



Lake Monitoring Report

1998-2001

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ANP Freshwater Monitoring Locations

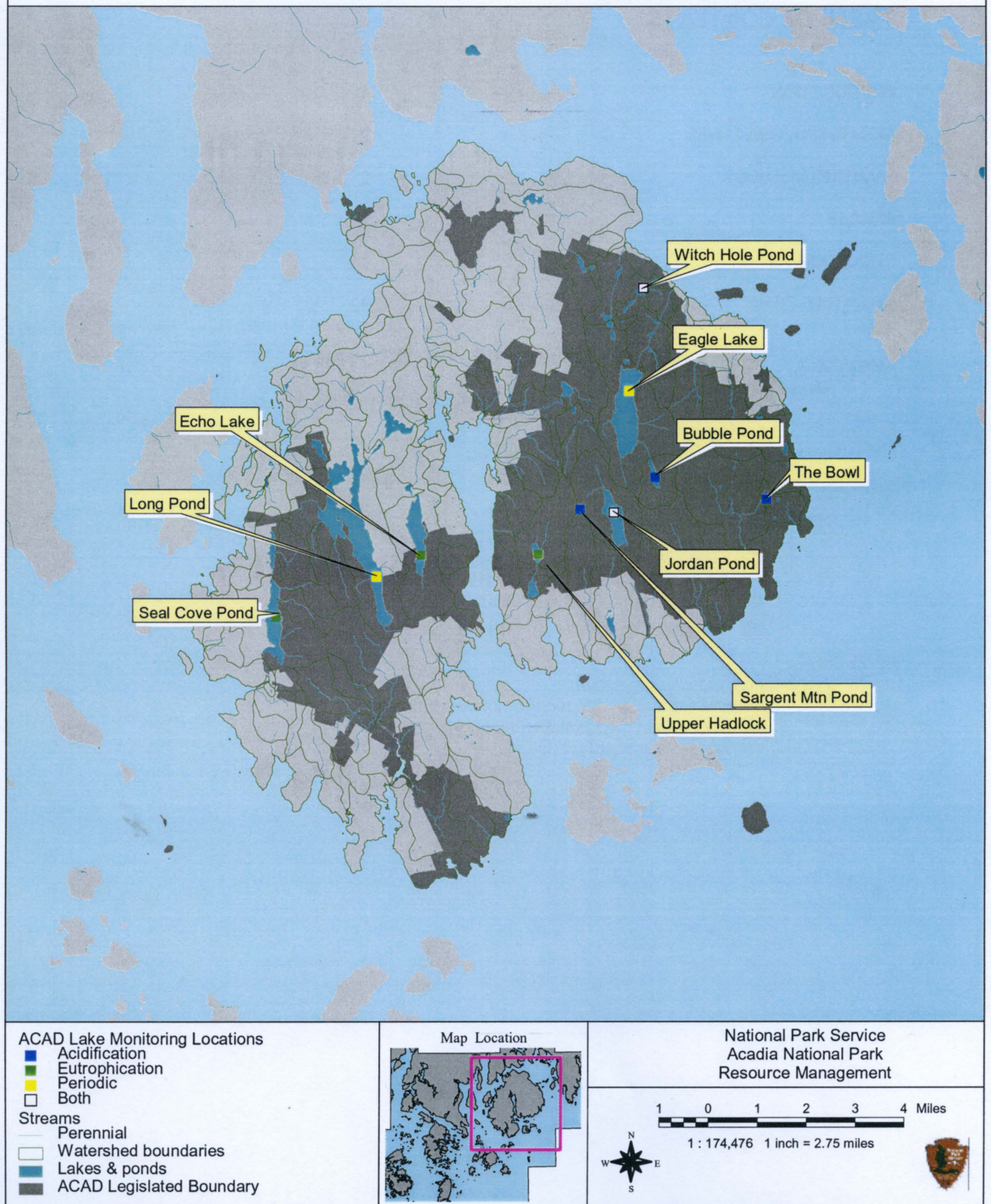


Figure 1.

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INTRODUCTION

Aquatic resources within or adjacent to the Acadia National Park (ANP) boundary include 24 named lakes and ponds, more than 25 streams, and numerous wetlands (Figure 1). This report provides a summary of lake monitoring activities conducted by the park during the years 1998-2001. Previous summaries (Gawley and Breen, 1996 and 1998) documented the early years of enhanced water quality monitoring of ANP lakes by park staff, and other historical water monitoring efforts on Mount Desert Island.

The current lake monitoring program has largely evolved from the recommendations of a 1997 workshop to develop long-term monitoring protocols for ANP aquatic resources, and guidance outlined in the Acadia National Park Water Resources Management Plan (WRMP) (National Park Service, 2000). The core program calls for annually sampling 10 lakes ranging in size from 1 acre to 897 acres, with maximum depths from less than 3 meters to more than 45 meters. Monitoring protocols were selected to assess the degree to which external stressors might be contributing to changes in aquatic ecosystem structure and function. Issues of concern include atmospheric deposition of acidic compounds, toxic contaminants, nutrient enrichment, and climate change. All water monitoring data are incorporated into a comprehensive ANP database that includes recent as well as historical water quality data for park waters. The program is a cooperative effort involving park staff, the US Geological Survey (USGS), University of Maine, Maine Department of Environmental Protection (MDEP), volunteers and others.

A related water resource program, conducted by park staff in cooperation with the Maine DEP, is the monitoring of benthic stream macroinvertebrates. Monitoring for biological parameters was identified in the WRMP as an important component of a comprehensive freshwater monitoring program and the current program was initiated in 1997. Stream macroinvertebrate monitoring results are reported in a separate report (Breen, et al, 2001).

Routine stream water sampling is not currently a part of the core long-term freshwater monitoring program conducted by park staff at ANP. However, the National Park Service has collaborated with investigators from the University of Maine and USGS to initiate a long-term monitoring and research effort utilizing paired calibrated watersheds and their associated streams at ANP. This comprehensive research effort funded by the USEPA/NPS PRIMENet program focuses on nitrogen and mercury deposition and cycling, and will be described in a separate report. In addition, the USGS also conducted monthly sampling of a number of selected ANP streams from 1999 to 2001 as part of a study funded by the NPS/USGS Water Quality Partnership Program. Measurements from the USGS stream study included stream discharge (flow) and major chemical parameters. A detailed account of the USGS stream study will also be presented in a separate report.

In addition to the freshwater monitoring activities performed by park staff, there are a number of other water related research studies currently being conducted in the park that will help to better define water quality, and watershed processes and function at ANP.

MONITORING OBJECTIVES

The process of establishing objectives and protocols for a long-term freshwater resource monitoring program was initiated at a workshop held in January of 1997 at ANP. Participants with multidisciplinary backgrounds, representing a variety of state, federal agencies and academia, identified key issues and proposed potential monitoring strategies. An Interim Report (Kahl and Manski, 1997) described workshop accomplishments, suggested monitoring priorities, and research and inventory needs. Current monitoring protocols were adopted based on recommendations from the Interim Report and guidelines identified in the WRMP. A Freshwater Monitoring Plan will be developed based on the workshop results and the evaluation of field testing of the draft protocols.

The primary objective of the ANP freshwater monitoring program is to better understand the natural processes and human-induced factors that affect aquatic ecosystem structure and function. In order to measure human-induced changes it is necessary to determine the normal variability inherent in natural aquatic systems, and to establish baseline conditions from which future changes can be detected.

Specific objectives of the freshwater monitoring program are:

- 1) To characterize existing water quality conditions and establish a baseline for future comparisons
- 2) To serve as an early warning system for anthropogenic impacts and threats such as non-point source pollution (cultural eutrophication), atmospheric deposition of acids, nitrogen and other nutrients, toxic contaminants, and climate change
- 3) To assist in identifying potential sources of pollution
- 4) To provide water quality data and information needed to manage and protect other ANP resources
- 5) To track trends

SAMPLING METHODS

The current lake monitoring activities at ANP were designed to provide a foundation upon which additional water related monitoring and research could be supported. Because of funding and staff limitations, annual comprehensive monitoring of all ANP lakes, streams and other surface waters is not realistic. However, since lakes largely reflect the hydrogeochemical processes that occur within their respective watersheds, the current program focuses on monitoring a subset of park lakes that provide a range of geophysical and ecological conditions. This allows for a preliminary assessment of how these representative systems respond to changes and impacts associated with atmospheric deposition and nutrient enrichment (cultural eutrophication).

Sampling locations:

The core monitoring design identifies three representative types of lakes to be sampled (Table 1). The first is a set of five lakes (*Jordan Pond, Bubble Pond, Sargent Mountain Pond, The Bowl, and Witch Hole Pond*) that are sampled to evaluate long-term acidification status. These

lakes were selected to be representative of:

- the main large/deep water lakes on Mount Desert Island that are most associated with ANP (*Jordan* and *Bubble Ponds*)
- smaller headwater and/or high elevation lakes most likely to show chronic acidification trends (*Sargent*, *The Bowl*)
- an organically affected (adjacent wetland) lake (*Witch Hole*)

The second set of five lakes (*Witch Hole Pond*, *Upper Hadlock*, *Seal Cove*, *Echo Lake*, and *Jordan Pond*) were chosen to be representative of the broad range of ANP lakes vulnerable to cultural eutrophication, primarily from surrounding development. This group was also selected to span a variety of physical and environmental characteristics (e.g. size/depth, morphology, trophic state, watershed/ ecosystem type, degree of watershed development, burn status in a major fire in 1947, amount/type of recreational and other human use). *Jordan Pond* was included on both the acidification and eutrophication lists because it is considered the "jewel" of Acadia waters and perhaps the entire state. Its outstanding water quality should be the standard against which other lakes are compared.

The third category of lake sampled are those with existing long-term monitoring histories (Secchi transparency, some chemical/physical parameters) that are not included in the first two lake sets. These lakes, *Eagle Lake*, *Long Pond (MDI)* and *Bubble Pond* (also included in the set of acidification lakes) are sampled a minimum of once monthly May through October for temperature and Secchi transparency, (and dissolved oxygen/temperature profile if possible). If funding is available, a set of nutrient chemistry variables is sampled each year in August.

Lake	Area (acres)	Max. Depth (m)	Wshed (acres) ¹	Flushing rate/yr. ²	Trophic state	ANP Bndry	Fishery type	Water supply	Monitoring Regime
<i>The Bowl</i>	6	8.8	59	---	Mesotrophic	within	---	No	Acidification
<i>Bubble Pond</i>	32	11.9	463	1.88	Oligotrophic	within	Cold	Yes	Acid / LT Eutr.
<i>Eagle Lake</i>	437	33.6	1850	0.26	Oligotrophic	within	Cold	Yes	LT Eutrophica.
<i>Echo Lake</i>	237	20.1	1782	0.61	Oligotrophic	borders	Cold	No	Eutrophication
<i>Jordan Pond</i>	187	45.7	1217	0.17	Oligotrophic	within	Cold	Yes	Acid / Eutroph.
<i>Long Pond (MDI)</i>	897	34.5	3410	0.32	Oligotrophic	borders	c/w	Yes	LT Eutrophica.
<i>Sargent Mtn</i>	1	3.0	8	---	Mesotrophic	within	---	No	Acidification
<i>Seal Cove Pond</i>	283	13.4	1778	1.92	Mesotrophic	borders	Warm	No	Eutrophication
<i>Upper Hadlock</i>	35	10.7	878	4.12	Mesotrophic	within	Cold	Yes	Eutrophication
<i>Witch Hole</i>	28	9.5	260	---	Mesotrophic	within	Cold	No	Acid / Eutroph.

¹ Watershed area calculated from watershed boundaries established in Perrin, 1996.

² Flushing rate data provided by Maine Department of Environmental Protection

Table 1: Lakes monitored by ANP in 1998-2001

Sample collection and analysis:

The analytes selected for the acidification and eutrophication sampling regimes (Table 2), and the annual monitoring schedule (Table 3) closely follow the recommendations of the 1997 workshop. Two additional measurements were added to the eutrophication sampling regime in 1999: water column light penetration profiles using a LI-COR radiation sensor, and weekly lake surface level (stage) monitoring. Light penetration profiles have not been collected on a regular basis because the optimum sampling frequency has yet to be determined. Although Tables 2 and 3 describe the ideal range and schedule of sampling, weather conditions, equipment malfunctions, and other factors can prevent collection of data for some parameters during certain sampling sessions.

The lake sampling regime entailed collecting half-meter deep grab samples from the "deep hole" (or center, in the case of lakes with uniform depth) of the lake for acidification chemistry, based on the assumption that early spring and late fall water columns are relatively homogeneous. For eutrophication chemistry, a composite core sample (maximum 10- meter depth, from deep hole) was collected from the epilimnion (if the lake was stratified) with a weighted Tygon® tube. Consideration was given to collecting a near bottom grab sample for phosphorus analysis during peak stratification, but recommendations from several experts suggested that this would not be necessary unless lower hypolimnion dissolved oxygen fell below 2 ppm.

	<u>Eutrophication</u>	<u>Acidification</u>
Field temperature	X	X
Secchi transparency	X	X
pH, closed cell	X	X
pH, equilibrated		X
ANC		X
Specific conductance	X	X
True color	X	X
DOC	X	X
DIC		X
Ca, Mg, K, Na		X
NH ₄ , Si		X
SO ₄ , Cl, NO ₃		X
Al (total dissolved)		X
Total P	X	
Total N	X	X
Chlorophyll a	X	
Lake Stage	X	X
DO/Temp. Profile	X	

Table 2: Analytes for eutrophication and acidification sampling

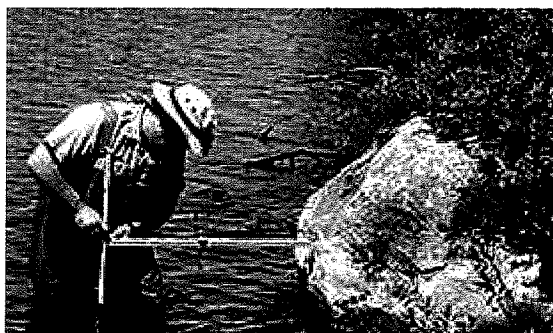
		early May	June	July	August	September	October
Jordan Pond	DO	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	eutroph. analytes		XXXXXX		XXXXXX		
	acidif. analytes	XXXXXX					XXXXXX
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Bubble Pond	DO				XXXXXX		
	Temp/Secchi	XXXXXX			XXXXXX		XXXXXX
	light profile				XXXXXX		
	eutroph. analytes						
	acidif. analytes	XXXXXX					XXXXXX
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Sargent Mt. Pond	DO						
	Temp/Secchi	XXXXXX					XXXXXX
	eutroph. analytes						
	acidif. analytes	XXXXXX					XXXXXX
The Bowl	DO						
	Temp/Secchi	XXXXXX					XXXXXX
	eutroph. analytes						
	acidif. analytes	XXXXXX					XXXXXX
Witch Hole Pond	DO	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	eutroph. analytes		XXXXXX		XXXXXX		
	acidif. analytes	XXXXXX					XXXXXX
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Upper Hadlock	DO	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	eutroph. analytes		XXXXXX		XXXXXX		
	acidif. analytes						
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Seal Cove Pond	DO	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	eutroph. analytes		XXXXXX		XXXXXX		
	acidif. analytes						
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Echo Lake	DO	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	eutroph. analytes		XXXXXX		XXXXXX		
	acidif. analytes						
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Long Pond	DO				XXXXXX		
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile				XXXXXX		
	eutroph. analytes						
	acidif. analytes						
Eagle Lake	DO				XXXXXX		
	Temp/Secchi	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
	light profile				XXXXXX		
	eutroph. analytes						
	acidif. analytes						
	lake stage	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

Table 3. Annual lake monitoring schedule

<u>Parameter</u>	<u>Method</u>	<u>Sensitivity</u>
Transparency	Secchi disk (w/viewing scope)	0.01m
DO/Temperature	YSI 54ARC meter (1998) YSI 52 meter (1999-2001)	0.1ppm/0.1°C 0.1ppm/0.1°C
Epilimnion core sample	10m x 1/2" ID Tygon® tube	1m graduation intervals
Light Penetration	LI-COR LI-193SA spherical sensor LI-COR LI-190SA surface sensor LI-COR 1400 datalogger	3µA per 1000µmol s ⁻¹ m ² 8µA per 1000µmol s ⁻¹ m ² n/a
pH	Orion 221 meter (1998-2000) VWR Model 8000 meter (2000-2001)	0.01 units 0.01 units
Specific conductance	Sybron/Barnstead PM-70CB meter (1998-2000) VWR "Traceable" meter (2000-2001)	0.1 µS/cm 0.01 µS/cm
ANC	Hach digital titrator for Gran titration	0.1 µeq/L
Apparent color	Klett-Summerson colorimeter, 400-450nm bandwidth (1998)	1 PCU
	Spectronic 20D+ spectrophotometer, 340nm wavelength (1999-2001)	1 PCU

Table 4: Acadia National Park sampling and analytical methods

Specific methods used by Acadia National Park resource management staff for field and lab measurements are listed in Table 4, and are described in detail along with sample collection techniques and QA/QC procedures in Acadia National Park Lake Monitoring Field and Laboratory Methods (Gawley, 1996). In addition to water sample collection, Secchi disk transparency, weather conditions, dissolved oxygen/temperature profiles, light penetration profiles, and lake stage were measured in the field.



Lake stage monitoring

Lake stage was measured from a randomly located drilled hole (marked with orange paint) in a large rock in each pond using a wooden stick with level bubble and a folding ruler. Stage monitoring locations were documented using digital photographs and Global Positioning System (GPS) coordinates. If water levels became too low (by receding beyond the lake bottom below the drilled hole) to measure, photographs were used to document stage conditions.

<u>Analyte</u>	<u>Method</u>	<u>Reference</u>
pH, closed cell	Electrode	Hillman <i>et al.</i> ⁶ , EPA 19.0 ⁵
pH, aerated	Electrode	Hillman <i>et al.</i> ⁶ , EPA 5.0 ⁵
Specific conductance	Wheatstone bridge	EPA 120.1 ² , EPA 23.0 ⁵
True color	Spectrophotometer, 457.5 nm	EPA 110.2 ²
ANC	Gran Titration	Hillman <i>et al.</i> ⁶ , EPA 5.0 ⁵
Anions: Cl, NO ₃ , SO ₄	Ion chromatography	EPA 300.0 ¹
Calcium	AAS with N ₂ O-acetylene flame	EPA 215.1 ²
Magnesium	AAS with N ₂ O-acetylene flame	EPA 242.1 ²
Sodium	AAS with air-acetylene flame	EPA 258.1 ²
Potassium	AAS with air-acetylene flame	EPA 273.1 ²
Aluminum, total	AAS with graphite furnace	EPA 200.9 ⁴
Dissolved Organic Carbon	IR C analyzer, persulfate oxidation	EPA 415.1 ²
Ammonium	Autoanalyzer	EPA 9.0 ⁵ and Bran & Luebbe 780-86T ⁷
Silica	Autoanalyzer	EPA 22.0 ⁵ and Bran & Luebbe 785-86T ⁷

AAS=atomic absorption spectrophotometry IR=Infrared Spectrophotometry

Method references:

¹ Methods for the Determination of Inorganic Substances in Environmental Samples, EPA 600/R-93-100, 1993.

² Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, 1979, Revised 1983.

³ Standard Methods for Examination of Water and Wastewater, 18th ed. 1992.

⁴ Methods for the Determination of Metals in Environmental Samples, EPA 600/4-91/010, 1991, Supplement 1, EPA 600/R-94/111, 1994.

⁵ Handbook of Methods for Acid Deposition Studies: Laboratory Analysis For Surface Water Chemistry, EPA 600/4-87-026, 1987.

⁶ Hillman, D.C., J. Potter, and S. Simon, 1986. Analytical methods for the National Surface Water Survey, Eastern Lake Survey. EPA/600/4-86/009, EPA Las Vegas.

⁷ Bran & Luebbe Manual

Table 5: Analytical Methods for the University of Maine Laboratory.

The Geochemistry and Environmental Engineering Research Laboratory at the University of Maine conducted laboratory analysis for most acidification and eutrophication parameters. The laboratory has been the national water quality laboratory for EPA EMAP (Surface Waters) since 1991. Analytical methods followed by the University of Maine lab are summarized in Table 5. Closed cell pH, specific conductance, acid neutralizing capacity (ANC), and color were also routinely analyzed at the ANP laboratory as part of the eutrophication sampling regime, and for some samples from the "long-term monitoring history" lakes. Laboratory methods at ANP for these four parameters closely followed those used at the University of Maine Lab.

The 1997 workshop recommended conducting an interlab comparison between the park lab and the University of Maine lab for closed cell pH, equilibrated pH, ANC, specific conductance, and color. The current eutrophication monitoring schedule only provides for laboratory analysis by the University of Maine lab in June and August. Ideally, we would prefer to obtain monthly data on these basic chemistry variables from June through September. The interlab comparison provided an opportunity for park staff to evaluate the in-house capability to perform these standardized analyses. A preliminary evaluation by park and University of Maine lab personnel suggested the ANP lab was able to adequately conduct closed cell pH, ANC, specific conductance, and color analyses. The final Freshwater Monitoring Plan will provide a formal review of the interlab comparison results.

The lake monitoring data collected during each sampling season are entered into a Microsoft Access database, which resides on the Air/Water program computers. A read-only copy of this file is found on the Resource Management drive of the park server. Data are proofed and verified by park staff, and are submitted annually to the Maine DEP Water Bureau (where they are merged with data from the rest of the state), and periodically to the NPS Water Resources Division.

RESULTS

The results of laboratory and field analysis for the 1998-2001 lake sampling period are presented in Appendix A. Graphs of multi-year data can be found in Appendix B. This report is not designed to provide a comprehensive statistical analysis of the ANP lake data. Simple descriptive statistics have been generated to provide a general overview of current and historic conditions. A more thorough statistical analysis of the lake data will be provided in the Freshwater Monitoring Plan final report.

Although park lakes are poorly buffered (some acid neutralizing capacities are among the lowest in Maine), most are circumneutral in pH, with trophic levels ranging from oligotrophic to eutrophic (most are mesotrophic). In general, the data indicate that concentrations for most water quality parameters were within their historical range and continued to meet park water quality objectives.

In the eutrophication lakes, annual and seasonal (June/August) variation for total phosphorus, total nitrogen and chlorophyll a also remained relatively stable with concentrations generally

within the historical range of variability for these lakes. Total phosphorus concentrations in Witch Hole Pond for 1998-2001 were the highest of the five lakes, with a mean concentration for this time period of 10.8 $\mu\text{g/L}$. Mean total phosphorus concentrations (1998-2001) in the other eutrophication lakes ranged from 2.44 $\mu\text{g/L}$ in Jordan Pond to 5.73 $\mu\text{g/L}$ in Upper Hadlock Pond. Upper Hadlock had an unexplainably high TP concentration of 12 $\mu\text{g/L}$ in June 2001, but dropped to 3.9 $\mu\text{g/L}$ in August. The high June value may represent sample contamination, laboratory error, or perhaps contamination from road runoff from state route 198 which runs adjacent to the west shore of the pond. During this same time period, total nitrogen ranged from a mean low of 0.136 mg/L in Jordan Pond to 0.451 mg/L in Witch Hole Pond. Mean chlorophyll *a* concentrations ranged from a low of <1.0 $\mu\text{g/L}$ in Jordan Pond to 4.43 $\mu\text{g/L}$ in Witch Hole Pond.

Results for the five acidification lakes indicate pH and acid neutralizing capacity (ANC) remained relatively stable both seasonally (spring/fall) and annually within each lake. From 1998-2001 Sargent Mountain Pond was the most acidic lake with a mean closed cell (field) pH of 4.92, and mean ANC of -12.61 $\mu\text{eq/L}$. Jordan and Bubble Ponds were the most circumneutral lakes with mean pH values of 6.9, and mean ANC of 55.7 $\mu\text{eq/L}$ and 53 $\mu\text{eq/L}$ respectively. Spring pH and ANC tended to be somewhat lower than fall values in the Bowl, Jordan, Bubble, and Witch Hole Ponds, while the reverse was true for Sargent Mountain Pond.

Temperature and dissolved oxygen (DO) profiles were obtained monthly for most lakes between May and October. Mean epilimnion and hypolimnion temperatures and DO concentrations for the eutrophication lakes are listed in the data tables in Appendix A. In the interest of brevity, the complete listing of the raw data have been omitted from the appendices. Graphs of 2001 temperature and dissolved oxygen profiles have been included in Appendix B to illustrate the extent of annual variation that we are accustomed to seeing in the core lake set. Profiles for 1998 through 2000 are similar to those in 2001, with Upper Hadlock and Seal Cove Ponds (and to a lesser degree, Echo Lake) becoming hypoxic at lower depths in late August. This hypoxia consistently occurs earlier and is more pronounced in Witch Hole Pond. Interestingly, the June through August 2001 Witch Hole profiles exhibited a DO "spike" in the metalimnion that had not been observed in previous years. Eagle Lake and Bubble, Jordan and Long Ponds are consistently well oxygenated throughout the water column. With the exception of Bubble Pond, all lakes were temperature stratified from May through October.

One of the water quality measurements with the longest data history available for the core lakes at ANP is Secchi disk transparency. Except for Sargent Mountain Pond, which is too shallow to measure with this method, graphs of mean annual transparency and trophic state index (derived from the transparency data) values for the other nine core ponds can be seen in Appendix B. Mean annual transparency has remained remarkably stable in the core ponds despite a number of different monitoring observers over the years. Some ponds appear to have experienced a slight increase in transparency since the mid-1990's, however this corresponds to a change in monitoring equipment. In 1995, the Secchi viewing scope was modified by adding two side flaps that shade the observer's eyes from peripheral light. These

flaps help to reduce the glare seen by the observer looking through the scope and tend to increase the transparency reading.

Precipitation is one factor that has had relatively large seasonal fluctuations over the years. Mean summer (June-August) precipitation volume was 27.2, 12.04, and 17.48 centimeters in 1998-2000 respectively. The 12.04 cm in 1999 was the lowest level since at least 1982. Annual mean summer precipitation measured at the McFarland Hill National Atmospheric Deposition Program (NADP) site at park headquarters for the period 1982-2000 (NADP, 2001) was 24.67 cm. Late spring precipitation (April, May) in 1999 was also very low at 8.79 cm, but September precipitation was 21.2 cm. 2001 has gone on record as being the driest year in the state of Maine since 1898. Although the summer precipitation total of 14.71 cm is the third lowest since 1982, the fall total was only 15.09 cm, considerably lower than any previous years. Total annual precipitation for 2001 was only 64.8 cm, which constitutes about 50% of the usual mean. A summary and graph of seasonal precipitation from 1982 through 2001 can be found in Appendix C.

Stage height monitoring of 7 lakes (May through November) began in 1999. All the lakes reacted closely to changes in precipitation (shown in graphs in Appendix C), although Upper Hadlock Pond appeared to exhibit the "flashiest" response. Upper Hadlock also had the greatest range of water level change in both 1999 (3.1 feet) and 2001 (3.15 feet). The mean range of water level change for all the lakes was lowest in 2000 (1.28 feet), and mean ranges for 1999 and 2001 were 1.51 feet and 1.75 feet, respectively. Three of the lakes (Eagle, Jordan, and Upper Hadlock) monitored are public water supplies, and further investigation is needed to determine the degree to which drinking water withdrawals contribute to changes in lake stage. Water levels in Eagle Lake, Upper Hadlock Pond, and Witch Hole Pond occasionally were not measurable, since they had receded too far from the location of the datum mark. When this occurred, the lakes continued to be checked weekly until water levels rose to the point of being measurable again.

Appendix B contains graphs of light penetration profiles for many of the core lakes for 2001. Since beginning this monitoring in 1999, we have noted very little seasonal variation within each of the lakes, with the exception of Upper Hadlock and Witch Hole Ponds in 2001. The individual lake profiles are also very consistent from year to year, which suggests that these profiles may be an effective, quantifiable monitoring tool. In 2001 we began recording the light level and percent transmission at each site's Secchi depth, and with continued monitoring hope to investigate the possibility of establishing a strong correlation between these values.

One noteworthy observation is that emergent vegetation at the Tarn and Aunt Betty ponds has greatly increased in recent years. Both of these ponds are naturally very shallow with summer water levels between 1 and 2 meters. Drought conditions in recent summers have lowered water levels in these ponds allowing for enhanced growth of emergent vegetation. These ponds appear to be slowly succeeding to freshwater wetlands as organic sediments accumulate on the pond bottom.

DISCUSSION

Attempting to determine long-term trends for specific water quality parameters is complicated by a variety of factors. Analytical methods for some analytes have changed in recent years from those used in earlier monitoring, making direct comparisons between different sets of data problematic. The University of Maine laboratory has performed most of the analysis on Acadia's samples since the mid-1990's. In many instances, data from this period can be compared to data from samples collected and analyzed by University of Maine in the early 1980's, such as a comprehensive re-sampling of lake chemistry in 1995 that used essentially the same sites and methodology as a 1985 study (Kahl, 1996). However, samples collected before 1980 were often analyzed using less comparable methods, or the methods are unknown.

Another factor making the analysis of trends difficult is the natural variation in annual and seasonal environmental/climatic conditions, especially in recent years. There has been great variation in seasonal and annual precipitation and temperature conditions in the past decade, as well as changes in atmospheric deposition patterns due to emission reductions as a result of amendments to the Clean Air Act in 1990. Differences in various data sets can be observed but these relatively short-term differences may not represent long-term trends.

The draft lake monitoring program is designed to provide critical baseline data on the chemical status of ANP lakes and the temporal variability of individual constituents inherent within each water body. Because the monitored lakes reflect the broad range of lake types within ANP, these data also provide an indication of the relative status of unmonitored park lakes. Although there has not yet been a formal evaluation of the draft lake monitoring protocols, park staff and others who have informally reviewed the draft protocols believe they represent a reasonable and cost effective basis for a 'core' long-term freshwater monitoring program. The 2001 monitoring season was the fifth year of using the draft protocols. A more comprehensive data analysis and evaluation of the draft protocols is expected in the final Freshwater Monitoring Plan report.

One type of lake that has not been represented in the post-workshop core monitoring scenario is the shallow, non-stratified, highly productive pond. Initially, it was difficult to obtain a cost-effective, long-term trophic state indicator for these water bodies, since they were too shallow for Secchi disk transparency. Since the acquisition of the LI-COR light meter, we now have a more quantitative means of obtaining similar information, particularly if a strong correlation between Secchi transparency and light penetration can be established. It is strongly suggested that this matter be addressed in the review of the draft monitoring protocols.

Although it is tempting to suggest expanding the program to encompass a greater number of lake types, careful consideration must be given to ensuring that all monitoring requirements are accomplished in a complete and timely manner. During the time period covered by this report, there are more than a few data gaps where samples were lost or not obtained due to weather conditions, equipment problems, scheduling constraints, or other factors. The final

Freshwater Monitoring Plan should identify the optimal sampling frequency, number of lakes and sample variables needed to meet program objectives that is consistent with park staff and funding capability.

In addition to the current lake and invertebrate monitoring programs a number of other research investigations are underway to more fully characterize freshwater and estuarine systems at ANP. USGS researchers are investigating water budgets and nutrient enhancement in major estuaries, identifying and characterizing key ecological indicators and developing long-term monitoring protocols for freshwater wetlands, and characterizing groundwater recharge and contamination potential. The University of Maine and the USGS are collaborating in a comprehensive paired watershed study to assess chemical cycling and the potential ecological impacts of atmospheric deposition on forested ecosystems. These additional water related research efforts point to the need for a more comprehensive evaluation of the ANP long-term water monitoring program in the next few years. The Vital Sign program currently being developed within the National Park Service to identify key indicators of ecosystem health and a long-term monitoring program for parks may provide an opportunity for that assessment. In addition, a comprehensive statistical analysis of the first 5 years of lake monitoring data, including an assessment of earlier lake monitoring data sets, is needed to determine if the current monitoring strategy will provide the data necessary to determine long-term trends in key water monitoring parameters. The park will seek a comprehensive evaluation of the current monitoring program in 2003.

LITERATURE CITED

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APPENDIX A

Acadia National Park Lake Monitoring Program

Acidification Analytes: 1998-2001

1998

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	EQpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	DOC (mg/L)	DIC (mg/L)	TN (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (ueq/L)	NO3 (ueq/L)	SO4 (ueq/L)	NH4 (ppm)	Si (ppm)	Al (ug/L)
BUBBLE POND	5/14/98	9.98	0.2	G	6.32	6.93	51.7	31.9	3	1.95	1.26	0.077	1.59	0.43	0.23	3.07	140	0	75	0.02	1.46	30.3
BUBBLE POND	5/25/98	9.4																				
BUBBLE POND	6/7/98	9.5																				
BUBBLE POND	7/9/98	7.1																				
BUBBLE POND	8/7/98	9.5																				
BUBBLE POND	9/16/98	9.7																				
BUBBLE POND	10/23/98	6.72	0.2	G	6.51	6.8	45.8	31.64	6	2.94	1.36	0.149	1.7	0.43	0.36	3.33	120	0.5	79	0.03	1.29	39
JORDAN POND	5/13/98	15.5	0.2	G	6.2	6.97	53.4	34.4	1	1.67	1.61	0.078	1.69	0.5	0.22	3.16	150	1.67	79	0.02	1.1	15
JORDAN POND	10/23/98	14.63	0.2	G	6.59		35	36.07	3	1.94	1.29	0.116	1.9	0.51	0.3	3.43	140	0.5	78	0.03	0.89	9
SARGENT MTN POND	5/14/98	N/A	0.2	G	4.93	4.91	-10.3	28.3	11	2.58	1.23	0.17	0.47	0.3	0.28	2.77	130	0	74	0.02	0.25	172
SARGENT MTN POND	10/27/98	N/A	0.2	G	4.81	4.74	-15.1	34.19	13	3.86	0.93	0.276	0.6	0.29	0.32	3.06	110	3.75	97	0.03	0.47	246
THE BOWL	5/5/98	8.1	0.2	G	5.61	6.33	14.2	35	3	1.84	0.98	0.17	0.89	0.51	0.21	4.13	210	0.46	71	0.03	0.53	16.5
THE BOWL	10/22/98	5.27	0.2	G	6.05		21.8	38.28	7	3.7	0.91	0.27	1.12	0.51	0.43	4.65	210	1.7	64	0.07	0.46	14.9
WITCH HOLE POND	5/13/98	4.3	0.2	G	5.7	6.71	22.2	28.1	27	4.5	1.03	0.217	0.86	0.37	0.16	2.85	130	0	41	0.02	0.26	38
WITCH HOLE POND	10/26/98	4.4	0.2	G	6.3	6.8	50.5	27.69	23	7.01	1.7	0.406	1.25	0.43	0.35	3.47	130	1.21	41	0.04	0.49	40.1

1999

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	EQpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	DOC (mg/L)	DIC (mg/L)	TN (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (ueq/L)	NO3 (ueq/L)	SO4 (ueq/L)	NH4 (ppm)	Si (ppm)	Al (ug/L)
BUBBLE POND	4/6/99	8.35	0.2	G	6.27	6.79	37.9	37.7	4	2	0.9	0.132	1.94	0.55	0.25	3.51	170	3.1	72	0.05	1.52	46.1
BUBBLE POND	10/27/99	9.85	0.2	G	6.32	6.72	53.3	38.5	4	2.1	1.6	0.15	1.76	0.49	0.31	3.93	190	0.3	78	0.05	1	16
JORDAN POND	4/6/99	17.30	0.2	G	6.26	6.89	47.6	36.2	2	1.6	1	0.146	1.99	0.57	0.26	3.36	150	2.69	78	0.05	1.08	14.8
JORDAN POND	10/27/99	12.47	0.2	G	6.39	6.77	61.7	36.1	2	1.7	1.1	0.16	1.73	0.48	0.3	3.55	160	0.9	81	0.05	0.92	28
SARGENT MTN POND	4/22/99	N/A	0.2	G	4.8	4.9	-13.4	34.6	18	2.8	1.6	0.16	0.63	0.39	0.3	3.4	160	0.76	78	0.05	0.74	305
SARGENT MTN POND	10/25/99	N/A	0.2	G	4.67	4.51	-22.4	40.6	11	3.6	0.6	0.3	0.61	0.35	0.32	3.97	180	4.6	94	0.05	0.75	256
THE BOWL	4/21/99	7.20	0.2	G	5.66	6.09	7.6	48.1	6	2	0.9	0.24	1.33	0.66	0.26	4.89	260	1.81	72	0.05	0.68	37.7
THE BOWL	10/21/99	5.50	0.2	G	6.3	6.47	28.7	44.5	9	3.6	1	0.33	1.13	0.57	0.4	5.34	270	0.4	59	0.05	0.58	20
WITCH HOLE POND	4/9/99	N/A	0.2	G	5.97	6.57	22.8	30	23	3.8	0.7	0.228	1.14	0.48	0.26	3.32	150	0.59	43	0.05	0.88	33.5
WITCH HOLE POND	10/27/99	3.25	0.2	G	6.08	6.55	48.1	35.2	24	6.9	1.2	0.42	1.22	0.51	0.34	4.11	180	0.9	48	0.05	0.94	49

- chemistry values from epilimnetic core and grab samples only.
- blank fields indicate no data collected
- in Samp. Type: C=core and G=grab.

Acadia National Park Lake Monitoring Program

Acidification Analytes: 1998-2001

2000

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	EQpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	DOC (mg/L)	DIC (mg/L)	TN (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (ueq/L)	NO3 (ueq/L)	SO4 (ueq/L)	NH4 (ppm)	Si (ppm)	Al (ug/L)
BUBBLE POND	5/5/00	10.55	0.2	G	6.19	6.7	43.0	41.2	3	2	1.2	0.130	1.81	0.52	0.28	4.37	191	1.5	78	0.01	1.57	53.8
BUBBLE POND	5/26/00	9.18	0.2	G	6.32			38.7	3													
BUBBLE POND	7/14/00	9.17																				
BUBBLE POND	9/26/00	11.85	0.2	G	6.64			42.2	3													
BUBBLE POND	10/24/00	11.73	0.2	G	6.69	6.95	55.6	43.6	2	1.8	1.2	0.114	1.92	0.56	0.25	4.59	6.75	0.005	3.74	0.005	1.01	86.1
JORDAN POND	5/3/00	13.08	0.2	G	6.29	6.9	54.4	40.6	4	1.7	1.1	0.120	1.83	0.52	0.27	3.83	160	1.4	80	0.06	1.07	12.7
JORDAN POND	10/23/00	13.35	0.2	G	6.57	7.09	63.7	40.5	6	1.8	1.1	0.122	1.95	0.57	0.3	4.07	6.04	0.005	3.74	0.005	0.9	9.9
SARGENT MTN POND	5/4/00	N/A	0.2	G	4.78	4.67	-14.3	40.5	13	3.3	0.8	0.170	0.5	0.36	0.27	4.06	177	0.2	81	0.01	0.56	282
SARGENT MTN POND	10/27/00	N/A	0.2	G	4.79	4.78	-16.3	38.8	4	0.56	1	0.148	0.56	0.37	0.12	4.49	6.32	0.005	4.37	0.005	0.29	209
THE BOWL	5/5/00	5.00	0.2	G	5.72	6.11	8.5	46.5	5	2.3	1.2	0.220	1.02	0.6	0.25	5.78	268	0.6	73	0.01	0.85	26.8
THE BOWL	10/26/00	4.59	0.2	G	6.03	6.67	28.5	47.8	7	3.9	0.8	0.256	1.21	0.64	0.38	6.04	9.83	0.005	4.13	0.05	0.35	10
WITCH HOLE POND	5/3/00	5.10	0.2	G	5.77	6.38	21.8	33.5	18	3.7	0.8	0.220	0.89	0.41	0.21	4	160	0.2	44	0.06	0.59	39.1
WITCH HOLE POND	10/24/00	4.27	0.2	G	6.38	6.97	55.6	33.5	19	5.4	1.1	0.369	1.22	0.51	0.24	4.37	6.04	0.005	1.58	0.005	0.42	22.7

2001

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	EQpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	DOC (mg/L)	DIC (mg/L)	TN (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Cl (ueq/L)	NO3 (ueq/L)	SO4 (ueq/L)	NH4 (ppm)	Si (ppm)	Al (ug/L)
BUBBLE POND	5/21/01	10.25	0.2	G	6.47	7.00	63.40	36.7	1	1.7	1.0	0.102	1.87	0.51	0.21	4.08	160	0.0	77	0.05	1.50	36.3
BUBBLE POND	7/30/01	13.80	0.2	G	6.36		105.18	37.3	2													
BUBBLE POND	10/5/01	11.75	0.5	G	6.72		79.46	36.2	2													
BUBBLE POND	10/24/01	11.94	0.2	G	6.80	7.20	73.00	38.2	1	1.5	1.0	0.112	1.93	0.53	0.22	3.58	180	0.0	35	0.05	1.00	10.0
JORDAN POND	5/17/01	12.82	0.2	G	6.56	7.00	62.90	36.5	1	1.5	1.0	0.107	1.90	0.55	0.25	3.95	160	1.3	78	0.05	1.10	13.0
JORDAN POND	10/29/01	18.44	0.2	G	6.69	7.10	67.20	36.1	1	1.5	1.5	0.106	2.16	0.60	0.29	3.36	170	0.0	82	0.05	0.81	10.0
SARGENT MTN POND	5/24/01	N/A	0.2	G	5.08	5.20	-3.20	27.8	4	2.5	0.6	0.167	0.46	0.30	0.27	3.58	130	0.0	72	0.05	0.37	126.0
SARGENT MTN POND	10/25/01	N/A	0.2	G	4.97	5.00	-4.50	34.8	4	2.2	0.6	0.259	0.90	0.41	0.35	3.48	160	1.4	90	0.05	0.21	116.0
THE BOWL	5/23/01	7.90	0.2	G	5.97	6.60	23.80	42.4	5	2.8	0.7	0.165	1.06	0.60	0.25	5.62	250	0.0	67	0.05	0.69	14.9
THE BOWL	11/2/01	N/A	0.2	G	5.84	6.70	33.20	44.7	6	3.7	1.3	0.263	1.22	0.68	0.29	4.88	260	0.0	65	0.05	0.19	10.0
WITCH HOLE POND	5/21/01	4.65	0.2	G	6.22	6.90	49.90	30.3	16	4.2	1.0	0.276	1.04	0.46	0.23	3.92	150	0.0	34	0.05	0.24	28.5
WITCH HOLE POND	10/22/01	3.79	0.2	G	6.39	7.10	58.00	34.0	17	5.0	3.6	0.422	1.24	0.53	0.26	3.87	155	0.0	71	0.05	0.43	13.8

- chemistry values from epilimnetic core and grab samples only.
- blank fields indicate no data collected
- in Samp. Type: C=core and G=grab.

Acadia National Park Lake Monitoring Program

Eutrophication Analytes: 1998-2001

1998

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	COND (uS/cm)	COLOR (pcu)	CHLA (ug/L)	DOC (mg/L)	TP (ug/L)	TN (mg/L)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
ECHO LAKE	6/19/98	8.44	10	C	6.49	63.07	4	2	2.96	4.1	N/A	15.81	9.71	9.36	6.89
ECHO LAKE	7/24/98	9.50										22.21	9.01	10.56	5.52
ECHO LAKE	8/21/98	9.6	9	C	6.56	60.9	4	1.2	3.01	3.8	0.18	21.12	9.16	11.2	3.32
ECHO LAKE	9/16/98	10.90										18.48	8.97	11.88	1.7
JORDAN POND	6/22/98	15.1	10	C	6.17	36.41	1	1.2	2.29	1.8	0.123	15.02	9.92	5.5	12.31
JORDAN POND	7/9/98	16.10													
JORDAN POND	7/24/98	14.10										20.99	9.01	4.65	11.92
JORDAN POND	8/20/98	15.8	10	C	6.6	34.96	2	0.9	1.88	2.6	0.14	20.02	9.2	5.72	10.88
SEAL COVE POND	6/19/98	6.42	10	C	6.33	46.9	7	2.5	3.98	6.3	0.202	16.71	9.42	11	2.57
SEAL COVE POND	7/23/98	8.20										23.13	8.29	13.55	1.3
SEAL COVE POND	8/21/98	8	9	C	6.47	39.8	9	2.9	4.28	6.2	0.23	21.12	8.28	13.23	0.03
SEAL COVE POND	9/17/98	10.00										17.76	8.12	13	0.2
UPPER HADLOCK	6/22/98	6.65	0.2	G	6.12	43.67	10	1.2	3.63	4.9	0.165	19.3	9.1	8.75	3.25
UPPER HADLOCK	7/22/98	6.20										23.55	8.3	9.83	1.55
UPPER HADLOCK	8/20/98	6.1	6	C	6.2	41.2	6	3.6	3.78	5.7	0.25	20.61	9.03	10.03	0.08
UPPER HADLOCK	9/25/98	6.80										15.04	8.62	10.1	0.2
WITCH HOLE POND	5/28/98	4.42										18	8.9	9.22	4.48
WITCH HOLE POND	6/26/98	3.6	0.2	G	6.22	59.4	27	3.4	5.29	8	0.28	21.05	8.45	9.7	1.2
WITCH HOLE POND	7/22/98	3.20										24.75	7.95	10	0.1
WITCH HOLE POND	8/24/98	4.35	3	C	6.23	27.6	26	4	6.8	11	0.5	20.98	8	10.18	0.08
WITCH HOLE POND	9/24/98	4.20										15.66	8.23	10.47	0.2

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Acadia National Park Lake Monitoring Program

Eutrophication Analytes: 1998-2001

1999

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	COND (uS/cm)	COLOR (pcu)	CHLA (ug/L)	DOC (mg/L)	TP (ug/L)	TN (mg/L)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
ECHO LAKE	6/7/99	9.90										17.66	9.28	10.47	9.03
ECHO LAKE	7/8/99	11.10	9	C	6.97	61.9	6	1.1	2.6	5.7	0.26	22.63	8.41	11.71	6
ECHO LAKE	7/30/99	10.37										23.43	8.25	12.2	3.94
ECHO LAKE	8/25/99	11.15	10	C	6.57	69.6	5	2	2.7	3.1	0.18	21.58	8.25	12.16	1.3
ECHO LAKE	10/8/99	8.18										14.88	8.84	12.2	0.28
JORDAN POND	5/27/99	21.27										11.18	8.01	4.54	10.59
JORDAN POND	7/1/99	20.50	10	C	6.52	31	3	0.5	1.6	1.5	0.14	20.43	8.68	6.08	12.65
JORDAN POND	8/23/99	15.40	10	C	6.85	41.5	3	0.5	1.7	2.5	0.14	20.12	8.89	6.52	12.88
JORDAN POND	10/6/99	14.50										14.97	9.61	5.8	10.99
SEAL COVE POND	6/7/99	7.00										19.86	8.89	12	2.2
SEAL COVE POND	7/8/99	6.70	7	C	6.79	42.3	9	2.5	3.8	4	0.18	23.29	8.21	14.2	1.86
SEAL COVE POND	8/2/99	7.00										24.56	7.56	14.3	0.07
SEAL COVE POND	8/25/99	7.54	9	C	6.57	46.4	7	3.5	4.1	7	0.26	21.49	7.79	13.97	0
SEAL COVE POND	10/8/99	8.90										13.31	9.42	12.2	9.55
UPPER HADLOCK	6/2/99	6.15										19.7	9.21	9.38	4.88
UPPER HADLOCK	7/1/99	5.10	5	G	6.33	42.9	8	3.6	3.5	4.2	0.23	22.84	8.03	11.55	1.56
UPPER HADLOCK	8/2/99	6.40										24.8	7.73	11.7	0
UPPER HADLOCK	8/26/99	6.85	7	C	6.29	52.3	6	2.4	3.2	3.9	0.22	21.39	8.21	12.15	0
UPPER HADLOCK	10/13/99	6.70										11.28	10.06	10.9	9.63
WITCH HOLE POND	6/7/99	4.25										20.33	8.87	7.8	3.33
WITCH HOLE POND	6/30/99	4.40	4	G	6.22	29.1	16	2.8	5.3	9.4	0.38	22.93	7.62	9.9	0.07
WITCH HOLE POND	8/3/99	4.20										24.9	7.4	10.37	0
WITCH HOLE POND	8/23/99	4.55	4	C	6.16	31.4	11	5.1	5.2	11	0.48	21.54	7.2	10.45	0
WITCH HOLE POND	10/12/99	3.68										12.1	9.22	11.5	8.41

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- blank fields indicate no data collected
- in Samp. Type: C=core and G=grab.

Acadia National Park Lake Monitoring Program

Eutrophication Analytes: 1998-2001

2000

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	COND (uS/cm)	COLOR (pcu)	CHLA (ug/L)	DOC (mg/L)	TP (ug/L)	TN (mg/L)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
ECHO LAKE	5/31/00	7.62	0.2	G	6.75	67.4	3					12.36	9.56		
ECHO LAKE	6/26/00	8.30	5.0	C	6.61	69.0	6	1.7				20.5	9.29	12.54	7.03
ECHO LAKE	7/5/00	8.80													
ECHO LAKE	7/19/00	9.15										20.38	8.55	12.73	4.61
ECHO LAKE	8/18/00	8.87	8.0	C	6.99	70.8	4	2.4	2.9	4.2	0.206	21.78	8.49	13.03	2.07
ECHO LAKE	9/29/00	7.40	0.2	G	6.52	72.2	4					16.5	8.63	12.83	0.02
JORDAN POND	5/30/00	12.74	0.2	G	6.56	35.9	1					10.84	11.07	6.07	12.16
JORDAN POND	6/14/00	15.30	10.0	C	6.75	38.4	5	0.4	2.2	3.3	0.145	13.19	10.33	6.29	12.06
JORDAN POND	7/21/00	13.12										19.08	8.93	6.48	11.79
JORDAN POND	8/17/00	14.60	10.0	C	6.51	36.5	2	1.1	1.8	2.0	0.152	20.7	8.73	6.58	11.82
JORDAN POND	9/25/00	16.72	0.2	G	6.60	42.3	3					16.99	11.29	6.56	10.95
SEAL COVE POND	5/31/00	6.63	0.2	G	6.21	47.0	11					14	8.83		
SEAL COVE POND	6/23/00	6.55	5.0	C	6.50	49.4	12	2.5	5	7.7	0.296	20.5	8.98	15.1	6.37
SEAL COVE POND	7/19/00	6.10										20.84	8.2	14.88	2.08
SEAL COVE POND	8/17/00	6.60	8.0	C	6.47	47.1	7	3.2	3.8	4.3	0.250	21.82	6.88	15.5	0.04
SEAL COVE POND	9/27/00	6.72	0.2	G	6.48	49.1	8					16.89	8.77		
UPPER HADLOCK	5/26/00	6.90	0.2	G	5.84	45.6	9					14.12	9.71	7.77	7.33
UPPER HADLOCK	6/21/00	6.15	3.0	C	6.36	45.8	13	2.9	3.8	6.4	0.219	20.65	8.44	8.5	4.59
UPPER HADLOCK	7/14/00	4.90										21.28	8.17	9	2.65
UPPER HADLOCK	8/18/00	5.40	5.0	C	6.30	50.4	8	2.9	3.5	4.8	0.227	21.35	7.83	9.44	0.37
UPPER HADLOCK	9/26/00	8.24	0.2	G	6.45	51.2	8					16	8.69	9.48	0.02
WITCH HOLE POND	5/25/00	4.30										13.02	7.4		
WITCH HOLE POND	6/21/00	2.90	2.0	C	6.29	31.1	21	7.3	6.5	15.0	0.585	21.47	8.35	12.14	1
WITCH HOLE POND	7/12/00	3.86										21.1	7.76	12.43	0.01
WITCH HOLE POND	8/21/00	4.20	4.0	C	6.27	34.1	22	3.8	5.4	9.6	0.420	20.9	7.24	12.65	0
WITCH HOLE POND	9/26/00	4.08	0.2	G	6.17	34.4	18					15.9	7.96	12.2	0.02

- chemistry values from epilimnetic core and grab samples only.
- blank fields indicate no data collected
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Acadia National Park Lake Monitoring Program

Eutrophication Analytes: 1998-2001

2001

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	CHLA (ug/L)	DOC (mg/L)	TP (ug/L)	TN (mg/L)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
ECHO LAKE	6/20/01	9.61	6.0	C	6.70		70.7	7	1.4	3.0	5.6	0.249	20.79	9.28	9.8	7.84
ECHO LAKE	7/25/01	9.43	0.2	G	6.88	93.59	69.1	1					24.22	8.69	10.46	6.31
ECHO LAKE	8/22/01	10.60	8.0	C	6.64	97.81	70.5	4	4.5	2.5	3.7	0.151	22.51	8.36	10.96	4.23
ECHO LAKE	10/1/01	11.27	0.2	G	7.05	97.91	73.7	4					17.45	8.92	11.1	0.63
JORDAN POND	6/14/01	13.02	10.0	C	6.24		37.7	2	1.3	1.8	3.4	0.138				
JORDAN POND	6/15/01												17.49	9.57	5.97	12.43
JORDAN POND	7/23/01	15.10	0.2	G	6.68	27.12	37.3	1					21.63	8.84	6.27	13.08
JORDAN POND	8/20/01	15.42	9.0	C	6.63	79.18	37.1	3	1.0	1.7	2.4	0.109	21.83	8.63	6.38	12.76
JORDAN POND	10/1/01	16.49	0.2	G	6.81	74.35	38.5	1					16.36	9.57	6.15	12.16
SEAL COVE POND	6/25/01	6.74	5.0	C	6.29		48.1	8	1.2	4.0	5.2	0.269	21.6	9.02	12.16	4.44
SEAL COVE POND	7/25/01	8.40	0.2	G	6.80	80.05	48.5	7					23.63	8.64	12.54	1.86
SEAL COVE POND	8/22/01	7.20	7.0	C	6.42	185.60	48.6	12	3.9	4.0	4.2	0.245	22.53	7.76	12.6	0.07
SEAL COVE POND	9/20/01	7.70	0.2	G	6.82	65.78	49.4	5					18.62	8.12	17.3	0.1
UPPER HADLOCK	6/18/01	7.13	0.2	G	6.56		53.7	6	2.2	3.2	12.0	0.181	23	7.99	9.12	4.45
UPPER HADLOCK	7/26/01	6.80	0.2	G	6.51	41.84	56.1	2					24.12	7.58	10.05	2.05
UPPER HADLOCK	8/20/01	8.25	5.0	C	6.42	115.97	56.6	10	4.0	3.5	3.9	0.284	23.26	8	10.37	0.46
UPPER HADLOCK	9/17/01	9.40	0.2	G	6.41	49.76	58.8	5					18.12	8.44	10.8	0
WITCH HOLE POND	6/25/01	3.71	3.0	C	6.40		31.1	19	6.0	5.7	12.3	0.499	21.83	7.93	8.2	0.36
WITCH HOLE POND	7/27/01	4.17	0.2	G	6.06	49.20	32.3	13					22.95	7.45	8.52	0
WITCH HOLE POND	8/16/01	4.70	3.0	C	6.51	75.29	33.3	22	3.0	5.3	10.0	0.464	22.5	7.49	9.23	0.05
WITCH HOLE POND	9/17/01	5.15	0.2	G	6.13	44.75	33.2	11					17.82	7.49	9.4	0.17

- chemistry values from epilimnetic core and grab samples only.
- blank fields indicate no data collected
- in Samp. Type: C=core and G=grab.

Acadia National Park Lake Monitoring Program

Additional Lakes Monitored*: 1998-2001

1998

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	COND (uS/cm)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
EAGLE LAKE	7/15/98	13.3	0.2	G	6.67	38.7	19.4	9	12.3	8.2
LONG POND (MDI)	7/15/98	10.2	0.2	G	6.2	91	20.4	8.8	7.7	9

1999

LAKE	DATE	SECCHI DEPTH (M)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
EAGLE LAKE	7/29/99	11.60	23.27	8.3		
EAGLE LAKE	10/6/99	9.95	16.27	8.77	13.25	1.01

2000

LAKE	DATE	SECCHI DEPTH (M)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
EAGLE LAKE	7/5/00	12.10				
LONG POND (MDI)	6/22/00	11.24	16.66	9.77	9.81	9.61
LONG POND (MDI)	7/19/00	9.30	20.22	8.69	9.75	7.59

2001

LAKE	DATE	SECCHI DEPTH (M)	DEPTH (M)	TYPE	CCpH	ANC (ueq/L)	COND (uS/cm)	COLOR (pcu)	Mean Epi. Temp (°C)	Mean Epi. DO (ppm)	Mean Hyp. Temp (°C)	Mean Hyp. DO (ppm)
EAGLE LAKE	7/12/01	11.47	9	C	6.53	48.9	1	37.8	20.06	8.87	10.58	10.46
EAGLE LAKE	7/31/01	12.65	0.2	G	6.51	43.1	1	38.2	22.08	9.54	11.68	10.03
EAGLE LAKE	10/3/01	11.5	0.2	G	6.79	47.8	1	39.1	17.28	9.41		
LONG POND (MDI)	7/5/01	9.40	0.2	G	6.95	63.0	5	47.5	20.1	9.36	7.71	10.63
LONG POND (MDI)	7/20/01	8.90										
LONG POND (MDI)	8/15/01	10.70	0.2	G	7.27	158.8	1	47.8	22.8	8.79	8.16	9.19
LONG POND (MDI)	10/5/01	11.35	0.5	G	6.52	121.5	1	46.7	17.1	8.63	8.09	6.88

- chemistry values from epilimnetic core and grab samples only.
- blank fields indicate no data collected
- in Samp. Type: C=core and G=grab.

* Lakes in this category are those with a long-term monitoring history.

APPENDIX B

TRANSPARENCY GRAPHS

Explanation of the Trophic State Index (TSI) (from Heiskary and Lindbloom, 1993)

The trophic state index, developed by limnologist Dr. Robert Carlson, is one means to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll *a*, and Secchi transparency. TSI values are calculated as follows:

$$\text{Secchi disk TSI} = 60 - 14.41 \ln(\text{Secchi depth in meters})$$

Interpretation:

TSI < 30: Classic oligotrophic lake- clear water, hypolimnion well-oxygenated throughout the year.

TSI 30-40: Deeper lakes exhibit classical oligotrophy, shallower lakes may become anoxic in the hypolimnion during the summer.

TSI 40-50: Water relatively clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50-60: Lower boundary of classic eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

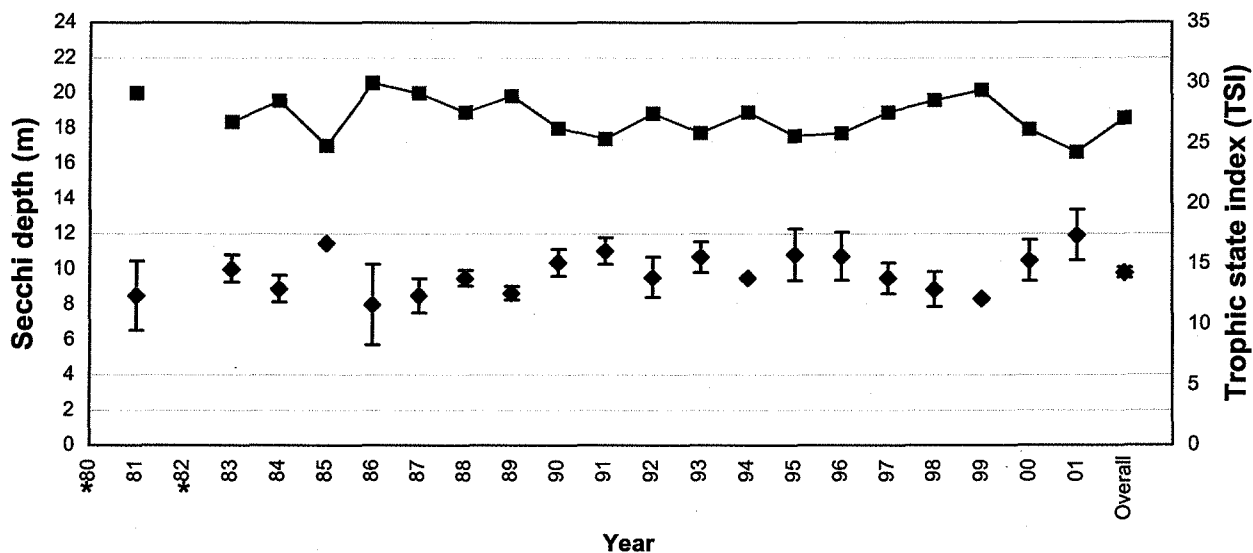
TSI 60-70: Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70-80: Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypertrophic.

TSI >80: Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

An increase of ten units represents a doubling of algal biomass

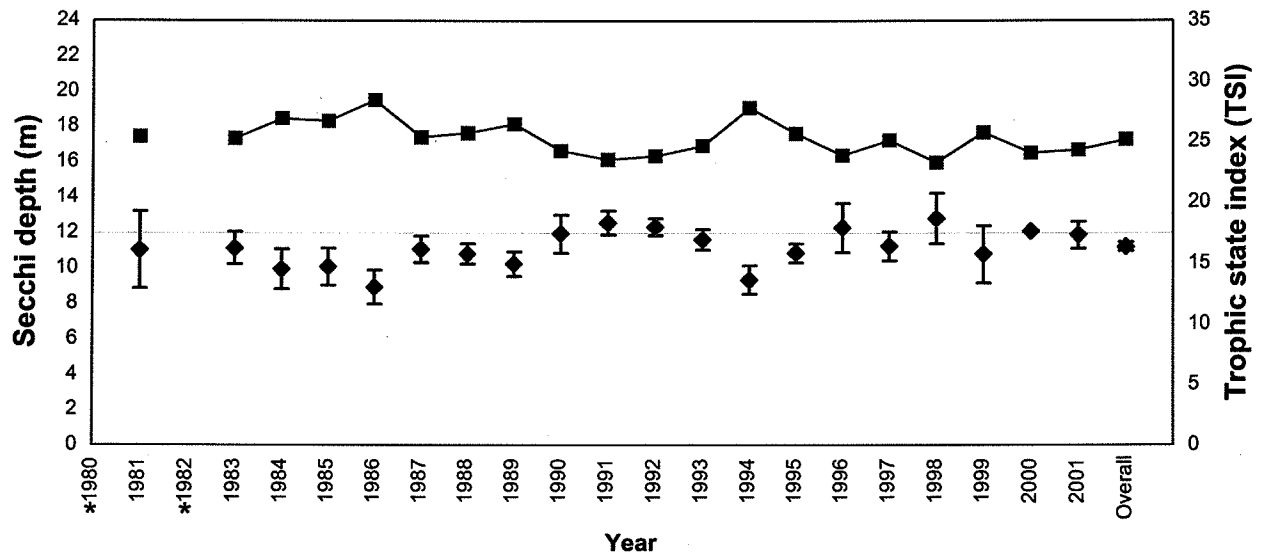
Annual Mean Transparency: Bubble Pond



*No sampling conducted in 1980, 1982

◆ Annual Mean —■ Secchi TSI (error bars represent 95% confidence interval)

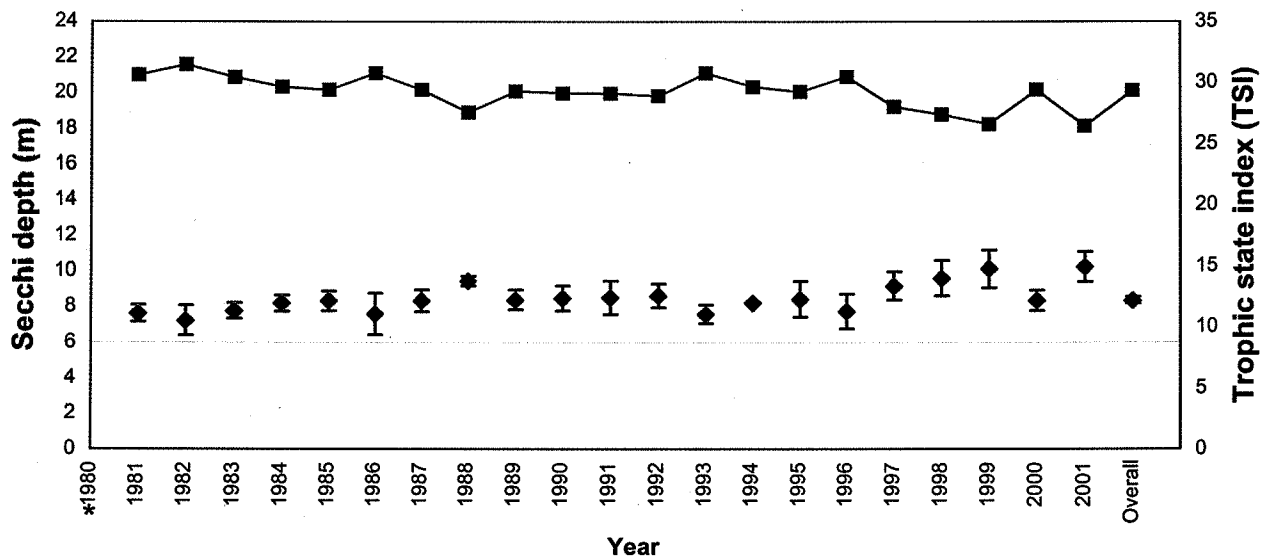
Annual Mean Transparency: Eagle Lake



*No sampling conducted in 1980, 1982

◆ Annual Mean —■ Secchi TSI (error bars represent 95% confidence interval)

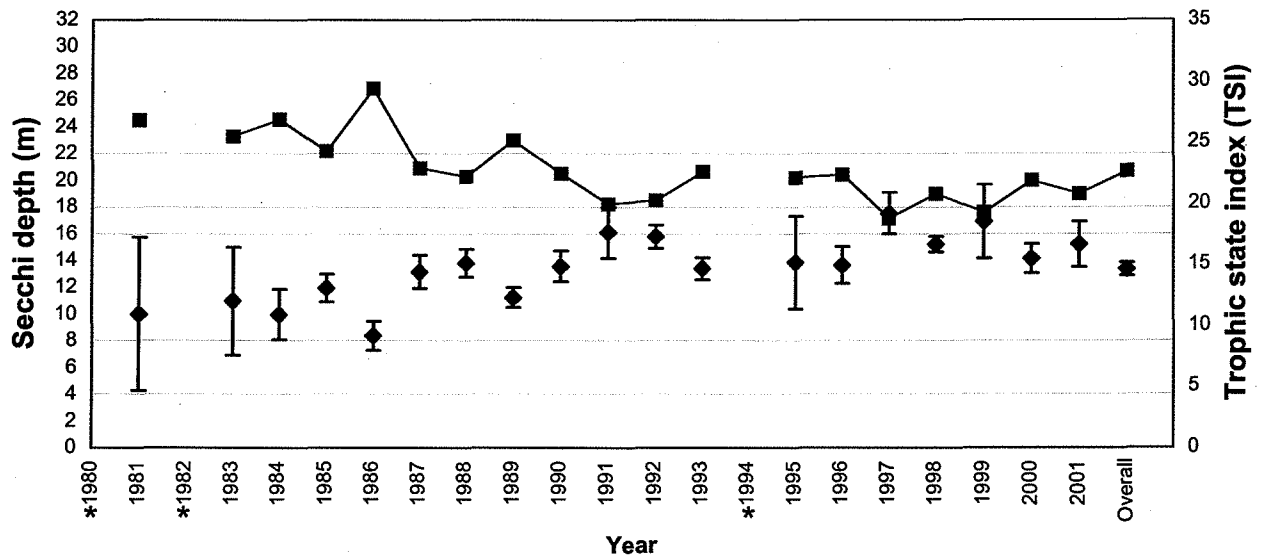
Annual Mean Transparency: Echo Lake



*No sampling conducted in 1980

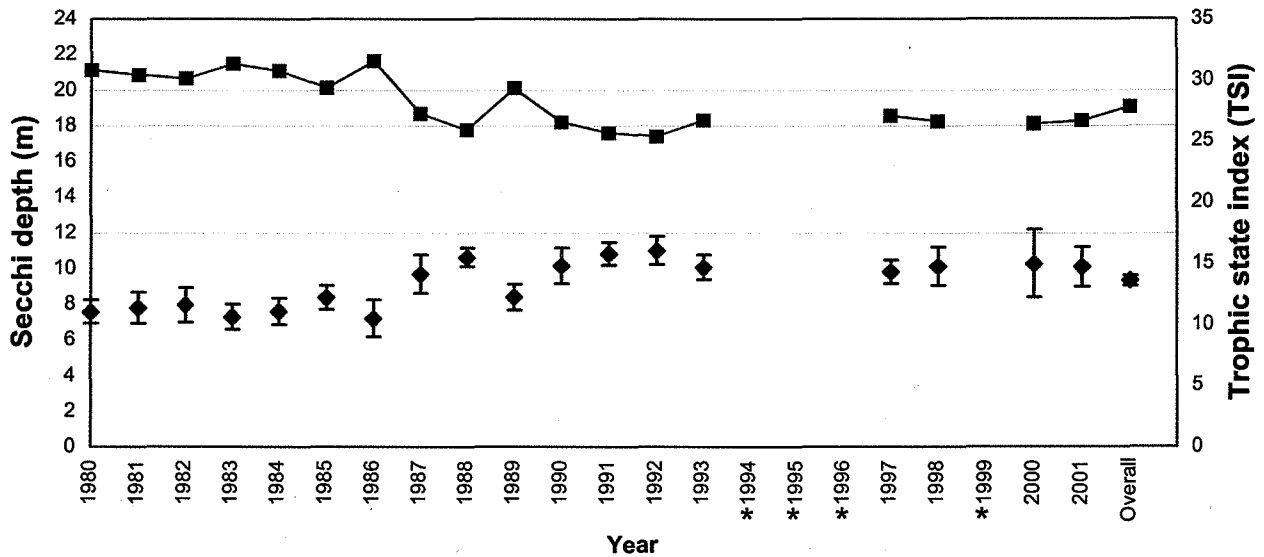
◆ Annual Mean —■ Secchi TSI (error bars represent 95% confidence interval)

Annual Mean Transparency: Jordan Pond



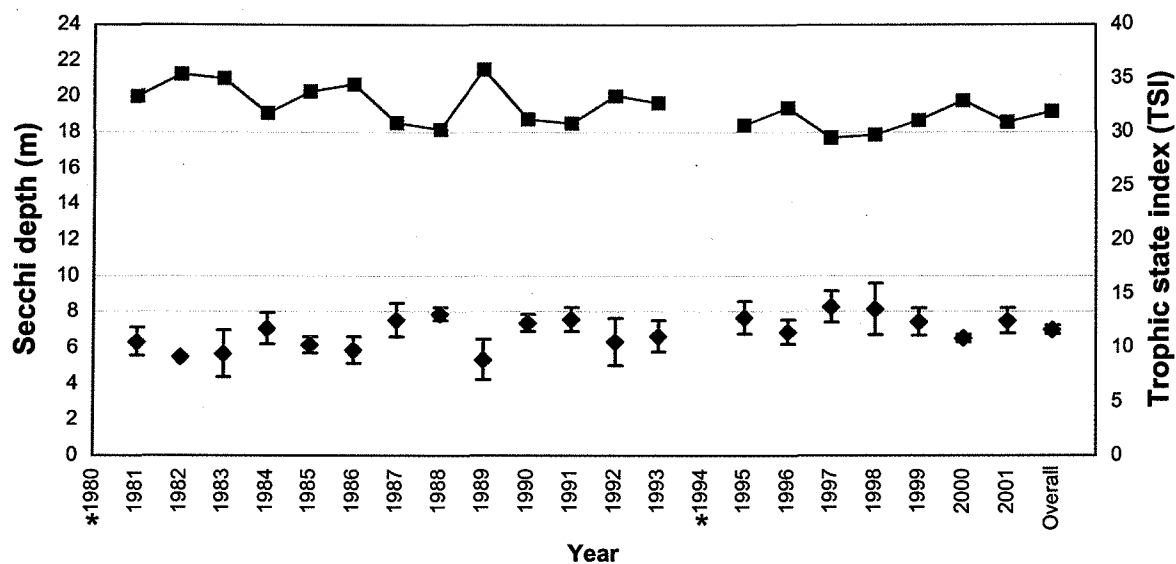
*No sampling conducted in 1980, 1982, 1994

Annual Mean Transparency: Long Pond

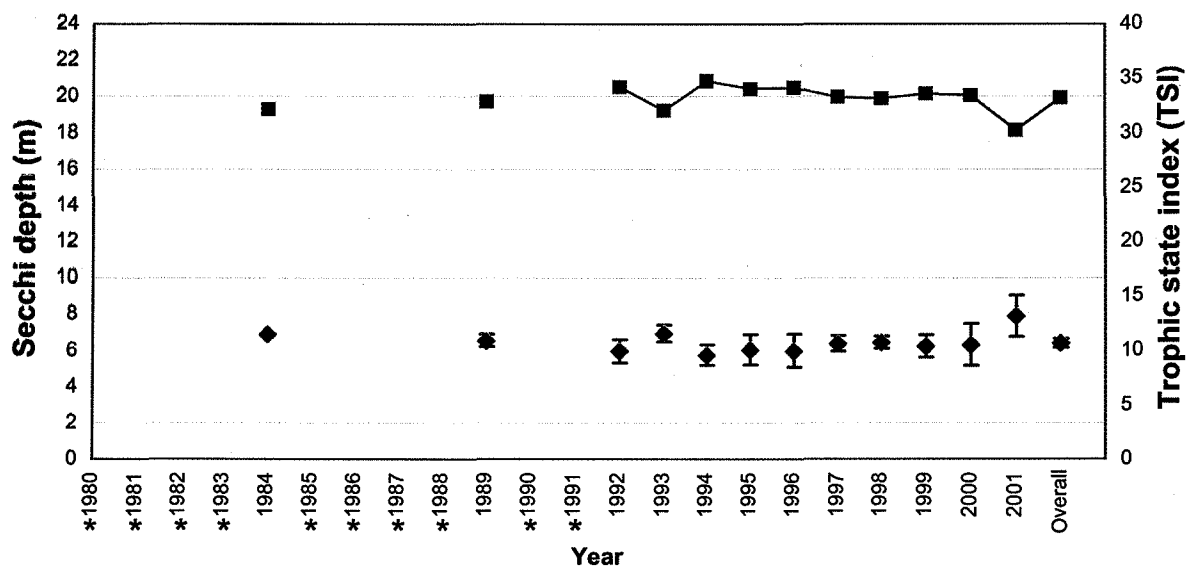


*No sampling conducted in 1994-96, 1999

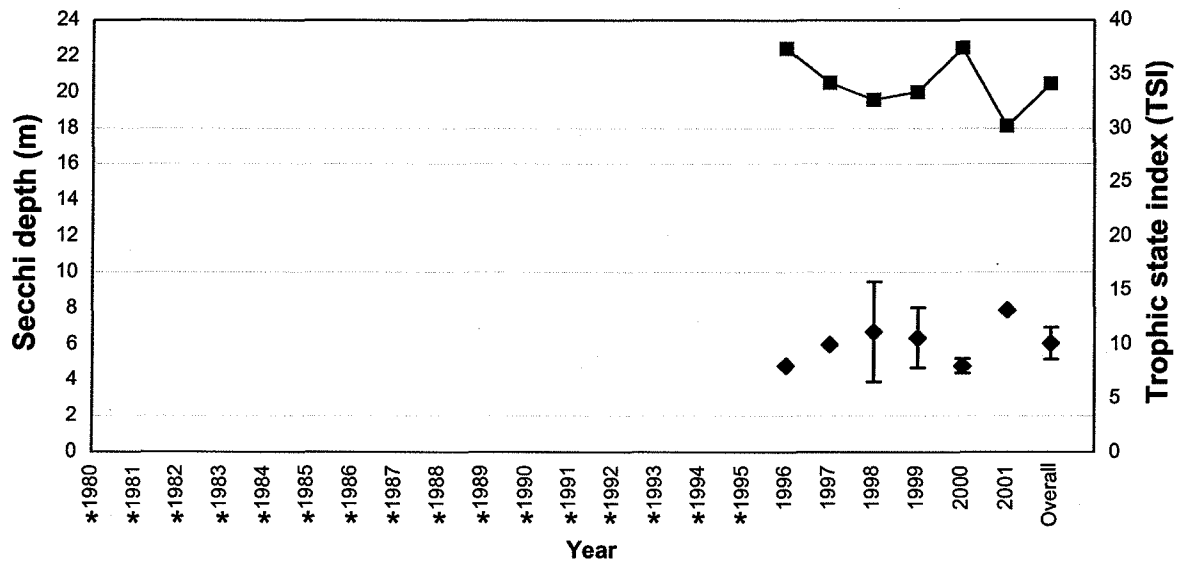
Annual Mean Transparency: Seal Cove Pond



Annual Mean Transparency: Upper Hadlock Pond



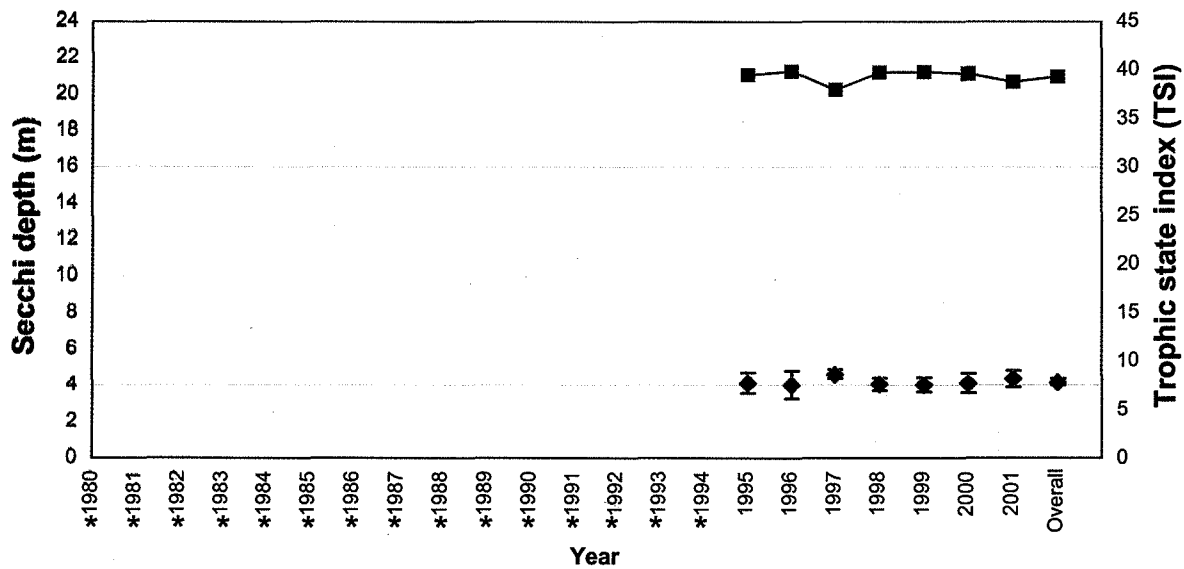
Annual Mean Transparency: The Bowl



*No sampling in 1980-1995

◆ Annual Mean —■ Secchi TSI (error bars represent 95% confidence interval)

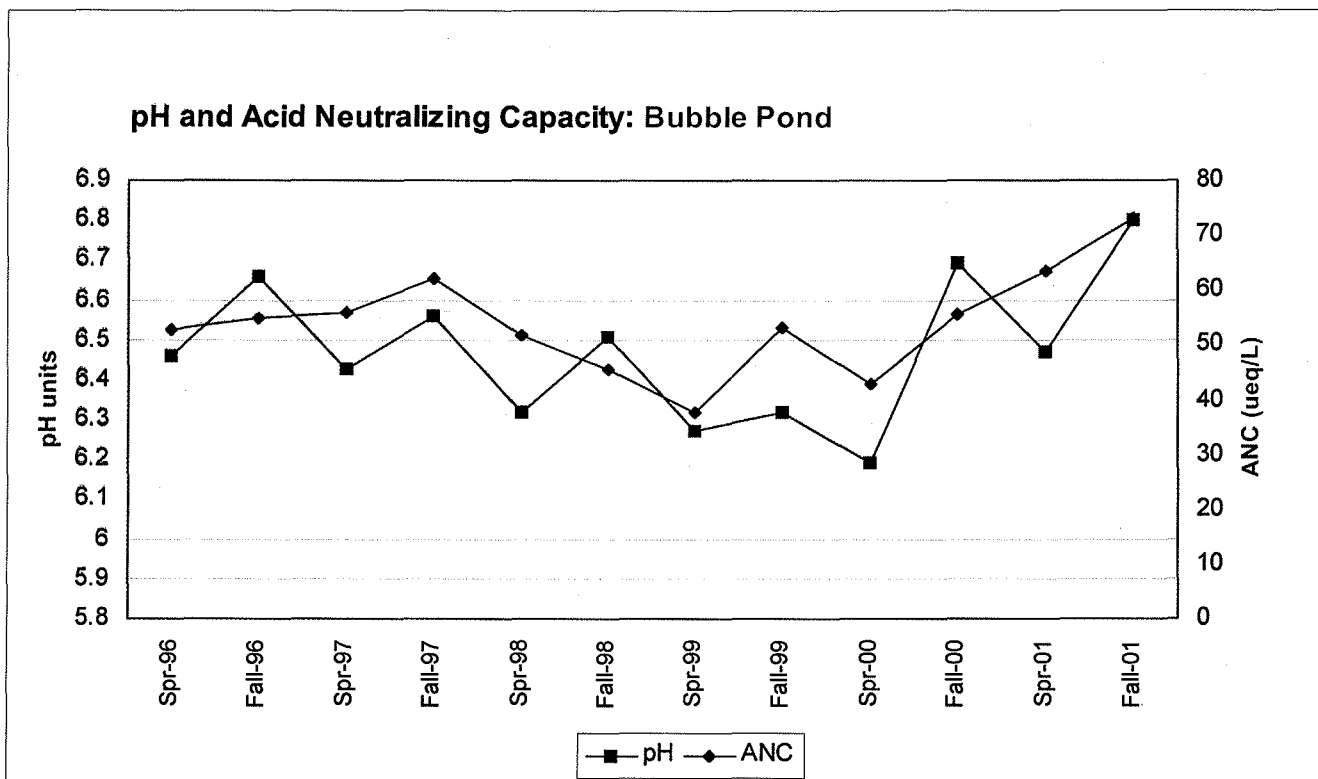
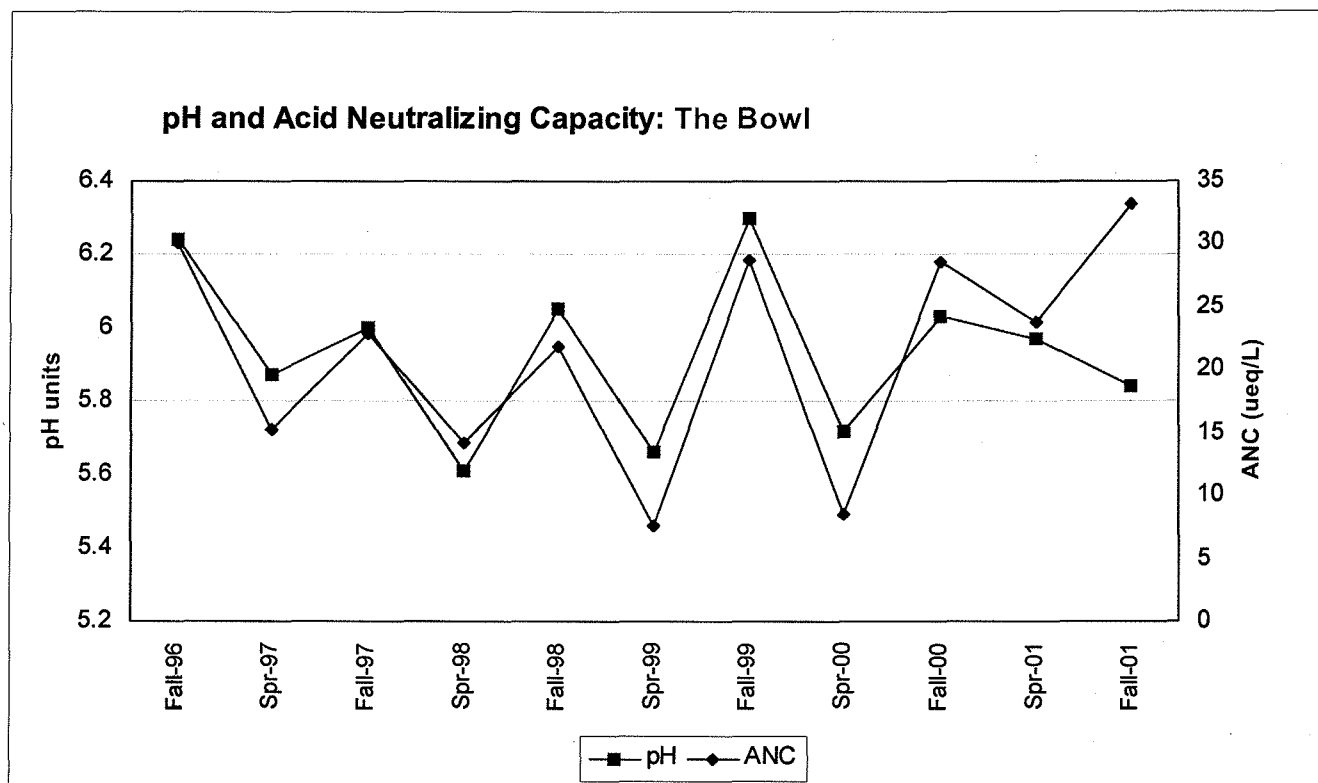
Annual Mean Transparency: Witch Hole Pond



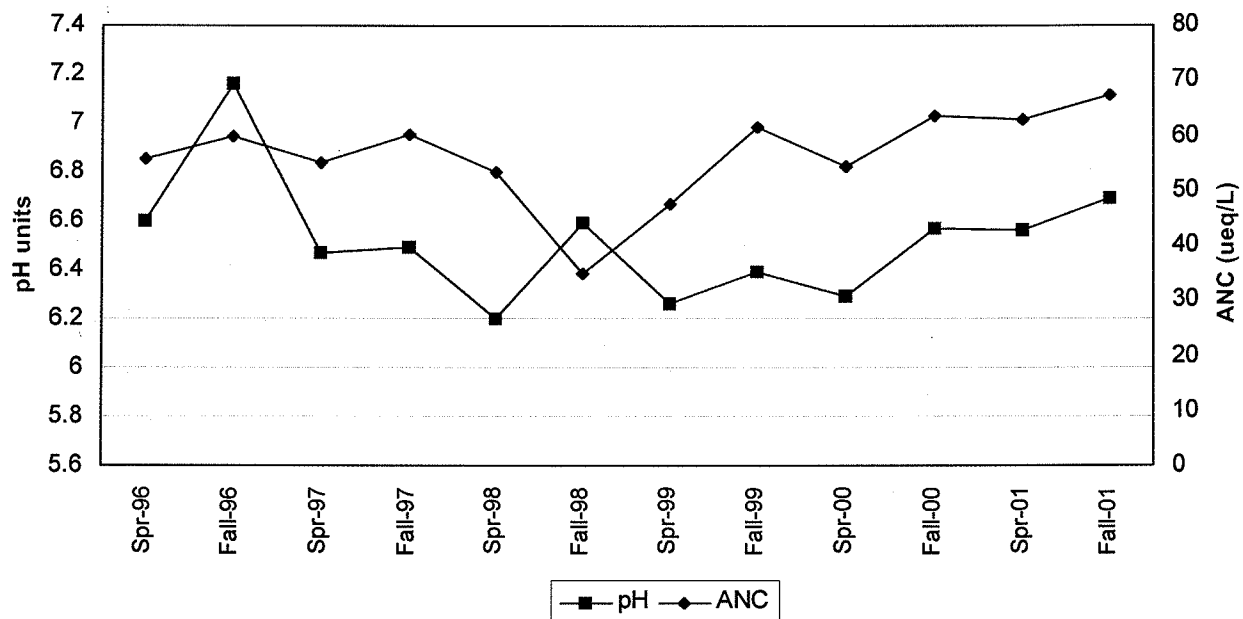
*No sampling in 1980-1994

◆ Annual Mean —■ Secchi TSI (error bars represent 95% confidence interval)

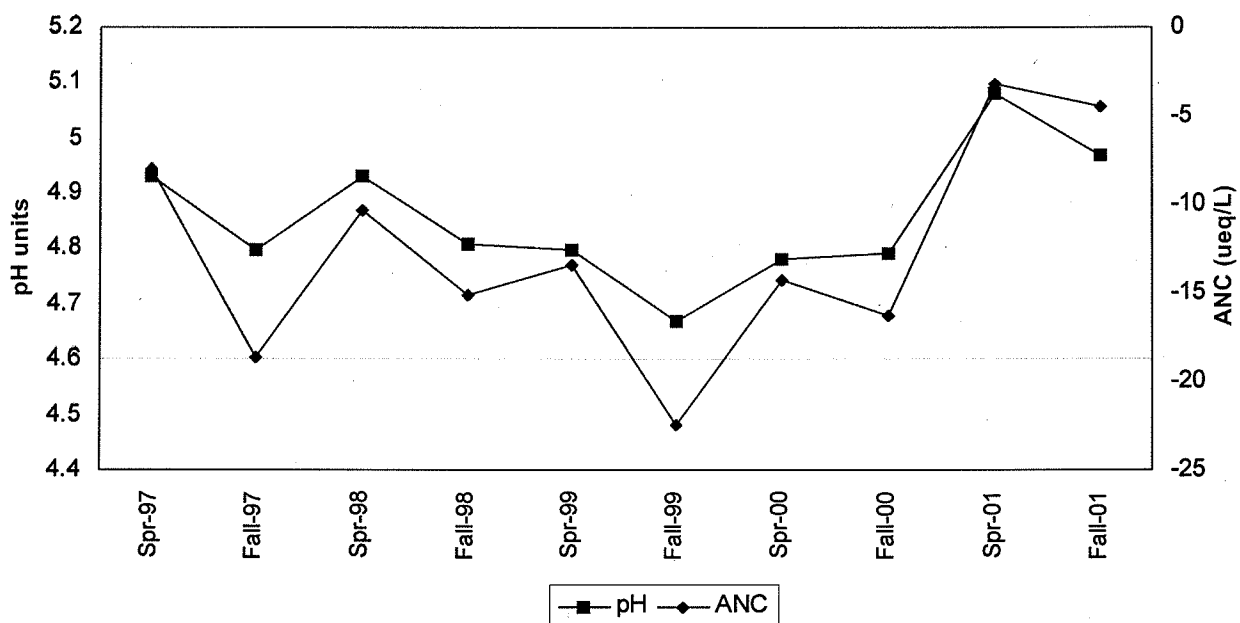
pH AND ANC GRAPHS



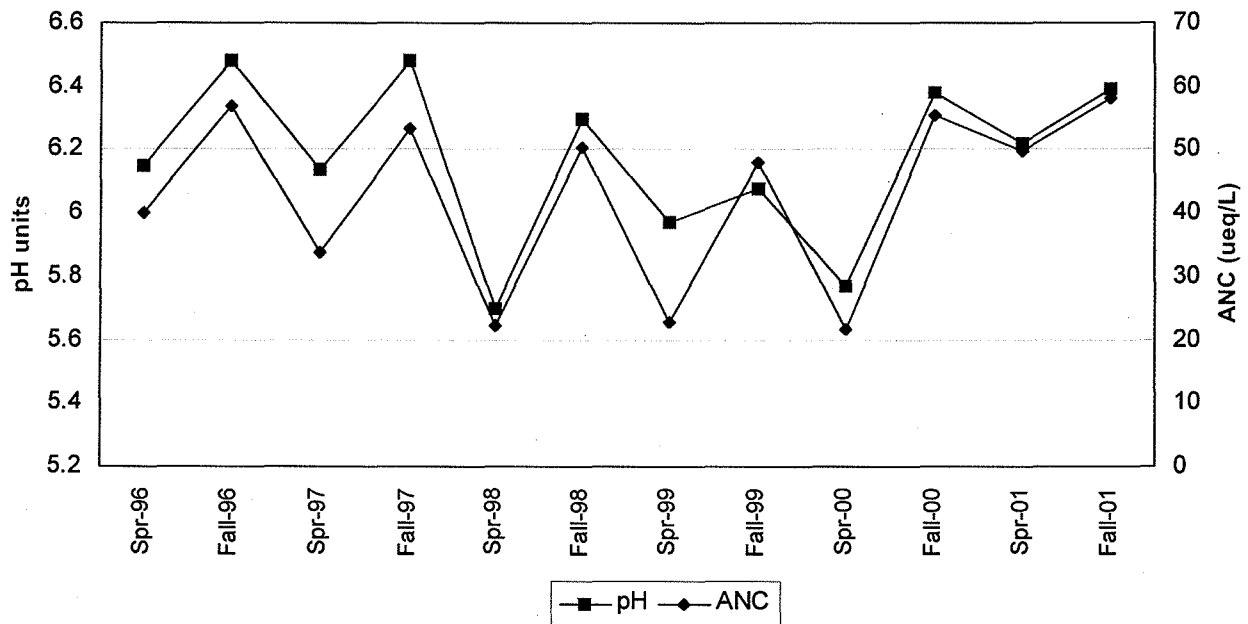
pH and Acid Neutralizing Capacity: Jordan Pond



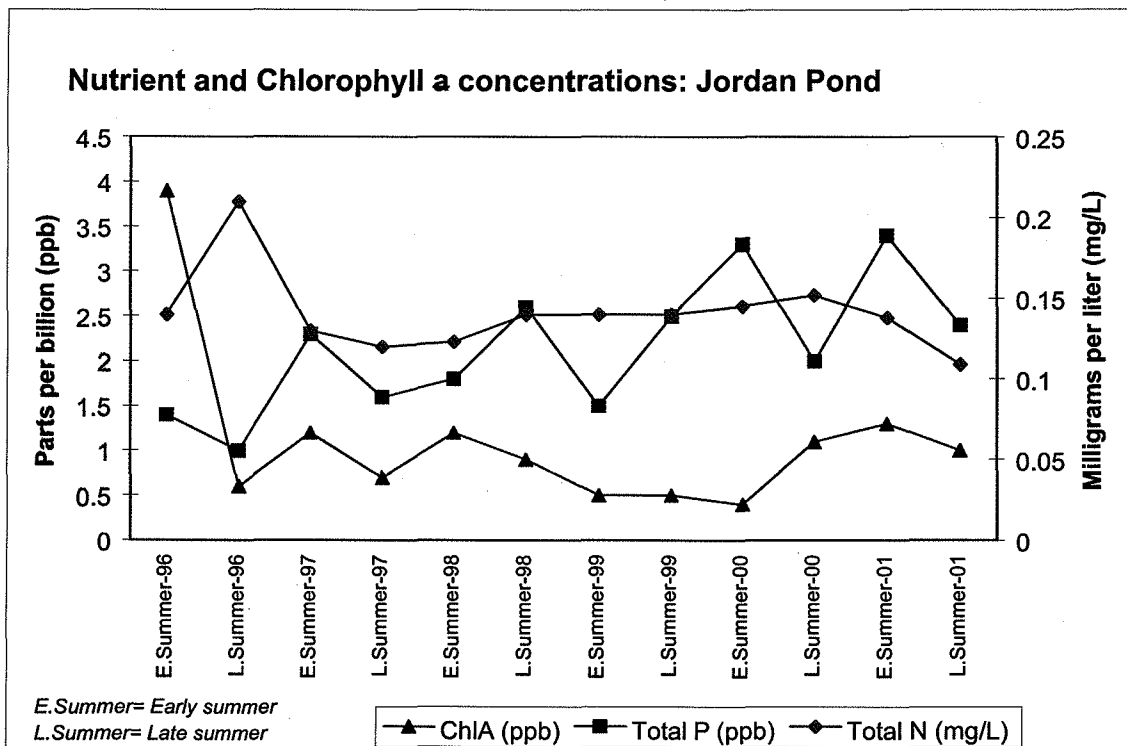
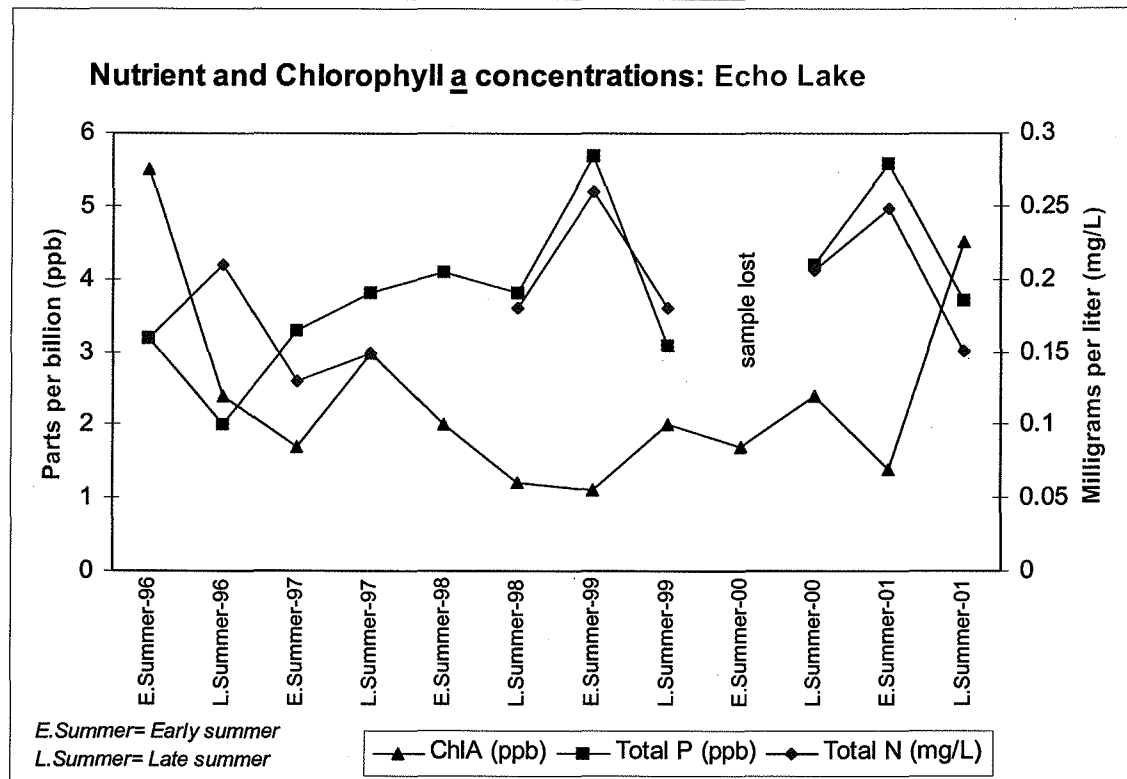
pH and Acid Neutralizing Capacity: Sargent Mountain Pond



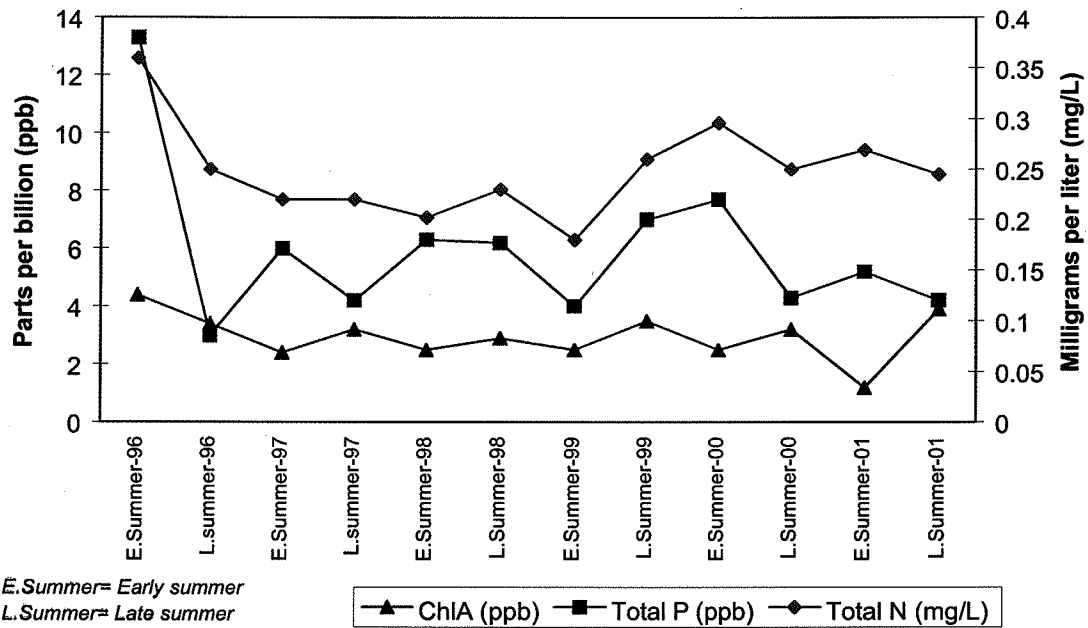
pH and Acid Neutralizing Capacity: Witch Hole Pond



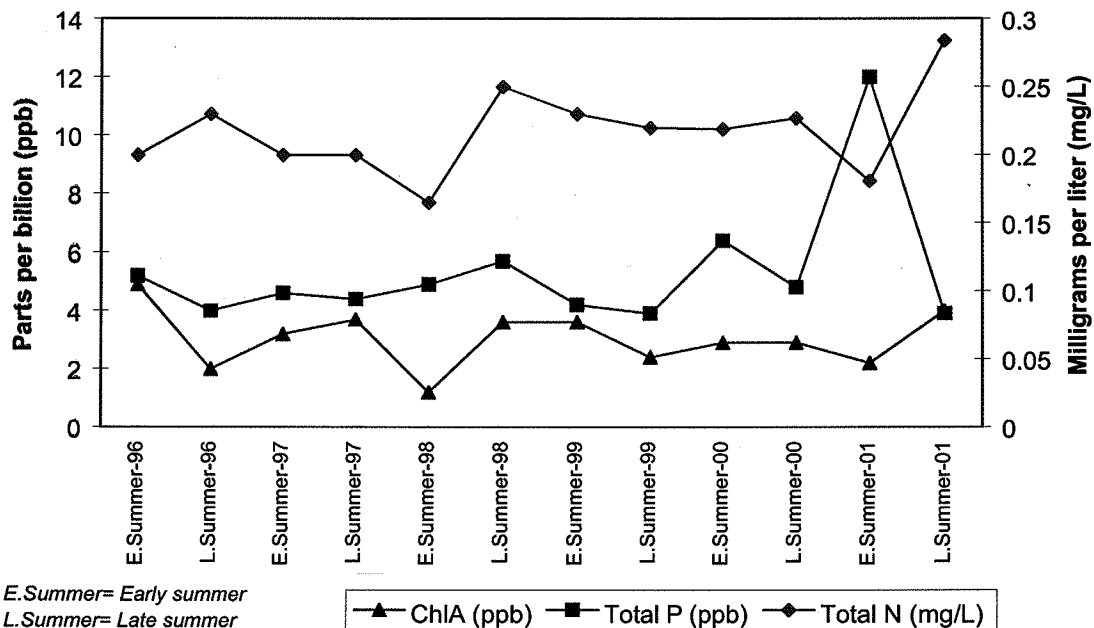
NUTRIENT AND CHLOROPHYLL a GRAPHS



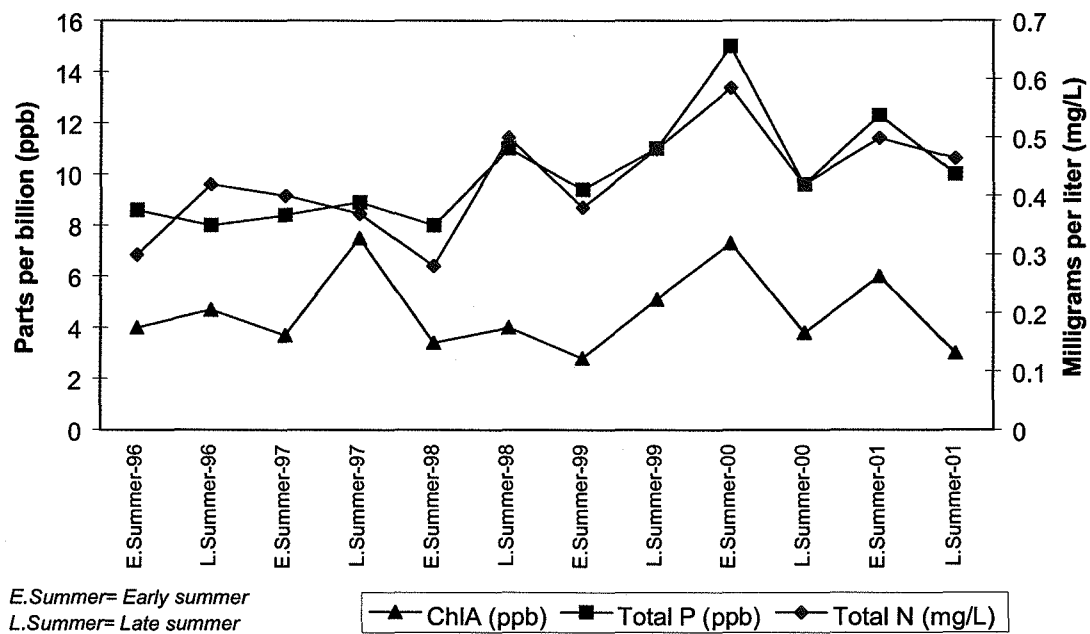
Nutrient and Chlorophyll a concentrations: Seal Cove Pond



Nutrient and Chlorophyll a concentrations: Upper Hadlock Pond

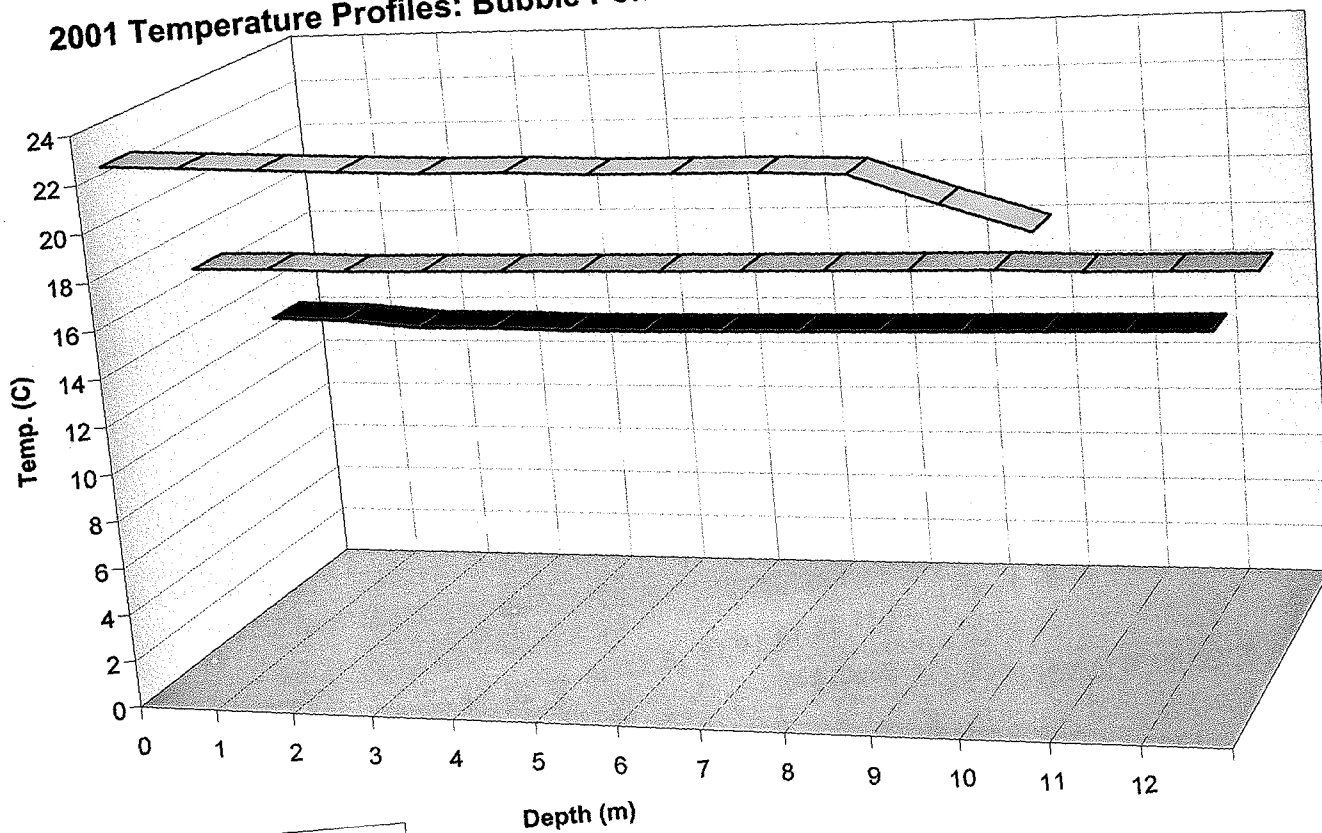


Nutrient and Chlorophyll a concentrations: Witch Hole Pond



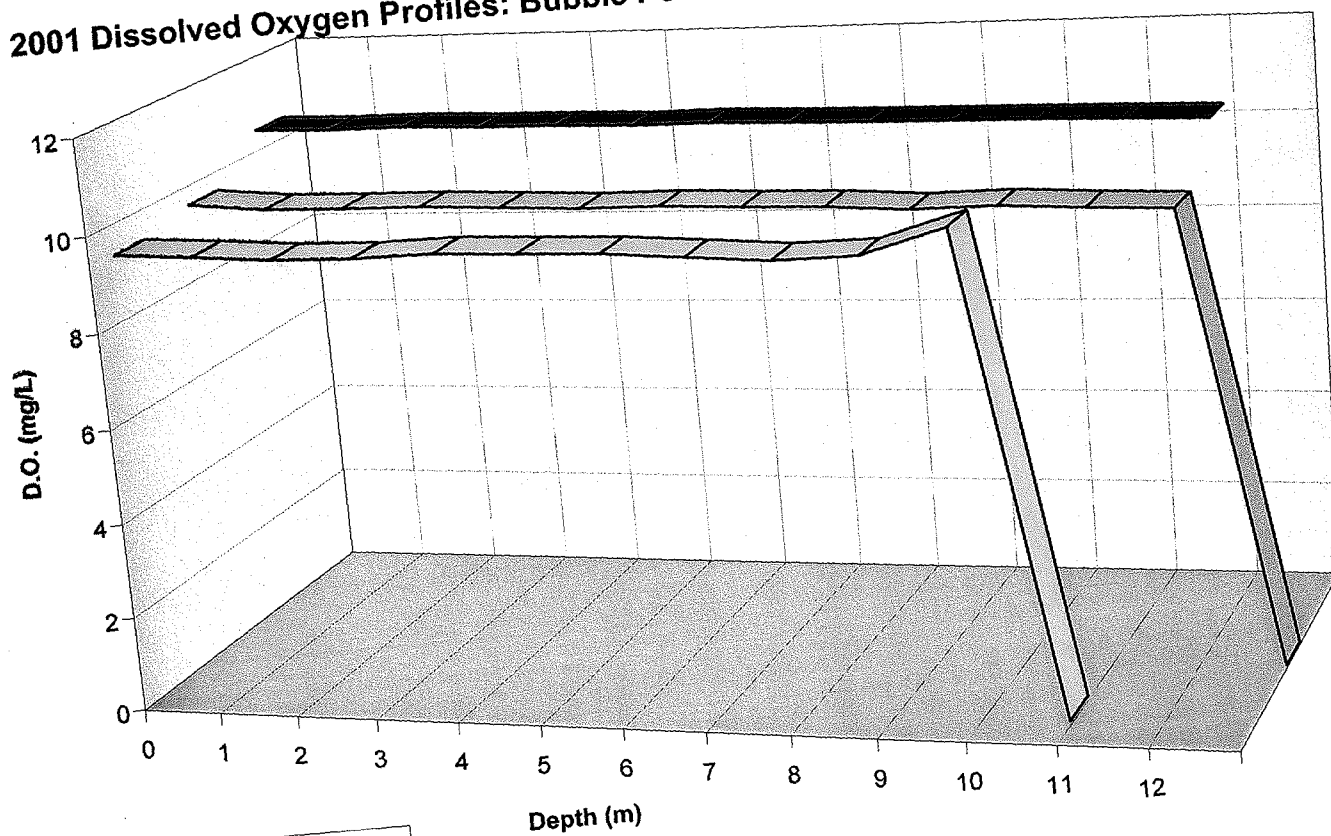
DISSOLVED OXYGEN AND TEMPERATURE GRAPHS

2001 Temperature Profiles: Bubble Pond



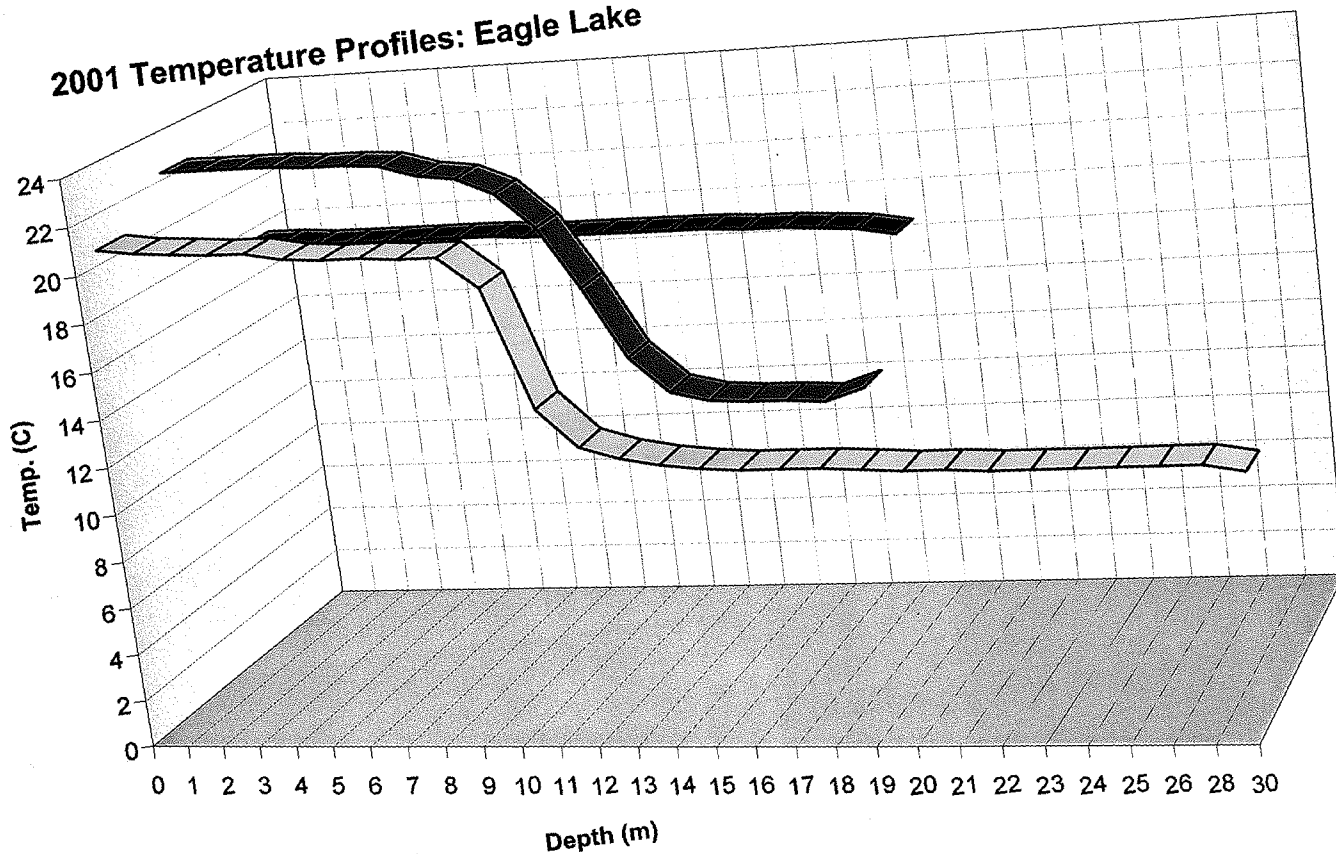
7/30/01 10/5/01 10/24/01

2001 Dissolved Oxygen Profiles: Bubble Pond



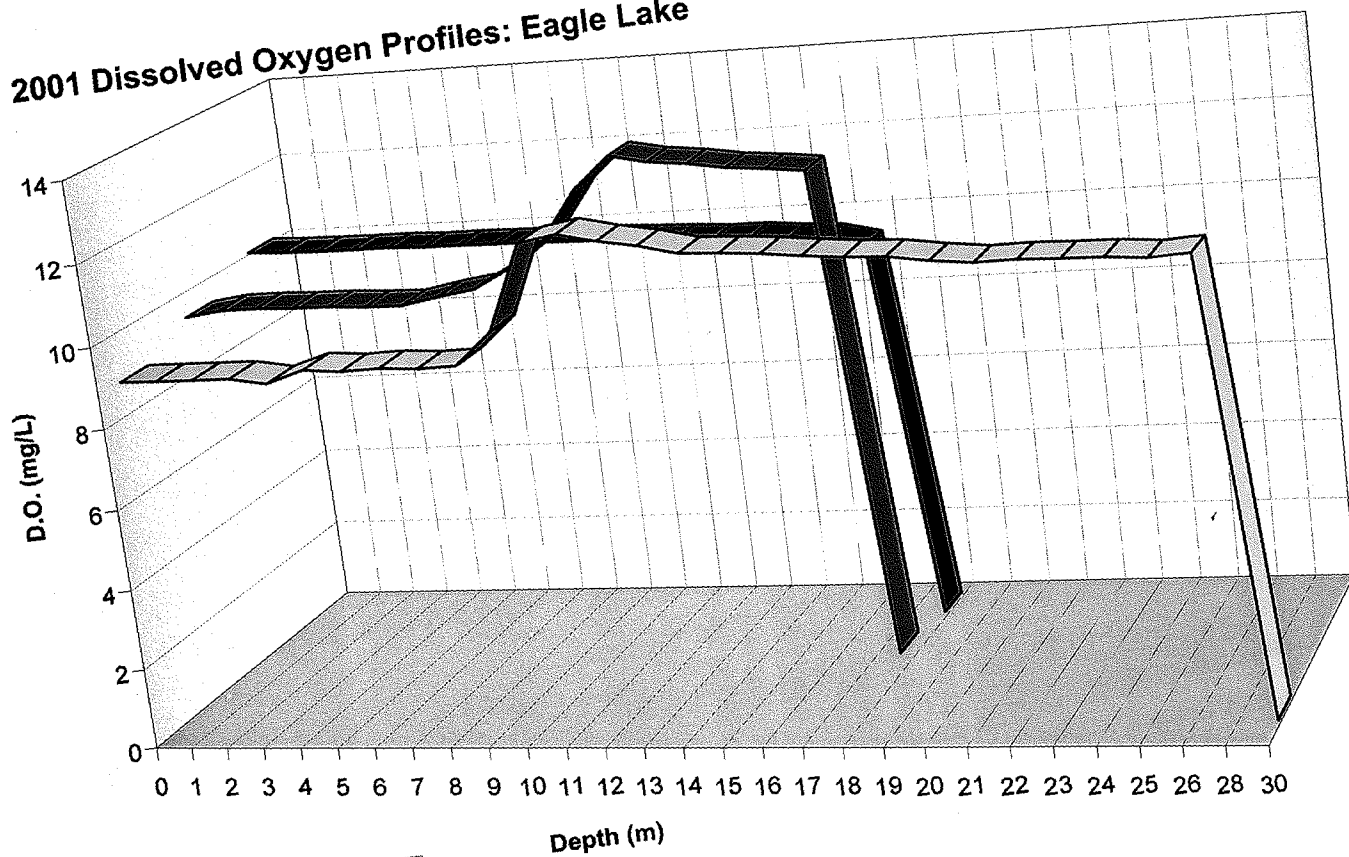
7/30/01 10/5/01 10/24/01

2001 Temperature Profiles: Eagle Lake



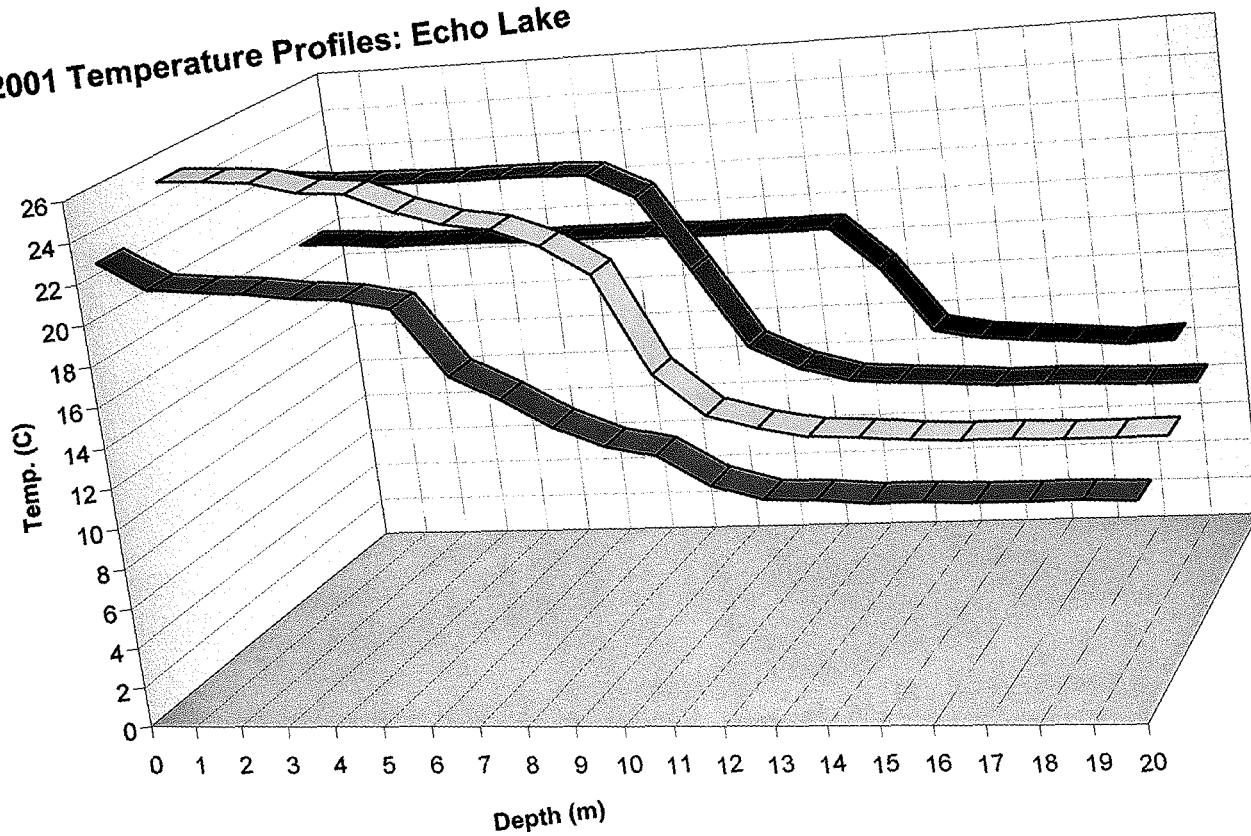
7/12/01 7/31/01 10/3/01

2001 Dissolved Oxygen Profiles: Eagle Lake

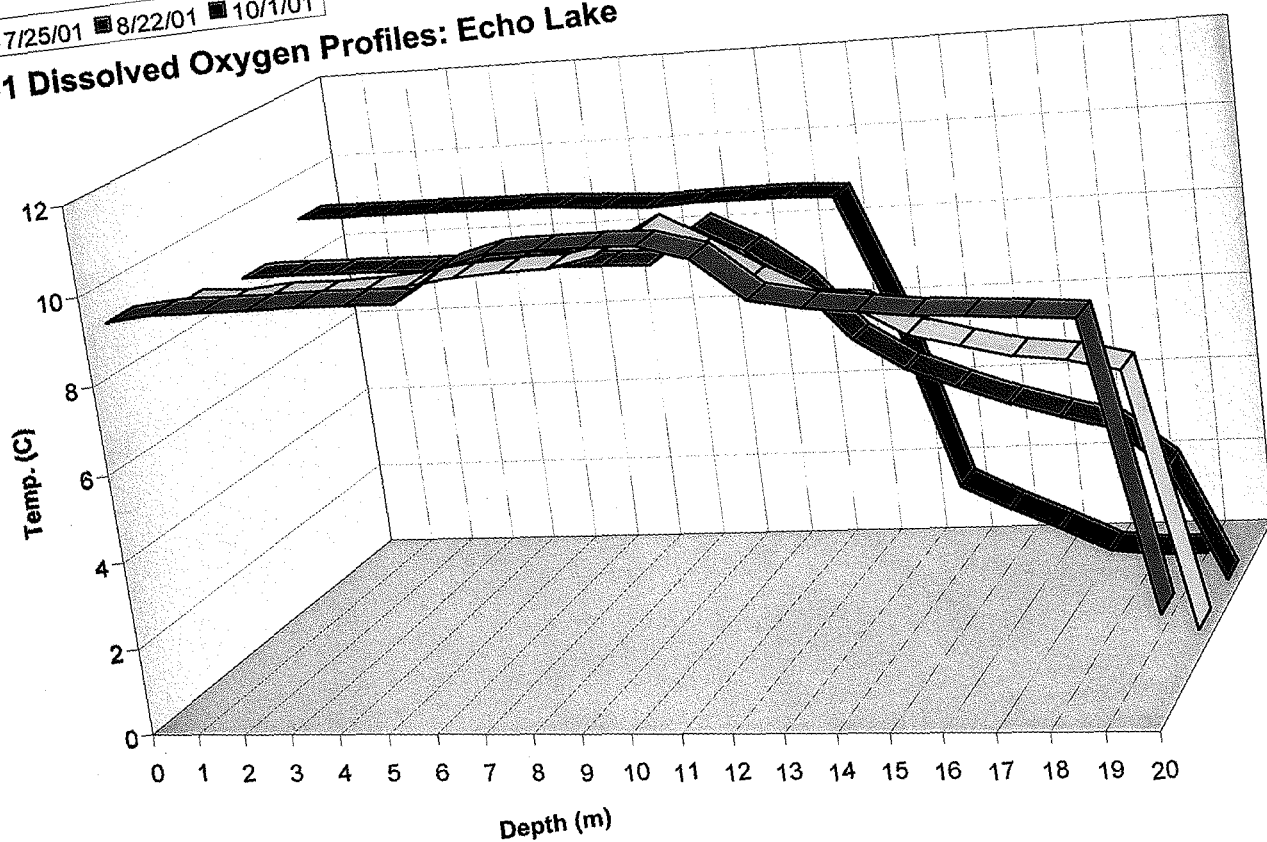


7/12/01 7/31/01 10/3/01

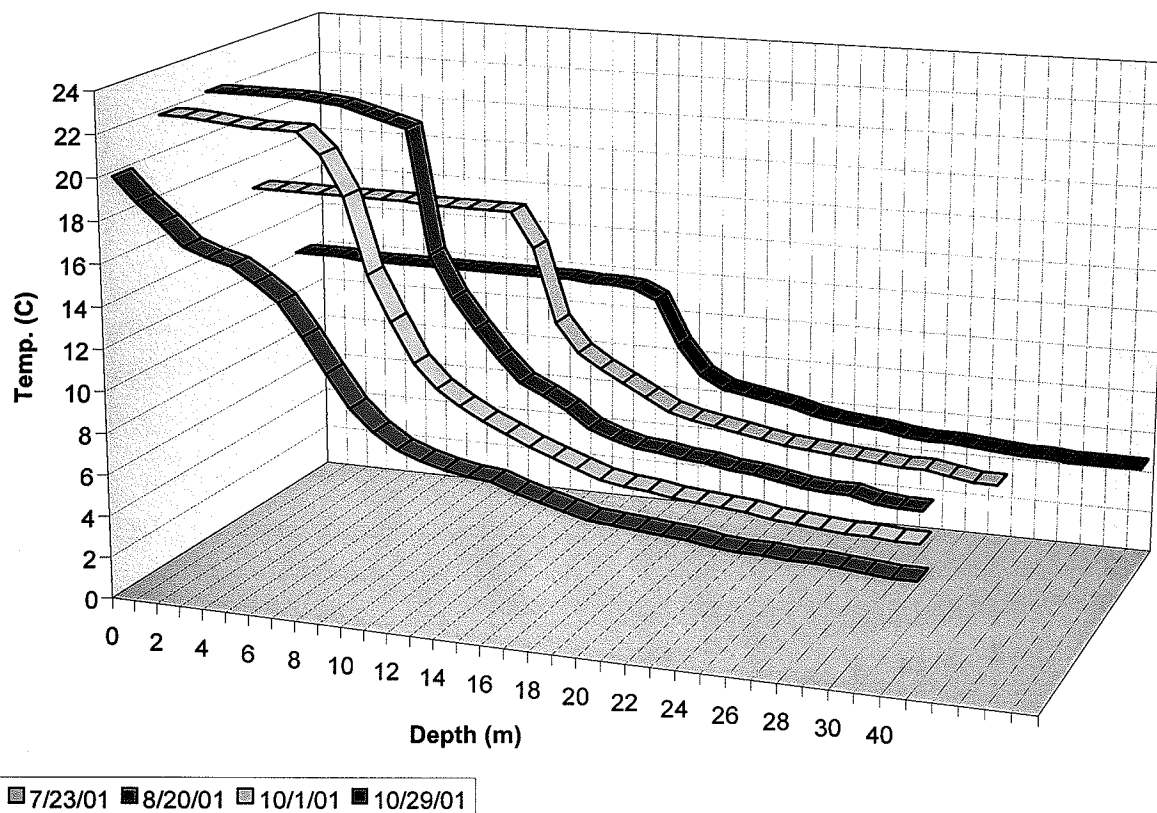
2001 Temperature Profiles: Echo Lake



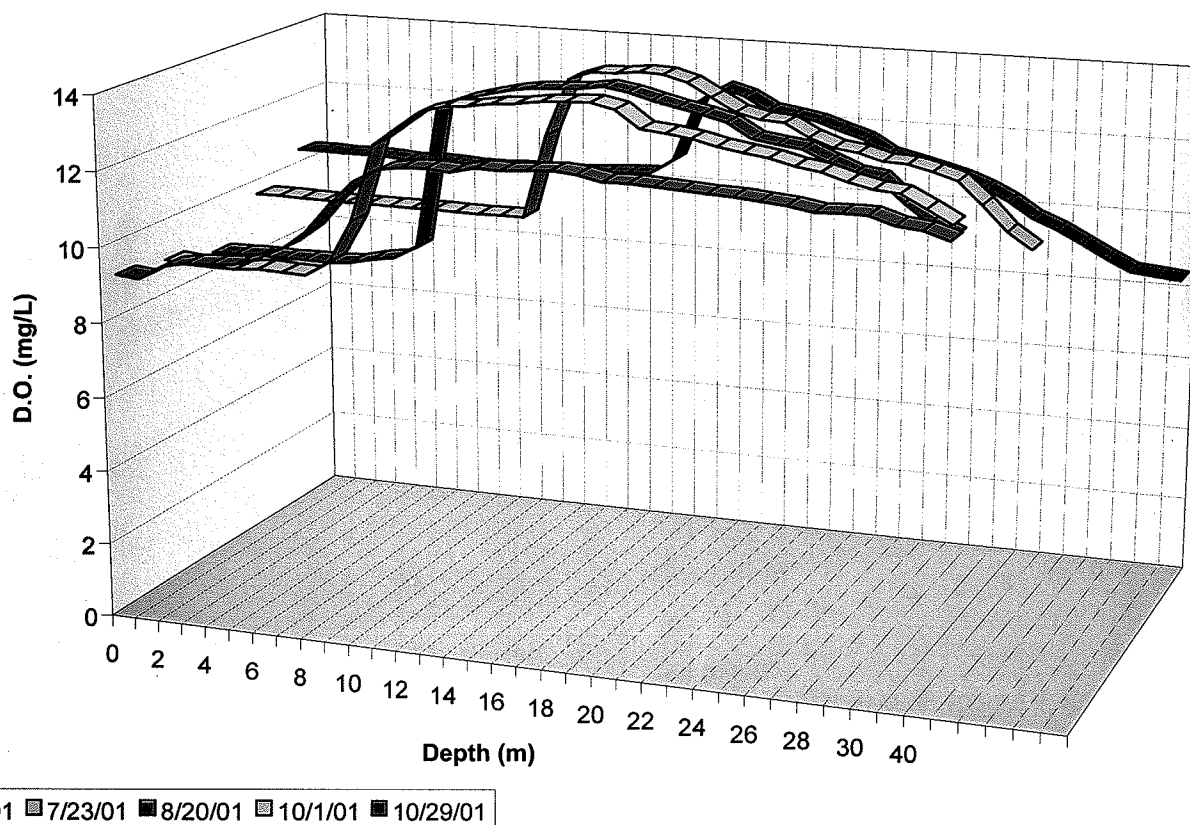
2001 Dissolved Oxygen Profiles: Echo Lake



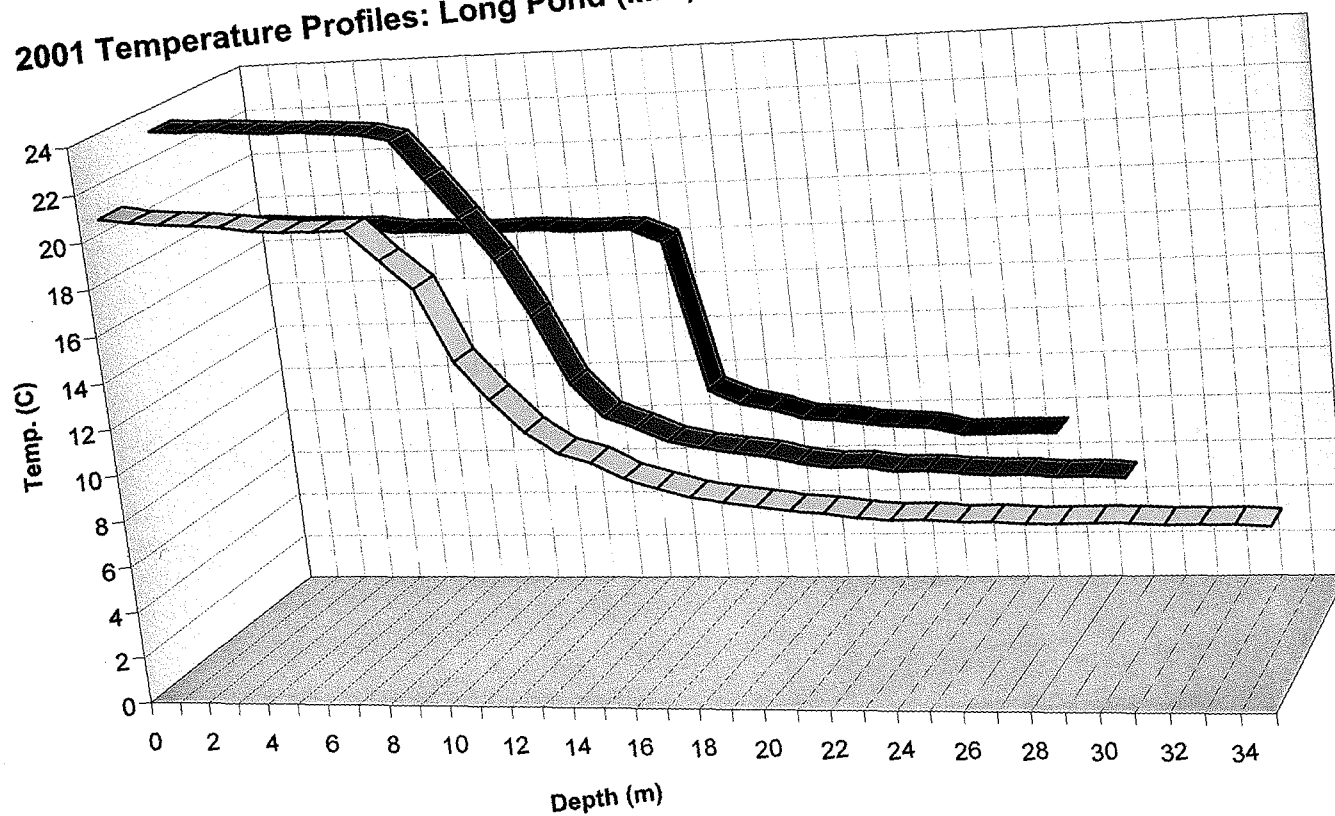
2001 Temperature Profiles: Jordan Pond



2001 Dissolved Oxygen Profiles: Jordan Pond

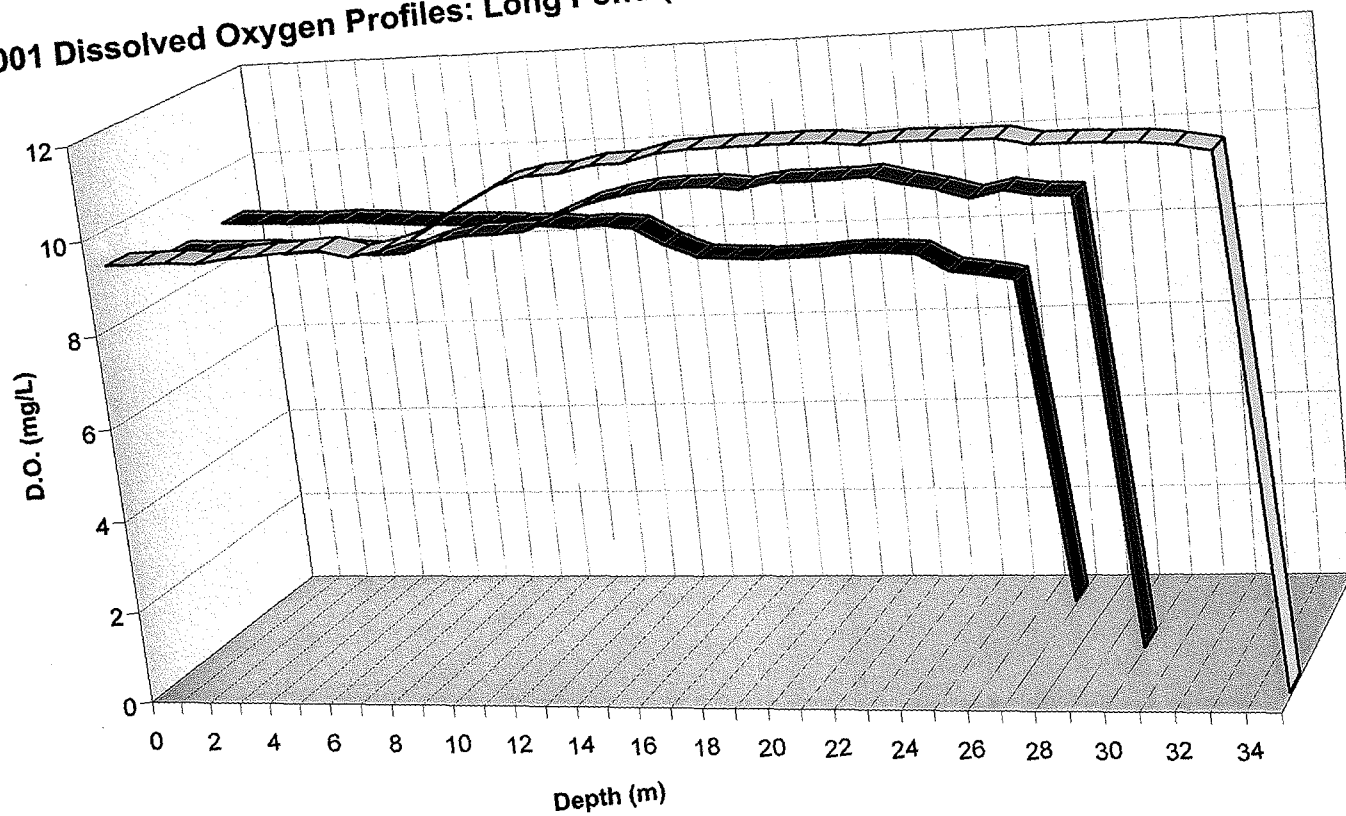


2001 Temperature Profiles: Long Pond (MDI)



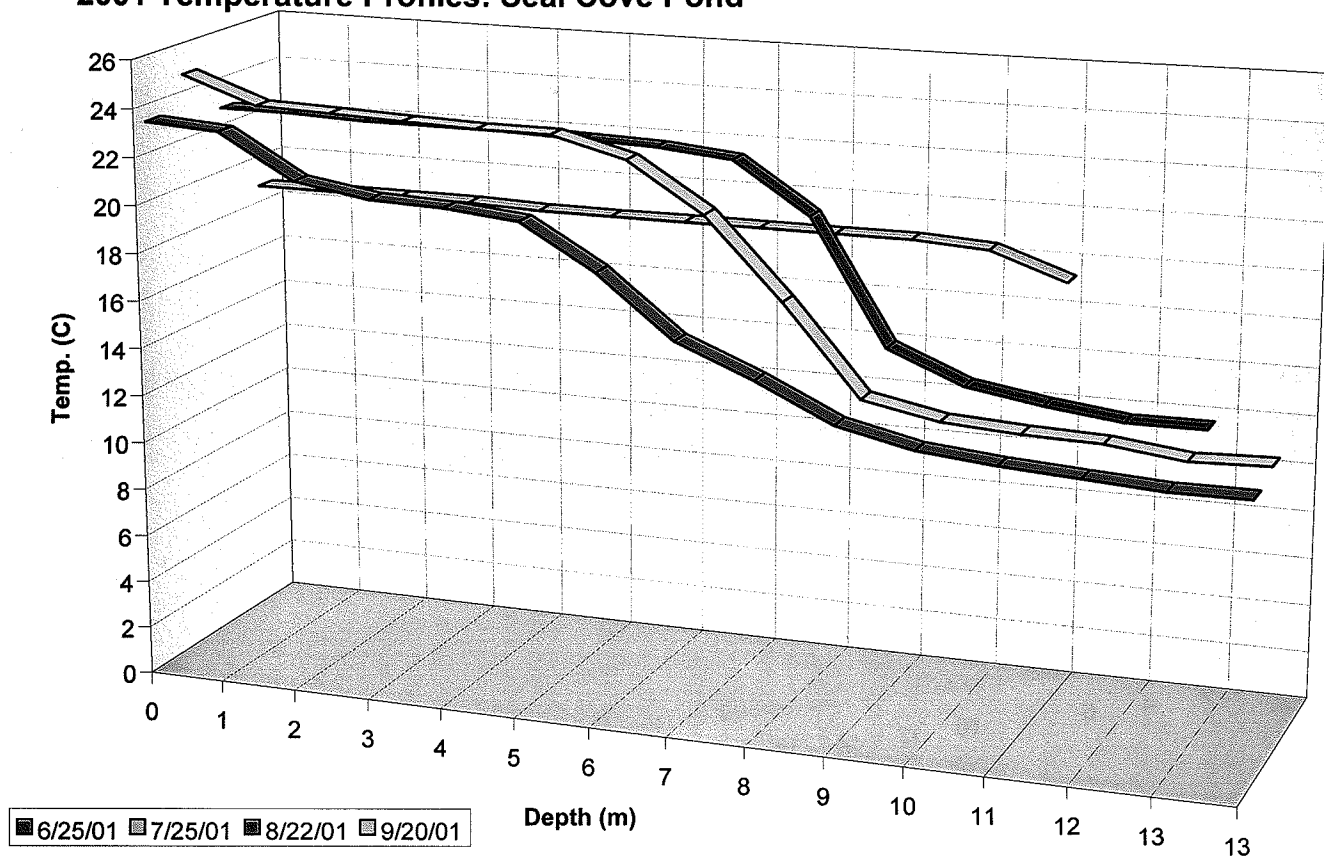
7/5/01 8/15/01 10/5/01

2001 Dissolved Oxygen Profiles: Long Pond (MDI)

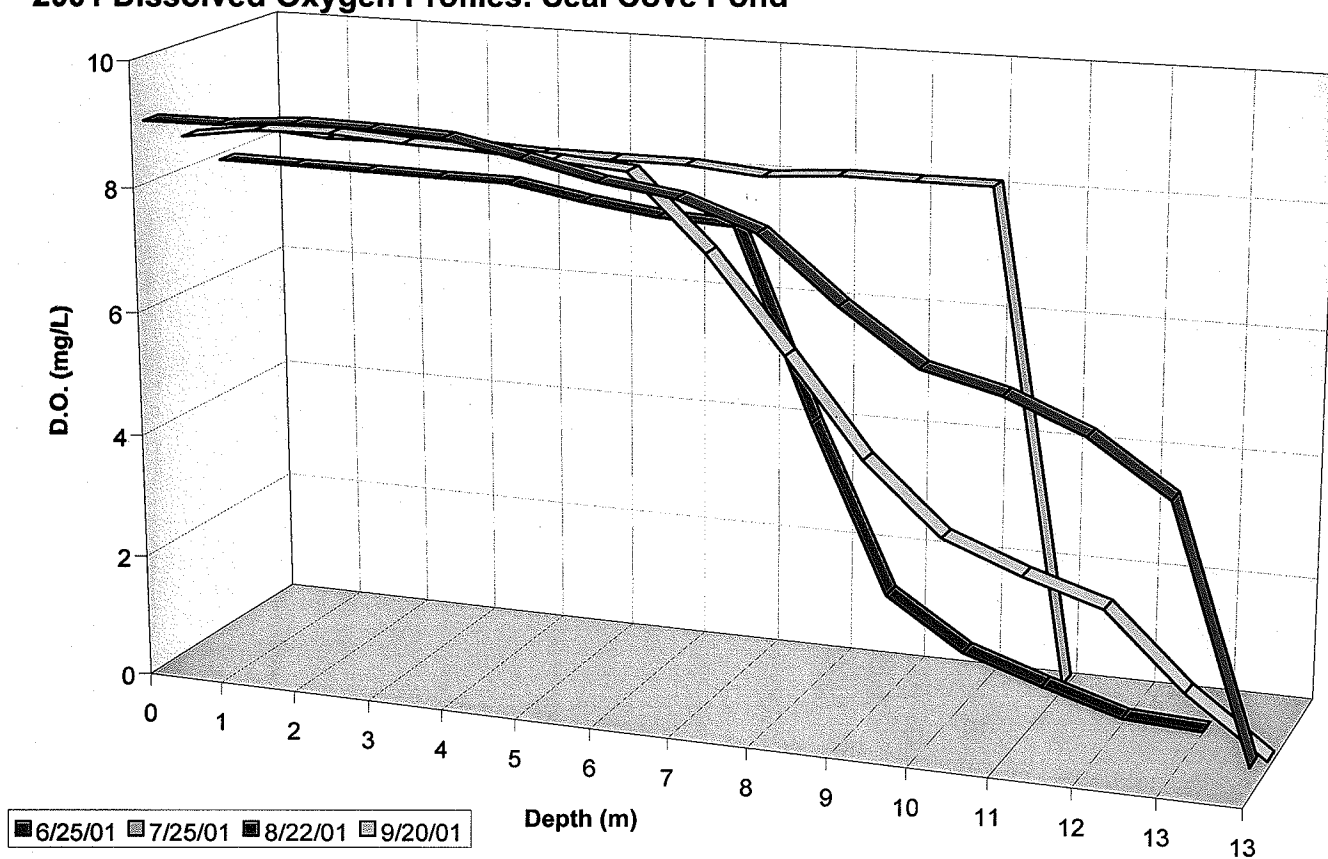


7/5/01 8/15/01 10/5/01

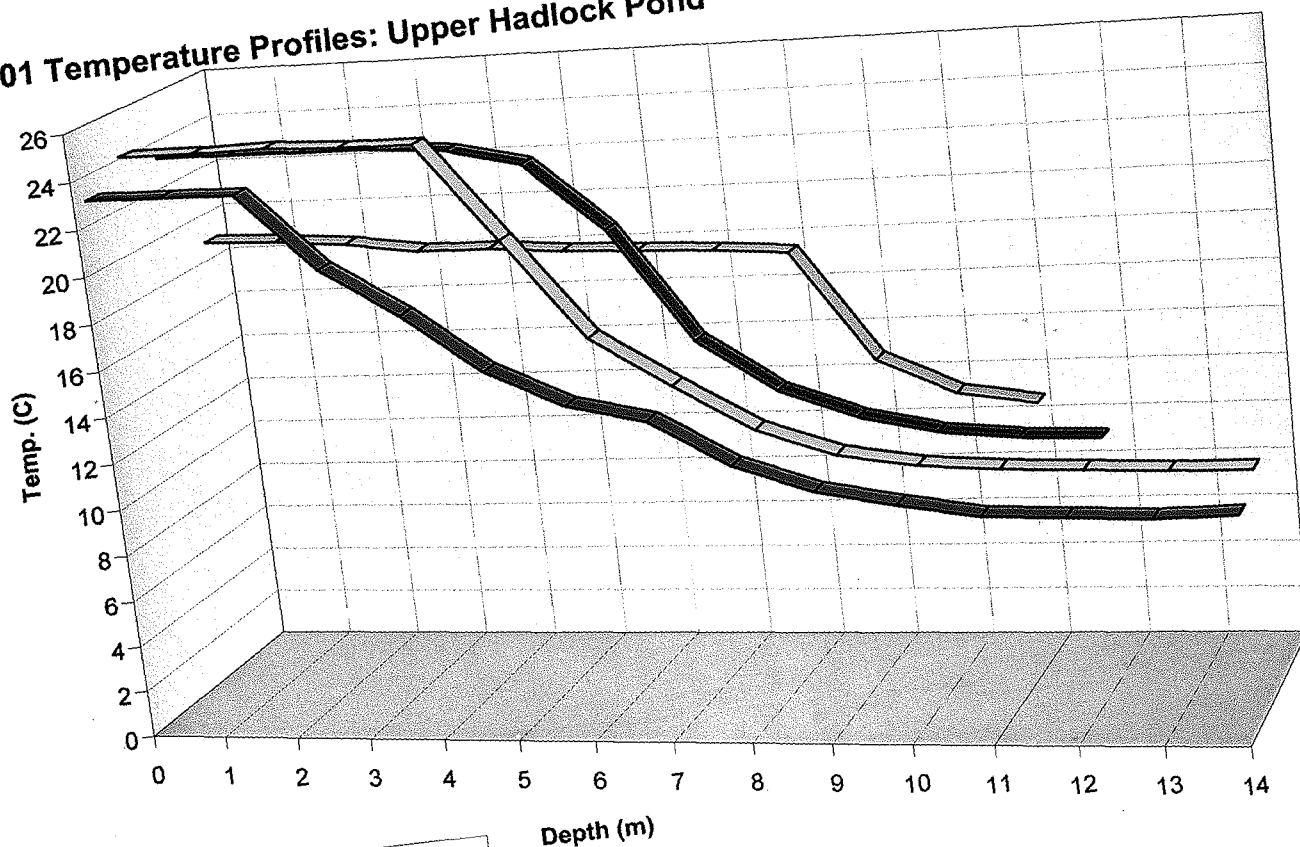
2001 Temperature Profiles: Seal Cove Pond



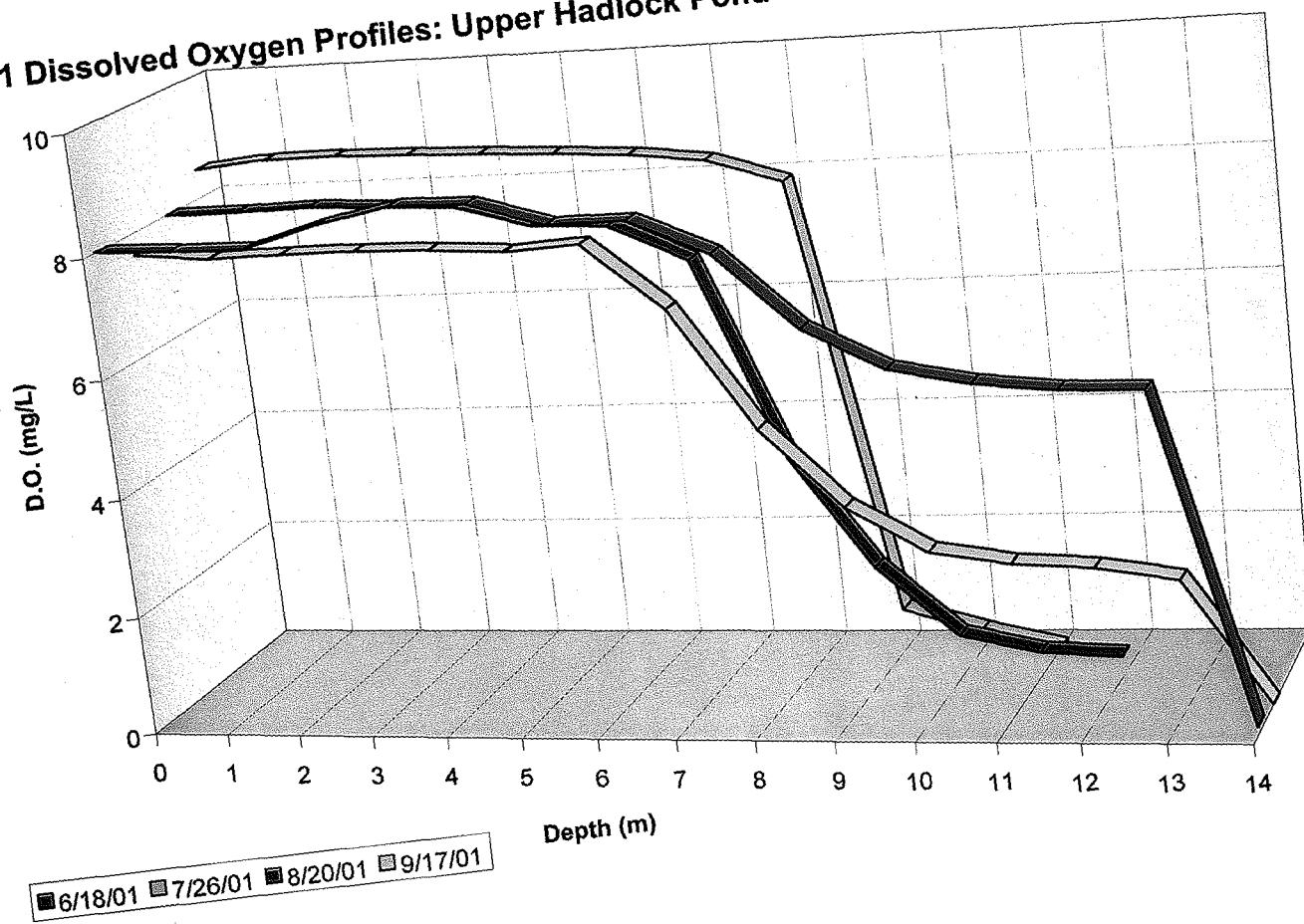
2001 Dissolved Oxygen Profiles: Seal Cove Pond



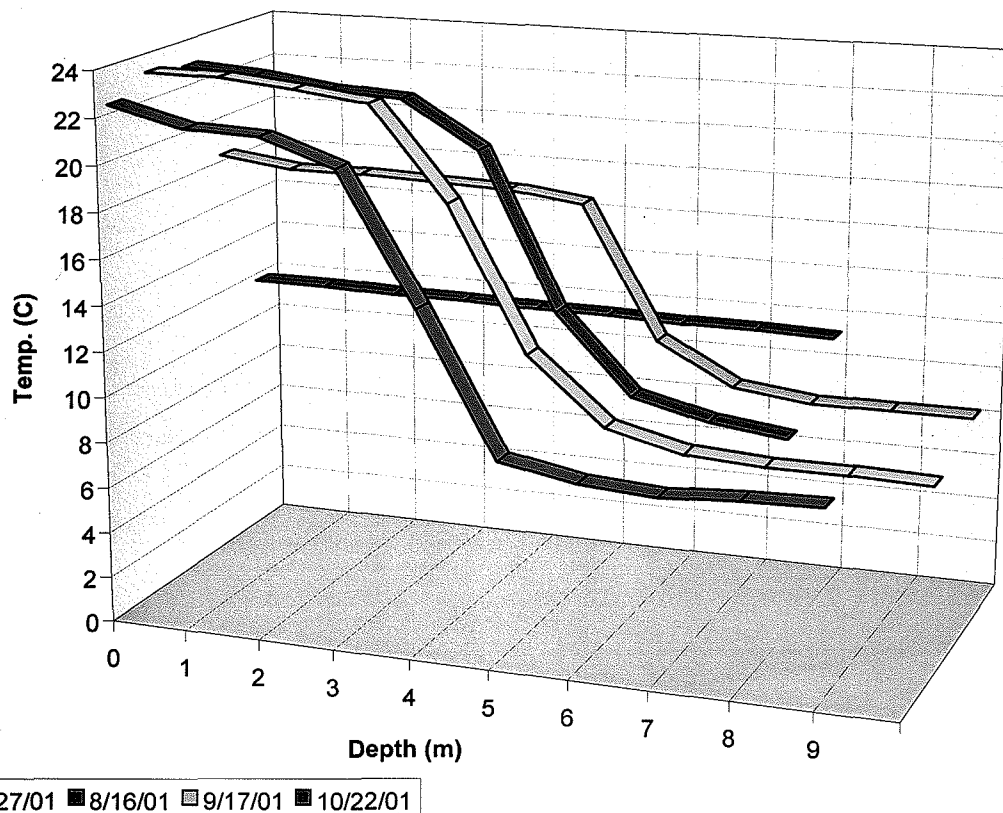
2001 Temperature Profiles: Upper Hadlock Pond



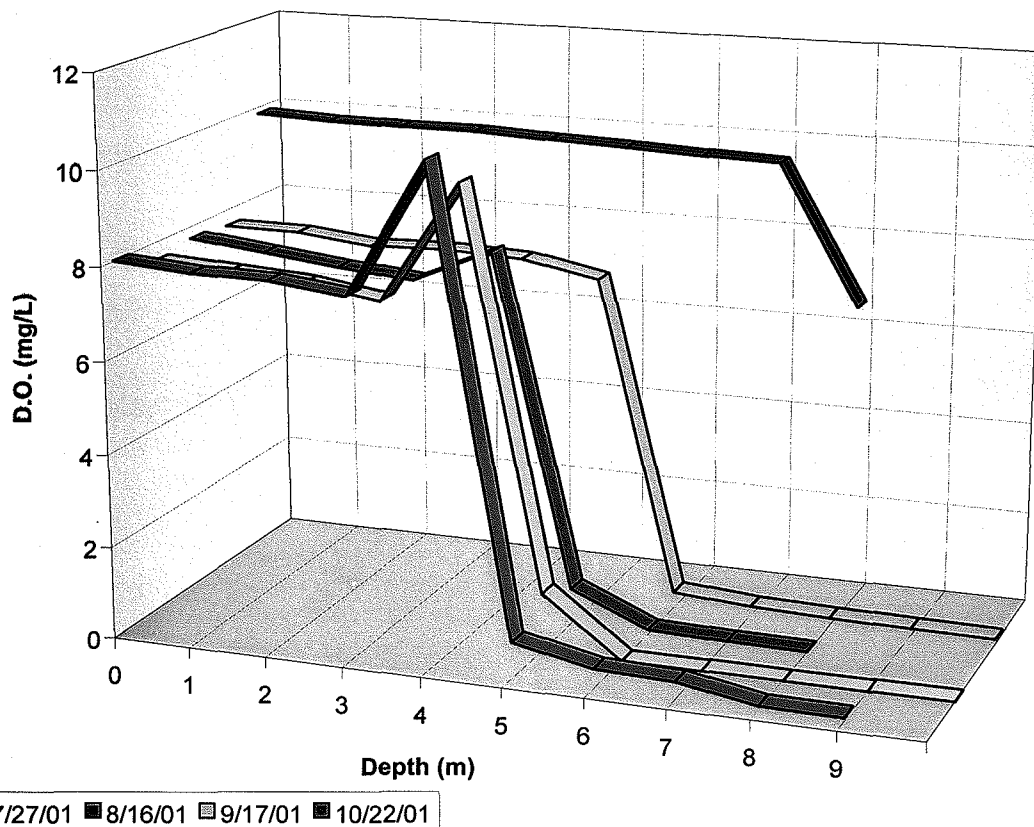
2001 Dissolved Oxygen Profiles: Upper Hadlock Pond



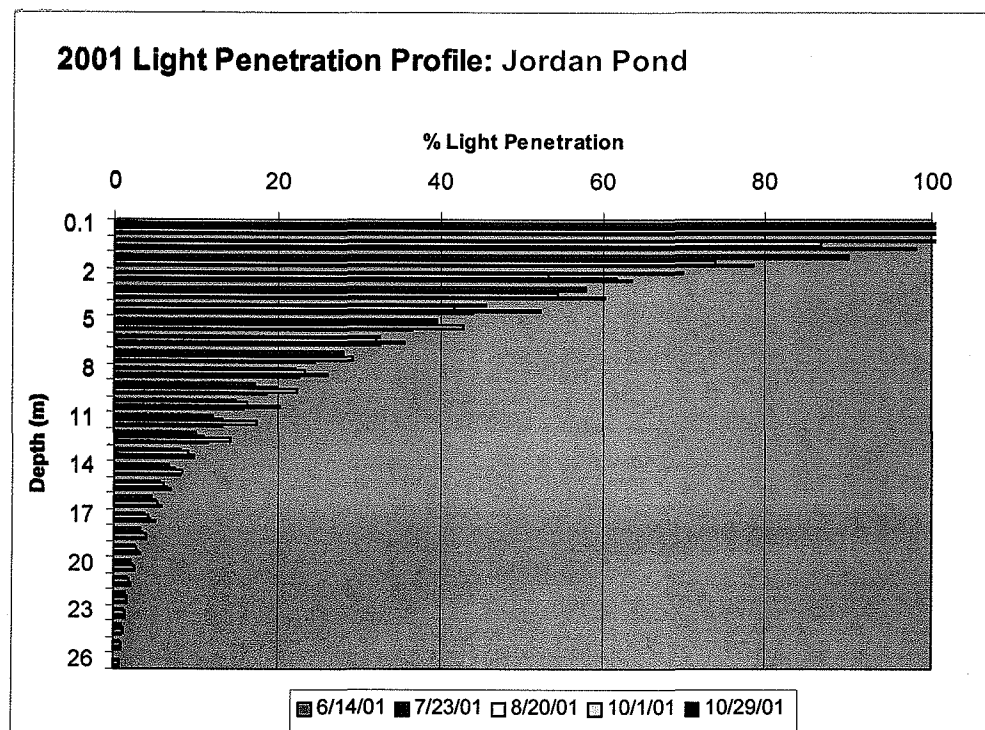
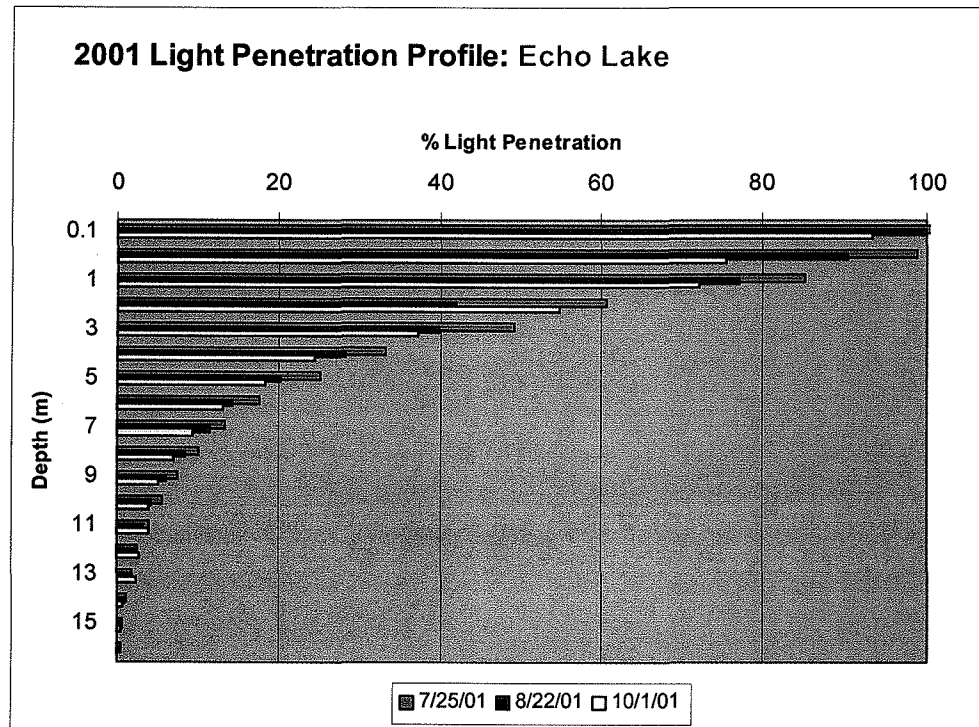
2001 Temperature Profiles: Witch Hole Pond



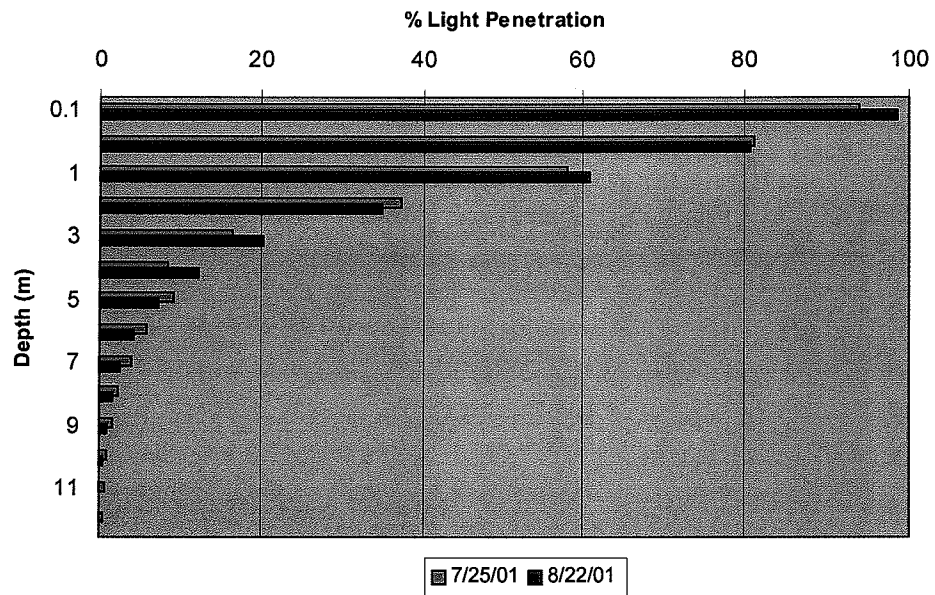
2001 Dissolved Oxygen Profiles: Witch Hole Pond



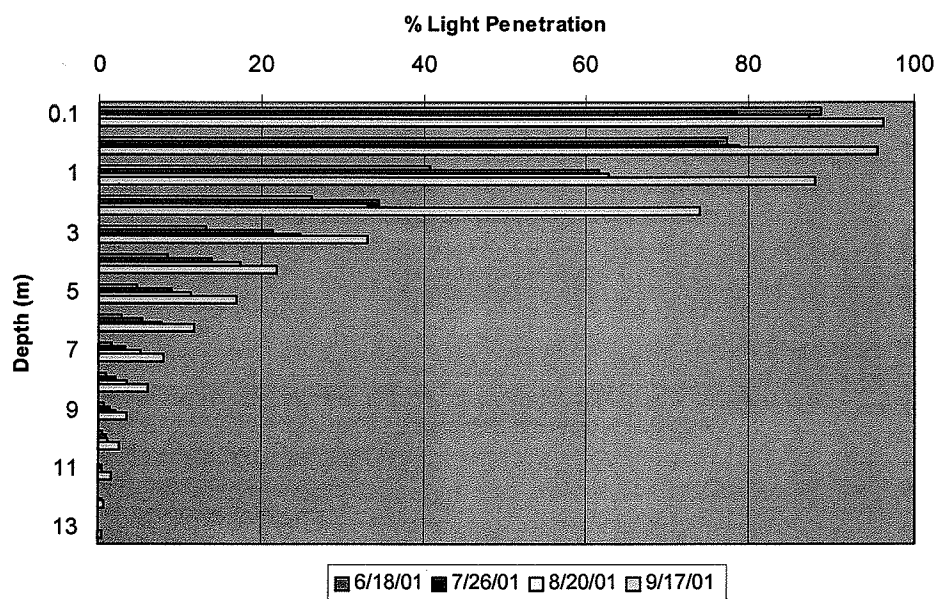
LIGHT PENETRATION PROFILE GRAPHS



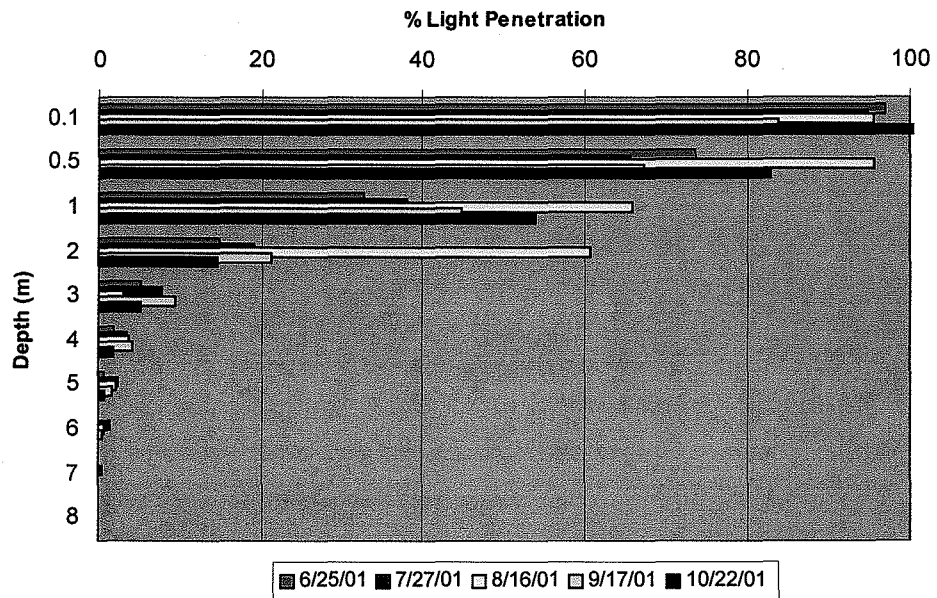
2001 Light Penetration Profile: Seal Cove Pond



2001 Light Penetration Profile: Upper Hadlock Pond



2001 Light Penetration Profile: Witch Hole Pond



APPENDIX C

Annual/seasonal precipitation summary (1982-2001)*

(in centimeters)

*Collected with Belfort recording rain gauge at Acadia National Park's McFarland Hill air quality monitoring station

Summary	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
period																				
Winter	50.6	30.23	51.2	20.02	29.87	41.17	34.01	21.54	36.09	32.87	46.97	31.01	40.94	43	36.48	40.46	60.45	39.07	33.64	21.06
Spring	29.95	64.47	49.96	27.89	34.08	24.98	24.21	43.44	35.55	42.59	19.52	38.7	50.31	36.96	46.13	37.19	37.16	21.92	46.58	17.86
Summer	30.29	21.16	34.14	34.01	32.06	20.21	23.22	24.33	33.41	31.23	28.35	16.27	18.69	14.13	31.84	18.62	27.2	12.04	17.48	14.71
Fall	26.88	59.93	20.4	35.75	33.91	49.23	54.88	44.53	46.38	40.98	30.73	45.33	42.98	54.08	38.58	25.02	27.93	51.66	31.34	15.09
Annual	122.4	193.56	142.94	111.16	139.8	128.53	133.32	142.44	153.16	142.29	121.88	148.81	144.41	148.68	153.32	115.09	146.75	134.3	128.63	

(source: National Atmospheric Deposition Program)

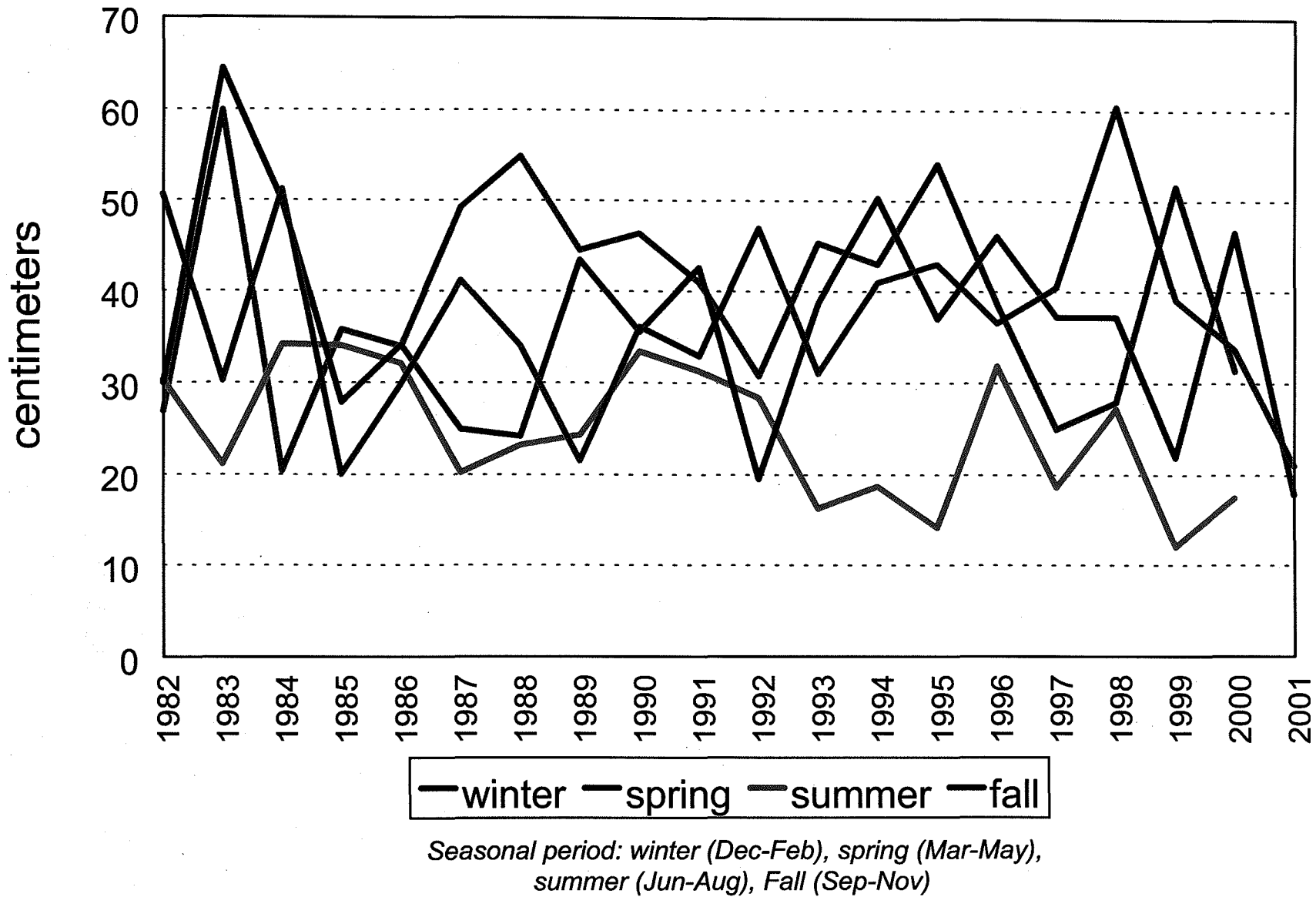
note: annual values based on Jan-Dec calendar year

seasonal period: winter (Dec-Feb), spring (Mar-May), summer (Jun-Aug), Fall (Sep-Nov)

Seasonal Precipitation Summary, 1982-2001

(in centimeters)

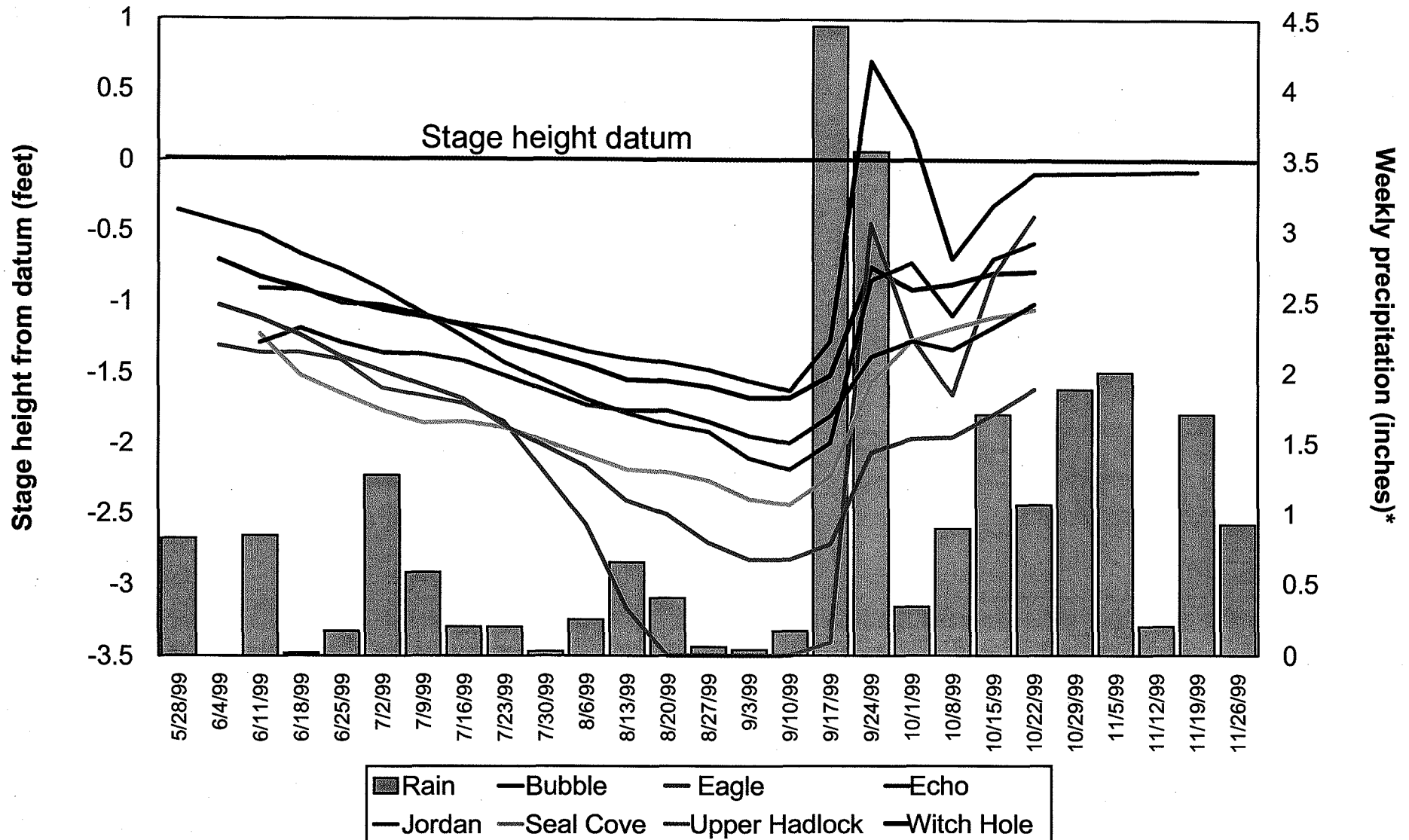
**Collected with Belfort recording rain gauge at Acadia National Park's McFarland Hill air quality monitoring station*



source: National Atmospheric Deposition Program

Weekly Lake Stage and Precipitation

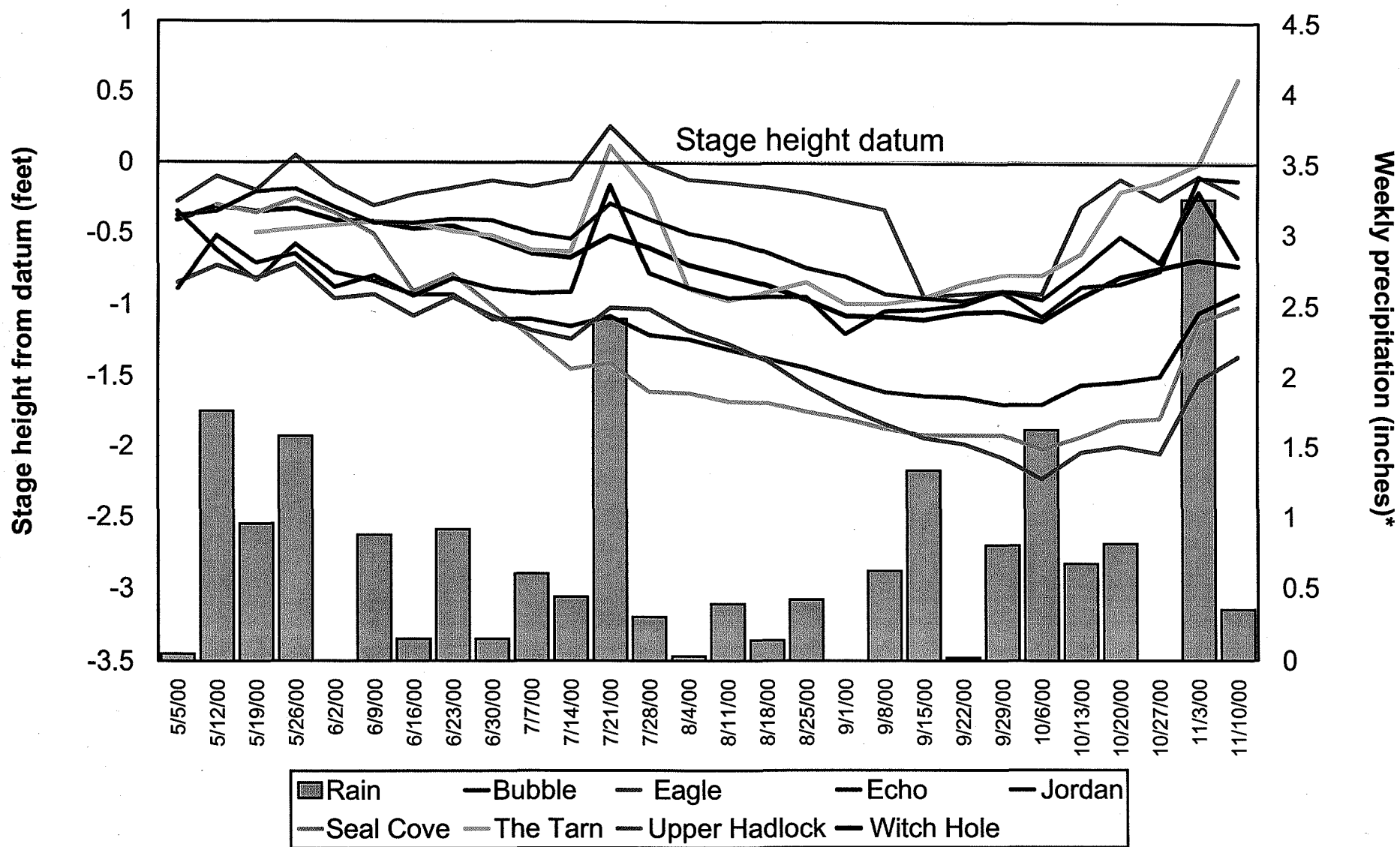
May- November 1999



*measured with Belfort rain gauge at McFarland Hill NADP site

Weekly Lake Stage and Precipitation

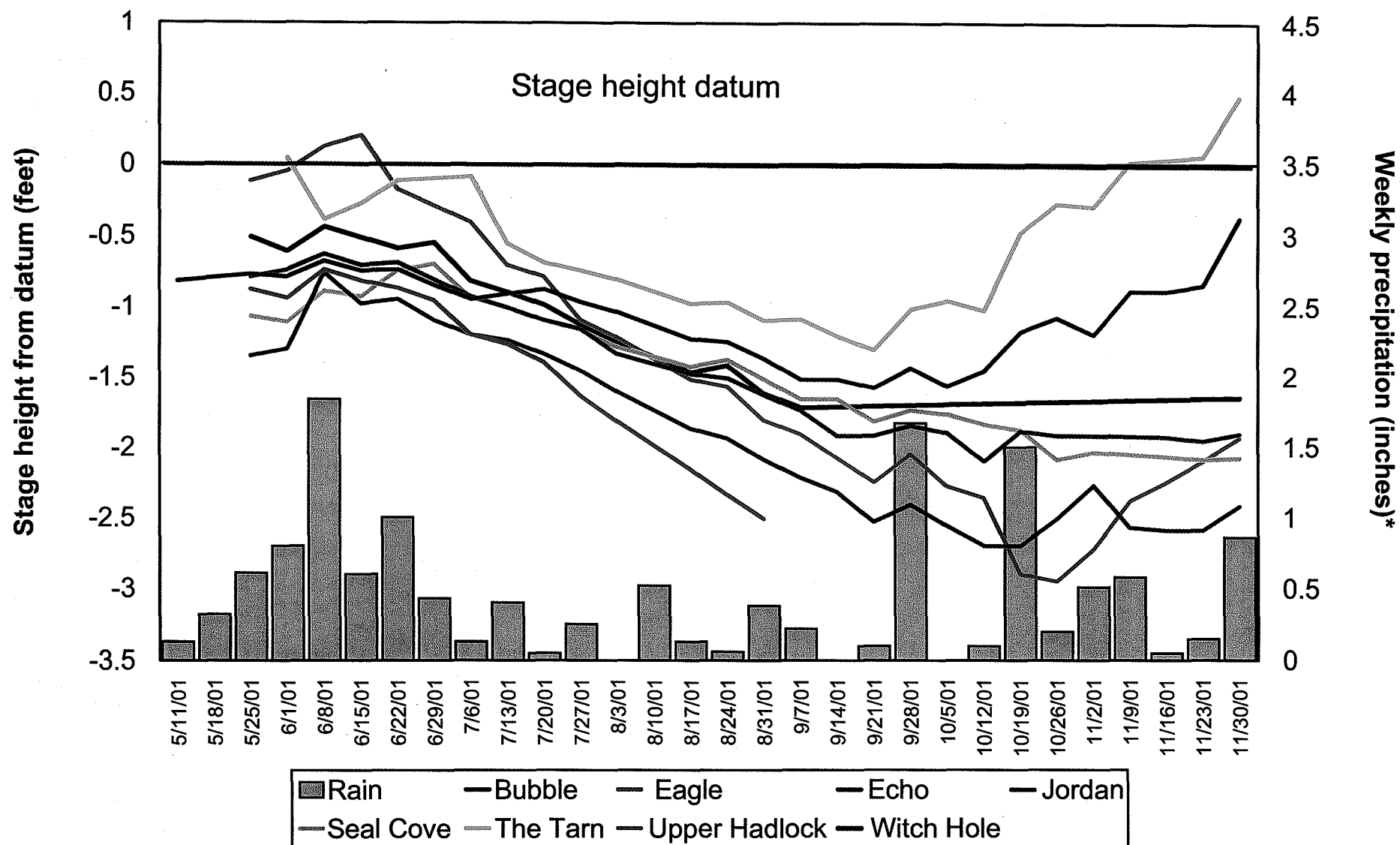
May- November 2000



*measured with Belfort rain gauge at McFarland Hill NADP site

Weekly Lake Stage and Precipitation

May- November 2001



*measured with Belfort rain gauge at McFarland Hill NADP site