Water Quality of Long, Cranberry, Buck and Round Ponds 1993 -1994

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Abstract

Long, Buck and Cranberry Ponds have very high concentrations of total phosphorus and chlorophyll a; that is, they have high levels of a nutrient that stimulates the growth of microscopic and macroscopic plants. This results in an overabundance of microscopic plant life as indicated by the exceedingly high chlorophyll levels observed. Long Pond appears to be the most productive followed by Buck Pond and then Cranberry Pond. Round Pond has relatively low chlorophyll and phosphorus levels compared to the other ponds. Round Pond does not appear to be impacted by cultural eutrophication.

Compared to nearby Lake Ontario, Lake Erie and Conesus Lake, Long, Buck and Cranberry Ponds are hypereutrophic. These results suggest that Long, Buck and Cranberry Ponds are receiving excessive amounts of nutrients from either the watershed or through auto-fertilization or both. Point and non-point sources of nutrients within the watershed should be identified through stress stream analysis (i.e. segment analysis of the stream) as a prelude to remedial action and the establishment of best management practices. The shallowness of these ponds does not preclude the problem of wind generated mixing of the phosphorus laden sediments (i.e. auto-fertilization) after any remediation.

Introduction

Round, Buck, Long and Cranberry Ponds are located along the Lake Ontario shoreline in the Town of Greece, Monroe County, New York. Along with Braddock Bay, they make up the Braddock Bay Fish and Wildlife Management Area. Considerable concern was expressed on the general "health" of the ponds by citizens in two public meetings in 1993-94. On July 21, 1993, over 100 people attended a public forum to hear presentations on what is known about the water quality and wildlife of the ponds. Although there were many opinions at the meeting regarding the management of the ponds, it appeared that the participants agreed that the four ponds and surrounding land should be managed so that people, fish and wildlife can benefit from its presence now and well in to the future.

Any management plan for these four shallow ponds should 1) ensure current and future human use, 2) ensure current and future uses by fish and wildlife, and 3) ensure that the water quality can support those uses. Very little quantitative information on the water quality of the ponds exists and results in an inability to answer some very basic questions, such as what is the current environmental health of the ponds? Are they over productive? Are they receiving an excess of nutrients? The lack of recent data on the water quality of the ponds has hindered our ability to recognize the extent of the problem; if one indeed exists. Thus, the objective of this study to was augment the limited information available on Long Pond (Makarewicz *et al.* 1990) with a yearlong study on the water chemistry of the four ponds to provide a "picture" of the current condition of the ponds and to provide a baseline or reference for future generations.

Cranberry Pond:

Cranberry Pond is located to the west of the other ponds. It has an area of approximately 240 acres (DEC 1985) and is bordered on the southwest side by a large wetland. The maximum depth of the pond is 2 meters. There are more than 60 shorefront homes, predominantly on the south shore of the pond. There are no major streams entering the pond, with the only outlet flowing from the southeast corner and discharging into Long Pond (Fig. 1).

Long Pond:

Long Pond is 2 km long and is the largest of the four ponds with a surface area of approximately 479 acres (DEC 1985). Its maximum depth is 2.5 meters and has the least amount of wetland around its perimeter. It has the greatest development of the shoreline of all the ponds with more than 100 homes on its shore. Inflow is from Black and Northrup Creeks with an outlet directly to Lake Ontario. A bathymetric map of Long Pond is presented in Fig. 2. Previous work on water quality was conducted in 1989 by Makarewicz *et al.* (1990) .

Buck Pond:

Buck Pond is surrounded on three sides by wetlands greater in size than the 175 acres (DEC 1985) of the pond itself (Fig. 1). The only access to the pond is from the northeast side which is bordered by Edgemere Drive. With a maximum depth of 1.5 meters, Buck Pond receives its inflow from Larkin Creek and discharges directly into Lake Ontario. This pond is maintained by NYSDEC as a preserve. No homes have been built on its shore.

Round Pond:

Round Pond is the smallest of the ponds and as a maximum depth of only 0.5 meters and an open water area of only 58 acres (DEC 1985). This pond is more of a wetland than an open body of water. The wetland that borders the western side of the pond is greater than three times the size of the pond itself. It receives its inflow from Round Pond Creek and it discharges directly into Lake Ontario. The pond is bordered by a few homes as well as some commercial buildings (Fig. 1).

Methods

General

Water samples were collected once a week in June and July, twice a week in August and September and once a month from October through May of 1993 and 1994. Sampling sites were chosen to be near the north end of the ponds due to the northerly discharge of each pond, adequate depth at these locations, and ease of access by canoe (Fig. 1). All water samples were taken with a 2 L Wildco Horizontal Van Dorn Sampler. Samples were taken at approximately half the depth (Buck - ~0.75m, Cranberry - ~2m, Long - ~1.75m, Round - ~0.25m) of the water column in each pond.

Water Chemistry:

All sample bottles were pre-coded so as to ensure exact identification of a particular sample. All filtration units and other processing apparatus were cleaned on a routine basis with phosphate-free RBS. Containers were rinsed with sample water prior to addition of the sample being collected. Sample water for dissolved nitrate+nitrite analysis was filtered immediately with 0.45 µm MSI Magna Nylon membrane filters and frozen if analysis was not to take place within two days. Dissolved oxygen and chlorophyll-a were analyzed within four hours of collection. In general, all analysis followed Standard Methods for the Analysis of Water and Wastewater (APHA 1992) or as otherwise stated.

Total Phosphorus: The automated colorimetric ascorbic acid method (APHA 1992) was used with a Technicon Autoanalyser, following the persulfate digestion procedure.

Chlorophyll-a: Chlorophyll a was measured by the fluorometric method of Wetzel and Likens (1991).

Specific Conductance and Temperature: A YSI 3000 TLC meter was used to measure conductivity and temperature in the field. Conductivity results were corrected to 25°C.

Dissolved Oxygen: Dissolved oxygen analyses followed the Azide Modified Winkler Method. Samples were fixed in the field and transported to the laboratory for final analysis (APHA 1992).

Sodium: Sodium levels were analyzed using atomic absorption spectrophotometry (Perkin-Elmer 3030)(APHA 1992).

Nitrates + Nitrites: Nitrate + nitrite nitrogen was analyzed by the automated cadmium reduction method (APHA 1992).

Quality Control

Multiple sample control charts (APHA 1992) were constructed for each parameter analyzed, except oxygen and conductivity. Good laboratory practices were followed for all analysis, along with a blind external quality control exercise. This biannual check uses reference solutions obtained from the New York State ELAP program. Results of the semiannual ELAP Non-Potable Water Chemistry Proficiency Test are presented in Table 1.

Results and Discussion

Temperature

A temperature profile was taken at one foot increments in each pond for each sample date. The vertical profile was averaged to find a mean pond temperature. Temperatures between the ponds paralleled each other very closely over the sample period. The ponds do not thermally stratify. The highest temperatures were recorded on July 21 where the ponds ranged between 24.7° and 26.6°C, with the lowest occurring in December and January (Fig. 4). The mean annual temperatures were as follows: Round Pond (11.3 °C), Buck Pond (11.7 °C), Long Pond (11.3 °C) and Cranberry Pond (11.7°C). The complete data set are presented in Appendix A.

Secchi Disk Transparency

Secchi disk depth is a measurement of transparency of water. Transparency is a function of the reflection of light from the surface of the disk and is therefore affected by the absorption characteristics of both the water and the dissolved and particulate matter contained in it. Thus, the more particles in the water the lower the transparency and the lower the secchi disk reading. Secchi disk readings for the ponds are all less than one meter (Table 2). These are extremely low values. For example, secchi disk readings in nearby Lake Ontario are generally in the 3 to 5m range and 2 to 4m in Conesus Lake. The extremely low secchi disk transparencies of Cranberry, Long and Buck Ponds is due to the over abundance of phytoplankton in these ponds. The secchi disk reading for Round Pond represent the depth of the pond; that is, the disk was visible sitting on the sediment (Appendix B).

Conductivity

Round Pond had the highest mean conductivity (699 µmhos/cm) followed by Buck (611 µmhos/cm), Long (564 µmhos/cm) and Cranberry (554 µmhos/cm) ponds. Mean annual values are listed in Table 2. Appendix C lists the entire data set.

Dissolved Oxygen

Oxygen solubility in water increases as the temperature decreases. This is demonstrated in the Greece ponds over the sampling period with an inverse correlation between temperature and dissolved oxygen (Figs. 3 &4). Mean annual dissolved oxygen concentrations indicate that the ponds are well oxygenated and the seasonal data indicate that they do not become anaerobic (Table 2, Fig. 3). The range of oxygen values observed for all the ponds range from 5 to 16 mg/L (Appendix D).

Sodium

Sodium levels would be expected to fluctuate between the seasons due to deicing salt usage and subsequent surface runoff. Buck, Round and Long Ponds all showed a marked increase during the winter months (Figure 5). Cranberry Pond maintained an almost constant sodium concentration over the sample period, with only slight changes during the winter months. This is probably due to the fact that no streams draining nearby roads flow into Cranberry Pond. Data are listed in Appendix E.

Total Phosphorus

Phosphorus is a nutrient that is generally considered the limiting factor to phytoplankton and macrophyte growth in aquatic systems. In freshwater systems phosphorus is usually responsible for the overproduction and eutrophication. Three out of four of the Greece ponds contain high concentrations of phosphorus. Total phosphorus concentrations in Long Pond were exceptionally high (mean: 168.1 μg P/L; range: 58.7 - 414.5 μg P/L) followed by Buck Pond (mean: 94.9 μg P/L; range: 24.5 - 241.0 μg P/L), Cranberry Pond (mean: 81.2 μg P/L; range: 34.8 - 427.0 μg P/L), and Round Pond (mean: 44.4 μg P/L; range: 20.6 - 124.1 μg P/L) (Table 2) (Appendix F). As a point of reference, these values are very high compared to total phosphorus concentrations in nearby Lake Ontario (13.0 μg P/L), Lake Erie (10.5 μg P/L) and Conesus Lake (19.8 μg P/L). Seasonally, total phosphorus was lowest in the winter and peaked in the summer in the ponds except in Round Pond where total phosphorus was slightly higher in the winter than the rest of the year (Fig. 6). Total phosphorus concentration did not increase from 1989 (Makarewicz et al. 1990) to 1994 ($P < 0.05$) in Long Pond (Fig. 7).

Nitrate and Nitrite

Nitrogen is often considered to be the second most limiting factor in aquatic ecosystems. These nutrients are often leached into a body of water from fertilized lawns or discharged from sewage treatment plants. Often, nitrate is completely removed from a lake because of uptake by plants and thus becomes limiting. This phenomenon generally occurs when phosphorus is present in excess of what plants require. Thus nitrate is present in P-limited lakes in the spring and is removed from the water column by the summer because of uptake by increased primary production of plants stimulated by excess phosphorus in the water. In the fall, when primary production of the pond slows, nitrate and nitrite quantities are consumed at a lower rate, and the levels become detectable (detection limit = 0.02 mg N/L) in the water column again. This is what essentially happens in the Greece Ponds with the exception of Round Pond. Over the sample period, Round Pond maintained detectable nitrate + nitrite levels (Fig. 8). In the other three ponds, nitrate+nitrite was present during the fall, winter and spring, but was not present in the summer (Fig. 8) (Appendix G). The appearance of nitrogen-fixing blue-green algae in the summer in these ponds is related to the lost of nitrate in the water column and ultimately to the excess of phosphorus in the system.

Chlorophyll a

Chlorophyll a provides an estimation of abundance of phytoplankton in bodies of water. If phosphorus is the limiting factor of phytoplankton growth, abundance of phytoplankton or concentrations of chlorophyll should be higher in those ponds with greater levels of phosphorus. Long Pond has the highest mean annual phosphorus concentration and should and does have the highest annual chlorophyll level (122 μg/L) (Table 2). It follows that Buck, Cranberry and Round Ponds have high but decreasing levels of chlorophyll that correlates with decreasing mean monthly phsophorus concentration (Fig. 9). Buck Pond had the second highest chlorophyll a level with a mean of 103.7 μg/L (range: 5.2 - 436.5 μg/L) followed by Cranberry Pond (mean = 93.4 μg/L; range: 17.0 - 126.5 μg/L) and Round Pond (mean = 6.1 μg/L; range: 1.9 - 18.9 μg/L) (Table 2)(Appendix H). Chlorophyll is highest in the summer and lowest in the winter (Fig. 10). The chlorophyll values for Long Pond, Cranberry Pond and Buck Pond are very high.

As a point of reference, these values are very high compared to mean summer total chlorophyll concentrations in nearby Lake Ontario (4.3 μg/L, 1985-87), Lake Erie (7.6 μg/L, 1985-87) and Conesus Lake (5.6 μg/L, 1985,88,91,93). There was not a significant difference ($P > 0.05$) between chlorophyll levels from the 1988-89 and 1993-94 in Long Pond (Fig. 11).

What is the Environmental Status of the Ponds?

Eutrophic lakes contain an overabundance of living organisms. This overabundance of organisms is caused by an excess of limiting nutrients, such as phosphorus from the watershed and sediments (auto-fertilization) that initially stimulate the production of plants. This process is accelerated by human activities such as the inappropriate use of fertilizer in the watershed and effluent discharge from sewage treatment plants into streams feeding the Lakes. Long, Buck and Cranberry Ponds have very high concentrations of total phosphorus and chlorophyll a; that is, they have high levels of a nutrient that stimulates the growth of microscopic and macroscopic plants. This results in an overabundance of microscopic plant life as indicated by the exceedingly high chlorophyll levels observed. Long Pond appears to be the most productive followed by Buck and then Cranberry Pond. Round Pond has a relatively low chlorophyll and phosphorus level compared to the other ponds. Round Pond does not appear to be impacted by cultural eutrophication.

Compared to nearby Lake Ontario, Lake Erie and Conesus Lake, Long, Buck and Cranberry Ponds are hypereutrophic. Similarly, the classification of lakes based on phosphorus described by Wetzel (1983) also suggest that these three ponds are hypereutrophic (Table 3). Considering the phosphorus loading to Long Pond and the summer chlorophyll levels and comparing these to other lakes, including Irondequoit Bay, Makarewicz *et al.* (1990) had similarly concluded that Long Pond was very productive. These results suggest that Long, Buck and Cranberry Ponds are receiving excessive amounts of nutrients from either the watershed or through auto-fertilization or both. Point and non-point sources of nutrients within the watersheds should be identified through stress stream analysis (i.e. segment analysis of the stream) (Makarewicz 1993) as a prelude to remedial action and the establishment of best management practices. The shallowness of these ponds does not preclude the problem of wind generated mixing of the phosphorus laden sediments (i.e. auto-fertilization) after any remediation. However, even though nearby Round Pond is shallow, its phosphorus and chlorophyll were low throughout the year suggesting that wind-generated phosphorus from the sediment was not playing a major role in the function of this pond. Since Round Pond does receive a high loading of nutrients during precipitation events Makarewicz (1989), the question arises as to why Round Pond has a fairly low phosphorus and concentration. We do not know and it was beyond this study to determine why. However, it may be related to the large wetland that Round Pond Creek has to pass through prior to reaching the Pond itself. The macrophytes may serve to remove nutrients from the water.

Literature Cited

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Table 1. Results of the semi-annual ELAP Non-Potable Water Chemistry Proficiency Test, January 1994. Score definition: 4 (Highest) = satisfactory, 3 = marginal.

Analyte	Mean/Target	Result	Score
Residue			
Solids, Total Suspended	58.2 mg/L	59.4 mg/L	4
Solids, Total Suspended	30.4 mg/L	31.3 mg/L	4
Hydrogen Ion (pH)			
Hydrogen Ion (pH)	6.00	5.97	4
Hydrogen Ion (pH)	3.02	3.01	4
Organic Nutrients			
Kjeldahl Nitrogen, Total	7.28 mg/L	7.91 mg/L	4
Kjeldahl Nitrogen, Total	4.61 mg/L	5.60 mg/L	3
Phosphorus, Total	0.8 mg/L	0.8 mg/L	4
Phosphorus, Total	4.3 mg/L	4.3 mg/L	4
Total Alkalinity			
Alkalinity	59.3 mg/L $CaCO_3$	61.1 mg/L $CaCO_3$	4
Alkalinity	482.0 mg/L $CaCO_3$	486.0 mg/L $CaCO_3$	4
Inorganic Nutrients			
Nitrate (as N)	3.45 mg/L as N	3.67 mg/L as N	4
Nitrate (as N)	6.36 mg/L as N	6.24 mg/L as N	4
Orthophosphate (as P)	3.4 mg/L as P	3.4 mg/L as P	4
Orthophosphate (as P)	4.7 mg/L as P	4.7 mg/L as P	4
Minerals			
Chloride	60.0 mg/L	59.3 mg/L	4
Chloride	140.0 mg/L	139.0 mg/L	4
Wastewater Metals I and II			
Calcium, Total	29.30 mg/L	30.20 mg/L	4
Calcium, Total	69.50 mg/L	70.30 mg/L	4
Magnesium, Total	4.67 mg/L	4.62 mg/L	4
Magnesium, Total	23.40 mg/L	22.00 mg/L	4
Potassium, Total	9.97 mg/L	10.70 mg/L	4
Potassium, Total	24.90 mg/L	25.00 mg/L	4
Sodium, Total	50.10 mg/L	50.00 mg/L	4
Sodium, Total	20.70 mg/L	21.70 mg/L	4

Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal

Table 2. Mean annual concentrations of various parameters measured in Round, Buck, Long and Cranberry Ponds.

	Round Pond	Buck Pond	Long Pond	Cranberry Pond
Total Phosphorus (µg/L)	44.4	94.9	168.1	81.2
Chlorophyll-a (µg/L)	6.13	103.72	122.02	93.39
Nitrate-Nitrite (mg/L)	0.49	0.28	0.31	0.03
Temperature (°C)	11.34	11.7	11.31	11.69
Dissolved Oxygen (mg/L)	10.33	10.75	10.98	10.63
Conductivity (µmho/cm)	699	611	564	554
Sodium (mg/L)	59.85	40.93	40.35	45.98
Secchi Disk (centimeters)	Bottom	37	39	36

Table 3. General ranges of ambient phosphorus concentrations in lakes of different trophic status (after Wetzel 1983). Values for Greece ponds are from the summer only.

	Total Phosphorus µg/L
Ultra-oligotrophic	<1-5
Oligotrophic	5-10
Mesotrophic	10-30
Eutrophic	30-100
Hypereutrophic	>100
Buck Pond	172
Cranberry Pond	126
Long Pond	319
Round Pond	45

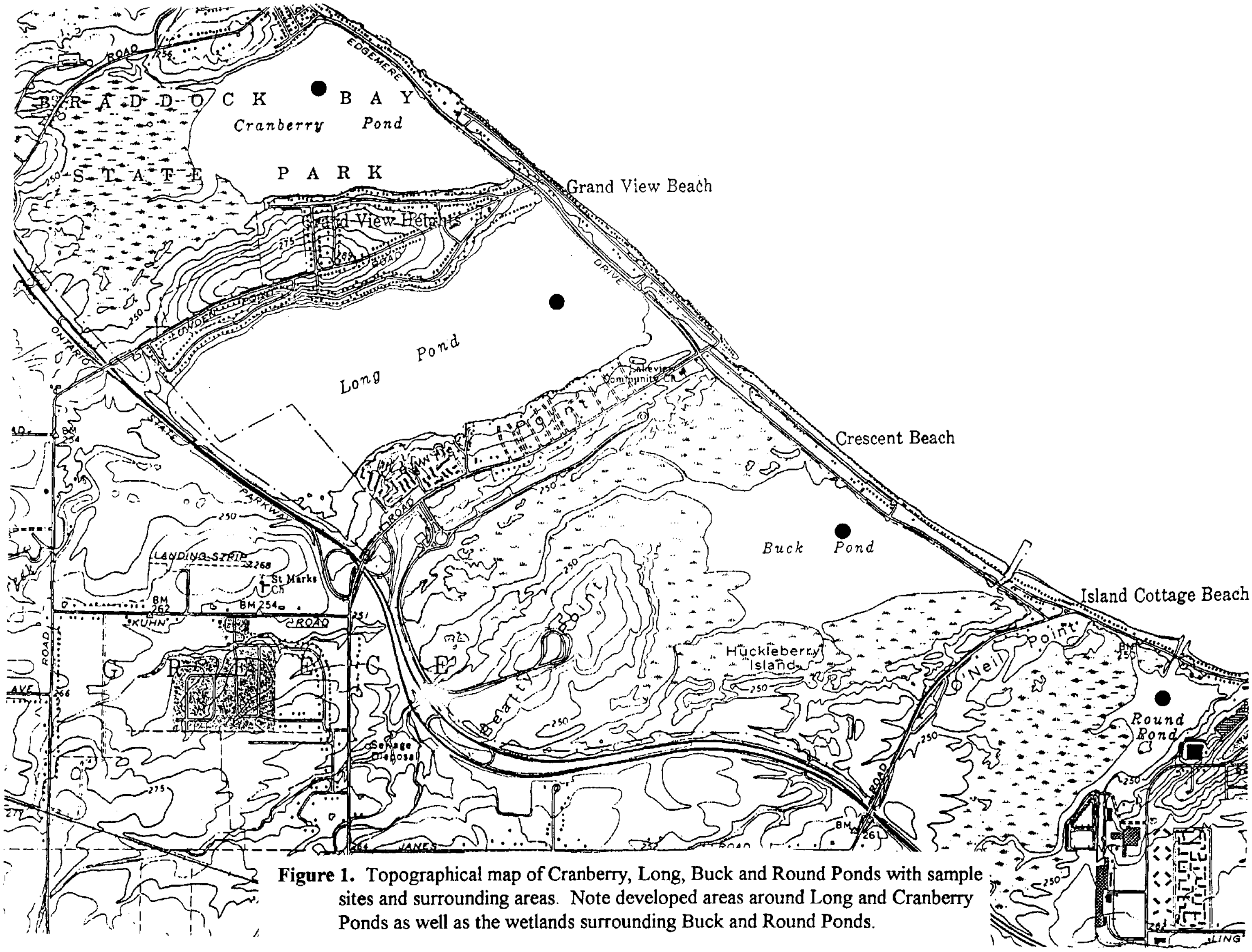

Figure 1. Topographical map of Cranberry, Long, Buck and Round Ponds with sample sites and surrounding areas. Note developed areas around Long and Cranberry Ponds as well as the wetlands surrounding Buck and Round Ponds.

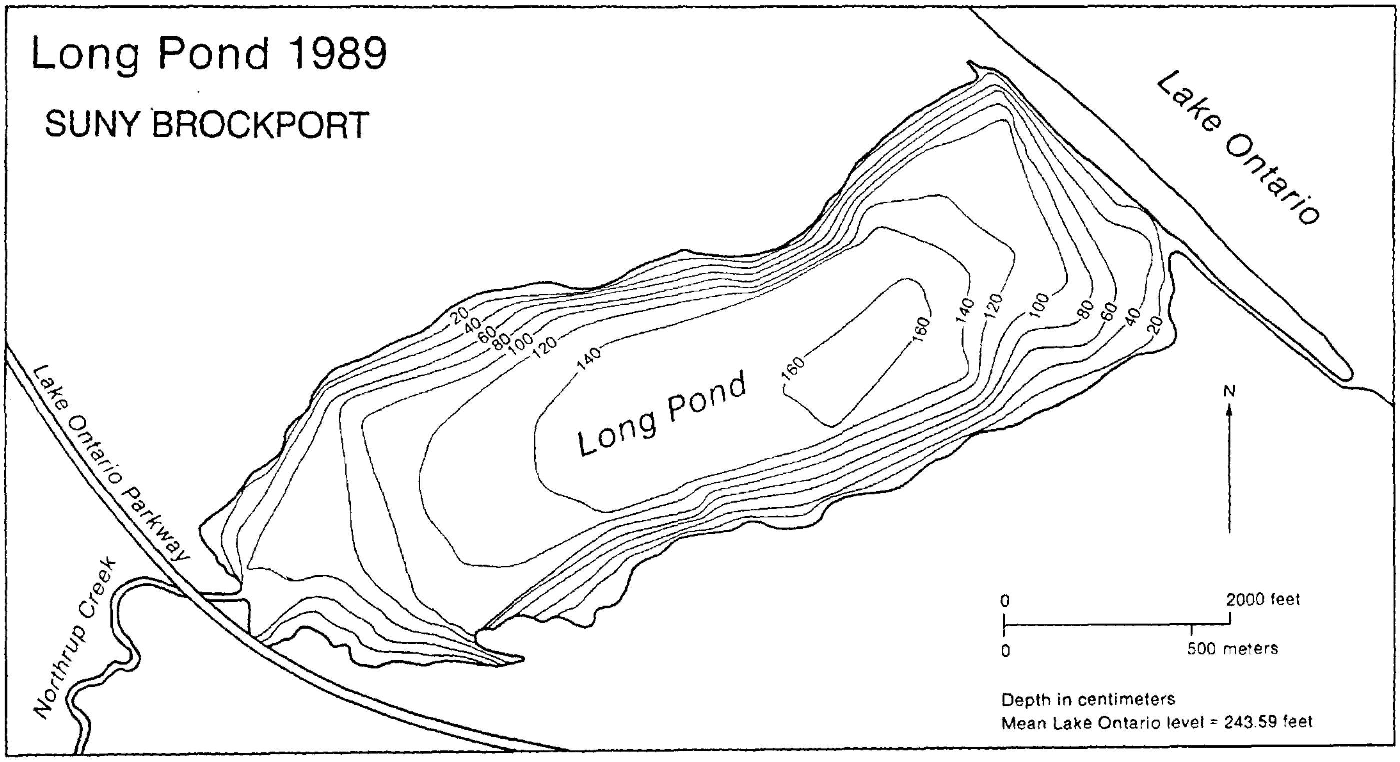

Figure 2. Bathymetric map of Long Pond. Map from Makarewicz et al. (1990).

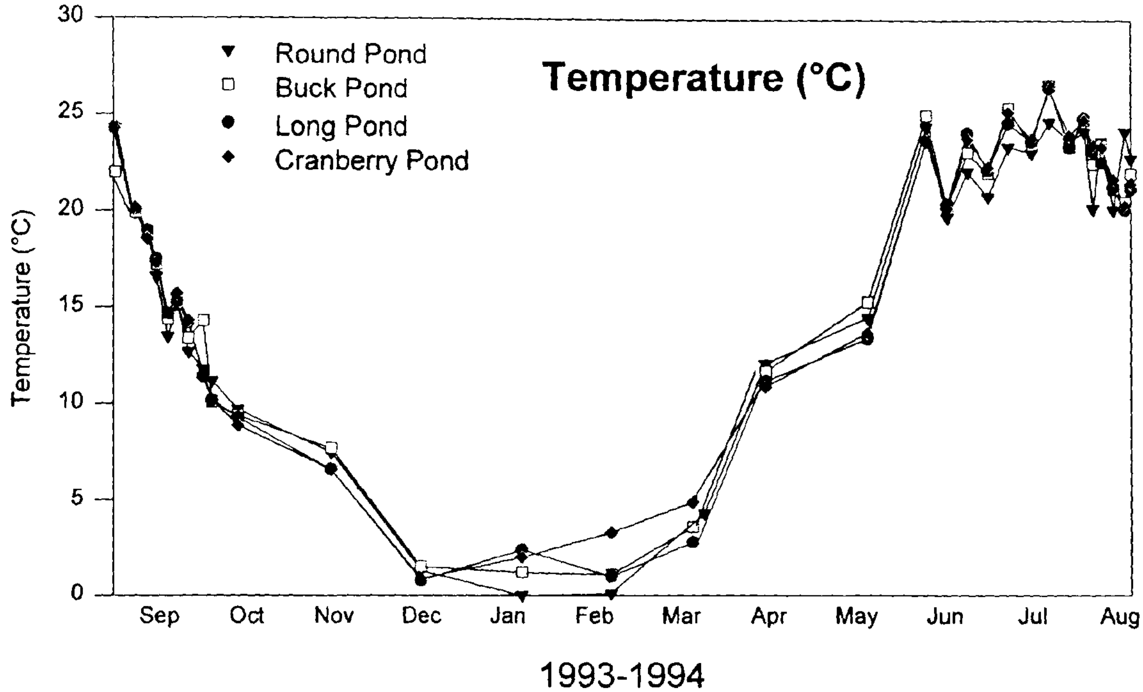

Figure 4. Seasonal changes in temperature.

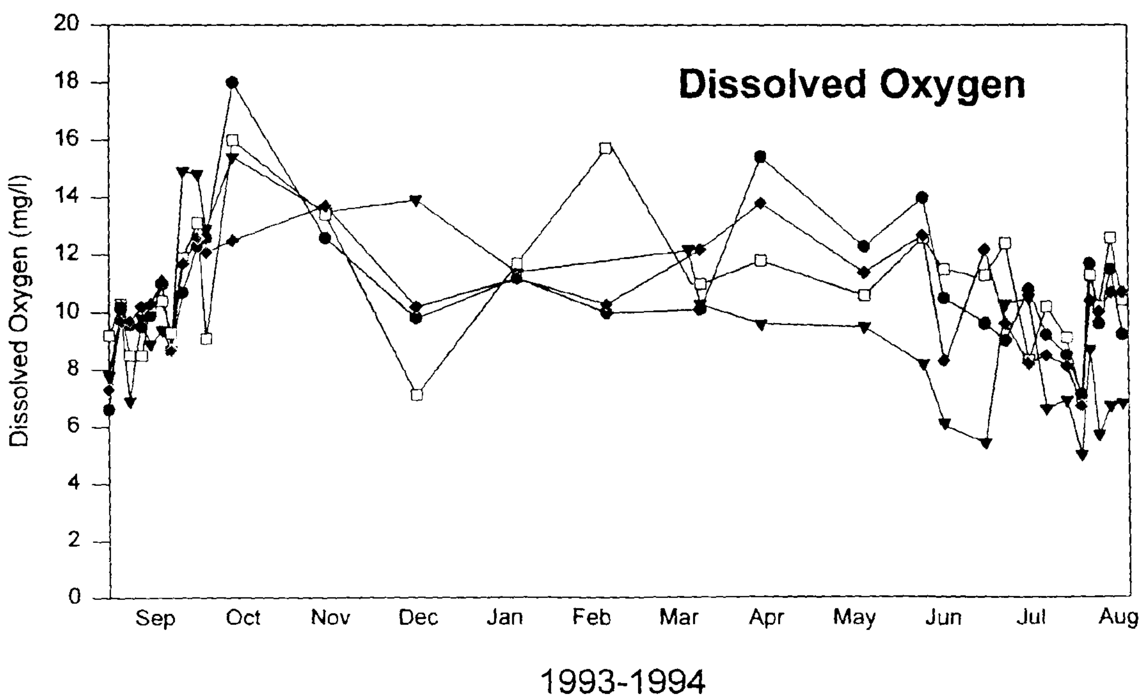

Figure 3. Seasonal changes in dissolved oxygen concentration.

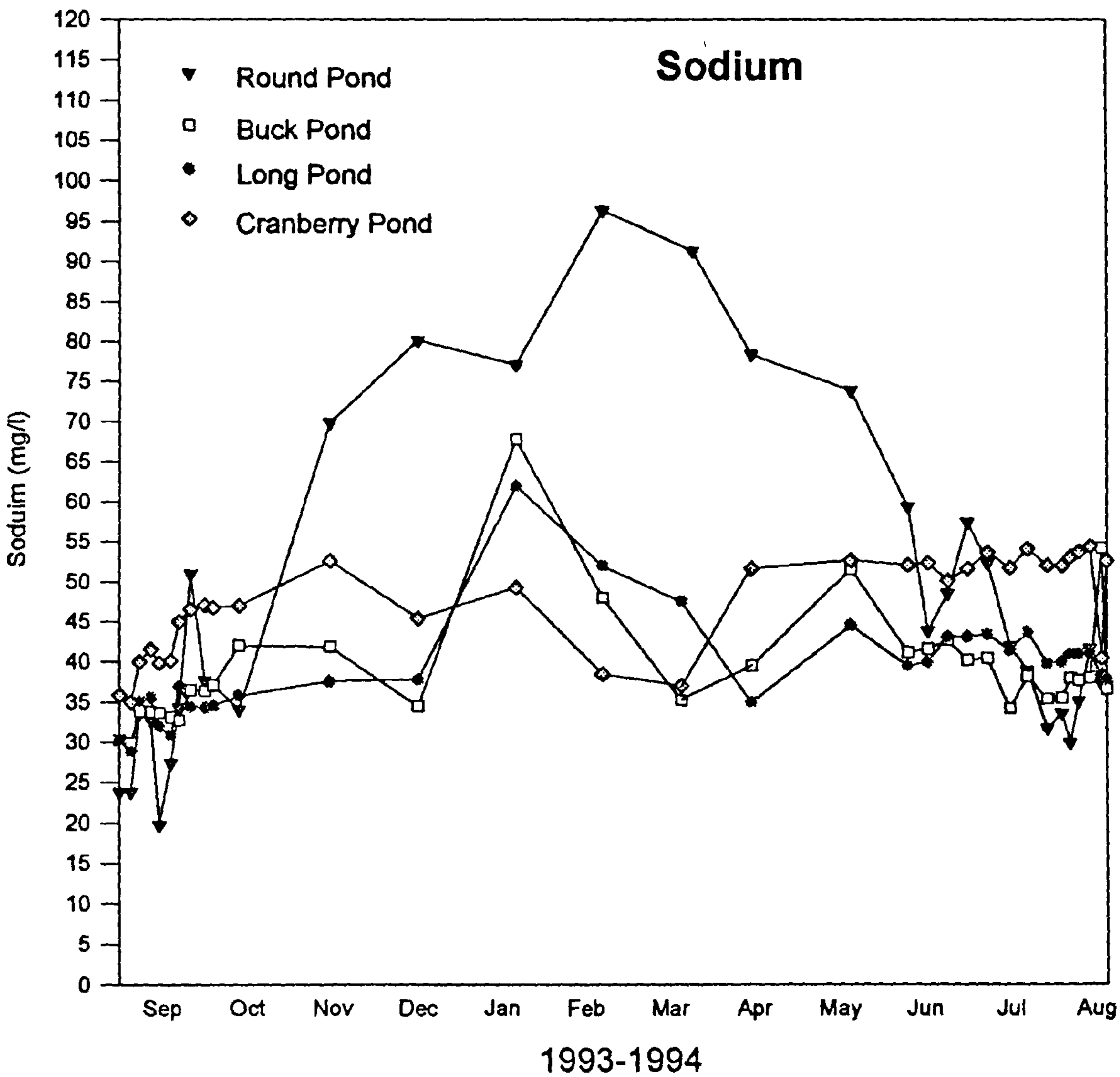

Figure 5. Seasonal changes in sodium concentration.

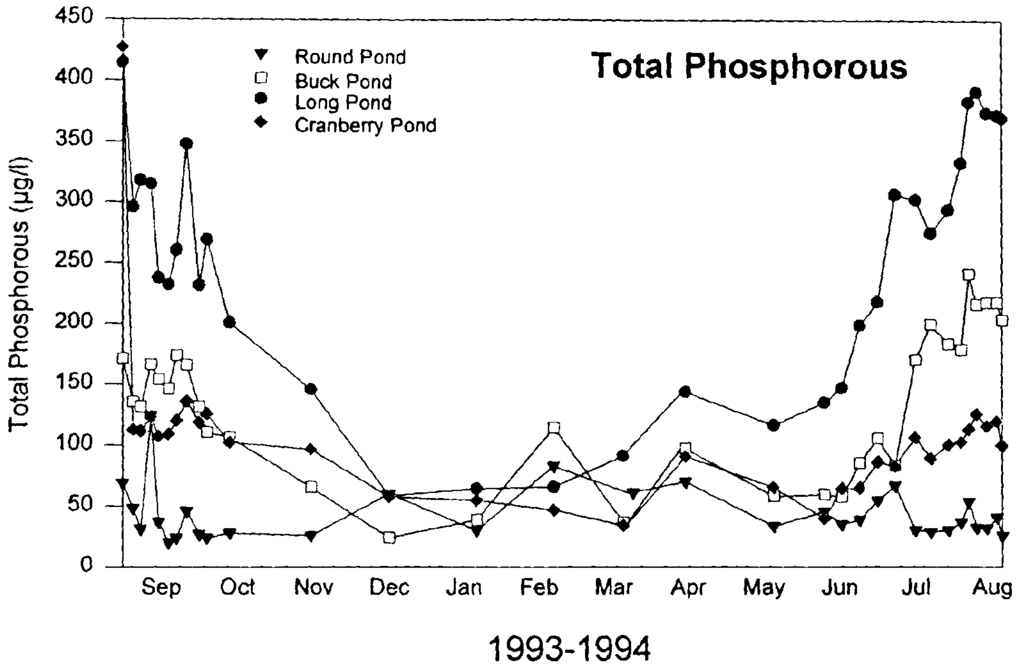

Figure 6. Seasonal changes in total phosphorus concentration.

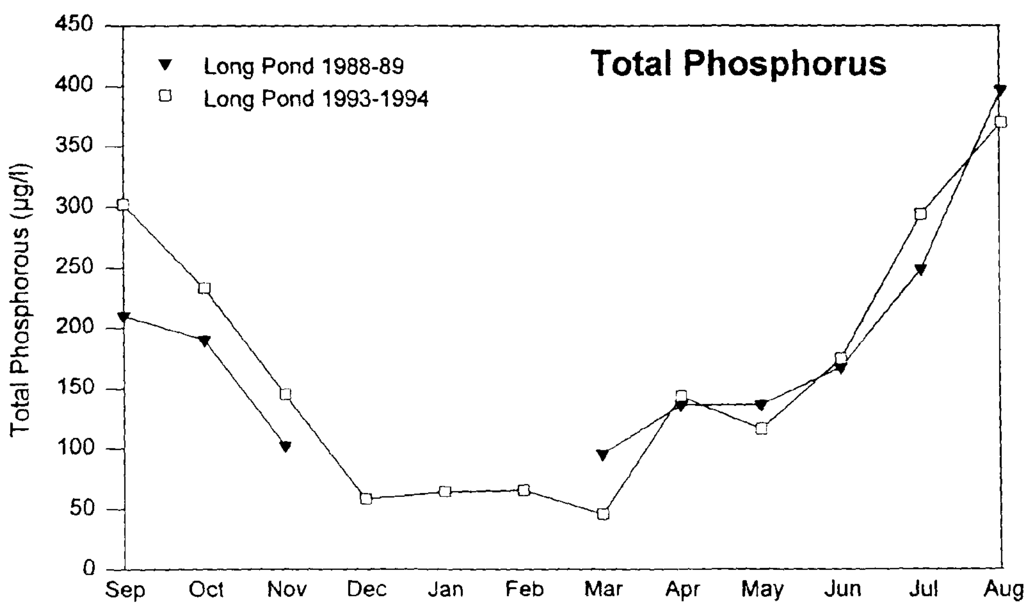

Figure 7. Comparison of 1989 and 1994 seasonal phosphorus concentrations in Long Pond.

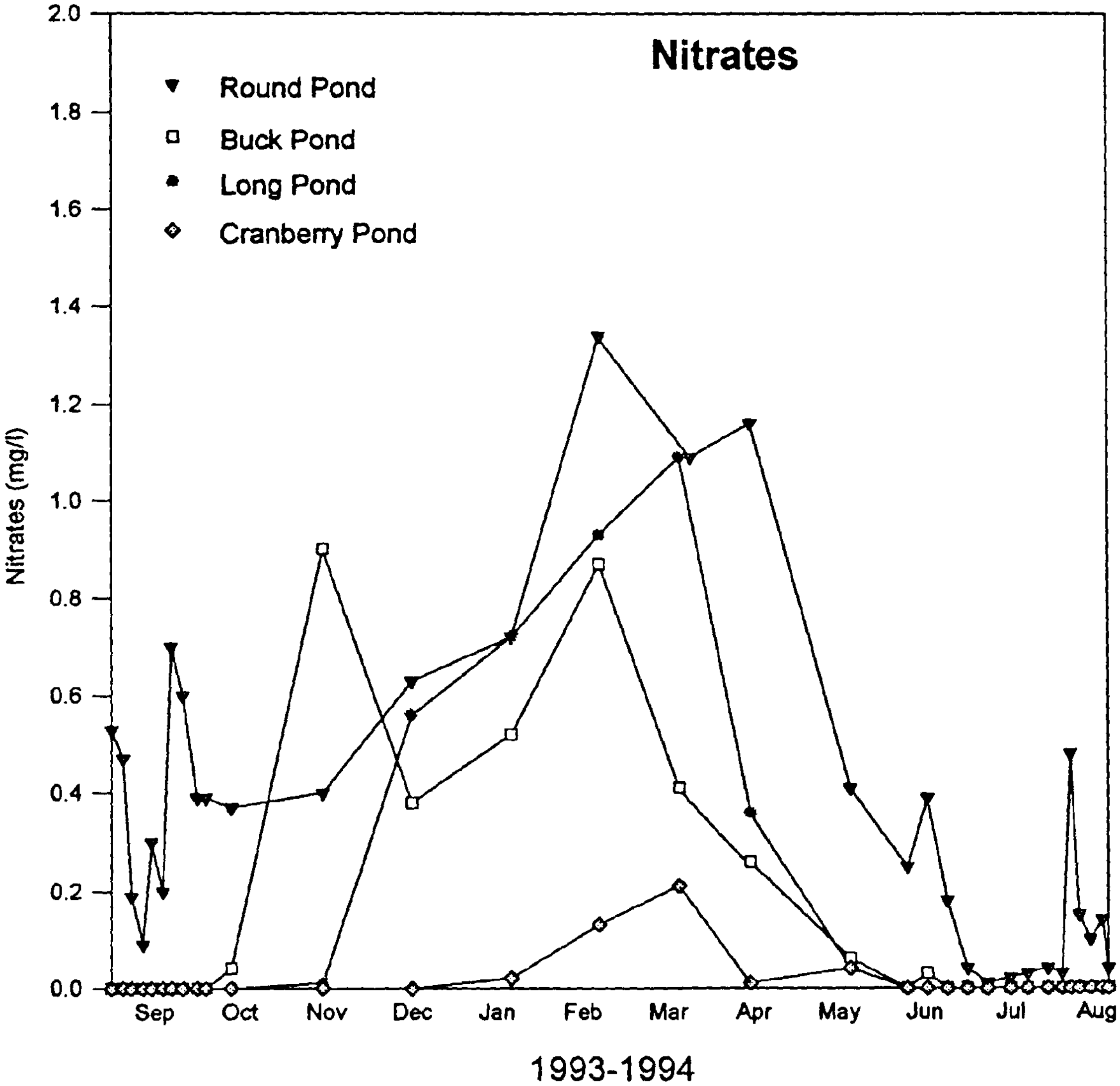

Figure 8. Seasonal changes in nitrate+nitrite concentration.

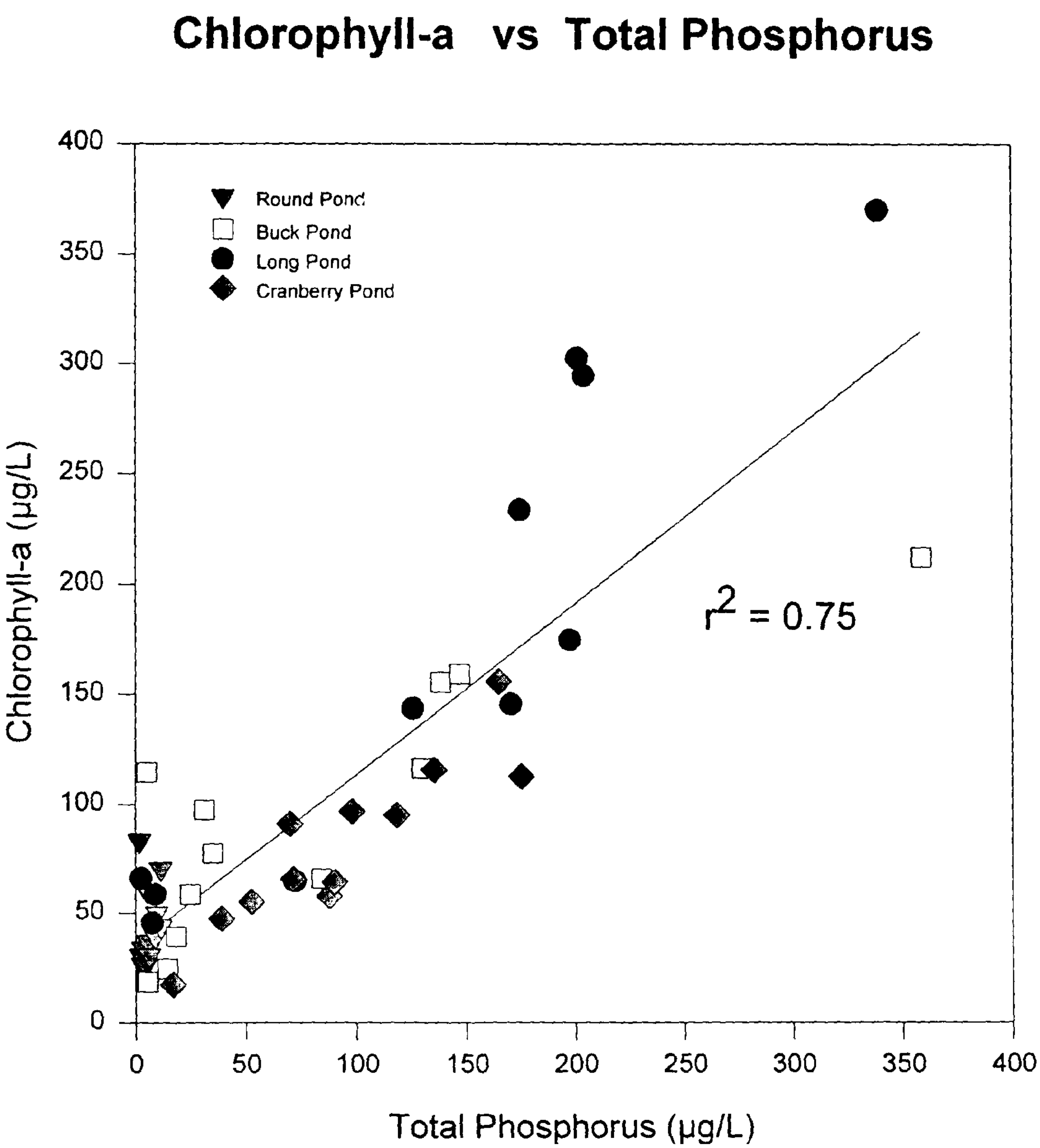

Figure 9. Mean monthly chlorophyll versus total phosphorus for the ponds.

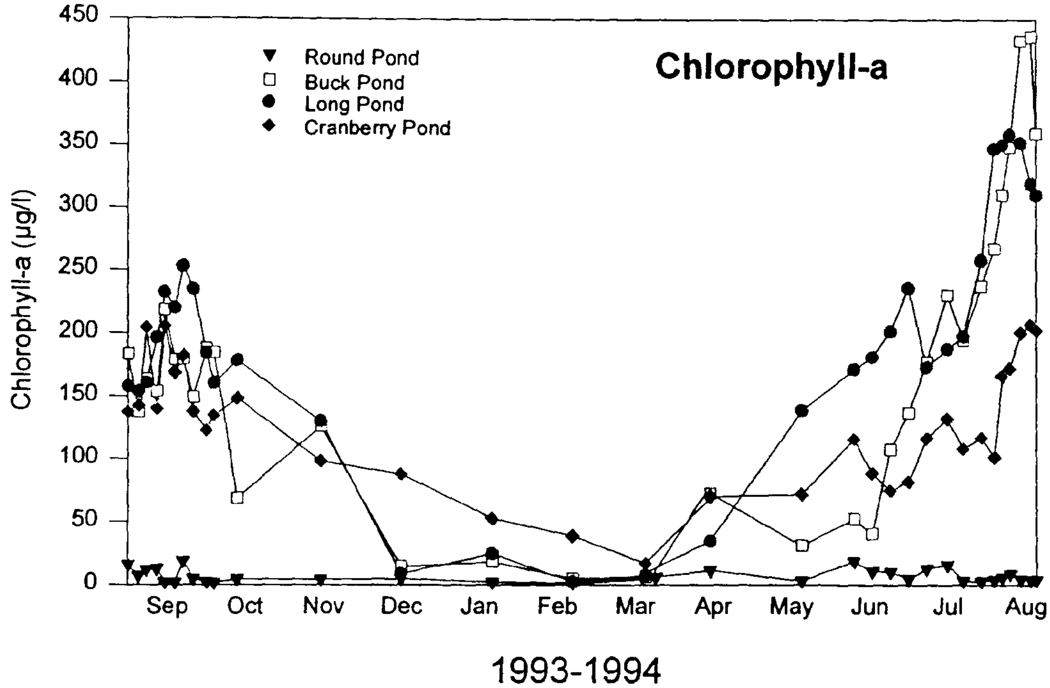

Figure 10. Seasonal changes in chlorophyll a concentration.

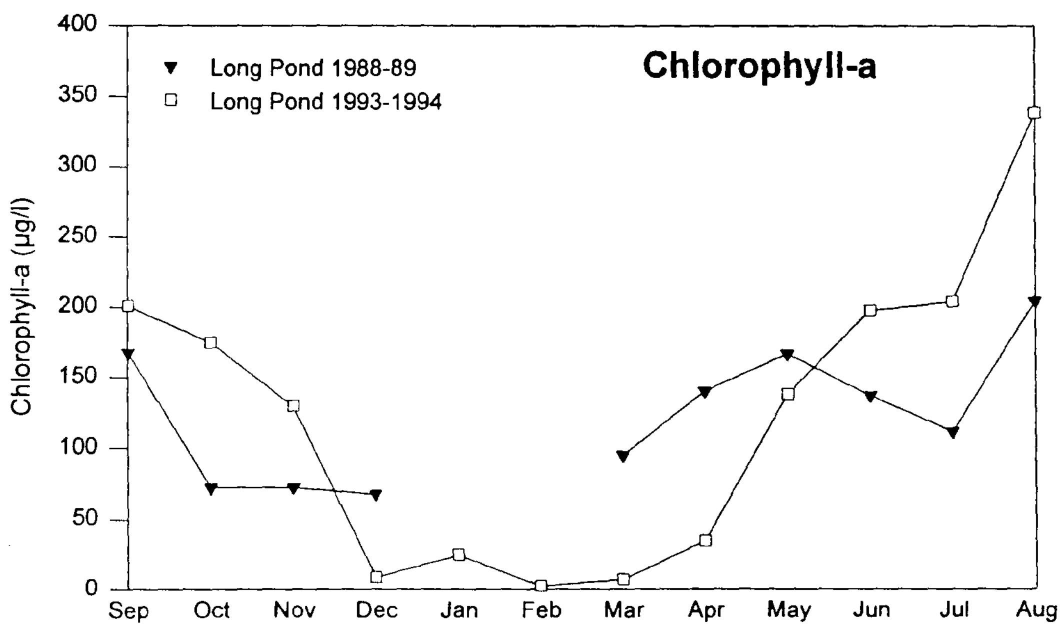

Figure 11. Comparison of 1989 and 1994 seasonal chlorophyll concentrations in Long Pond.

Appendix A. Average temperature readings for Buck, Cranberry, Long and Round Ponds in 1993-94. Values are the average for the water column (one foot intervals). NA = Data not available.

Mean Temperature (°C)				
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	24.3	22.0	24.3	24.3
10-Sep-93	19.9	19.9	20.1	20.2
14-Sep-93	19.0	18.7	19.0	18.6
17-Sep-93	16.6	17.2	17.5	17.3
21-Sep-93	13.5	14.4	14.7	14.7
24-Sep-93	15.2	15.2	15.3	15.7
28-Sep-93	12.7	13.4	14.2	14.3
03-Oct-93	11.8	14.3	11.4	11.5
06-Oct-93	11.2	10.1	10.2	10.2
15-Oct-93	9.7	9.4	9.3	8.9
16-Nov-93	7.5	7.7	6.6	6.6
17-Dec-93	1.3	1.5	0.8	0.9
21-Jan-94	0.0	1.2	2.4	2.0
21-Feb-94	0.1	1.1	1.0	3.3
21-Mar-94	NA	3.6	2.8	4.9
25-Mar-94	4.3	NA	NA	NA
15-Apr-94	12.1	11.7	11.2	10.9
20-May-94	14.5	15.3	13.4	13.7
09-Jun-94	24.4	25.0	23.7	23.7
16-Jun-94	19.7	20.2	20.4	20.2
23-Jun-94	22.1	23.1	24.1	23.8
30-Jun-94	20.8	22.0	22.2	22.3
07-Jul-94	23.4	25.4	24.6	25.2
15-Jul-94	23.1	23.5	23.7	23.8
21-Jul-94	24.7	26.6	26.5	26.4
28-Jul-94	23.7	23.4	23.4	24.0
02-Aug-94	24.2	24.8	24.9	24.8
05-Aug-94	20.2	22.5	23.2	23.5
08-Aug-94	23.7	23.5	22.6	23.4
12-Aug-94	20.1	21.2	21.3	21.7
16-Aug-94	24.2	20.5	20.1	20.3
18-Aug-94	22.8	22.0	21.2	21.5

Appendix B. Transparency readings for Buck, Cranberry, Long and Round Ponds in 1993-94. Bottom indicates that the secchi disk was visible on the bottom of the pond.

	SECCHI DEPTH (centimeters)			
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	bottom	30	15	46
07-Sep-93	bottom	30	15	23
10-Sep-93	bottom	20	20	25
14-Sep-93	bottom	30	30	36
17-Sep-93	bottom	20	20	25
21-Sep-93	bottom	36	25	25
24-Sep-93	bottom	25	20	25
28-Sep-93	bottom	25	20	28
03-Oct-93	bottom	36	15	28
06-Oct-93	bottom	33	25	30
15-Oct-93	bottom	38	25	28
16-Nov-93	bottom	38	43	51
17-Dec-93	41	61	137	46
21-Jan-94	ice	ice	ice	ice
21-Feb-94	ice	ice	ice	ice
21-Mar-94	ice	ice	ice	ice
25-Mar-94	ice	ice	ice	ice
15-Apr-94	64	25	30	41
20-May-94	76	61	36	38
09-Jun-94	84	41	25	25
16-Jun-94	48	41	23	25
23-Jun-94	56	36	20	46
30-Jun-94	28	30	20	20
07-Jul-94	33	28	20	36
15-Jul-94	bottom	28	28	30
21-Jul-94	bottom	25	20	30
28-Jul-94	bottom	25	25	28
02-Aug-94	bottom	23	18	30
05-Aug-94	46	23	18	30
08-Aug-94	bottom	20	20	36
12-Aug-94	bottom	18	18	36
16-Aug-94	bottom	20	18	28
18-Aug-94	bottom	18	18	30

Appendix C. Conductivity readings for Buck, Cranberry, Long and Round Ponds in 1993-94. Values are the mean for the water column. NA = Data not available.

DATE	ROUND	BUCK	LONG	CRANBERRY
Conductivity (umhos/cm)				
03-Sep-93	0.445	0.454	0.473	0.491
10-Sep-93	0.535	0.451	0.462	0.464
14-Sep-93	0.508	0.453	0.461	0.482
17-Sep-93	0.589	0.460	0.459	0.482
21-Sep-93	0.485	0.464	0.484	0.456
24-Sep-93	0.505	0.460	0.437	0.480
28-Sep-93	0.555	NA	0.454	0.477
03-Oct-93	0.548	0.473	0.450	0.479
06-Oct-93	0.481	0.471	0.450	0.477
15-Oct-93	0.554	0.552	0.554	0.483
16-Nov-93	0.717	0.578	0.594	0.503
17-Dec-93	0.891	0.605	0.602	0.521
21-Jan-94	0.418	1.111	0.591	0.802
21-Feb-94	1.116	0.883	0.900	0.644
21-Mar-94	NA	0.659	0.713	0.628
25-Mar-94	0.917	NA	NA	NA
15-Apr-94	0.853	0.519	0.462	0.533
20-May-94	0.790	0.627	0.497	0.504
09-Jun-94	0.720	0.570	0.463	0.502
16-Jun-94	0.573	0.567	0.459	0.514
23-Jun-94	0.467	0.525	0.632	0.566
30-Jun-94	0.636	0.514	0.538	0.472
07-Jul-94	0.636	0.550	0.467	0.520
15-Jul-94	0.568	0.415	0.469	0.525
21-Jul-94	0.512	0.420	0.482	0.528
28-Jul-94	0.501	0.412	0.472	0.451
02-Aug-94	0.504	0.410	0.490	0.540
05-Aug-94	0.363	0.407	0.481	0.545
08-Aug-94	0.483	0.397	0.466	0.533
12-Aug-94	0.539	0.405	0.470	0.536
16-Aug-94	0.504	0.405	0.457	0.530
18-Aug-94	0.516	0.402	0.466	0.529

Appendix D. Dissolved oxygen concentrations for Buck, Cranberry, Long and Round Ponds in 1993-94. NA = Data not available.

	DISSOLVED OXYGEN (mg/L)			
DATE	ROUND	BUCK	LONG	CRANBERRY
07-Sep-93	7.8	9.2	6.6	7.3
10-Sep-93	10.0	10.3	10.2	9.7
14-Sep-93	6.9	8.5	9.6	9.7
17-Sep-93	9.8	8.5	9.5	10.2
21-Sep-93	8.9	10.2	9.9	10.3
24-Sep-93	9.4	10.4	11.0	11.1
28-Sep-93	8.7	9.3	8.7	8.7
03-Oct-93	14.9	11.9	10.7	11.7
06-Oct-93	14.8	13.1	12.3	12.6
15-Oct-93	12.9	9.1	12.6	12.1
16-Nov-93	15.4	16.0	18.0	12.5
17-Dec-93	13.5	13.4	12.6	13.7
21-Jan-94	13.9	7.1	9.8	10.2
21-Feb-94	11.4	11.7	11.2	11.2
21-Mar-94	NA	15.7	10.0	10.3
25-Mar-94	12.2	NA	NA	NA
15-Apr-94	10.3	11.0	10.1	12.2
20-May-94	9.6	11.8	15.4	13.8
09-Jun-94	9.5	10.6	12.3	11.4
16-Jun-94	8.2	12.6	14.0	12.7
23-Jun-94	6.1	11.5	10.5	8.3
07-Jul-94	5.4	11.3	9.6	12.2
15-Jul-94	10.3	12.4	9.0	9.6
21-Jul-94	10.5	8.3	10.8	8.2
28-Jul-94	6.6	10.2	9.2	8.5
02-Aug-94	6.9	9.1	8.5	8.1
05-Aug-94	5.0	7.0	7.1	6.7
08-Aug-94	8.7	11.3	11.7	10.4
12-Aug-94	5.7	10.2	9.6	10.0
16-Aug-94	6.7	12.6	11.5	10.7
18-Aug-94	6.8	10.4	9.2	10.7

Appendix E. Sodium concentrations for Buck, Cranberry, Long and Round Ponds in 1993-94. NA = Data not available.

Sodium (mg/L)				
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	23.86	30.31	30.33	35.91
07-Sep-93	23.84	29.91	28.87	35.01
10-Sep-93	33.67	33.85	35.14	40.01
14-Sep-93	32.73	33.75	35.51	41.56
17-Sep-93	19.78	33.67	32.01	39.85
21-Sep-93	27.42	33.08	30.89	40.19
24-Sep-93	34.27	32.69	36.95	45.02
28-Sep-93	51.02	36.53	34.42	46.56
03-Oct-93	37.72	36.40	34.31	47.08
06-Oct-93	37.21	37.08	34.55	46.78
15-Oct-93	34.07	42.00	35.79	47.00
16-Nov-93	69.90	41.90	37.60	52.60
17-Dec-93	80.18	34.52	37.84	45.44
21-Jan-94	77.12	67.82	61.96	49.28
21-Feb-94	96.39	47.98	51.98	38.53
21-Mar-94	NA	35.29	47.50	37.11
25-Mar-94	91.29	NA	NA	NA
15-Apr-94	78.36	39.55	35.05	51.64
20-May-94	73.92	51.58	44.60	52.72
09-Jun-94	59.38	41.25	39.59	52.08
16-Jun-94	43.95	41.70	40.05	52.41
23-Jun-94	48.54	42.78	43.18	50.20
30-Jun-94	57.48	40.28	43.22	51.68
07-Jul-94	52.34	40.52	43.48	53.70
15-Jul-94	42.08	34.24	41.48	51.76
21-Jul-94	38.96	38.28	43.76	54.10
28-Jul-94	31.78	35.44	39.82	52.02
02-Aug-94	33.66	35.54	40.02	51.96
05-Aug-94	30.00	38.02	40.96	53.12
08-Aug-94	35.20	37.76	41.10	53.72
12-Aug-94	41.72	38.06	41.04	54.40
16-Aug-94	37.36	54.16	38.48	40.56
18-Aug-94	37.18	36.62	37.90	52.66

Appendix F. Total phosphorus concentrations for Buck, Cranberry, Long and Round Ponds in 1993-94. NA = Data not available.

TOTAL PHOSPHOROUS (ug/L)				
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	69.1	171.4	414.5	427.0
07-Sep-93	48.4	135.5	295.6	112.7
10-Sep-93	31.7	131.4	318.0	111.9
14-Sep-93	124.1	166.0	315.0	122.9
17-Sep-93	37.2	153.7	237.7	107.3
21-Sep-93	20.6	146.2	232.4	109.0
24-Sep-93	24.1	173.8	260.6	119.9
28-Sep-93	46.1	165.9	347.8	136.1
03-Oct-93	27.1	131.4	231.6	118.9
06-Oct-93	24.1	110.7	269.1	125.7
15-Oct-93	28.3	106.5	200.7	102.5
16-Nov-93	26.3	65.8	145.6	96.8
17-Dec-93	60.5	24.5	58.7	57.8
21-Jan-94	30.6	39.2	64.7	55.2
21-Feb-94	83.4	114.6	66.1	47.5
21-Mar-94	NA	37.4	91.3	34.8
25-Mar-94	61.6	NA	NA	NA
15-Apr-94	70.4	97.4	143.7	91.0
20-May-94	33.9	58.5	116.6	65.6
09-Jun-94	45.8	59.9	135.3	40.5
16-Jun-94	35.6	58.0	147.1	64.8
23-Jun-94	39.5	85.7	198.6	65.2
30-Jun-94	55.2	105.9	217.8	86.5
07-Jul-94	67.2	83.5	306.6	83.5
15-Jul-94	30.7	169.9	302.4	106.8
21-Jul-94	29.0	199.4	274.9	89.2
28-Jul-94	30.5	183.3	294.2	100.5
02-Aug-94	37.0	178.4	332.8	102.9
05-Aug-94	53.9	241.0	382.7	113.0
08-Aug-94	32.4	216.0	391.0	125.5
12-Aug-94	32.1	217.7	373.5	116.0
16-Aug-94	41.0	217.7	371.5	119.5
18-Aug-94	25.7	203.0	369.0	99.7

Appendix G. Nitrate-Nitrite concentration for Buck, Cranberry, Long and Round Ponds in 1993-94. ND = Non-detectable. NA = Data not available.

NITRATE-NITRITE mg/L				
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	0.53	ND	ND	ND
07-Sep-93	0.47	ND	ND	ND
10-Sep-93	0.19	ND	ND	ND
14-Sep-93	0.09	ND	ND	ND
17-Sep-93	0.30	ND	ND	ND
21-Sep-93	0.20	ND	ND	ND
24-Sep-93	0.70	ND	ND	ND
28-Sep-93	0.60	ND	ND	ND
03-Oct-93	0.39	ND	ND	ND
06-Oct-93	0.39	ND	ND	ND
15-Oct-93	0.37	0.04	ND	ND
16-Nov-93	0.40	0.90	0.01	ND
17-Dec-93	0.63	0.38	0.56	ND
21-Jan-94	0.72	0.52	0.72	0.02
21-Feb-94	1.34	0.87	0.93	0.13
21-Mar-94	NA	0.41	1.09	0.21
25-Mar-94	1.09	NA	NA	NA
15-Apr-94	1.16	0.26	0.36	0.01
20-May-94	0.41	0.06	0.04	0.04
09-Jun-94	0.25	ND	ND	ND
16-Jun-94	0.39	0.03	ND	ND
23-Jun-94	0.18	ND	ND	ND
30-Jun-94	0.04	ND	ND	ND
07-Jul-94	0.01	ND	ND	ND
15-Jul-94	0.02	ND	ND	ND
21-Jul-94	0.03	ND	ND	ND
28-Jul-94	0.04	ND	ND	ND
02-Aug-94	0.03	ND	ND	ND
05-Aug-94	0.48	ND	ND	ND
08-Aug-94	0.15	ND	ND	ND
12-Aug-94	0.10	ND	ND	ND
16-Aug-94	0.14	ND	ND	ND
18-Aug-94	0.04	ND	ND	ND

Appendix H. Chlorophyll concentrations for Buck, Cranberry, Long and Round Ponds in 1993-94. NA = Data not available.

Chlorophyll a (µg/L)				
DATE	ROUND	BUCK	LONG	CRANBERRY
03-Sep-93	16.1	183.6	158.0	137.5
07-Sep-93	7.4	137.2	153.9	142.5
10-Sep-93	11.9	163.8	160.8	204.5
14-Sep-93	12.8	153.7	196.6	140.2
17-Sep-93	2.0	218.4	232.2	205.9
21-Sep-93	2.1	179.4	220.1	169.0
24-Sep-93	18.9	179.7	252.8	182.5
28-Sep-93	5.0	149.2	234.9	137.7
03-Oct-93	2.9	188.2	184.7	123.1
06-Oct-93	1.9	184.8	160.7	134.5
15-Oct-93	4.7	68.6	178.6	148.5
16-Nov-93	4.5	125.9	130.0	98.1
17-Dec-93	5.0	14.5	8.9	87.8
21-Jan-94	2.5	18.4	24.8	52.7
21-Feb-94	1.9	5.2	2.6	39.0
21-Mar-94	NA	6.3	7.5	17.0
25-Mar-94	6.3	NA	NA	NA
15-Apr-94	11.4	72.1	35.0	70.0
20-May-94	3.5	31.2	138.5	71.6
09-Jun-94	18.8	52.1	171.6	115.8
16-Jun-94	11.1	40.5	181.5	88.6
23-Jun-94	10.5	107.5	201.8	74.8
30-Jun-94	5.1	136.6	236.1	81.6
07-Jul-94	12.9	177.5	173.3	116.6
15-Jul-94	16.1	230.6	188.1	132.0
21-Jul-94	3.6	195.0	198.0	108.1
28-Jul-94	3.1	237.6	257.6	117.0
02-Aug-94	4.2	267.0	346.5	101.7
05-Aug-94	6.4	310.3	349.6	166.7
08-Aug-94	8.9	347.7	357.9	172.5
12-Aug-94	4.8	433.1	351.5	201.4
16-Aug-94	4.3	436.5	319.1	207.0
18-Aug-94	4.1	358.8	310.1	203.5