dissolved color average for participating **Pemaquid Watershed** lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# MCCURDY POND – SITE 1 BASIN



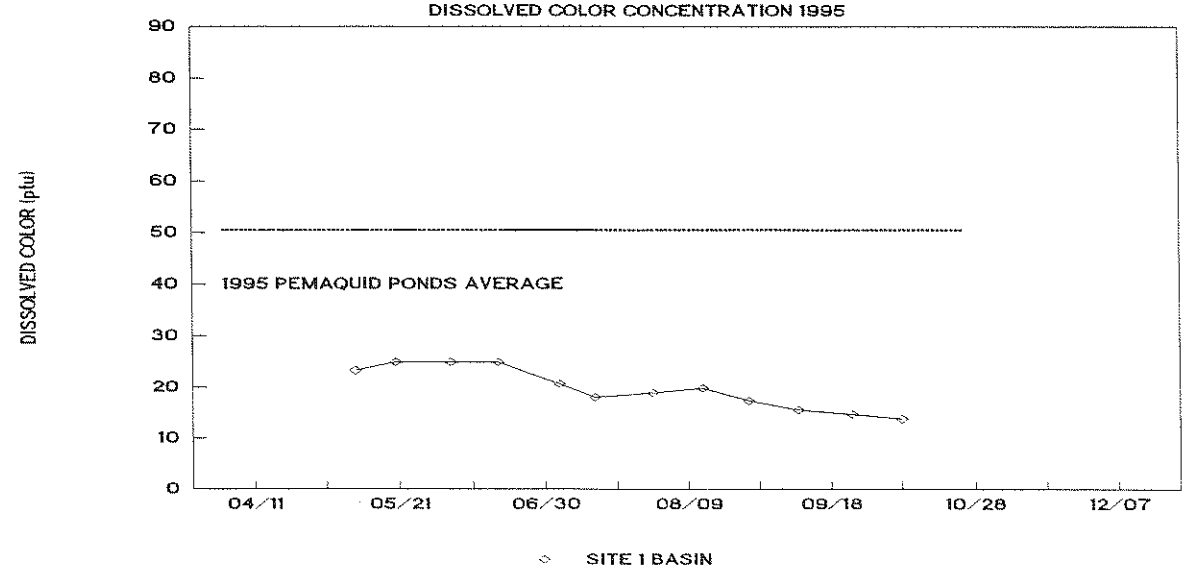
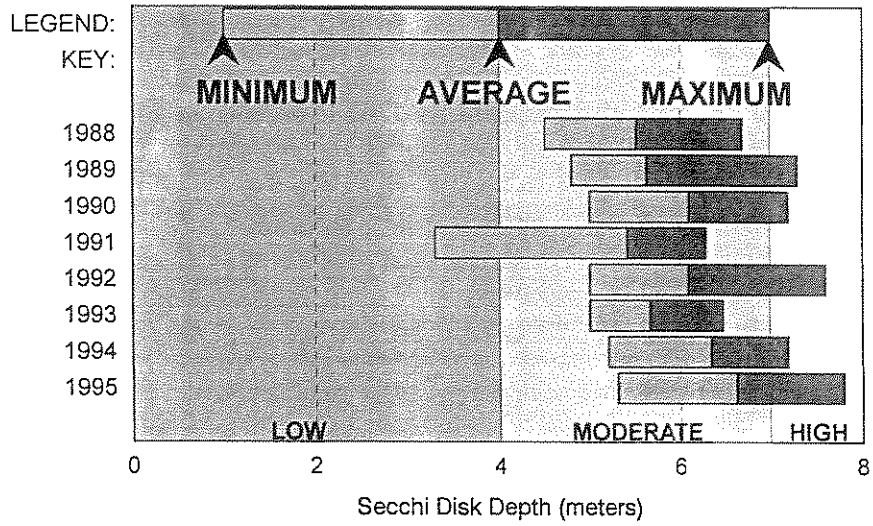



**Figure 47.**Comparison of the 1995 McCurdy Pond lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

**Figure 48.**Comparison of the 1995 McCurdy Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# MCCURDY POND - SITE 1 BASIN
# LAY MONITOR SECCHI DISK DATA

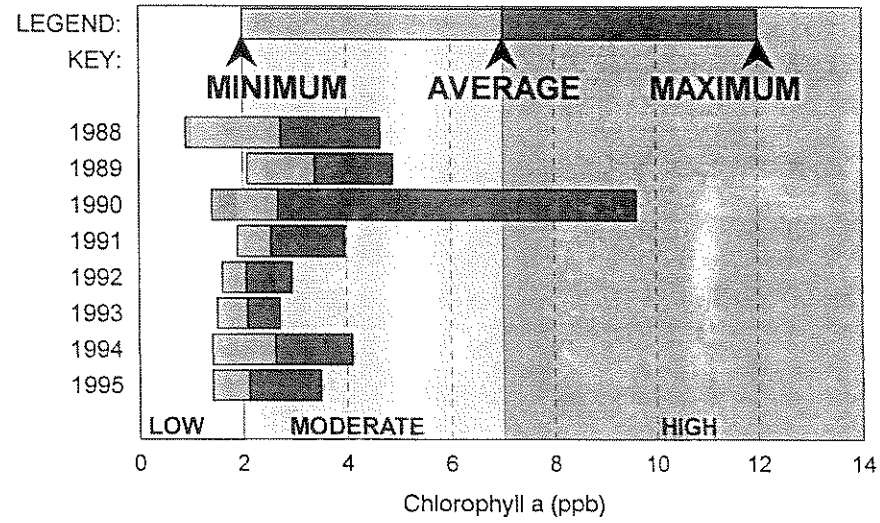
## YEARLY COMPARISONS (1988-1995)




**The higher value = clearer water**

# MCCURDY POND - SITE 1 BASIN
# LAY MONITOR CHLOROPHYLL a DATA

## YEARLY COMPARISONS (1988-1995)




**The higher value = more algal growth**

# Table 6. Paradise Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Paradise Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 3.2 | (1995: | 4 | values; | 2.5 | - | 3.6 | range) |
| Average chlorophyll: | 4.1 | (1995: | 13 | values; | 1.9 | - | 6.4 | range) |
| Average Lake Phos.: | 19.6 | (1995: | 2 | values; | 19.0 | - | 20.3 | range) |
| Average color, 440: | 64.5 | (1995: | 13 | values; | 46.4 | - | 85.0 | range) |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 2 Bottom | 08/27/1995 | ---- | ---- | 19.0 | ---- | ---- | ---- |
| 2 North | 05/14/1995 | 2.5 | 6.0 | 20.3 | ---- | ---- | 85.0 |
| 2 North | 05/26/1995 | 3.0 | 6.1 | ---- | ---- | ---- | 81.6 |
| 2 North | 06/09/1995 | 3.6 | 3.9 | ---- | ---- | ---- | 79.9 |
| 2 North | 06/24/1995 | Bottom | 3.9 | ---- | ---- | ---- | 77.3 |
| 2 North | 07/09/1995 | Bottom | 4.2 | ---- | ---- | ---- | 64.4 |
| 2 North | 07/16/1995 | Bottom | 5.9 | ---- | ---- | ---- | 63.6 |
| 2 North | 07/30/1995 | 3.5 | 6.4 | ---- | ---- | ---- | 63.6 |
| 2 North | 08/11/1995 | Bottom | 3.1 | ---- | ---- | ---- | 63.6 |
| 2 North | 08/27/1995 | Bottom | 3.3 | ---- | ---- | ---- | 61.0 |
| 2 North | 09/10/1995 | Bottom | 2.3 | ---- | ---- | ---- | 56.7 |
| 2 North | 09/24/1995 | Bottom | 3.2 | ---- | ---- | ---- | 49.0 |
| 2 North | 10/08/1995 | Bottom | 3.1 | ---- | ---- | ---- | 46.4 |
| 2 North | 10/29/1995 | Bottom | 1.9 | ---- | ---- | ---- | 46.4 |

<< End of 1995 listing, 14 records >>

# PARADISE POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the Paradise Pond deep sampling station, Site 2 North, between May 14, 1995 and October 29, 1995 (Refer to Table 6 and Figures 49 through 53). The following section summarizes the 1995 Paradise Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 Paradise Pond water clarity (Secchi Disk transparency) measurements ranged from 3.2 to 3.7 meters (at which time the Secchi Disk rested on the lakebottom). Due to the shallowness of the pond, water clarity measurements cannot be classified based on the criteria employed by the **Maine Department of Environmental Protection (DEP)**.

2) The 1995 Paradise Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were moderate (Figure 50). The seasonal average chlorophyll *a* concentration (4.1 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a moderately productive lake (Figure 53). The 1995 seasonal average Paradise Pond chlorophyll *a* concentration decreased relative to the 1994 seasonal average chlorophyll *a* concentration (4.5 mg $m^{-3}$) and remained within the range of historical values.

3) The 1995 Boyd Pond seasonal average dissolved lakewater color levels (a measure on naturally occurring "background" color) were moderate (50.9 chloroplatinate color units; cpu) but slightly less than the 1994 seasonal average dissolved color concentration of 55.1 cpu.

4) The 1995 Paradise Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations were high and measured 20.3 ppb in the surface waters on May 14, 1995 and measured 19.0 ppb near the lakebottom on August 27, 1995. The 1995 total phosphorus concentrations exceed the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a highly productive lake.

5) Paradise Pond temperature profiles collected by Steve O'Bryan indicate Paradise Pond remained thermally constant (i.e. no temperature change from the pond surface to the pond bottom) throughout the summer sampling season, typical of shallow water bodies. With the lack of temperature stratification, the pond remains well oxygenated throughout the water column. However, during periods of inclement weather, there is a greater chance of resuspending accumulated matter off the bottom

of Paradise Pond than would occur in a deeper, stratified lake or pond (i.e. Biscay Pond, McCurdy Pond and Pemaquid Pond). The resuspension of particulate matter can diminish water clarity and mobilize nutrients, which adhere to the sediment and detrital (decaying organic matter) particles, and can than be utilized by certain algal forms.

6) For all measurements considered and averaged for the season, Paradise Pond is classified as a moderately productive, mesotrophic, lake. However, the total phosphorus concentrations are more characteristic of a higher level of productivity; eutrophy.

7) The primary purpose of the Paradise Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and interrelationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transparency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or preferably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

Water quality data collected from the Paradise Pond deep sampling station (representative of the average pond conditions) between 1988 and 1995 indicate variable seasonal average chlorophyll *a* concentrations over the eight year span (Note: the Paradise Pond

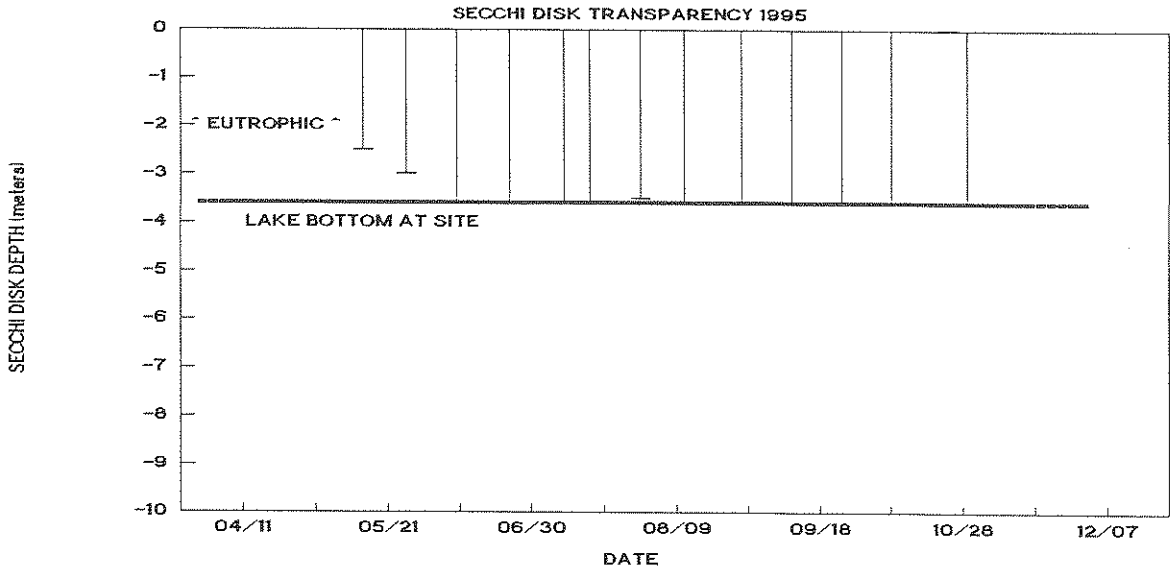
sampling station shifted from Site 1 Reed Island, 1988-1990, to Site 2 North, 1991-1995) and might contribute to the variability in the water quality data. If localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

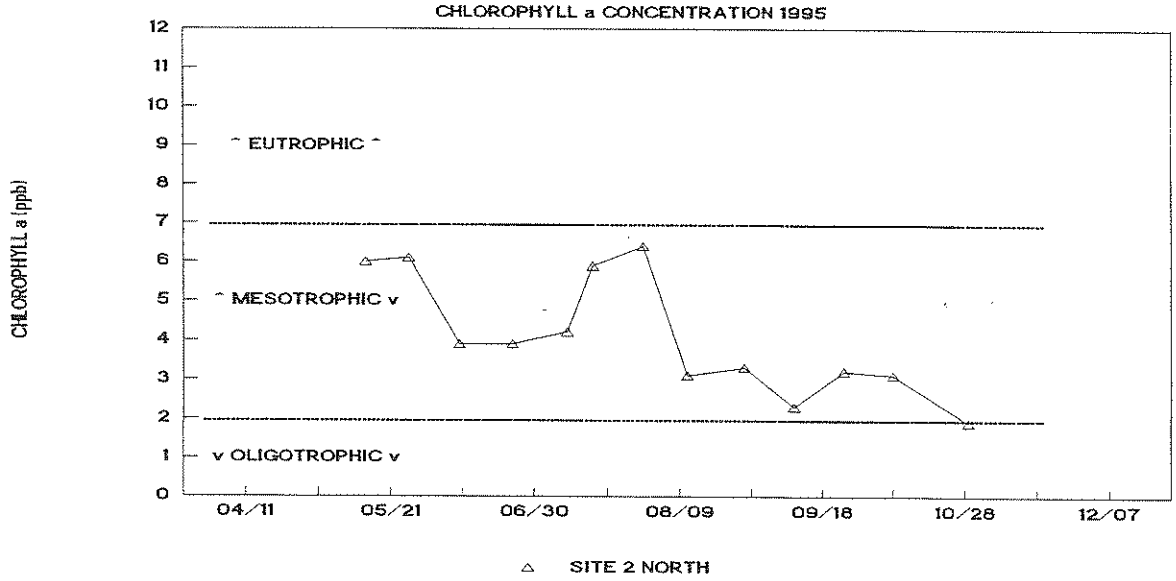
**Figure 49.**Paradise Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 2 North. The double solid horizontal line denotes the maximum site depth. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 50.**Paradise Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 2 North. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 51.**Paradise Pond, 1995. Seasonal dissolved color trends of lay monitor Site 2 North. The dotted horizontal line represents the dissolved color average for participating Pemaquid Watershed lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# PARADISE POND - SITE 2 NORTH



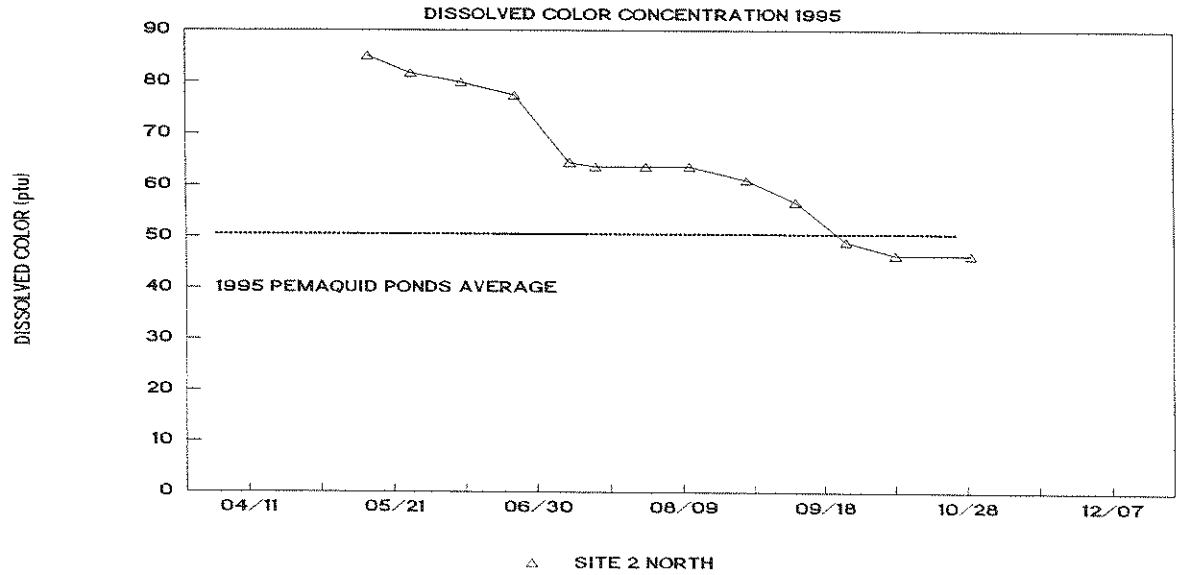
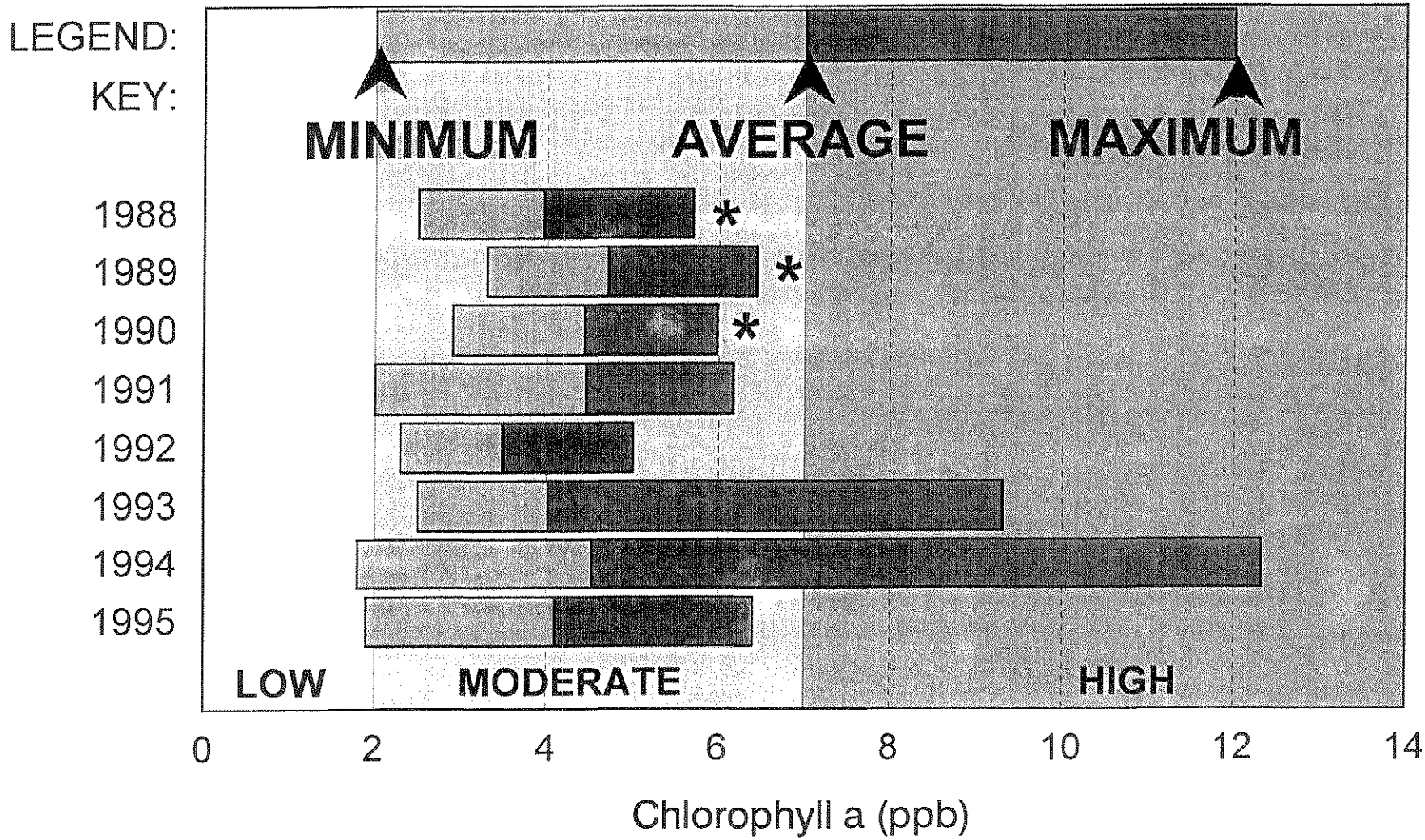



**Figure 52.**Comparison of the 1995 Paradise Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# PARADISE POND - SITE 2 NORTH
# LAY MONITOR CHLOROPHYLL a DATA
## YEARLY COMPARISONS (1988-1995)




**The higher value = more algal growth**

*** Denotes data collected at a more southerly sampling station; Site 1 Reed Island.**

# Table 7. Pemaquid Pond - Trophic Indicators, 1995

Lakes Lay Monitoring Program, U.N.H.
[Lay Monitor Data]

Pemaquid Pond, Maine
-- subset of trophic indicators, all sites, 1995

1995 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 4.5 | (1995: | 9 | values; | 3.8 | - | 5.5 | range) |
| Average chlorophyll: | 3.2 | (1995: | 9 | values; | 1.9 | - | 5.4 | range) |
| Average Lake Phos.: | 17.4 | (1995: | 3 | values; | 11.9 | - | 24.1 | range) |
| Average color, 440: | 45.4 | (1995: | 9 | values; | 34.4 | - | 57.6 | range) |

| Site | Date | Trans-parency (m) | Chl a (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 Basin | 06/04/1995 | 4.4 | 2.1 | 16.2 | ---- | ---- | 57.6 |
| 1 Basin | 06/19/1995 | 3.8 | 2.2 | ---- | ---- | ---- | 57.6 |
| 1 Basin | 07/04/1995 | 4.7 | 3.4 | ---- | ---- | ---- | 43.8 |
| 1 Basin | 07/16/1995 | 4.6 | 5.4 | ---- | ---- | ---- | 44.7 |
| 1 Basin | 08/02/1995 | 4.1 | 3.8 | ---- | ---- | ---- | 43.0 |
| 1 Basin | 08/17/1995 | 4.5 | 3.9 | ---- | ---- | ---- | 47.2 |
| 1 Basin | 08/31/1995 | 4.1 | 3.6 | ---- | ---- | ---- | 36.9 |
| 1 Basin | 09/19/1995 | 4.8 | 1.9 | ---- | ---- | ---- | 43.8 |
| 1 Basin | 10/01/1995 | 5.5 | 2.3 | ---- | ---- | ---- | 34.4 |
| 1 Hypo | 08/02/1995 | ---- | ---- | 24.1 | ---- | ---- | ---- |
| 20 BisStr | 04/13/1995 | ---- | ---- | 11.9 | ---- | ---- | ---- |

<< End of 1995 listing, 11 records >>

# PEMAQUID POND
# 1995 NON-TECHNICAL SUMMARY

Bi-weekly water quality data were collected at the Pemaquid Pond deep sampling station, Site 1 Basin, between June 4, 1995 and October 1, 1995 (Refer to Table 7 and Figures 53 through 57). Additional early season (April 13, 1995) tributary sampling was undertaken in the Biscay Stream to assess the phosphorus (nutrient) concentrations following spring snowmelt. The following section summarizes the 1995 Pemaquid Pond water quality data and when applicable, incorporates historical data into the interpretation. A more detailed discussion of the water quality parameters is included in the section of the report titled "Discussion of Lake Monitoring Measurements".

1) The 1995 Pemaquid Pond water clarity (Secchi Disk transparency) measurements are representative of a moderately productive lake based on the water quality criteria employed by the **Maine Department of Environmental Protection (DEP)**. The 1995 seasonal water transparency average of 4.5 meters (14.9 feet) falls within the range of historical water transparency readings (Figure 56).

2) The 1995 Pemaquid Pond microscopic plant "algal" concentrations (reported as chlorophyll *a*) measured in the surface waters were moderate (Figure 54). The seasonal average chlorophyll *a* concentration (3.2 milligrams per cubic meter; mg $m^{-3}$) falls within the **Maine DEP** criteria for a moderately productive lake (Figure 57). The 1995 seasonal average Pemaquid Pond chlorophyll *a* concentration decreased slightly relative to the 1994 seasonal average chlorophyll *a* concentration (3.3 mg $m^{-3}$) but remained within the range of historical seasonal chlorophyll *a* averages.

3) The 1995 Pemaquid Pond seasonal average dissolved lakewater color level (a measure on naturally occurring "background" color) was moderate (45.4 chloroplatinate color units; cpu) but slightly less than the 1994 seasonal average dissolved color average of 52.5 cpu.

4) 1995 Pemaquid Pond total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations were high when measured in the surface waters on June 4 (16.2 parts per billion; ppb) and when measured in the bottom waters (hypolimnion) on August 2 (24.1 ppb). Higher bottom water total phosphorus concentration, relative to the surface waters, are often associated with internal nutrient loading (nutrients released from the bottom sediments). An early season total phosphorus sample collected in the Biscay Stream measured 11.9 ppb on April 13, 1995. The 1995 Pemaquid Pond total phosphorus concentrations exceed the range of historical total phosphorus values recorded by the **NH LLMP** and the **Maine DEP** and fall within the range characteristic of a highly productive lake.

5) Pemaquid Pond temperature profiles collected by David McLeod indicate the upper mixed layer of water extended to about 5.0 meters during the period of summer thermal stratification, typical of a northern temperate lake. Historical dissolved oxygen data, collected by the **Maine DEP** (1975, 1976, 1977, 1978, 1981, 1984 1988, 1987 1991), indicate reduced dissolved oxygen concentrations in the bottom (hypolimnetic) waters of Pemaquid Pond during thermal stratification. Lower hypolimnetic dissolved oxygen concentrations are indicative of accumulating organic matter from both internal (i.e. decaying aquatic animal and vegetative matter) and external (i.e. leaf litter from watershed runoff) sources. As dissolved oxygen concentrations are reduced below 1 milligram per liter the potential for internal nutrient release (nutrient are resuspended from the sediments) increases significantly and might explain the elevated hypolimnetic total phosphorus concentration documented in Pemaquid Pond on August 2, 1995.

6) For all measurements considered and averaged for the season, Pemaquid Pond is classified as a moderately productive, mesotrophic, lake. However, the 1995 Pemaquid Pond total phosphorus concentrations border more productive, eutrophic, levels.

7) The primary purpose of the Pemaquid Pond volunteer monitoring effort is to document long term changes in the pond's productivity and identify any improper land use practices within the watershed that are contributing to water quality degradation. However, "background" variability in seasonal precipitation and temperature patterns can actually mask the effects of cultural eutrophication, or in some cases, augment the process, and in turn make trend (eutrophication) detection difficult. Increases in precipitation will often result in increased nutrient loading to a lake that in turn stimulates primary productivity (plant production), but can also result in increased flushing of the aquatic system that can mask the effects of internal nutrient loading (i.e. large precipitation events can dilute nutrient concentrations in highly productive lakes). Increasing temperature will also effect the aquatic community, as most aquatic organisms will increase their activity (i.e. higher chlorophyll *a* concentrations or decreased Secchi Disk transparencies) during these periods, reflecting the thermal variations but not necessarily variations in available nutrients or other limiting resources that are commonly associated with poor land-use practices. As more data become available, the impact and interrelationship of these variables can be assessed for the study lake and the impact of land use changes can be evaluated.

A second important component of trend assessment involves the frequent collection of water quality data. The most basic measurement, water clarity (measured as Secchi Disk transparency), is commonly used as an indicator of algal productivity (measured as chlorophyll *a*), although it also reflects the impact of dissolved colored (organic) compounds as well as suspended sediments. Chlorophyll *a* levels undergo daily fluctuations which require frequent monitoring to document short term fluctuations in chlorophyll *a* concentrations. Likewise, the dissolved color and total phosphorus concentrations can vary, particularly early in the season during and following "peak" watershed runoff, as well as, following

summer storm events. Only through frequent monitoring can these short term water quality perturbations be documented, which is important since they are often precursors to more detrimental "long-term" shifts in the trophic state (productivity). We therefore recommend continued monitoring on a frequent basis (bi-weekly or preferably weekly) during the summer months to more accurately identify both short term fluctuations (weekly and at times daily fluctuations) and long term trends in water quality measurements.

Water quality data collected from the Pemaquid Pond deep sampling station, Site 1 Basin, (representative of the average pond conditions) between 1988 and 1995 indicate a trend of increasing Secchi Disk transparency between 1988 and 1992 followed by more "erratic" Secchi Disk transparencies between 1993 and 1995. Chlorophyll *a* concentrations are more variable and display no distinct water quality trend at this time.

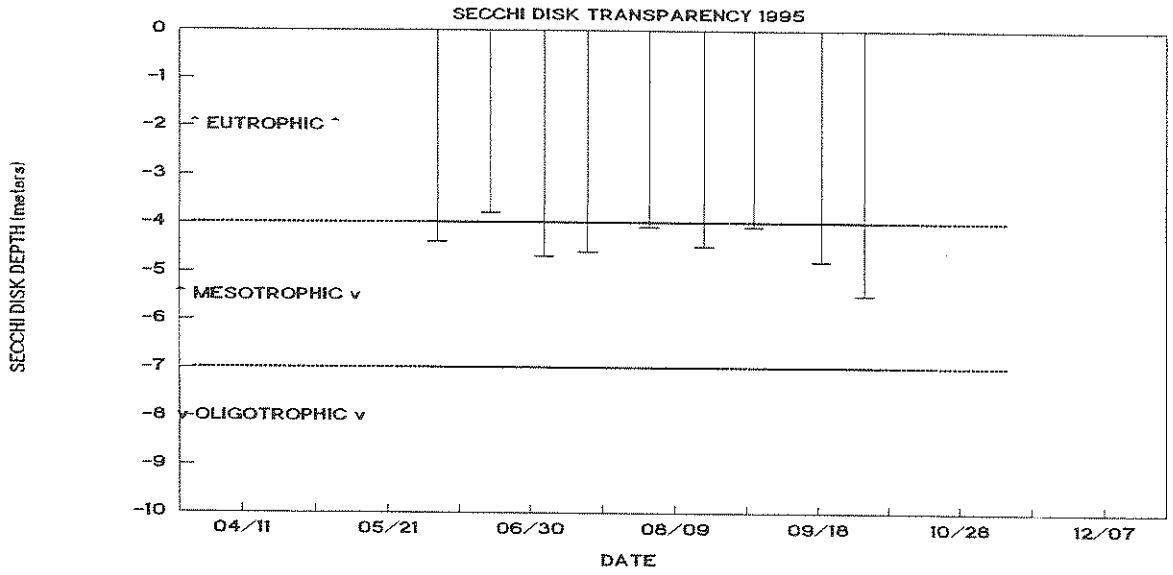
Comparison of historical Secchi Disk transparency data collected at Site 1 Basin and Site 2 Basin (2 North) indicate the seasonal average Secchi Disk transparencies have been consistently lower at the northern (Site 2 Basin) sampling station (Figure 58). It is difficult to discern the cause of these differences as no chlorophyll *a* or dissolved color measurements were collected at the northern sampling site. Future monitoring in Pemaquid Pond should include the second (northerly) sampling site and if localized problems (i.e. improperly installed and failing septic systems, improper soil conservation procedures and practices, excessive fertilizer applications, etc.) are suspected, we recommend performing a shoreline survey of the pond or a watershed wide survey to locate problem areas. We can then expand, or revise, the monitoring program to address more localized problematic regions if warranted.

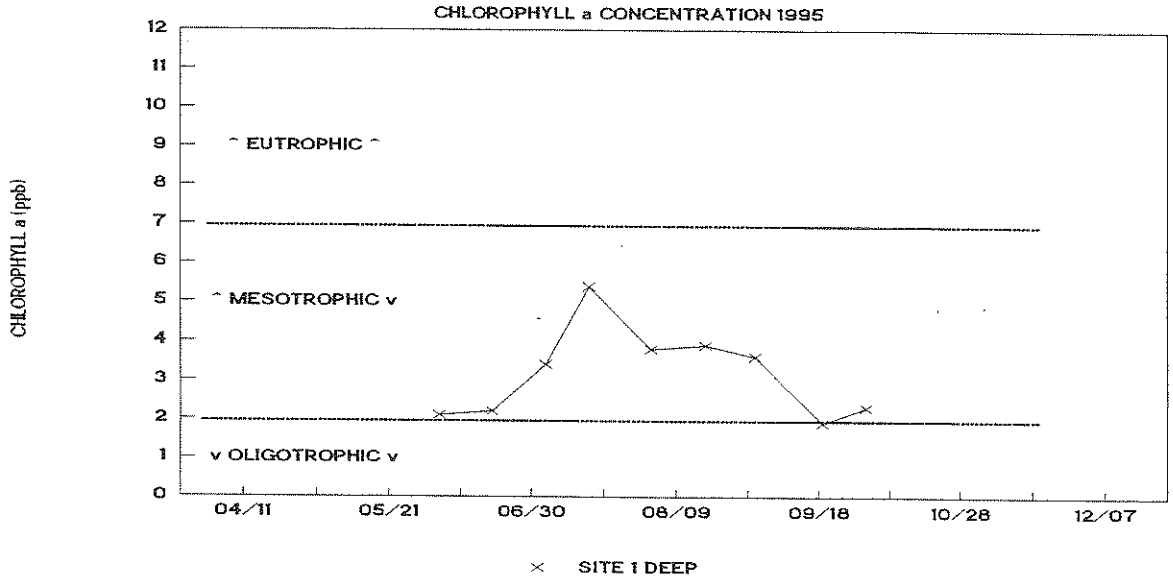
**Figure 53.**Pemaquid Pond, 1995. Seasonal water transparency (Secchi Disk Depth) trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Secchi Disk measurements are reported to the nearest tenth (0.1) of a meter.

**Figure 54.**Pemaquid Pond, 1995. Seasonal chlorophyll *a* trends of lay monitor Site 1 Basin. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 55.**Pemaquid Pond, 1995. Seasonal dissolved color trends of lay monitor Site 1 Basin. The dotted horizontal line represents the dissolved color average for participating Pemaquid Watershed lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# PEMAQUID POND – SITE 1 DEEP



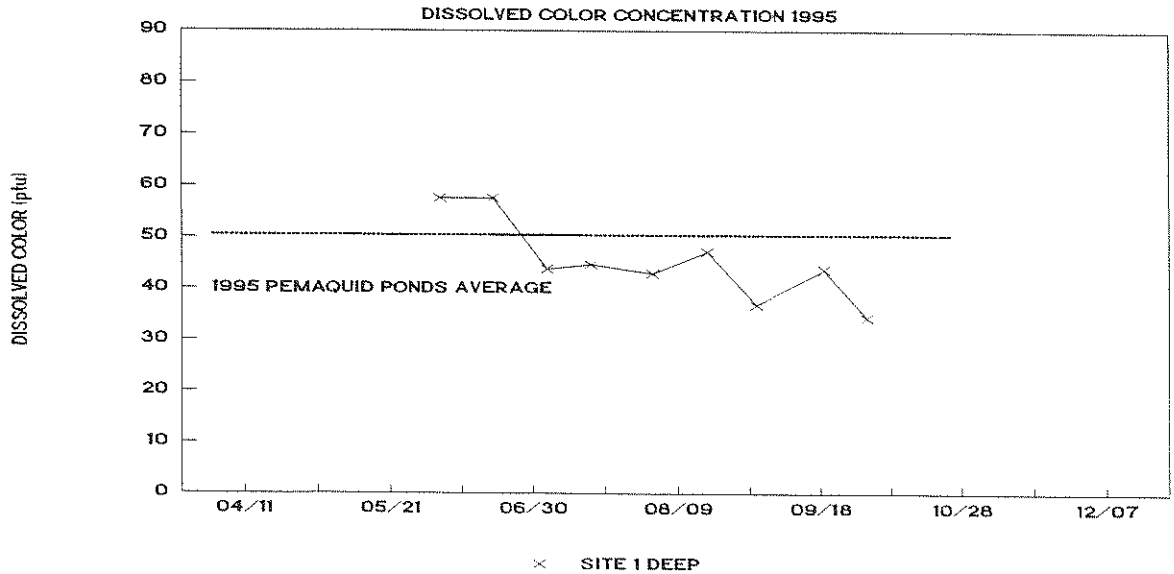
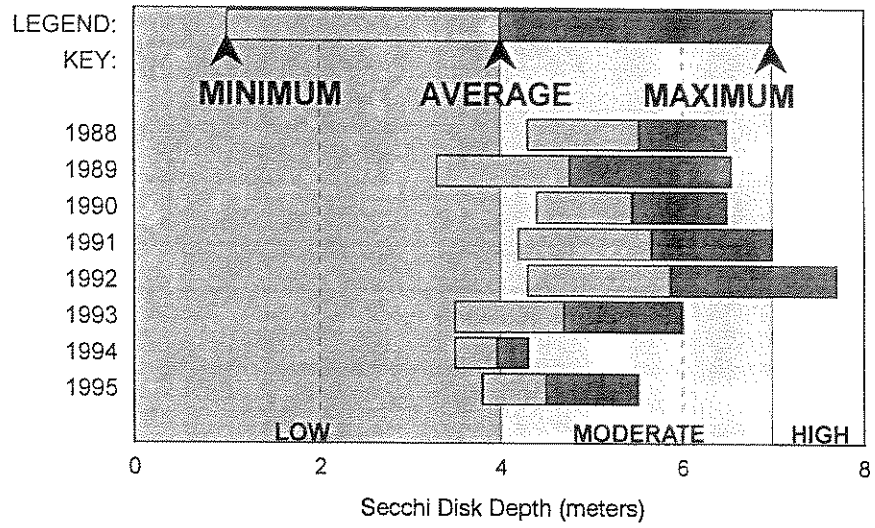



**Figure 56.**Comparison of the 1995 Pemaquid Pond lay monitor Secchi Disk transparency data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

**Figure 57.**Comparison of the 1995 Pemaquid Pond lay monitor chlorophyll *a* data with previous yearly data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** chlorophyll *a* standards for low, moderate and high chlorophyll *a* concentrations. The higher the chlorophyll *a* value, the greener the water (more algal growth).

# PEMAQUID POND - SITE 1 DEEP
# LAY MONITOR SECCHI DISK DATA

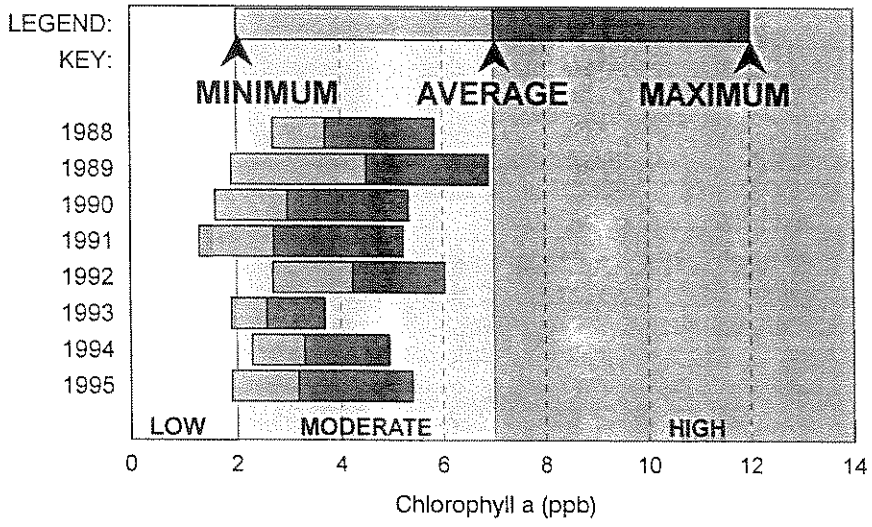
## YEARLY COMPARISONS (1988-1995)




The higher value = clearer water

# PEMAQUID POND - SITE 1 DEEP
# LAY MONITOR CHLOROPHYLL a DATA

## YEARLY COMPARISONS (1988-1995)

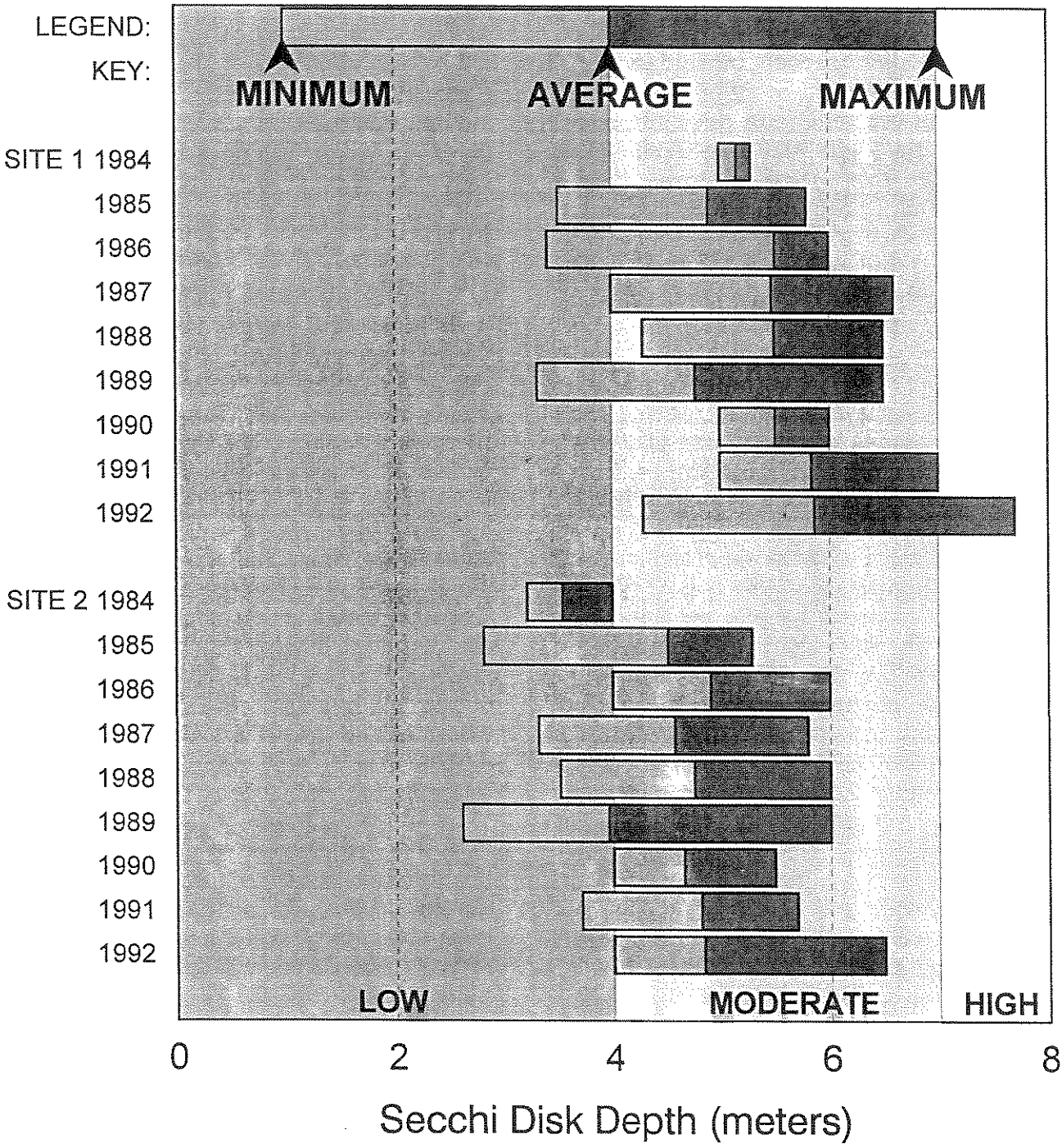



The higher value = more algal growth

**Figure 58.**Comparison of the historical Pemaquid Pond, Site 1 Basin and Site 2 North (2 Basin), Secchi Disk transparency data. The patterns of the bars display the minimum, average and maximum values for the respective years sampled while the length of the bars represents the total range of values. The shaded regions on the graph denote the **Maine DEP** Secchi Disk standards for low, moderate and high water clarities. The higher the Secchi Disk value the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

# PEMAQUID POND - SITE INTERCOMPARISON: SITES 1 BASIN AND SITE 2 (NORTH) LAY MONITOR SECCHI DISK DATA

## YEARLY COMPARISONS (1984-1992)




**The higher value = clearer water**

# COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating association, including **the Pemaquid Watershed Association**, continue to develop its data base on lake water quality through continuation of the long-term monitoring program. The data base currently provides information on the short and long-term cyclic variability that occurs in Biscay Pond, Boyd Pond, Duckpuddle Pond, McCurdy Pond, Paradise Pond and Pemaquid Pond and through continued monitoring will enable more reliable predictions of water quality trends.

2) We recommend continued in-lake total phosphorus sampling during the 1996 sampling season. Total phosphorus samples should be obtained from Duckpuddle Pond on a bi-weekly basis. These should include integrated samples (collected with the weighted garden hose) supplemented by point "grab" samples collected 1 meter off the lake-bottom whenever the pond is thermally stratified. You should consider taking triplicate integrated samples and replicate point samples at least monthly. This type of sampling will help eliminate "random" inaccuracies which can occur when only single samples are analyzed. Note: this recommendation was proposed by Roy Bouchard of the **Maine DEP**.

Additional total phosphorus sampling should be undertaken at the remaining ponds (Biscay, Boyd, McCurdy, Paradise and Pemaquid) as frequently as possible to more completely assess the condition of the ponds and determine the seasonal cycles.

3) We recommend collecting Secchi Disk measurements on intermittent weeks, when chlorophyll *a* samples are not taken, to document the short term fluctuations which occur in the Pemaquid Ponds. If new monitors are interested, we can set up a training session to familiarize the participants with the methodologies employed by the **NH LLMP**.

4) We recommend collecting bi-weekly dissolved oxygen profiles in the deeper ponds (Biscay, McCurdy and Pemaquid Ponds) to monitor the rate of oxygen depletion following the onset of thermal stratification. Continued collection of dissolved oxygen profiles in Duckpuddle Pond is also recommended. The data will provide a more complete assessment of the trophic state of these ponds and will add to the baseline data that have been generated. Knowledge of the dissolved oxygen concentrations is also useful when assessing the condition of the ponds' fisheries, as well as, to what degree internal nutrient cycling is contributing to the nutrient (phosphorus) pool.

5) We recommend continued algal (microscopic plant) sampling to detect seasonal differences in the phytoplanktonic community structure. Knowledge of the algal forms will provide additional insight into the trophic state of the Pemaquid Ponds. Since the cost associated with this type of sampling is currently subsidized by the **NH LLMP**,

this type of sampling is highly recommended.

6) We suggest collecting daily precipitation data from locations near the participating **PWA** ponds (rain gauges were supplied by the **NH LLMP** free of charge). The data generated through this endeavor will help discern the influence of precipitation levels on seasonal fluctuations in the trophic parameters (i.e. Secchi Disk, chlorophyll *a*, dissolved color and total phosphorus). Contact Bob Craycraft (603-862-3546) for further information

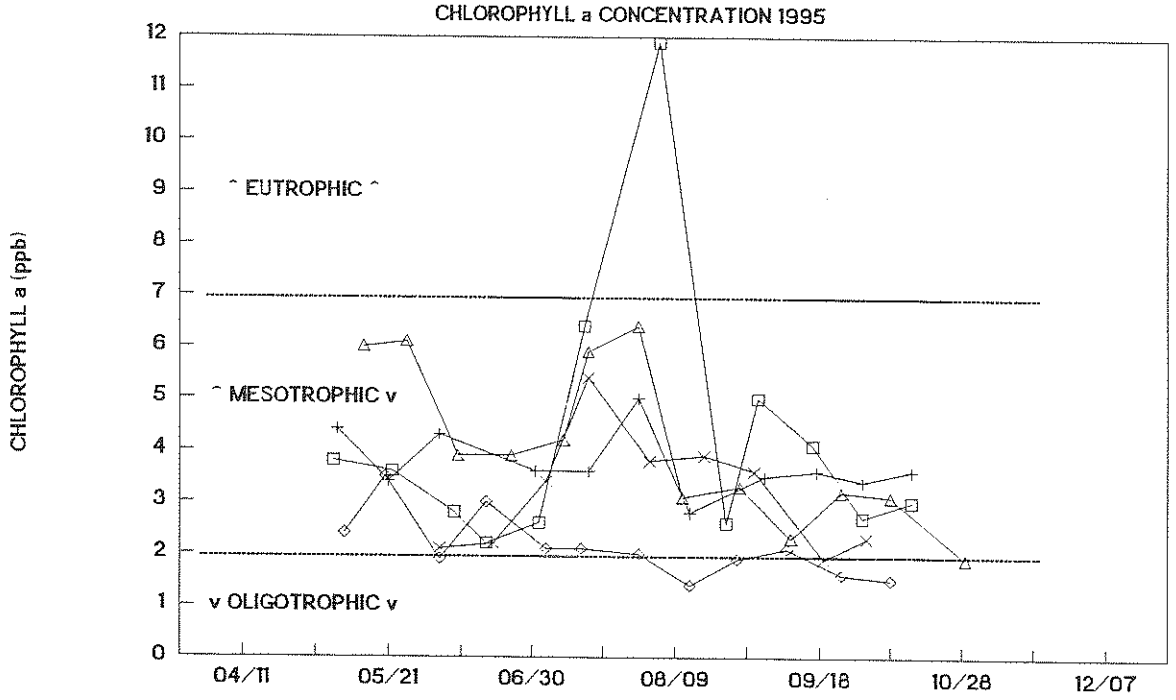
7) We recommend reinitiating water quality monitoring in the Northerly Pemaquid Pond sampling station (Figure 7). Historical seasonal average water clarity data collected at Site 2 North were consistently lower than the seasonal average water clarities collected at the more southerly sampling site (Site 1 Basin) and warrant further investigation (Figure 58). The collection of chlorophyll *a*, dissolved color, Secchi Disk and total phosphorus data are recommended to help discern the cause of the water clarity variations between the sites. If necessary, further efforts can focus on more localized areas of concern if desired.

**Figure 59.**Seasonal chlorophyll *a* trends in Biscay Pond, Boyd Pond, McCurdy Pond, Paradise Pond and Pemaquid Pond. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Chlorophyll *a* concentrations are reported as parts per billion (ppb) of chlorophyll *a*.

**Figure 60.**Seasonal dissolved color trends in Biscay Pond, Boyd Pond, McCurdy Pond, Paradise Pond and Pemaquid Pond. The dotted horizontal line represents the dissolved color average for participating Pemaquid Watershed lakes. Dissolved color is expressed as chloroplatinate color units (ptu).

# PEMAQUID PONDS

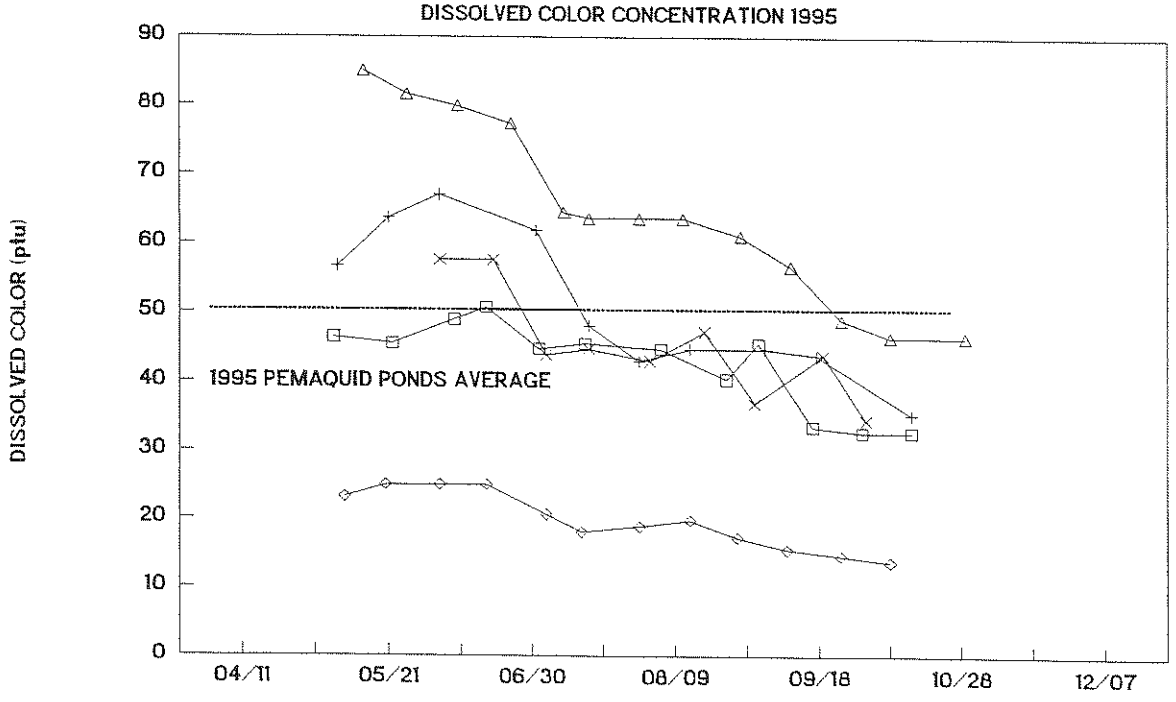
CHLOROPHYLL a CONCENTRATION 1995




□ BISCAY POND + BOYD POND ◇ MCCURDY POND △ PARADISE POND
× PEMAQUID POND

# PEMAQUID PONDS

DISSOLVED COLOR CONCENTRATION 1995




□ BISCAY POND + BOYD POND ◇ MCCURDY POND △ PARADISE POND
× PEMAQUID POND

# DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the New **Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1995 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

## Thermal Stratification in the Deep Water Sites

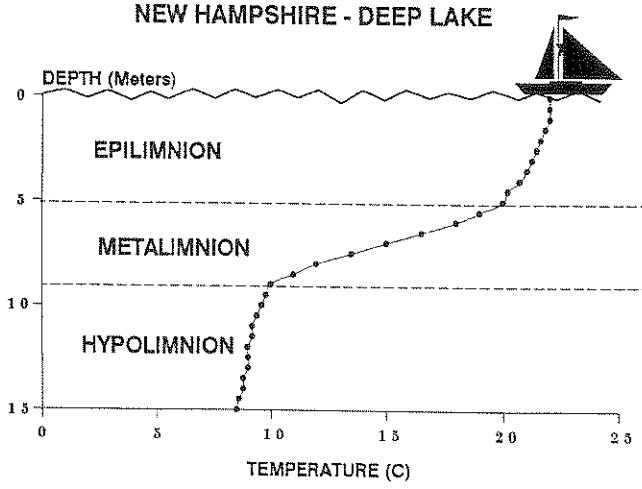
Lakes in New England display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (figure 61). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion. The deeper Pemaquid Ponds (Biscay, McCurdy and Pemaquid) became stratified into three distinct thermal layers, discussed above, while Duckpuddle and Boyd Ponds became only partially stratified, forming an epilimnetic and metalimnetic layer. No thermal stratification was documented in Paradise Pond as this pond is shallow and remained thermally stable due to wind induced mixing.

## Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Based on the wa-

Figure 61



ter quality criteria employed by the **Maine DEP**, transparency values greater than 7 meters are generally considered an indication of clear, unproductive lakes, while values of 4 meters or less are generally an indication of productive lakes. Water clarity values between 4 and 7 meters are considered typical of a moderately productive lake. In 1995 the average transparency for lakes participating in the **NH LLMP** was 5.6 meters with a range of 0.6 to 12.7 meters.

Secchi Disk readings collected at Biscay Pond, Boyd Pond, McCurdy Pond and Pemaquid Pond remained within the range common to a moderately productive lake. The water clarity of Duckpuddle Pond, on the other hand, was typical of a productive lake and was characterized by decreasing Secchi Disk transparencies from June 19 through July 18 which corresponded to the formation of an algal bloom during that period. Refer to table 8 for the 1995 Pemaquid Ponds summary Secchi Disk data (note: data from Paradise Pond are not characterized trophically due to the shallowness of the pond.

**Table 8. 1995 Lay Monitor Secchi Disk Data comparison of the Pemaquid Ponds.**

| Site | Transparency (m) Minimum | Transparency (m) Average | Transparency (m) Maximum | Trophic State |
|---|---|---|---|---|
| Biscay | 4.1 | 4.8 | 5.7 | Moderate |
| Boyd | 3.7 | 4.0 | 4.3 | Moderate |
| Duckpuddle | 0.6 | 1.7 | 3.5 | Poor |
| McCurdy | 5.3 | 6.6 | 7.8 | Moderate |
| Paradise | 2.5 | 3.2 | 3.6 | XXXXXX |
| Pemaquid | 3.8 | 4.5 | 5.5 | Moderate |

## Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. The following classification scheme is based on the standard employed by the **Maine DEP**. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg $m^3$ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations are generally less than 2 mg $m^3$. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 2 mg $m^3$ and 7 mg $m^3$ (note: reports written between 1988 and 1992 employed a classification scheme devised by Forsberg and Rydig (1980) while the 1993 through 1995 reports employ a classification scheme devised by the **Maine DEP**). In 1995, the average chlorophyll *a* concentration for lakes participating in the **NH LLMP** was 2.4 mg $m^3$ with a range of 0.2 to 24.9 mg $m^3$. Refer to table 9 for a summary of the 1995 Pemaquid Ponds chlorophyll *a* data.

**Table 9. 1995 Lay Monitor Chlorophyll *a* Data comparison of the Pemaquid Ponds.**

| Site | Chl *a* (ppb) Minimum | Chl *a* (ppb) Average | Chl *a* (ppb) Maximum | Trophic State |
|---|---|---|---|---|
| Biscay | 2.2 | 4.2 | 11.9 | Moderate |
| Boyd | 2.8 | 3.7 | 5.0 | Moderate |
| Duckpuddle | 2.3 | 10.0 | 24.9 | Poor |
| McCurdy | 1.4 | 2.1 | 3.5 | Moderate |
| Paradise | 1.9 | 4.1 | 6.4 | Moderate |
| Pemaquid | 1.9 | 3.2 | 5.4 | Moderate |

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

## Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lakebottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

## Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing activities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information is important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. In 1995 the average dissolved color for participating **NH LLMP** lakes was 21.9 ptu with a range of 0.9 to 94.5 ptu. Refer to

table 10 for the 1995 Pemaquid Ponds dissolved color summary statistics.

**Table 10. 1995 Lay Monitor Dissolved Color Data comparison of the Pemaquid Ponds.**

| Site | Color (ptu) Minimum | Color (ptu) Average | Color (ptu) Maximum | Sample Size |
|---|---|---|---|---|
| Biscay | 32.6 | 42.6 | 50.7 | 12 |
| Boyd | 35.2 | 50.9 | 67.0 | 10 |
| Duckpuddle | 54.1 | 78.3 | 94.5 | 9 |
| McCurdy | 13.7 | 19.7 | 24.9 | 12 |
| Paradise | 46.4 | 64.5 | 85.0 | 13 |
| Pemaquid | 34.4 | 45.4 | 57.6 | 9 |

## Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 15 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

The **Maine DEP** classifies lakes containing 6 ppb total phosphorus or less as unproductive while those containing total phosphorus concentrations of 13 ppb and greater fall into the classification of a productive lake. Lakes with total phosphorus concentrations between 6 ppb and 13 ppb are considered moderately productive. Table 11 characterizes the trophic state of the Pemaquid Ponds based on the 1995 in-lake total phosphorus data and the corresponding **Maine DEP** criteria.

**Table 11. 1995 Epilimnetic Total Phosphorus Results and the Corresponding Maine DEP Trophic Classification.**

| Lake | Date | Total Phos. (ppb) | Maine Water Quality Category |
|---|---|---|---|
| Biscay | 11/18 | 9.1 | Moderate |
| Boyd | 10/14 | 18.0 | High |
| Duckpuddle | 05/09 | 13.4 | High |
| Duckpuddle | 05/21 | 16.2 | High |
| Duckpuddle | 06/04 | 22.3 | High |
| Duckpuddle | 06/19 | 20.3 | High |
| Duckpuddle | 07/02 | 24.6 | High |
| Duckpuddle | 07/18 | 21.0 | High |
| Duckpuddle | 07/31 | 20.3 | High |
| Duckpuddle | 08/13 | 28.9 | High |
| Duckpuddle | 08/27 | 35.5 | High |
| Duckpuddle | 09/10 | 28.1 | High |
| Duckpuddle | 10/01 | 30.7 | High |
| McCurdy | 05/09 | 11.2 | Moderate |
| McCurdy | 10/08 | 13.7 | High |
| Paradise | 05/14 | 20.3 | High |
| Pemaquid | 06/04 | 16.2 | High |

## Streamflow

Streamflow is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is

important when determining the amount of nutrients and other contaminants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

## pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH of 5.5 or higher for successful growth and reproduction.

## Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1 ) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

The classification scheme employed by the **Maine DEP** considers alkalinity concentrations of less than 4 ppm as low (more susceptible to acidification) while lakes with alkalinities greater than 10 ppm are considered highly alkaline (more resistant to acidification).

## Specific Conductivity *

The specific conductance of a water sample indicates concentrations of

dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micromhos (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS).

## Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

## Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer al-

lows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

## Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

**Total coliform** includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamination. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high concentrations of coliform at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

## Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes.

As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Bluegreen bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

## Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake.

As discussed above for phytoplankton, zooplankton undergo seasonal population cycles and the results discussed below are most representative of the collection dates and not necessarily of other times during the ice-free season, especially during the early spring and late fall.

## Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the

water body. The caddisflies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

## Fish Condition

The assessment of fish species "health" is another biological indicator of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

## Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwa-

ters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

**Inspect** your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

**Flush** the cooling system, bilge areas and live wells with tap water.

**Leave** unused bait behind and discard bait bucket water away from surface waters.

**Keep** your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

**Wash** down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

**Learn** more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

**Share** information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

**Report** any sightings to the **New Hampshire Lakes Lay Monitoring Program.** Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

**Jeff Schloss**
**Lakes Lay Monitoring Program**
**109 Pettee Hall**
**University of New Hampshire**
**Durham NH 03824-3512**
**(603) 862-3848**

or

**Julia Dahlgran**
**Sea Grant/Cooperative Extension**
**Kingman Farm**
**University of New Hampshire**
**Durham NH 03824-3512**
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# Rainfall... People... and Lake Water Quality

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High quality lakes will always remain an invaluable attraction to people, thus an important element of New Hampshire's economy. Questions about changes in water quality and clarity are often asked. Now data which have been gathered by University of New Hampshire researchers, in cooperation with many volunteer monitors, are beginning to provide some answers to questions such as: *Have our lakes degraded in this century? Is water quality currently deteriorating? What is causing changes to occur?* Now we can begin to answer these questions.

## Dynamic Lakes

In order to understand the answers, one must have some awareness of Limnology - the study of the geologic, physical, chemical and biological dynamics of lakes. It is important to be alert to the changing nature of lakes, their sensitivity to disturbances, and their likelihood to degrade or improve in quality in response to poor or good protection strategies.

It is possible to identify many characteristics that determine the uniqueness of each lake and help to distinguish a blue jewel from a septic waste depot. Volunteer monitors from the **N.H. Lay Lake Monitoring Program (LLMP)** have amassed data from more than 100 New Hampshire lake sites over the past decade. The objective of this effort, established in 1978, was to develop information to scientifically document long-term trends in water quality.

It is now possible to understand the kinds of disturbances that modify the characteristics of a lake for better or worse. This cooperative effort between lakeshore property owners and UNH researchers has established how lake water quality changes over the decades. Based upon accumulated data it is possible to use a model to predict these events.

## The Overview

Although each New Hampshire lake is unique, and there is a diversity of lake types in the state, the **LLMP** data reveal a remarkably common pattern in the "behavior" of most lakes. Researches anticipated that multiple sites within any given lake would have the same characteristics. There is also strong evidence that large and small lakes follow a similar pattern of changes, within the ice-free period of a single year as well as

through nearly two decades of observations. This is quite a surprise! *How can unique lakes in unique watershed "behave" in such a similar manner?*

The "long-term" changes in water quality characteristics are not always monotonously negative, but appear to fluctuate corresponding to 11-year cycles of solar flares or sunspots. What is the role of human behavior? There is no cyclic pattern to human activity on lakes.

*Why, for example, did Squam Lake become greener from 1979 through 1984, then suddenly clarify in 1985? Why did the clarity of nearly all lakes in the* ***LLMP*** *program improve in 1985? Why did the chlorophyll (the major pigment in microscopic plants) decrease significantly in the same year? Furthermore, why was total phosphorous in the water very low in 1985? Why was there a relatively high Acid Neutralizing Capacity in that year? (ANC is the capacity of a lake to absorb or buffer higher levels of acidity in the water). Finally, why have all these water quality parameters changed together in the reverse direction from 1986 to 1993?*

A few lakes have "misbehaved" and followed opposite trends during the same period, but this can be attributed to their unique characteristics, and to site-specific circumstances.

## The Hunch

New Hampshire is a relatively small state. Despite other diversities, our lakes are all subjected to the climate we enjoy at 43° to 44° North latitude. The whimsical nature of New England weather, difficult to predict, variable from season to season and year to year, is well known. *Could it be that our lakes are responding to climatic variation and global warming? What was unique about 1985?*

A reasonable hunch was that changes in total rainfall could be the "pied piper" playing the tune to which the lakes have danced. A comparison of rainfall data from 30 National Oceanographic and Atmospheric Administration weather stations confirmed that the state is basically a single climate region. While rainfall is much higher in some areas than others, the pattern is similar no matter where one looks. A dry year is a dry year and a wet year is a wet year, statewide. The record rainfall between July 1984 and June 1985 occurred during a period of sub-normal rainfall relative to 30-year averages.

So! We have a clue.

## The Model

The majority of New Hampshire's lakes are what is known as "nutrient limited." This means that certain nutrients, especially phosphorus and nitrogen, when present in lake water stimulate high levels of growth in microscopic aquatic plants such as algae and phytoplankton. Humans, along with other creatures, process these nutrients quickly and deposit them in lakes or in water flowing down a watershed.

In addition, most watersheds in New Hampshire are small and have steep topography. The streams within these watersheds are typically short and fast-flowing, delivering rainwater to lakes very quickly. Thus, episodes of high rainfall deliver more nutrients by washing them into lakes from watersheds. Prolonged periods (up to one year) of high rainfall lead to more nutrient loading and higher total phosphorus levels, therefore greener and less transparent lakes. In addition, sulfur dioxide in rainwater--the ingredient that causes acid rain -- and solutes (dissolved acids) collected within the

watershed, lowers the ANC of our lakes, i.e., the capacity of lakes to buffer the effects of acidity is diminished.

At its present state of development, the **LLMP** model suggests that the total volume of rainfall is the cause of both seasonal and long-term annual changes in lake water quality throughout New Hampshire. Most lakes "improved" in dry years such as 1985 and "degrade" in wetter years such as 1984 and 1986. The model works to the extent that the loading of nutrients into nutrient-deprived lakes is dependent on rainfall, and this appears to be the case.

Further verification of the model comes from the few more productive lakes, i.e., those higher in naturally occurring levels of nutrients. The "richer" in nutrients a lake, the "greener" it tends to be. Such "rich" lakes tend to be "diluted" by the loading of stormwater running off the watershed. This again directly implicates rainwater as the "piedpiper" which causes such lakes to be somewhat less productive, therefore "improved," during wet years.

## Implications

At least two important predications can be developed when interpreting the **LLMP** model. First, changes in rainfall volume associated with global warming will influence lake water quality directly. If New Hampshire becomes drier, the lakes will tend to remain transparent and on that basis, will likely "improve" in water quality. Otherwise, a wetter future will likely deplete water quality to some extent.

Second, the model provides substantial evidence that our lakes are sensitive to changes in nutrient loading. Such loading can be controlled to a large extent by the choices people make with regard to activities within a watershed area. Such activities include land use and development patterns and practices within the watershed area, as well as along the shoreland areas of lakes and streams. Human activity on the water can also have some impact on nutrient loading of lakes (see Spring 1995 *Lakeside*).

Efforts to minimize nutrient loading can make a difference. Such practices as:

- routine pumping of septic systems
- erosion control
- maintaining buffer and wooded areas near lakes and within watershed
- control of storm water run-off from roof tops, impermeable driveways and parking lots

all help to minimize nutrient transport to lakes.

## Future Concerns

While we can predict lake water quality parameters based upon weather patterns in a given year or over a period of years, there are a number of issues that require more comprehensive and thoughtful policy development if New Hampshire's lakes are going to remain the blue gems that we take for granted.

here are some of the unresolved issues:

- The survival of each lake given the multiple uses which they receive now, and will receive in the next millennium.
- The study of lake capacity, or use beyond which a lake becomes undesirable.

- The possibility that lakes will lose their aesthetic and economic value if they visibly degrade over time.
- The establishment of a comprehensive statewide lake use plan to manage our lakes effectively.

# The Zebra Mussel Threat to New Hampshire

The Zebra Mussel, a non-native freshwater mollusk that has successfully invaded a host of lakes and rivers throughout northeastern and central North America, continues its expansion towards New Hampshire. In the past three years, primarily due to the efforts of state agencies like **New Hampshire Fish Game** and **New Hampshire Department of Environmental Services (DES)**, the New Hampshire Lakes Association as well as local lake associations, residents and visitors have started to become aware of this non-native aquatic nuisance. All of these groups have been assisted by the University of New Hampshire (UNH) SeaGrant and Water Resource Extension Programs of the Northern New England Mussel Watch.

These tenacious little shellfish have caused almost a billion dollars worth of trouble in the Great Lakes region of the US and Canada. More recently, they impacted water suppliers and a federal fish hatchery on Lake Champlain in neighboring Vermont to the tune of millions of dollars. Thus, there is great concern with this potential threat to New Hampshire's precious fresh waters. But given the fact that many lakes and streams have very soft waters (they contain low mineral content especially that of calcium which is important for reproduction and shell construction) how concerned should we be?

Table 12 breaks down the colonization potential of Zebra Mussels according to the water conditions they encounter. As can be seen, most of our fresh waters meet their temperature, algae, salinity and oxygen requirements. Limiting colonization for a majority of our lakes is pH and calcium content. It is ironic that the conditions that

## TABLE 12:

## ZEBRA MUSSEL COLONIZATION POTENTIAL

Based on environmental tolerances of known wild and lab populations in Europe and North America

(modified from C. O'Neill, NY SeaGrant Zebra Mussel Clearing House 6/95)

| Variable | High Potential | Moderate Potential | Low Potential | Very Low Potential | NH Summer Range * | NH Summer Average * |
|---|---|---|---|---|---|---|
| SALINITY (ppt) | 0 - 1 | 1 - 4 | 4 - 10 | 10 - 35 | none | less than 0 |
| CALCIUM (mg/L) | > 25 | 20 -25 | 9 - 20 | < 9 | <1 - 32 | 3.4 |
| pH (units) | 7.4 - 8.5 | 7.0 - 7.4<br>8.5 - 9.0 | 6.5 -7.0 | < 6.5<br>> 9.0 | 4.4 - 9.6 | 6.0 |
| WATER TEMP.°C) | 18 - 25 | 16 -18<br>25 -29 | 9 -15<br>28 - 30 | < 8<br>> 30 | 9.8 - 30 | varies by depth |
| DISSOLVED OXYGEN (ppm) | 8 - 10 | 6 - 8 | 4 - 6 | < 4 | 0 - 12 | generally > 6 in upper layer |
| CONDUCTIVITY (umhos at 25°C) | > 83 | 37 - 82 | 22 - 36 | < 21 | 13 - 350 | 55 |
| CHLOROPHYLL | Greater than | 2 ppb | CHL a | (algae level) | 0.1 - 144 | 7.2 |

* Summer upper water (epilimnetic) layer data from UNH Freshwater Biology Group and NH DES Limnology Center

data bases 1978 to 1993; total of 597 NH lakes sampled.

> = greater than; < = less than.

hurt us most in combating acid rain impacts may be our saving grace in preventing dense colonies of mussels. Of the two parameters, calcium is the more critical in that the pH of even the softest waters can increase to more tolerable levels due to the photosynthetic activity of submerged plants and algae (the removal of carbon dioxide from the water raises the pH in dense weed beds and in more productive lakes).

Care must be taken in concluding how safe we really are from infestation. These data are only from known zebra mussel habitats. In the lab, zebra mussels have successfully reproduced at salinities as high as 15 parts per thousand. Also, the lower limit of the calcium requirement continues to fall with time.

So which of our waters are most susceptible to Zebra Mussel colonization? Table 13 lists those waters with calcium concentrations of 9 parts per million or greater. There are two lakes that have water conditions highly conducive to colonization, three lakes with moderate potential and at least 16 lakes with low potential (an additional 8 lakes have calcium levels just under 9 parts per million). Most are located somewhere near the Connecticut River that has limestone deposits that can contribute calcium to nearby waters. The others are in the lower Merrimack River valley. There are also some close to the sea coast. UNH Sea Grant has initiated monitoring for adult mussels on the majority of these lakes through existing **NH LLMP (UNH), VLAP (DES)** and Cooperative Extension/SeaGrant monitoring programs.

**Table 13. Lakes Most Susceptible to Zebra Mussel Colonization.**

| Lake | | Town |
|---|---|---|
| Horseshoe | (low risk) | Merrimack |
| Harris Pond | | Pelham |
| Kimball Pond | | Canterbury |
| Post Pond | | Lyme |
| Sebbins Pond | (med. risk) | Bedford |
| Wilder Lake | | Lebanon |
| Cobbetts Pond | | Windham |
| Crystal Lake | | Manchester |
| Ogontz Lake | | Lyman |
| Moses Pond | | Plainfield |
| Dorrs Pond | | Manchester |
| World End Pond | | Salem |
| Otternick Pond | | Hudson |
| Fish Pond | | Columbia |
| Flints Pond | | Hollis |
| Taylor River | | Hampton |
| Kendall Pond | | Londonderry |
| Stevens Pond | | Manchester |
| Lime Pond | (high risk) | Columbia |
| Mill Pond | | Portsmouth |

While our current understanding of the mussels may allow for a brief sigh of relief on the part of our low calcium lakes, boaters and anglers should still continue to take the proper precautions on <u>all</u> waters. We are still continuing to amass all of the available information and research on these persistent little shellfish. The most frightening information indicates that these critters are becoming more at home in a wider range of water conditions; the water conditions within the mussels American range are much wider than those found in the mussels native habitat in Central Europe. Zebra Mussels have only been in our country since sometime around 1988 while they have been known to occur in large freshwater lakes such as the Black, Caspian and Aral seas for hundreds if not thousands of years. This means that the invading mussels have been adapting quickly. Remember also that our native shellfish have adapted very well to our soft waters.

That is the reason zebra mussel warning signs have been posted with information posters and pamphlets at public areas and boat-launch sites. These materials are in place at lakes with higher calcium levels as well as high boat traffic areas. In addition, these precautions will minimize the risk of introducing non-native weeds like mil-

foil and other new plant and animal invaders that could eventually find a way into New Hampshire.

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# APPENDIX A

## GLOSSARY OF LIMNOLOGICAL TERMS

**Aerobe**- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

**Algae**- See phytoplankton.

**Alkalinity**- Total concentration of bicarbonate and hydroxide ions (in most lakes).

**Anaerobe**- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

**Anoxic**- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

**Benthic**- Referring to the bottom sediments.

**Bacterioplankton**- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

**Bicarbonate**- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

**Buffering**- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

**Chloride**- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

**Chlorophyll a**- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

**Circulation**- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

**Density**- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

**Dimictic**- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

**Dystrophy**- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

**Epilimnion**- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

**Eutrophy**- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

**Free CO2**- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

**Holomixis**- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

**Humic Acids**- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

**Hydrogen Ion**- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

**Hypolimnion**- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

**Lake**- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs. marshes, etc.

**Lake Morphology**- The shape and size of a lake and its basin.

**Littoral**- The area of a lake shallow enough for submerged aquatic plants to grow.

**Meromixis**- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by pecu-

liar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

Mesotrophy- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

Metalimnion- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

Mixis- Periods of lakewater mixing or circulation.

Mixotrophy- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

Oligotrophy- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

Overturn- See circulation or mixis

pH- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of $10^{-5}$ molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

Photosynthesis- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

Phytoplankton- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

Parts per million- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

Parts per billion-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of

algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

**Plankton**- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

**Saturated**- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

**Specific Conductivity**- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

**Stratum**- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

**Thermal Stratification**- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

**Thermocline**- Region of temperature change. (See metalimnion.)

**Total Phosphorus**- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

**Trophic Status**- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

**Z**- A symbol used by limnologists as an abbreviation for depth.

**Zooplankton**- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia, Cyclops, Bosmina*, and *Kellicottia*.