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AT LAKE GEORGE

REPORT ON THE LAKE GEORGE

OFFSHORE CHEMICAL MONITORING PROGRAM

2001

Submitted to

The FUND for Lake George

by

Lawrence W. Eichler, Research Scientist
Jeffrey S. Bartkowski, Lab Technician
Shannon M. Shaver, Lab Technician
&
Dr. Charles W. Boylen, Associate Director

Darrin Fresh Water Institute
Rensselaer Polytechnic Institute
Bolton Landing, NY 12814

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INTRODUCTION

The Lake George Offshore Chemical Monitoring Program, since its inception in 1980, has been providing valuable data on the chemical status of the lake. The unchanging goals of this program are to:

1. record the ambient water chemistry of Lake George;
2. characterize any degradation in chemical water quality;
3. assist in finding solutions to water quality problems; and
4. provide baseline water chemistry data in order to encourage continued research within the Lake George watershed.

The Offshore Chemical Monitoring Program is largely an open-water testing program. That is, the sites selected have been a series of deep-water locations along the south to north axis of the lake from Tea Island in the south to Rogers Rock in the north and a series of shallower bay locations around the lake (Figure 1). This monitoring program represents the backbone of the Lake George limnological database. It provides a yearly barometer of the chemical water quality of the lake.

Lake George is considered an oligotrophic lake, meaning in lay terms that the lake possesses high water clarity indicative of very low turbidity and algal productivity in its open waters. However, human activity and changing land use around the lake (perturbation of the watershed) in the last 15 to 20 years is suspected of increasing the rate at which nutrients and other pollutants are coming into the lake. Slowing or moderating these impacts will require the utmost vigilance on the part of the Lake George community if the pristine character of the lake is to be saved for later generations to enjoy.

METHODS, SITES, and COLLECTION SCHEDULES

A total of 250 discrete samples were collected from 13 individual sampling locations throughout the lake for the 2001 Lake George Offshore Chemical Monitoring Program. A map showing the sampling sites is presented in Figure 1. One through-the-ice sampling was conducted on March 1. The Lake was not completely frozen over, however sufficient ice was available through-the-ice sampling and ice-out was April 22. Bimonthly sampling commenced in early May, and continued through the end of June. This intensive sampling scheme allows for the tracking of certain episodic nutrient trends that are often overlooked or minimized with monthly sampling. Such episodic events include remnants of nutrient inputs from the rapid flushing of terrestrial areas from snowmelt, the thawing of soils, and substantial rainfall events resulting in large, rapid runoff inputs to the lake. Monthly sampling occurred thereafter through October. Biweekly sampling was then reinstated through fall overturn to better characterize changes in water quality at this time. Table 1 lists the sampling dates for the 2001 sampling season.

Table 1. Offshore sampling dates for the 2001 sampling season.

March	1	July	24-25
May	1-2	August	21-22
May	15-16	September	20-21
May	29-30	October	17-19
June	12-13	November	6-7
June	26-27		

Water samples and on-site measurements were obtained from all sites on a monthly basis, with specific additions as shown above. Integrated surface water samples were collected at all sites, and deep water point-samples were obtained at sites where the water depth exceeded 20 meters. Table 2 lists the chemical analyses and the samples for which they were conducted.

Table 2. Chemical analyses conducted for the Offshore chemistry program.

Analysis	Samples	Analysis	Samples
pH	all	Silica	all
Specific Conductance	all	Sodium	all
Total Nitrogen	all	Calcium	all
Total Phosphorus	all	Chloride	all
Total Soluble Phosphorus	all	Sulfate	all
Soluble Reactive Phosphorus	all	Chlorophyll a	Surface samples
Nitrate	all	Magnesium	all
Ammonia	all	Alkalinity	selected surface samples

The methods used for determining the physical and chemical parameters measured either at each site or from the samples taken from each site have been described in previous reports and are given in tabular form in Appendix B. Most chemical parameters measured are reported as milligrams or micrograms per liter of the respective element. For example, total phosphorus is reported as micrograms per liter of the element phosphorus (P) not the phosphate (PO_4) ion. One exception to this would be alkalinity, which is reported as milligrams of calcium carbonate per liter.

Climatic conditions can produce short and long term changes in chemical water quality. Precipitation, both rain and snow, and the resultant stormwater runoff are a substantial source of nutrients to aquatic algae. In 2001, severe drought conditions occurred. Seven months were below average for precipitation in 2001. Average precipitation values used in this report for the Lake George watershed reflect the results of this monitoring site since 1992 (Figures 20 and 21). This station was installed in June of 1991, and therefore total annual averages are not computed using 1991 data due to the lack of a complete data set for the full annual cycle.

Table 3. Precipitation records for the Lake George basin in 2001 (Sutherland, 2001).

Precipitation Records for NYS DEC Cedar Lane Station		
Month	**Precipitation (inches)**	**1992 – 2001 Average Precipitation (inches)**
January	0.98	3.62
February	1.85	2.05
March	5.47	3.41
April	1.10	3.46
May	3.00	3.48
June	4.67	3.24
July	2.06	4.14
August	1.35	2.77
September	3.83	3.35
October	1.40	2.87
November	2.00	3.31
December	1.56	2.56
Total	***29.27***	***38.28***

RESULTS and DISCUSSION

Thermocline

Weak thermal stratification was apparent at Smith Bay in the north basin by late May of 2001. By mid-June, the thermocline was set at all sites between 6 and 10 meters. In August, the thermocline stretched from 10 to 11 meters throughout the lake. By September, the thermocline had begun to move deeper, as deep as 13 meters in the north to 14 meters in the south. At the October sampling only Rogers Rock and Smith Bay in the north basin and Basin Bay in the south basin were still stratified, at 18 to 23 meters. The final sampling in November showed no thermal stratification in the lake. The period and configuration of thermal stratification in 2001 was typical for the Lake George basin.

Transparency

Water clarity or transparency is recorded in two ways, Secchi disk and submarine photometer. Mean annual Secchi transparency (Figure 2, Table 4) ranged from a low of 7.6 ± 1.3 m (SD) at Tea Island to a high of 10.3 ± 2.1 m (SD) at Sabbath Day Point. Lake-wide, the mean Secchi transparency was 8.9 ± 2.1 (SD). As reported for previous years' data, a trend toward increasing transparency on a south to north axis was observed. The greatest difference in mean transparency (1.0 m) was found between the French Point and Sabbath Day Point sites in the north basin.

Table 4. Mean annual Secchi transparencies for the open water monitoring sites in 2001 (n=10).

Site	**Secchi Depth (m)**	**Standard Deviation**
Tea Island	7.6	1.3
Basin Bay	8.5	2.0
Dome Island	7.9	2.1
Northwest Bay	8.7	1.7
French Point	9.3	2.1
Sabbath Day Point	10.3	2.1
Smith Bay	9.9	2.1
Rogers Rock	8.9	1.7

One percent of surface light intensity is commonly used to determine the depth limit for the growth of phytoplankton. This limit roughly translates to the compensation depth or depth at which algal respiration equals energy production. Below this depth, algae cannot survive. Early spring transparencies for the lake were normal, at 18 meters. Light transmission (transparency) was greatest lake-wide in late May with an average compensation depth of 20 meters across the lake. Early June saw a significant decline in transparency, below 18 meters. This may be due to a large amount of precipitation prior to the June sampling, washing spring fertilizers from lawns and roads into the water column of the lake. Compensation depth (1% of surface light transmission) averages rose back up above 19 meters by the end of June, and slowly began to fall for the rest of the summer season. There was also a difference noted in the compensation depth from south to north, with the lowest values at Tea and Dome Islands, and the highest at Smith Bay. Typically, south basin seasonal averages were approximately two meters less than the seasonal averages for the north basin. The greatest difference in compensation depth occurred between French Point and Sabbath Day Point where the average for the year differed by two meters. Lake-wide, the compensation depth averaged 19 meters for 2001 (Figure 23).

Dissolved Oxygen

As discussed in previous years' reports, the deep basin (hypolimnion) at the southernmost portion of the lake has shown substantial declines of dissolved oxygen in the deeper waters during the late summer. This is indicative of a more mesotrophic lake condition rather than oligotrophic, the typical designation for Lake George. The Tea Island site, located in the southernmost basin, recorded dissolved oxygen levels in the near-sediment waters that were near 20% of saturation during early October, while at a site of comparable depth in the North Basin (Sabbath Day Point) levels of dissolved oxygen never fell below 65% saturation for that same timeframe. The near-sediment waters at Tea Island showed declining saturation levels below 70%, upon thermal stratification in late June. A steady decline continued on through the end of the sampling season in November. Over that time period, dissolved oxygen levels were as low as 2.6 mg/l (22% saturation) at depths below 28 meters, with lowest concentrations recorded within 1 meter of the lake bottom. Dissolved oxygen concentrations in hypolimnetic waters at the Sabbath Day Point sampling site remained greater than 7.7 mg/l (90% saturation) over the same period at comparable depths. Dissolved oxygen concentrations for each site in 2001 can be found in Figures 18 and 19 of the appendix.

The decomposition processes occurring in the sediments of the lake bottom require oxygen, which is supplied by the overlaying waters. As more organic matter in the form of decomposing phytoplankton is supplied to the sediment bacteria, the demand for oxygen becomes greater. Where substantial dissolved oxygen declines are seen in hypolimnetic waters, it is often indicative of greater productivity (algal growth) occurring in the epilimnetic waters. This is the case when comparing the southernmost basin of Lake George to other deep-water areas throughout the lake.

Hypolimnetic oxygen depletion is not a characteristic considered desirable for most lakes. The decrease of dissolved oxygen in the deeper waters can limit the habitat for the cold-water fishery of Lake George where portions of the lake become less than ideal to support trout or salmon. These fish require rather high levels of dissolved oxygen to maintain their metabolic processes. If hypolimnetic oxygen depletion were to continue to rise higher in the water column, the range of these fish will be significantly diminished. Also of importance is the ability of the sediments to release phosphorus when the overlaying waters become depleted of oxygen. This additional input of phosphorus becomes an added shock on a phosphorus-limited system and eventually increases the productivity of the lake.

Phosphorus

Phosphorus is one of the most important parameters in a monitoring program of a low-nutrient lake such as Lake George. Phosphorus is frequently the limiting nutrient in the water column, meaning that it is an essential requirement for growth and productivity in the lake ecosystem, and is the least available of any of the other necessary nutrients. Phosphorus is measured as three different forms: Total Phosphorus (TP), Total Soluble Phosphorus (TSP), and Orthophosphorus (OP). TP is exactly as the name implies; measuring all forms of phosphorus in the water column at the time of sampling. TSP is a measure of all forms of phosphorus dissolved in the water column, and OP is the amount of phosphorus in the water column that is most readily available for consumption by the phytoplankton.

Total Phosphorus measurements (TP) for the open water sites for the year are shown in Figure 3. These sites show two times of peak TP levels, once in the spring and once in the fall. The spring peak is due to the rapid influx of nutrients, including P, from snowmelt and runoff throughout the basin. This rapid influx of nutrients outpaces the biological uptake and removal of phosphorus by sedimentation from the upper waters. Throughout the summer months TP levels decline due to the sedimentation of organisms that have taken up the P, and its removal from the water column via uptake by rooted aquatic plants. The fall overturn brings P into the surface waters from deeper strata. The soluble P becomes available for the primary producers (algae) in the trophogenic zone (surface waters) and can often cause phytoplankton blooms in the fall.

The near-shore sites (Figure 4) generally show the same pattern of phosphorus concentrations through the sampling season. The Warner Bay site (0-2m) reveals a somewhat differing pattern of TP concentrations throughout the year. As the summer progresses, TP values continue to increase to levels not seen at the other near-shore sites (avg. TP 8.8 ± 2.3 μg P/l). The most likely source of phosphorus to this site under normal conditions is organic phosphorus containing material from the adjacent wetland system. Release from the wetland often causes the water in Warner Bay to take on a brown color and is the result of dissolved organic compounds. This is a common occurrence in freshwater wetland systems.

Mean concentrations varied at the open water sites from 3.6 ± 0.7 µg P/l at Roger's Rock in the north basin to 4.7 ± 0.7 µg P/l at Tea Island in the south basin. Historically, higher values are seen in the southern basin. Similar results are seen for average TP values in the near-shore waters (Figure 4). Again, the Warner Bay site shows the greatest average TP values due to its unique source of nutrients not seen at the other shallow water sites.

The deep-water (hypolimnetic) sampling areas (Figure 5) show a different seasonal TP pattern. At spring overturn, the phosphorus is distributed throughout the entire water column resulting in TP values comparable to surface waters. As summer stratification progresses, TP values increase in the lower waters due to the settling of dead organisms (largely plankton) that have taken up the phosphorus in the upper waters. Also at work in some of these deep-water sites is the release of P from sediments during the late summer due to the decreased dissolved oxygen found in these waters. The Tea Island 30 m site shows the most marked increase of P where levels reached 6.9 µg P/l in October, just prior to fall destratification. This also suggests that while thermal stratification is absent in November, chemical stratification was still present. This has been the case at T30 since severe oxygen depletion (< 5 mg/l) was first observed in 1985.

Total Filterable Phosphorus (TFP) levels for the open water and near-shore sites followed much the same seasonal trends as TP only at lesser values. The deep-water sites showed a somewhat differing seasonal pattern in TFP than in TP. All sites showed a decrease in TP after the July sampling, but by August and early September most sites had returned to previous levels observed earlier in the summer. TFP values tended to mimic the trend set by the TP values for the course of the sampling season, with the exception of the deep-point values, which remained relatively stable year-round. This shows in part that the phosphorus increase in the deeper waters is particulate in nature, indicative of materials settling and accumulating from the upper waters. This is also clearly shown when comparing average TP to average TFP. The T30 site recorded the greatest average TP of 5.8 ± 1.1 (SD) µg P/l with T25 having a TP average concentration of 5.5 ± 0.9 (SD) µg P/l. In comparison, the average TFP for both sites was similar at 2.8 ± 0.8 (SD) and 2.6 ± 0.7 (SD) µg P/l, respectively. This indicates the more particulate nature of the P containing compounds in the near sediment waters than hypolimnetic waters slightly higher in the water column.

Average orthophosphate (OP) levels were close to the limit of detection (1.0 µg P/l) for most open-water sites. This is a common occurrence in Lake George where phosphorus is the limiting nutrient for primary productivity. When available, phosphorus (as OP) is quickly taken up within the biomass of phytoplankton and rooted macrophytes. A majority of the epilimnetic samples from the open water sites ranged between 1.0 and 3.3 µg P/l for the 2001 sampling season. Tea Island was the highest in average OP for the 2001 sampling season at 1.6 µg P/l.

Near-shore waters behave somewhat differently than open waters when considering OP, or any other soluble nutrient for that matter. Detectable levels are more commonly seen due to the close proximity to their sources, namely the adjacent shoreline. Warner Bay generally has the highest average OP levels, and in 2001 the average was 2.9 ± 1.0 (SD) µg P/l. Warner Bay is relatively remote from the main water body of Lake George and is not as likely to mix with those waters, causing little dilution of the nutrients. In addition, inputs from the attached wetland complex and a developed shoreline into its shallow bay often cause Warner Bay to have detectable levels of soluble nutrients. The Lake George Village sampling site is located near inputs from several tributaries. Both sampling sites are in shallow waters with relatively intense recreational use. Resuspension of nutrients from the lake bottom in shallow waters frequented by recreational boaters is a commonly reported phenomenon.

Nitrogen

Nitrogen is important to the functioning of freshwater ecosystems as it is a major component of cellular material and has a great effect on lake productivity. This program measures two important soluble forms that nitrogen takes in freshwater systems, nitrate (NO_3) and ammonia (NH_4). These nitrogen-containing compounds are the most readily available forms for bacteria and phytoplankton to utilize; they are the organisms that establish the foundation of the food chain in lakes. Total nitrogen concentrations are also recorded for all samples.

The seasonal fluctuations of nitrate in the Lake George surface waters are usually quite predictable where nitrate concentration is normally elevated in the spring following snowmelt and its rapid runoff into the lake. As summer thermal stratification becomes established, the utilization of NO_3 by phytoplankton outpaces inputs and levels fall to equal to or below the limit of detection, 0.01 mg N/l. Figure 6 shows this pattern development for all the surface water sites during 2001. The greatest levels of NO_3 were seen at Tea Island 30 m at various dates throughout the sampling season, ranging from 0.02 to 0.10 mg N/l at the highest levels. Basin Bay also measured somewhat higher levels in the deep waters in late summer (0.05 – 0.07 mg N/l). Most nitrate values were above the detection limit in March, and the deeper waters of Tea Island were the highest for March, reaching 0.10 mg N/l. Nitrate levels began to decrease in early April after snowmelt runoff, and by late May/early June, all detectable nitrate had been removed from the surface waters at the open water sites. Most deep point samples continued to show measurable levels for NO_3 for the rest of the sampling season.

Ammonia was at the limit of detection (0.01 mg N/l) at the sites that were sampled through the ice in March, with the exception of Smith Bay, which had a value of 0.027, the highest reading for ammonia on Lake George for the 2001 sampling season. For most open water sites in 2001, the ammonia levels were rarely above the limit of detection. Tea Island exhibited slightly elevated levels of ammonia in June and July at the deep points.

Total nitrogen is a measure of the total amount of nitrogen present in the water samples, both dissolved and bound in cellular and detrital materials. Total nitrogen values for Lake George ranged from 0.08 to 0.64 mg N/l (Figure 7). Maximum concentrations were observed in Warner Bay in March, which also exhibited higher than normal ammonia and nitrate values (Figure 8). Total nitrogen values followed seasonal trends similar to those described for total phosphorus.

Chlorophyll *a*

Figure 9 gives the average chlorophyll *a* measurements for the open water sites. Tea Island recorded the greatest average chlorophyll *a* for the open water sites with 1.9 ± 1.0 (SD) µg/l and

Roger's Rock the least with 1.3 ± 0.3 (SD) µg/l. There is a general trend of decreasing average chlorophyll _a_ moving northward from Tea Island in the south to Rogers Rock in the north. The sites of the south basin all show a similar pattern of chlorophyll _a_ levels throughout the year. The pattern of chlorophyll _a_ closely follows the changing availability of the major nutrients needed for algal growth, namely phosphorus and nitrogen, where the spring and fall of the year show greater concentrations of chlorophyll _a_ than the summer. Rapid nutrient inputs from spring rains and snowmelt create a situation ideal for phytoplankton growth, allowing their populations to expand. As the rates of nutrient utilization and incorporation into biomass outpace inputs to the lake, populations die off and sink into the deeper waters, carrying with them the nutrients absorbed. Late in the summer the thermocline moves down into the deeper waters, making those nutrients available for the phytoplankton in the trophogenic zone of the lake. This availability of nutrients is reflected in the fall increase of chlorophyll _a_ concentrations.

The shallow waters do not behave in as predictable a manner. Being relatively close to a major source of nutrients to the lake at the shoreline, phytoplankton populations can fluctuate quickly as nutrients become available. The Warner Bay site is a good example of this (Figure 10) as chlorophyll _a_ concentrations fluctuate widely throughout the summer. Chlorophyll levels in the near-shore areas of the south basin generally increased throughout the sampling season. Lake George Village increased at a fairly steady rate, with a small spike in June. Warner Bay experienced a large jump in early June and another in July before returning to lower levels for the rest of the year. Chlorophyll levels in the north basin remained fairly stable across the sampling season.

Silica

Although the reactivity of silica (SiO_2) is relatively low, it can play a major role in freshwater systems as related to the growth of diatomaceous algae. Diatoms use silica to create their frustules, or exoskeletons. The flux of silica in the waters of lakes most often is tied to diatom production and population sizes.

Average silica levels in the open waters of Lake George are similar throughout the lake, ranging from an average low at Sabbath Day and Smith Point of 0.70 mg Si/l to a high of 0.80 mg Si/l at Tea Island. Near-shore sites did not differ substantially from their open-water counterparts, with Huletts Landing and Hearts Bay averaging the lowest at 0.7 mg Si/l and Warner Bay recording the highest average for the lake in 2000 with 1.1 mg Si/l. However, there are distinct and often predictable fluctuations of SiO_2 on a seasonal basis (Figure 11). Peaks in SiO_2 concentrations generally occur in the spring when inputs from groundwater and surface runoff are greatest. As the summer progresses, SiO_2 levels begin to decrease as diatom populations expand and assimilate the silica into their frustules. This uptake of silica and its subsequent removal from the waters through sedimentation outpaces inputs, resulting in mid-summer minima in SiO_2 levels. As diatom populations diminish due to lowered soluble nutrient availability, SiO_2 levels return to approximate spring concentrations by fall overturn.

Chloride

The levels of chloride in the waters of Lake George generally vary with season. Figure 12 shows levels of chloride present in all surface waters throughout the year. At the Tea Island site, a spring maximum is observed, which can be attributed to the runoff of road deicing materials, or road salt. The greatest average chloride concentrations of surface waters are found in the southernmost portion of Lake George, at Lake George Village (15.9 mg Cl/l), Tea Island (13.8 mg Cl/l) and Warner Bay (14.8 mg Cl/l) sites. These sites are in close proximity to sources of runoff from roads salted heavily during the winter and spring of the year. The open water sites of Basin Bay and Dome Island recorded levels of 12.6 and 12.4 mg Cl/l, respectively from the south basin. Rogers Rock had an average level of 11.1 mg/l from the north basin. The whole lake average for chlorides was 12.5 ± 2.0 (SD). Typically, the southern basin shows greater levels of chloride than the northern basin. The greatest differences were observed between the Caldwell sub-basin (Tea Island and Lake George Village). These differences may be attributable to stormwater runoff from the urbanized portion of the Lake George basin.

Alkalinity

Alkalinity is the measurement of the ability of water to neutralize the inputs of acids. This measurement is quite important in the northeast region of the United States, and the Adirondacks in particular, because of the effects acid precipitation has had on many lakes and ponds. The natural functioning of these ecosystems has been altered by acidification. The waters of Lake George have fortunately been spared the major impacts of acid precipitation due primarily to its large volume. Alkalinity measurements taken from the open water sites showed stable levels throughout the year where 2001 averages ranged from 27 to 29 mg $CaCO_3$/l for all open-water sites on Lake George. The mean alkalinity, lake wide, was 27.3 mg $CaCO_3$/l. These levels of acid neutralizing ability appear sufficient at the present to protect Lake George from the detrimental impacts of acid precipitation.

Specific Conductance

Specific Conductance is a general indicator of the total ionic substances dissolved in the water, measured by the ability of the water to carry an electric current. As more ionic substances become dissolved in the water, specific conductance increases. Lakewide, specific conductance was recorded as 108.8 umhos ± 4.4 (SD). The waters of the South Basin show somewhat greater average specific conductance than the North Basin where the greatest measurements were recorded in the surface waters at Lake George Village, Warner Bay and Tea Island, (117, 112, & 111 umhos respectively). The waters of the North Basin showed lower average measurements ranging from 105 to 106 umhos, with near-shore values similar to open lake values.

pH

The pH measurements for all surface waters are shown in Figure 13. pH measurements follow a seasonal trend with somewhat depressed pH values associated with spring runoff. Maximum (most alkaline) measurements are observed in midsummer in all surface water samples. In hypolimnetic waters, as summer stratification persists, the acidity levels increase slightly as a result of the input of CO_2 from oxidation processes in the lake bottom sediments. The average pH value at all sites for 2001 was 7.48.

Calcium

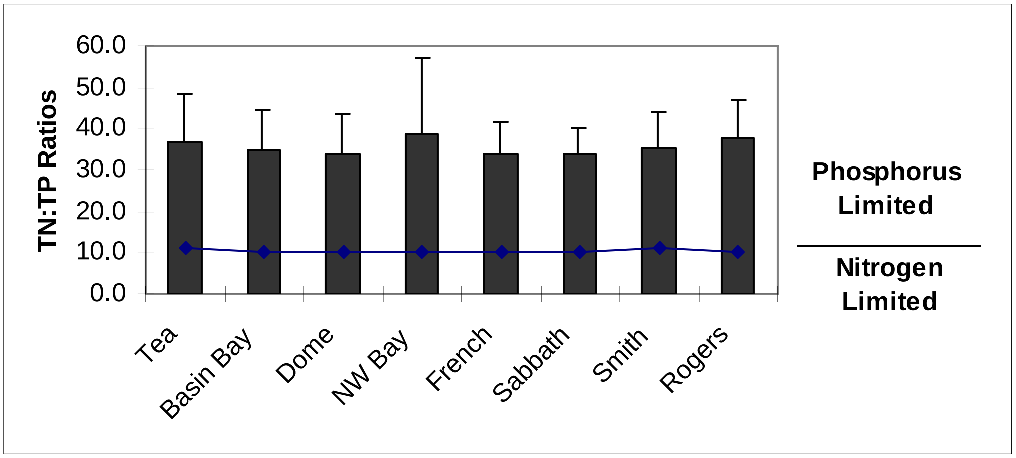
Lake-wide, Lake George calcium concentrations averaged 10.2 ± 0.6 (SD) mg/l Ca. The range of these averages was 9.8 – 10.3 mg/l Ca. Calcium levels lake-wide remained relatively constant throughout the sampling period, with the exception of a slight decline in June to just below 10 mg/l (Figure 22). In recent years, calcium has become an element of concern due to the introduction of the zebra mussel (*Dreissena polymorpha*), a bivalve from Europe. Bivalves require certain levels of calcium at various stages in their life cycle, primarily for the construction of their shells. The first two weeks of their life cycle, in the larval stage, are the most critical for shell development and consequently calcium concentrations in the water column play a major role at this point. For zebra mussel larvae to develop shells, they require a minimum of 20 mg/l Ca in the water column (Hinks and Mackie, 1997). However, once the larvae develop into the juvenile adult stage, mussels are found to have positive growth in waters containing as little as 8-9 mg/l Ca.

Nutrient Ratios

Ratios of Total Nitrogen to Total Phosphorus are commonly used to predict species dominance in phytoplankton populations. Low N:P ratios (less than 30) typically favor blue-green algae and diatoms. Higher ratios generally favor green algae. Lake-wide, N:P ratios generally ranged between 13 and 71. N:P ratios show a seasonal pattern, with highest values observed in mid-summer, and values were again on the rise in November after fall turnover (Figure 14). Low N:P ratios are observed in the spring and fall, typical times of diatom dominance.

Nutrient limitation of algal growth has always been attributed to lack of phosphorus. The 2001 data (Figures 14 &15) support this supposition, however more interesting are the differences between basins of the lake. The south basin group includes sites at French Point in the Narrows and Northwest Bay. Ratios of Total Nitrogen (TN) to Total Phosphorus (TP) support the contention that more phosphorus is available in the south basin. Identification of the sources of phosphorus to the basin and means to curtail inputs is warranted.

Figure 15. Ratios of Total Nitrogen to Total Phosphorus for mid-lake sites. Error bars are 1 Standard Deviation (n=12).

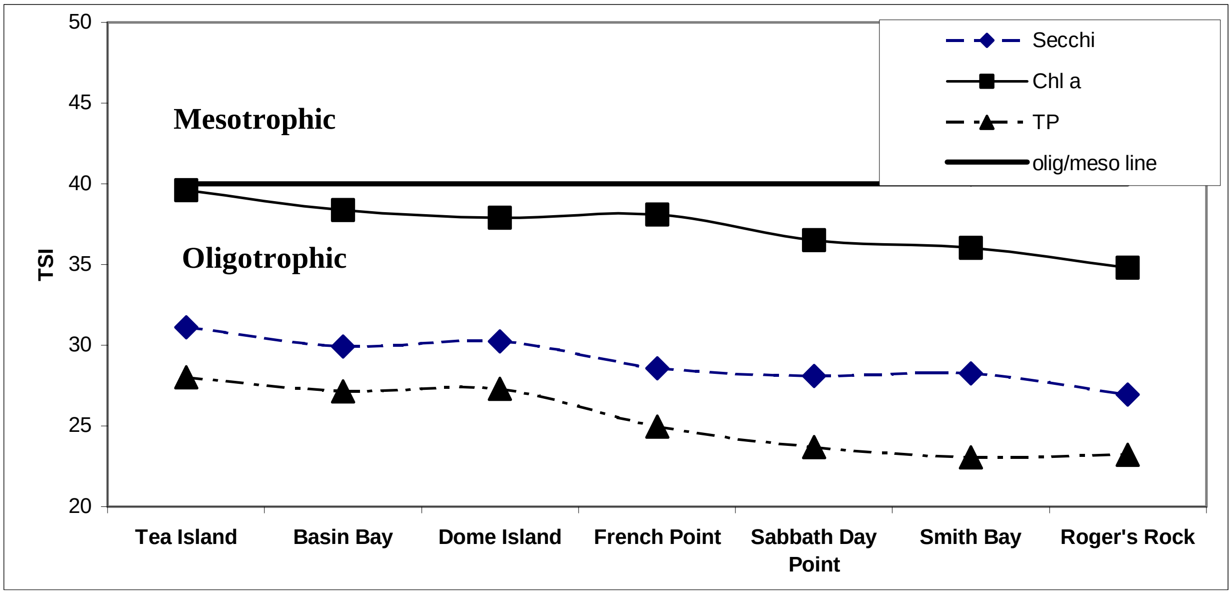


Silica limitation has also been suggested as a controlling factor for phytoplankton speciation and abundance. Lake-wide, Si:P ratios ranged from a low of 62 at Warner Bay to a high of 362 at Huletts Landing (Figure 16). In the south basin open water sites, ratio averages ranged from 162 at Basin Bay to 176 at Dome Island. In the north basin, the range was 172 at French Point to 204 at Rogers Rock. On one occasion the Si:P ratios for mid-lake samples was less than 100, a level considered to limit diatom growth. This occurred at French Point in July, with a ratio of 87. Other exceptions were Warner Bay and Lake George Village, producing Si:P ratios below 100 at various times throughout the course of the sampling season, and at a few deep points. This suggests that if the Si:P ratio were to decrease much farther, diatom growth in Lake George would become limited by silica instead of phosphorus. This trend would first be observed in the shallower bays of the lake, and then the trend would gradually move into the open waters of Lake George.

Trophic State

A lake with a high level of nutrients is generally known as eutrophic; conversely, a lake with low levels of nutrients and aquatic biota is called oligotrophic. The term mesotrophic is used to describe all lakes that fall between the two extremes. The Carlson Trophic State Index (TSI) relates to the amount of nutrients available for consumption by various organisms in the lake. The index describes all shades of the trophic process on a scale ranging from 0 to 100 (0 being highly oligotrophic). A decrease of 10 points on the TSI scale (e.g., from 30 to 20) represents a doubling of Secchi depth in meters (e.g., from 9 to 18 meters). Chlorophyll and total phosphorus values can also be applied to the TSI model. Figure 17 is a chart relating the Carlson Trophic State Index values to the classic definitions of trophic states. The TSI values used to determine trophic status are based on values published by the US EPA and the NYS DEC.

Figure 17. Carlson trophic state index (TSI) for Lake George, based on Secchi depth, total phosphorus and chlorophyll concentration.



TSI values were generated using Secchi readings, chlorophyll and total phosphorus data. TSI values indicate that all midlake sites sampled should be classified as oligotrophic. A south to north trend in TSI is apparent for all parameters with values indicating the lowest water quality present in the south basin. This section of the lake basin also has the greatest amount of urbanization. Elevated nutrient levels and reduced transparency in Lake George have been attributed to urbanization and resultant storm water runoff and its associated pollutants (Eichler et al., 1993; Sutherland et al., 1983).

The 2000 Chemical Monitoring Program on Lake George marked the 20th anniversary of the program. In 1990, a report was written summarizing the results of the first decade of the program (Boylen *et al*, 1992). This data was used to predict the concentrations of total phosphorus, chloride, and chlorophyll for the three basins of the lake in 2000. Based on a calculated rate of change for these three analytes, predicted concentrations for 2000 were:11.01 mg/l Chloride, 4.54 µg/l Total Phosphorus, and 1.43 µg/l Total Chlorophyll. The actual observed values for these analytes in 2000 were: 12.15 mg/l Chloride, 4.45 µg/l Total Phosphorus, and 2.05 µg/l Total Chlorophyll. In 1990 rates of change were 0.23 mg/l/y chloride, 0.04 µg/l/y TP, and 0.03 µg/l/y chlorophyll. Using the full twenty year data set, new rates of growth for these analytes were predicted to be: 0.31 mg/l/y chloride, -0.03 µg/l/y TP, and 0.02 µg/l/y chlorophyll. Based on a calculated rate of change for these three analytes, predicted concentrations for 2001 were:12.46 mg/l Chloride, 4.42 µg/l Total Phosphorus, and 1.45 µg/l Total Chlorophyll. The actual observed values for these analytes in 2001 were: 12.3 mg/l Chloride, 4.1 µg/l Total Phosphorus, and 1.5 µg/l Total Chlorophyll. It should be noted that the rates of growth for chlorophyll and total phosphorus are minimal, suggesting that for this time period there has been little change in the concentrations of these two analytes in the water column of Lake George. Chloride concentration has increased significantly, and as noted above, this change can be largely attributed to extensive use of road salt in the Lake George basin.

CONCLUSIONS

As in past years, major changes in chemical and physical parameters of the epilimnetic waters of mid-lake sites were not observed. However, some areas sampled as a part of this program show signs of decreased water quality, namely the deep waters at the Tea Island site. This site has continued to show near anaerobic conditions in the deep waters concomitant with phosphorus and nitrate accumulation during the later stages of summer stratification. Such conditions are not only stressful to cold water fish (e.g. trout and salmon) which require oxygen levels above 4.0 mg/l, but also promote the dissolution of nutrients. Nutrients, primarily nitrogen and phosphorus, which are normally tied-up in the sediments under aerobic conditions, are available to promote greater algal growth (productivity) when oxygen levels are depleted.

Nutrient limitation of algal growth has always been attributed to lack of phosphorus. The 2001 data supports this supposition, however more interesting are the differences between basins of the lake. Ratios of Total Nitrogen (TN) to Total Phosphorus (TP) support the contention that more phosphorus is available in the south basin. Identification of the sources of phosphorus to the basin and means to curtail inputs is warranted. A FUND supported effort by the Lake George Park Commission to improve the quality of phosphorus budgets for the lake, thereby identifying sources of phosphorus and their relative contributions, is underway. Continued monitoring to evaluate the success or failure of mitigation efforts is also necessary.

Seasonal trends observed in dissolved nutrients and other essential constituents can be attributed in many cases to primary production among the phytoplankton. Soluble nutrients have shown maximum concentrations in past years following snowmelt episodes and the resulting terrestrial runoff. The drought conditions in 2001 can affect the composition of various components of the water column. This in turn can affect other biological and chemical qualities of the water. For example, chlorophyll and phosphorus distributions throughout the water column might be limited in the spring due to the lack of runoff. Lower phosphorus levels provide fewer nutrients for the algae. This in turn can affect zooplankton populations, and so on up the food chain. Differences in overall water quality were observed between the north and south basins of Lake George in 2001. These differences generally indicated poorer water quality in the southern, more urbanized portion of the lake. The largest differences were found to occur between the Tea Island (Caldwell) sub-basin and the adjacent basin to the north; quantified by the sites at Dome Island and Basin Bay. The ultimate consequences of human activity in the basin will be demonstrated through continued long-term monitoring of the sites contained within this program.

ACKNOWLEDGMENTS

We would like to thank the FUND for Lake George for its continued financial support, which makes possible the continuing long-term study of the chemical water quality of Lake George. We would also like to thank Jeffrey Bartkowski, David Winkler, Keren Murphy, Katherine Offerman, Paul Thorn, and Valerie Van Leuven for their aid in data collection and analysis. Jim Sutherland provided the 1992-2001 precipitation data used in the report. Carol Collins provided technical review of the manuscript; their assistance is appreciated.

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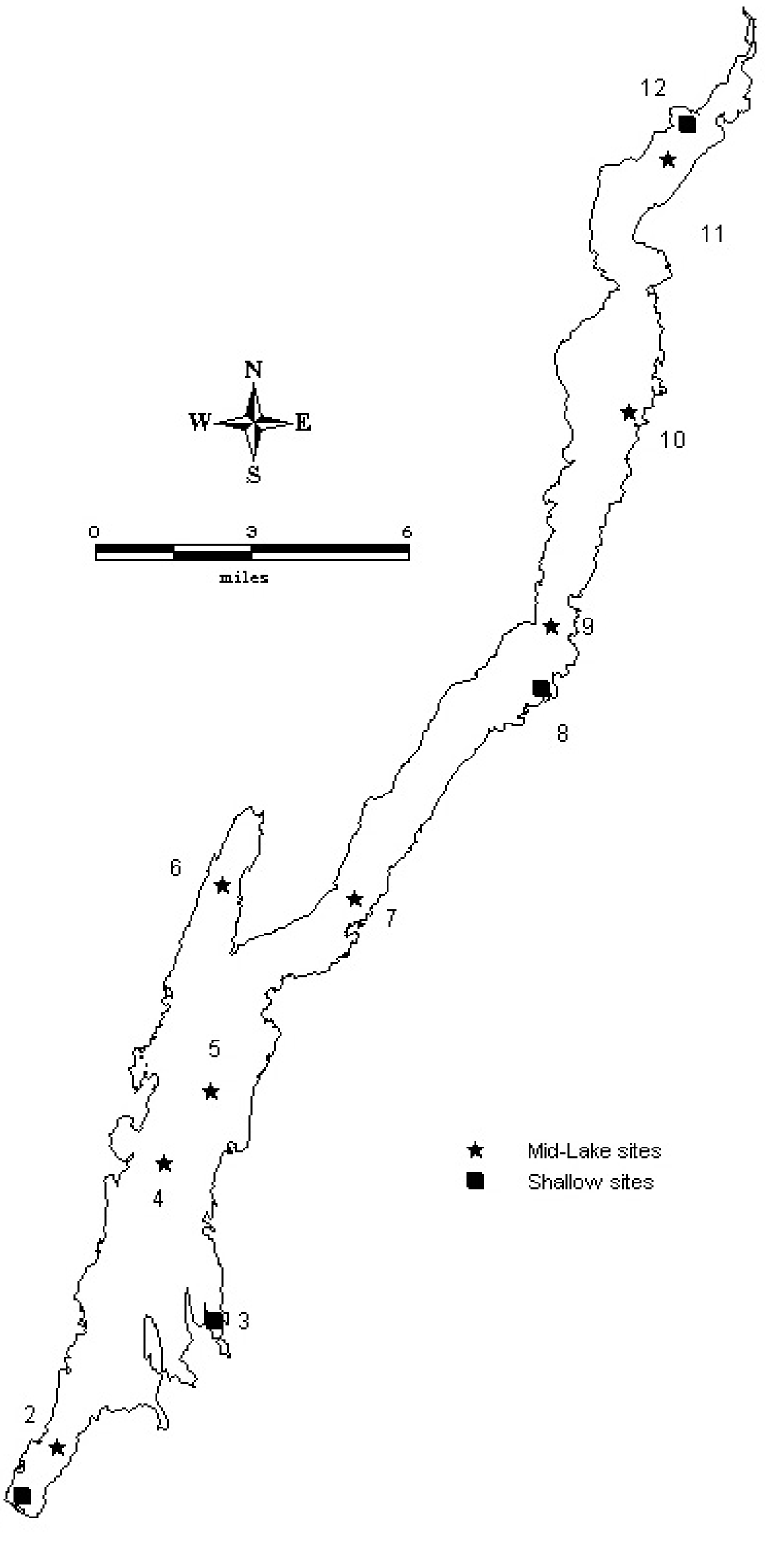
Appendix A Figures for Offshore 2001

Figure 1. Location of the Offshore Program sampling sites.

1. Lake George Village
2. Tea Island
3. Warner Bay
4. Basin Bay
5. Dome Island
6. Northwest Bay
7. French Point
8. Hulett's Landing
9. Sabbath Day Point
10. Smith Bay
11. Roger's Rock
12. Hearts Bay



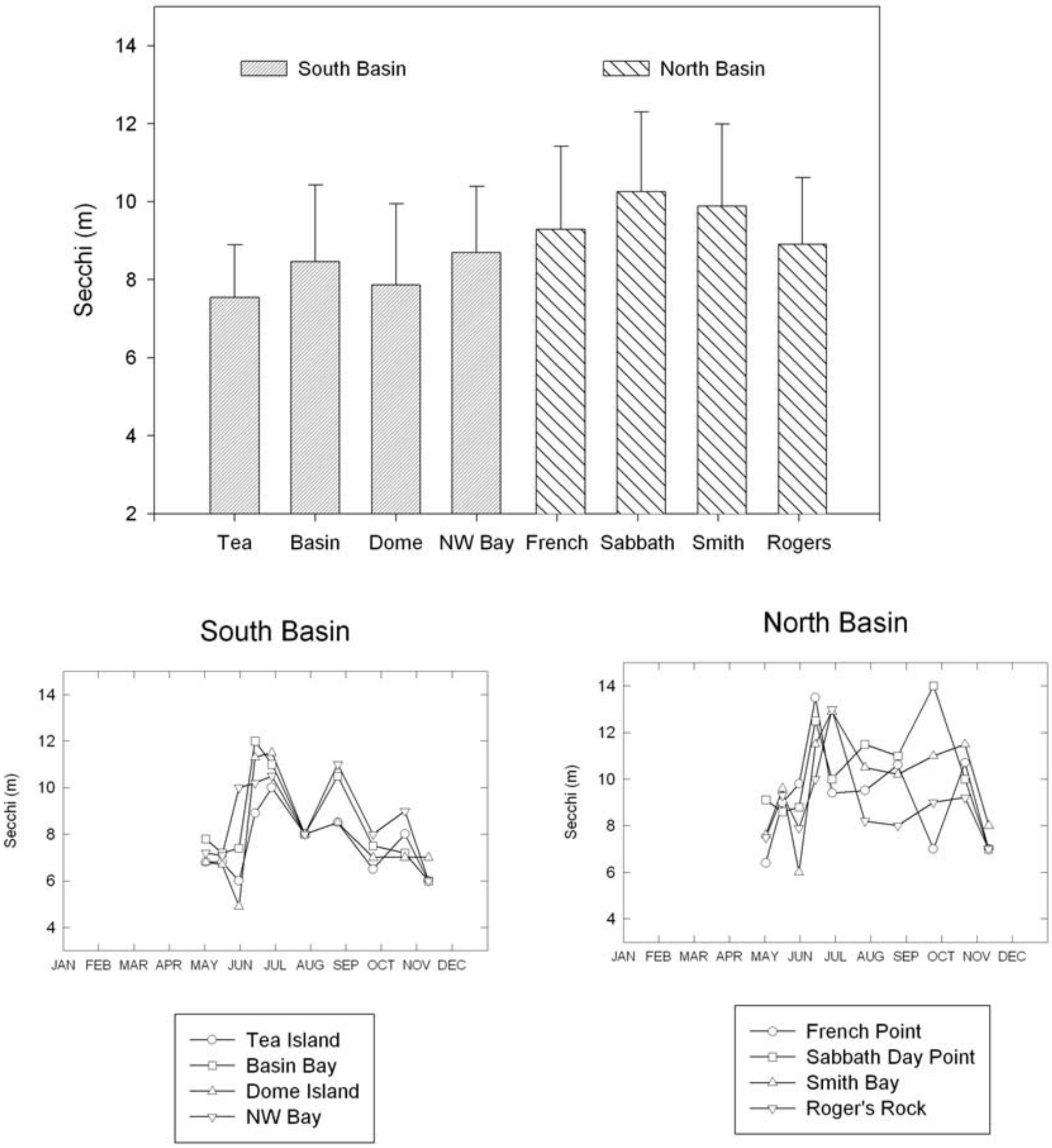


Figure 2. 2001 Average Secchi Transparencies for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

Figure 3. 2001 Average Total Phosphorus concentrations for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

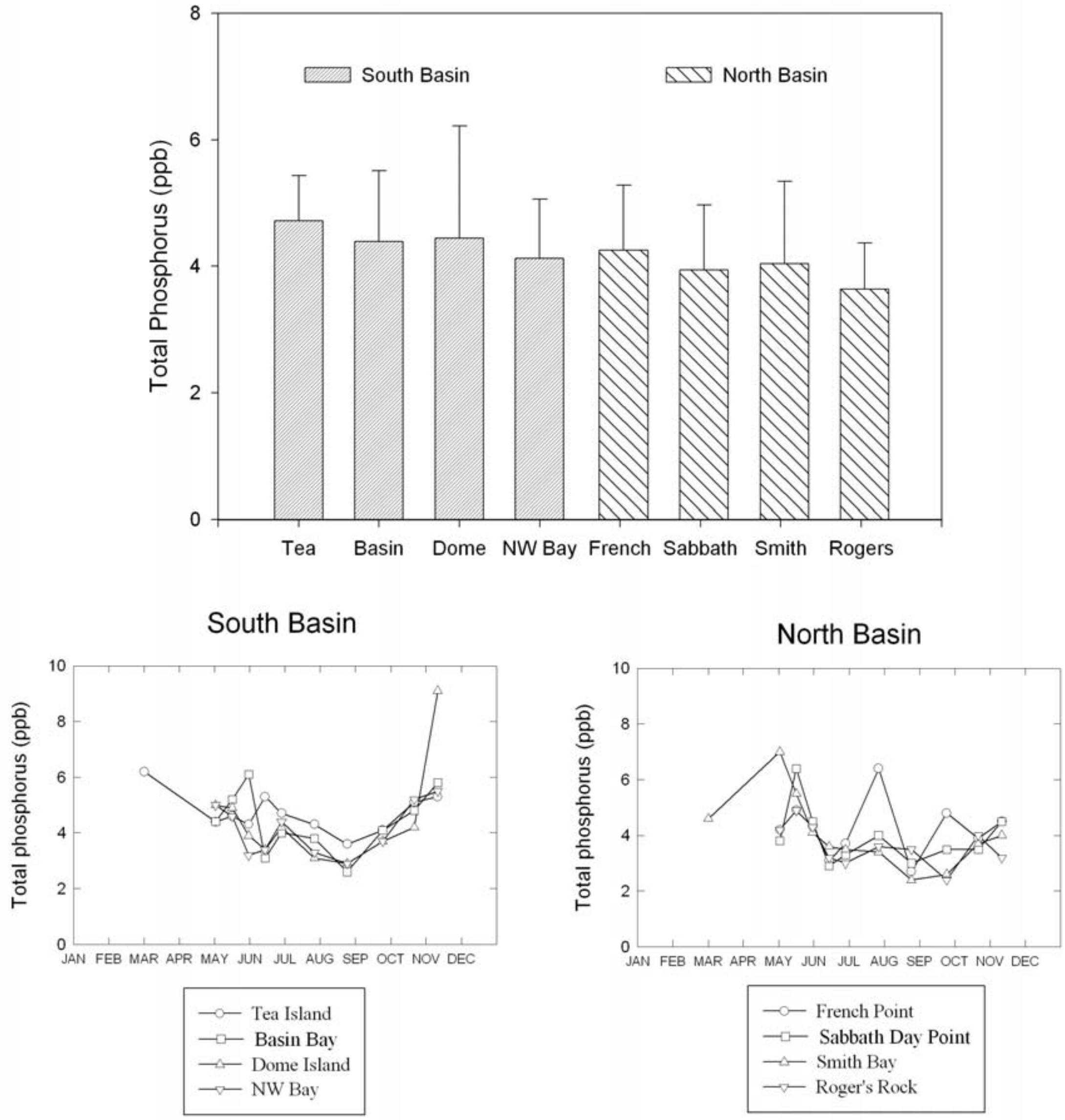


Figure 4. 2001 Average Total Phosphorus data for all near-shore sites in Lake George, NY.
Average and seasonal data by site.

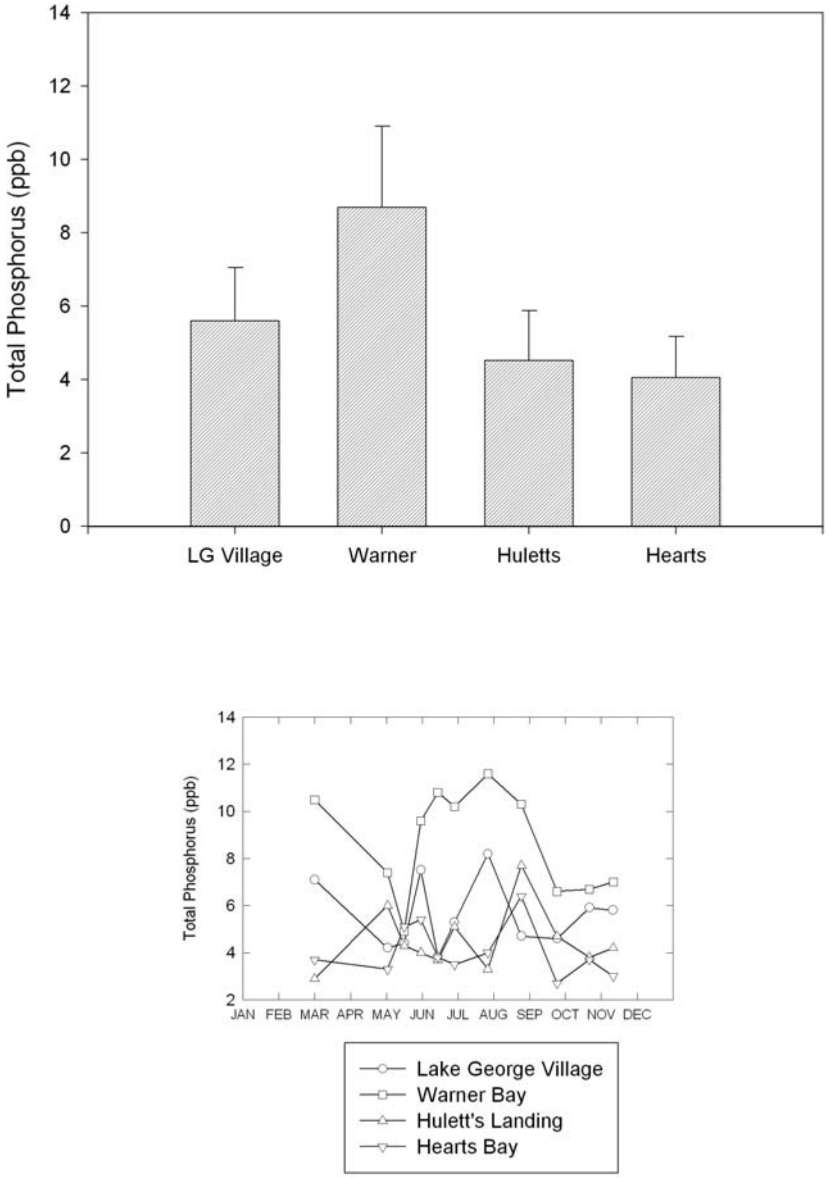


Figure 5. 2001 Average Total Phosphorus concentrations for all hypolimnetic sites in Lake George, NY. Average and seasonal data by site.

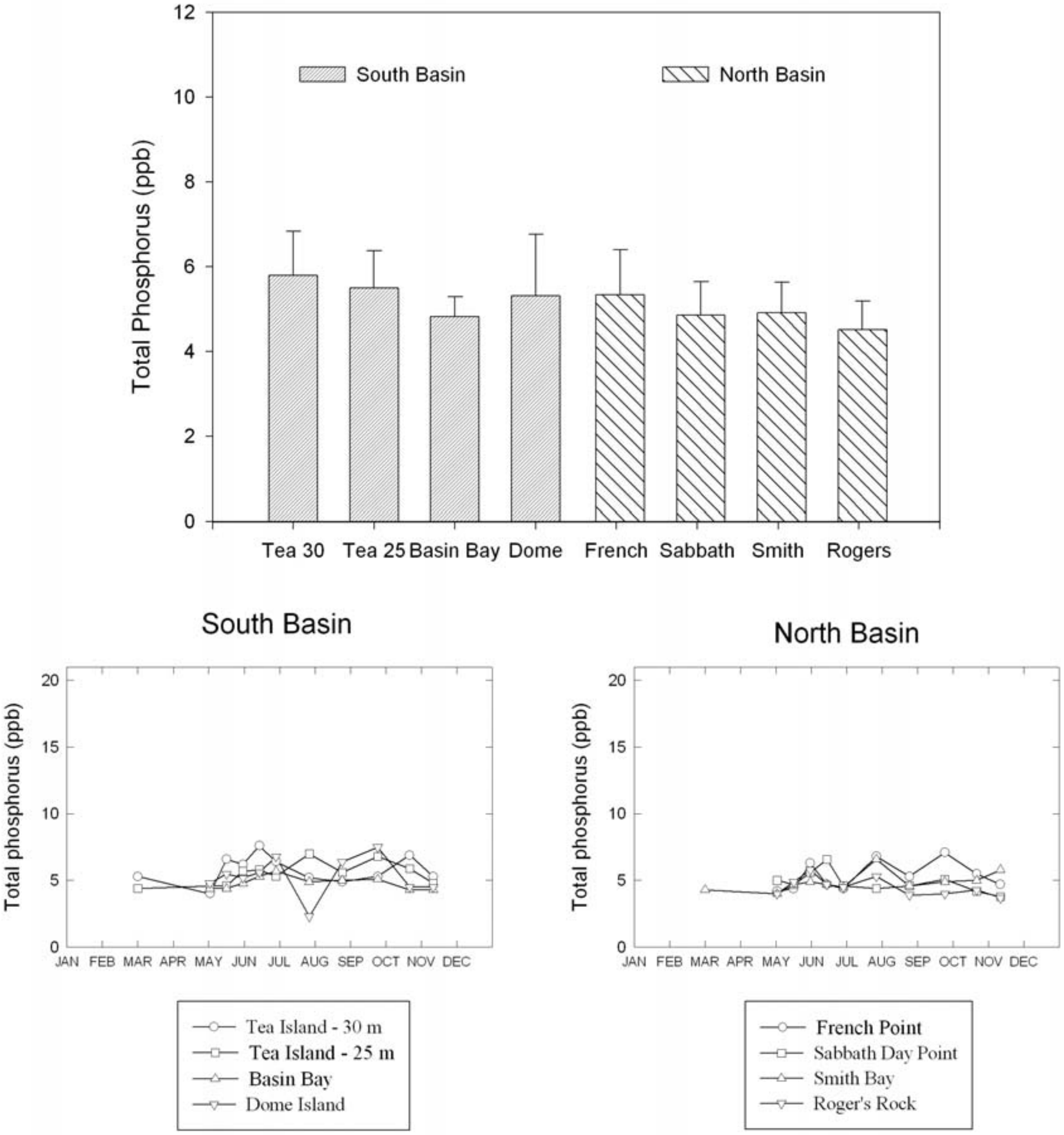


Figure 6. 2001 Average Nitrate concentrations for mid-lake sites in Lake George, NY. Average and seasonal data by site.

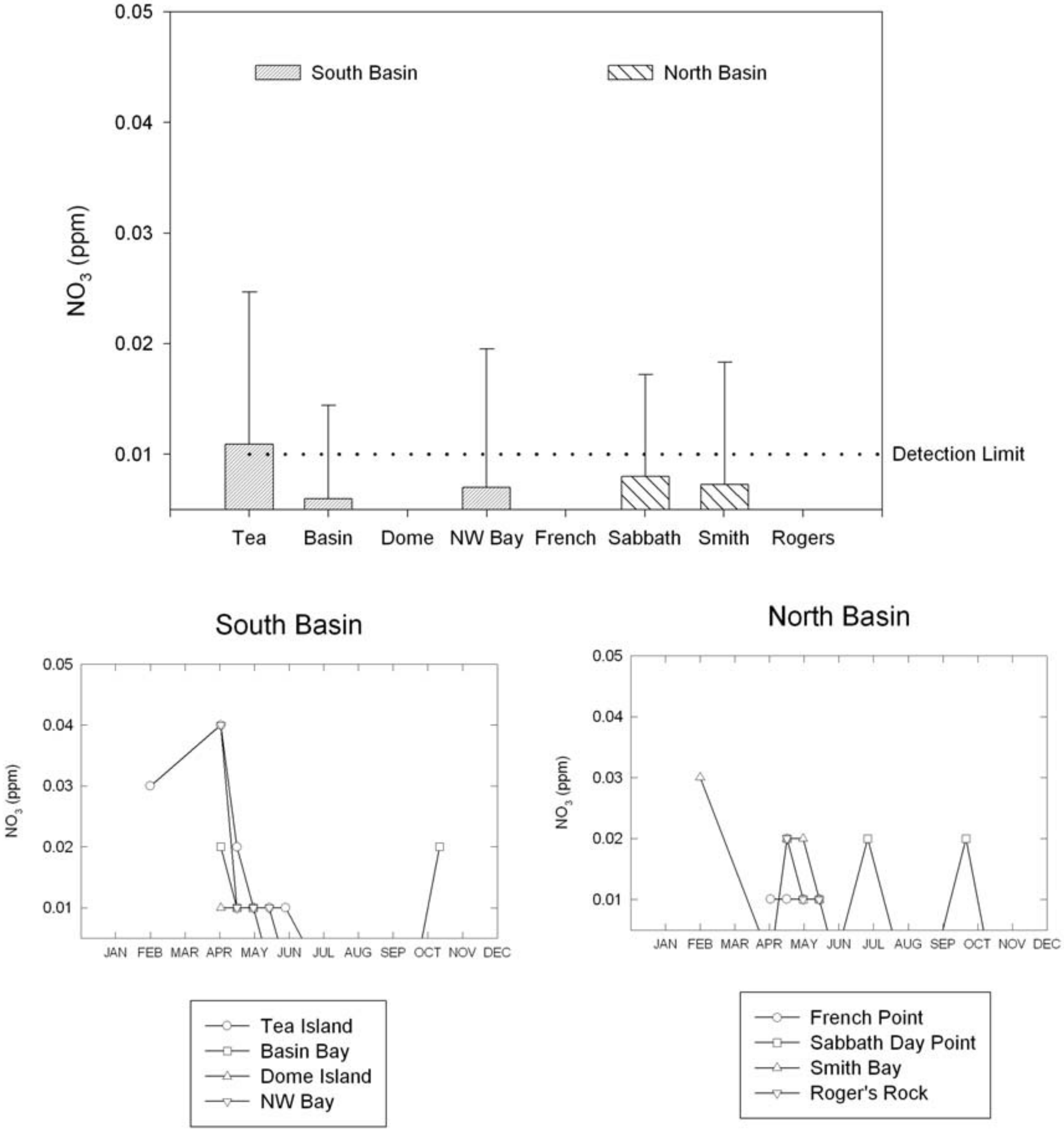


Figure 7. 2001 Average Total Nitrogen concentrations for all mid-lake sites in Lake George, NY.
Average and seasonal data by site.

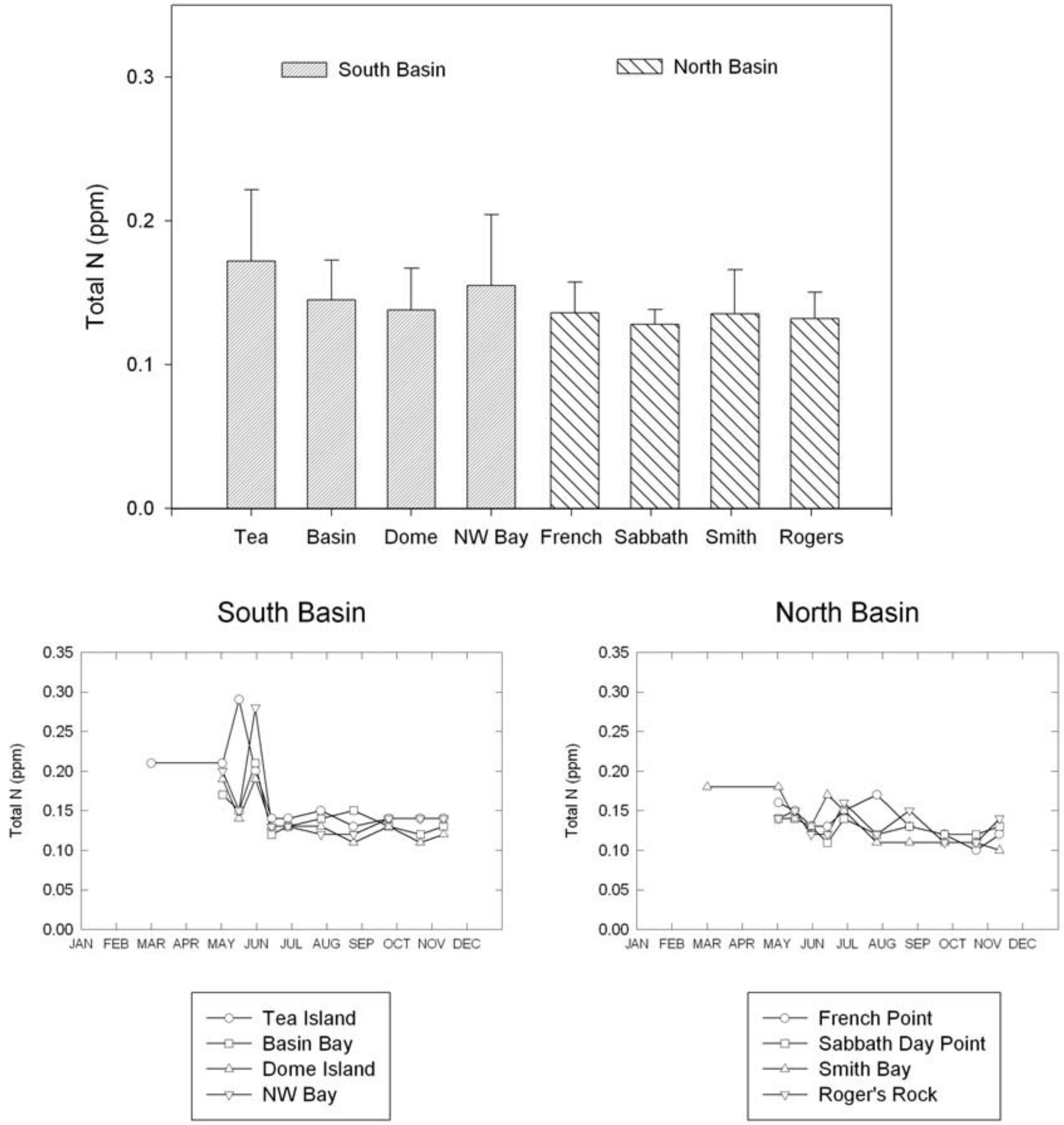


Figure 8. 2001 Average Total Nitrogen data for all near-shore sites in Lake George, NY.
Average and seasonal data by site.

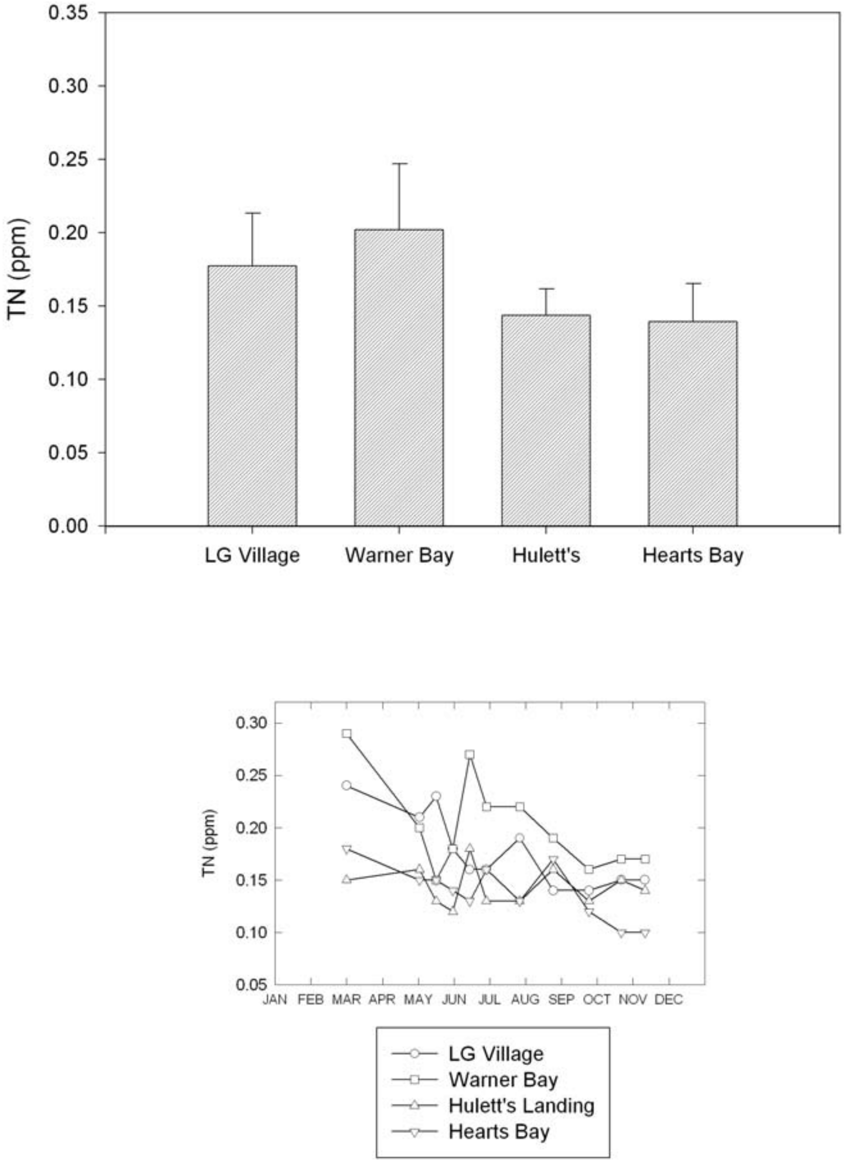


Figure 9. 2001 Average Total Chlorophyll concentrations for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

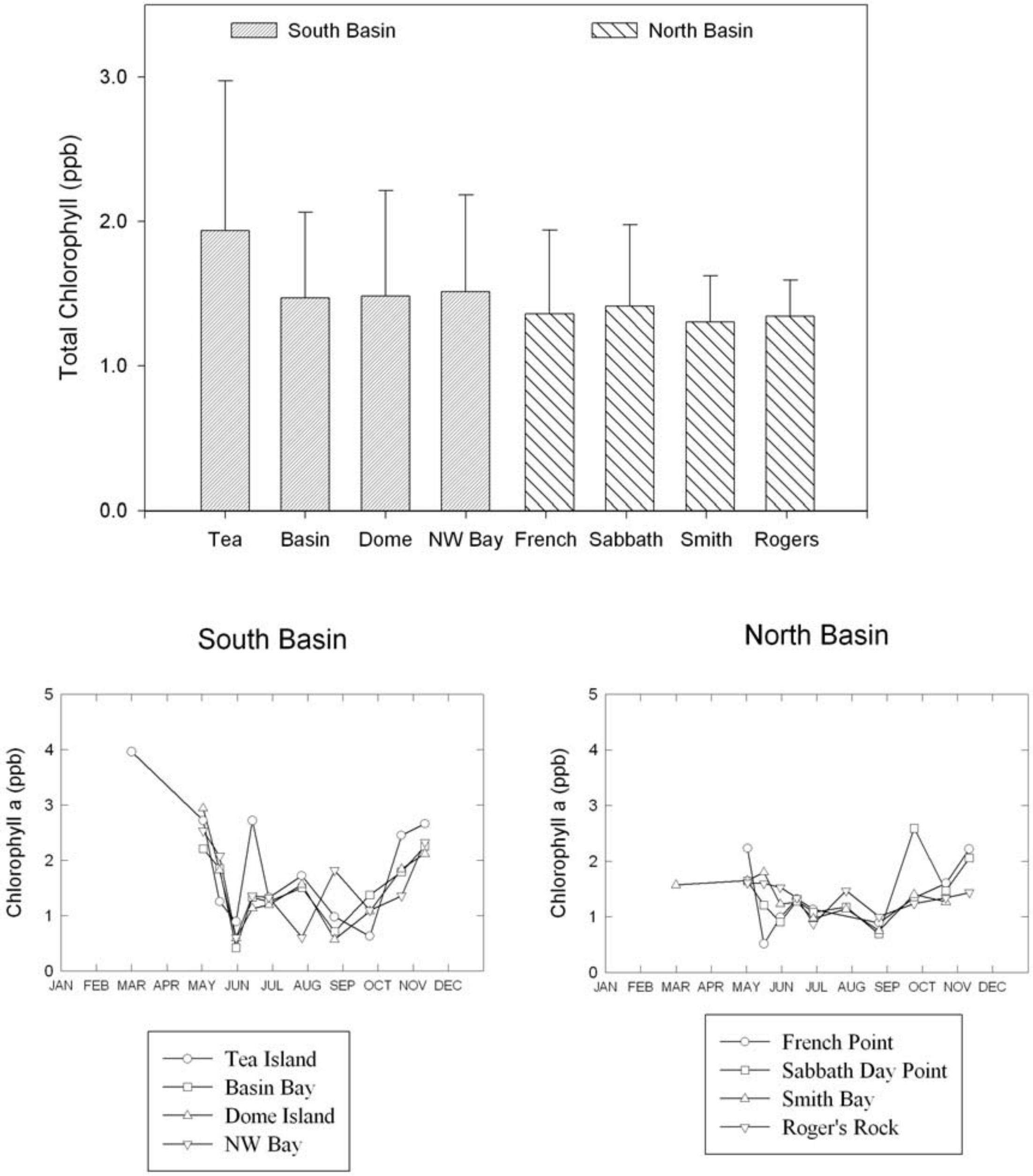


**Figure 10. 2001 Average Total Chlorophyll data for all near-shore sites in Lake George, NY.
Average and seasonal data by site.**

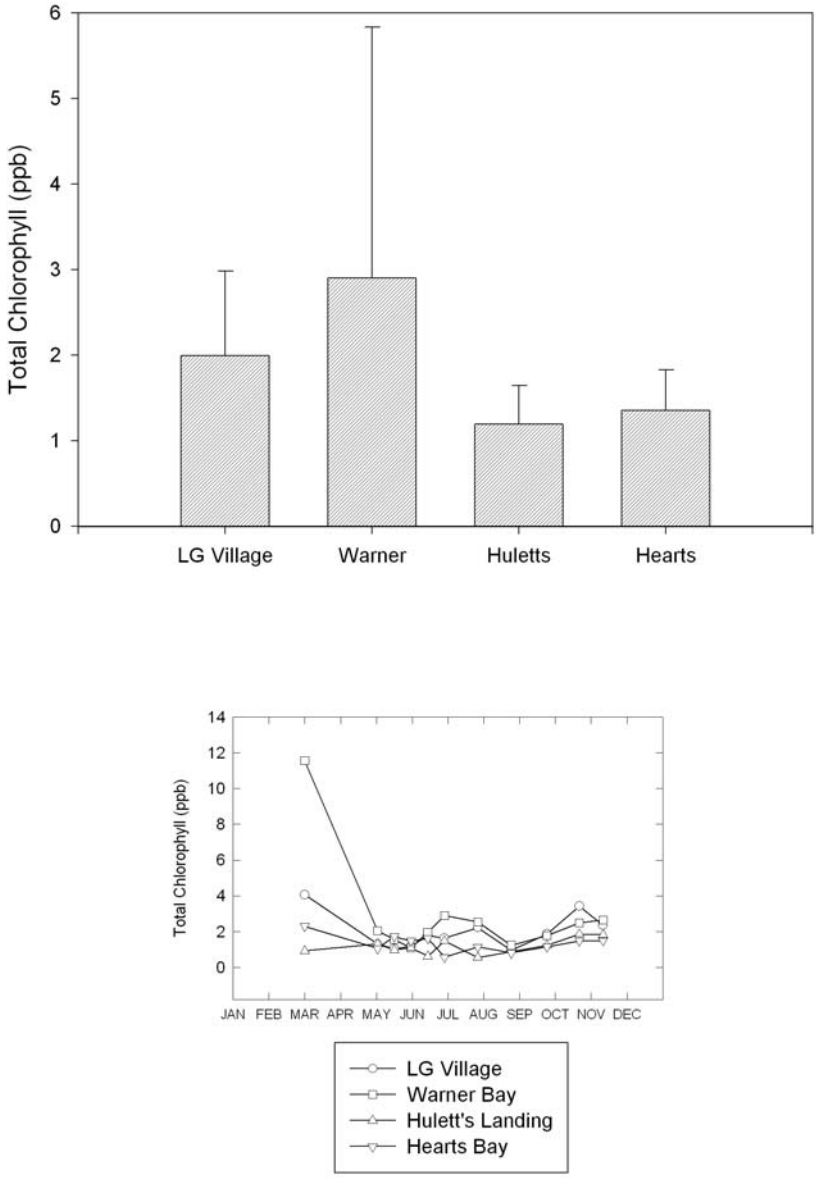


Figure 11. 2001 Average Soluble Silica concentrations for all mid-lake sites in Lake George, NY.
Average and seasonal data by site.

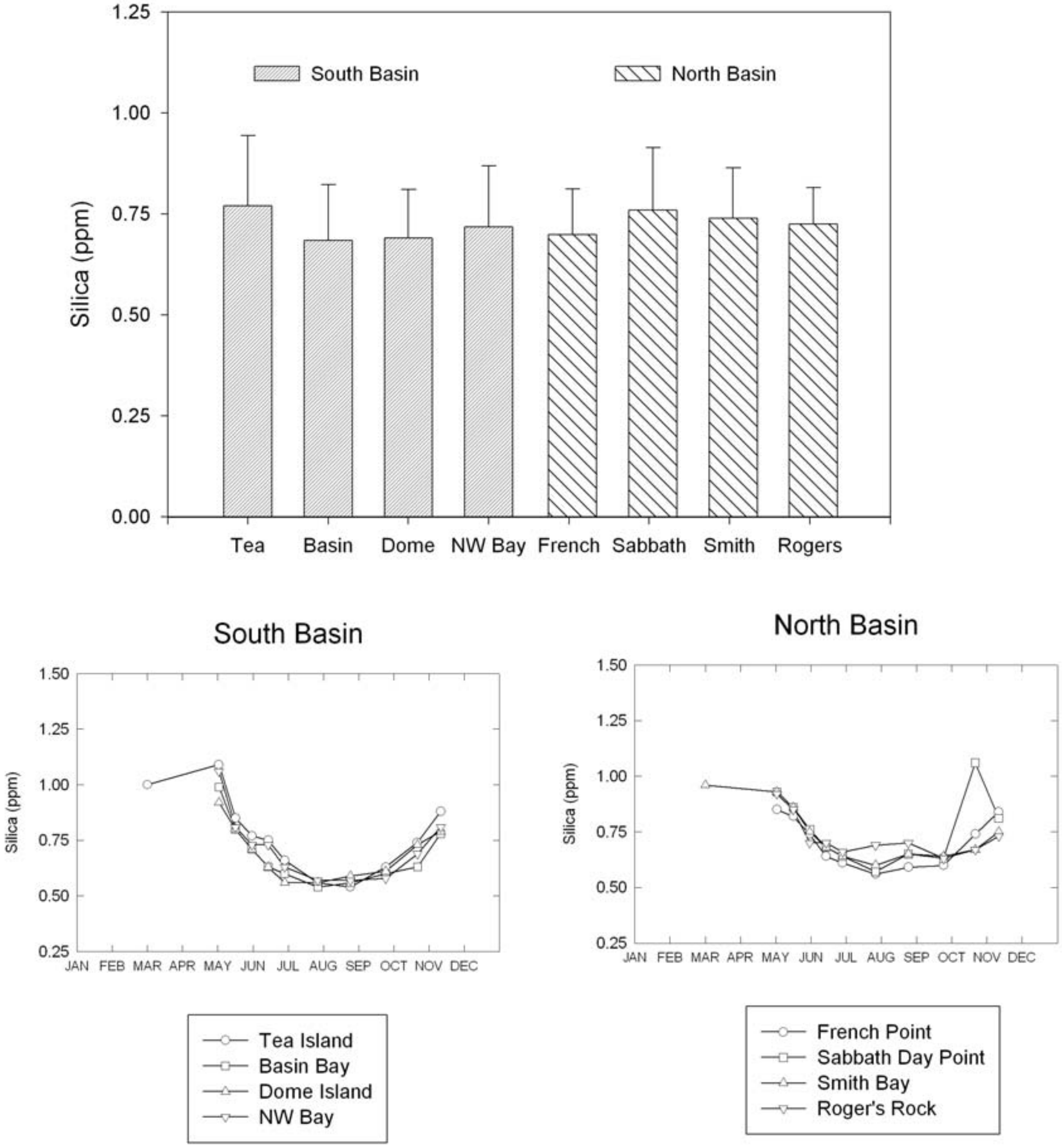


Figure 12. 2001 Average Chloride concentrations for mid-lake sites in Lake George, NY.
Average and seasonal data by site.

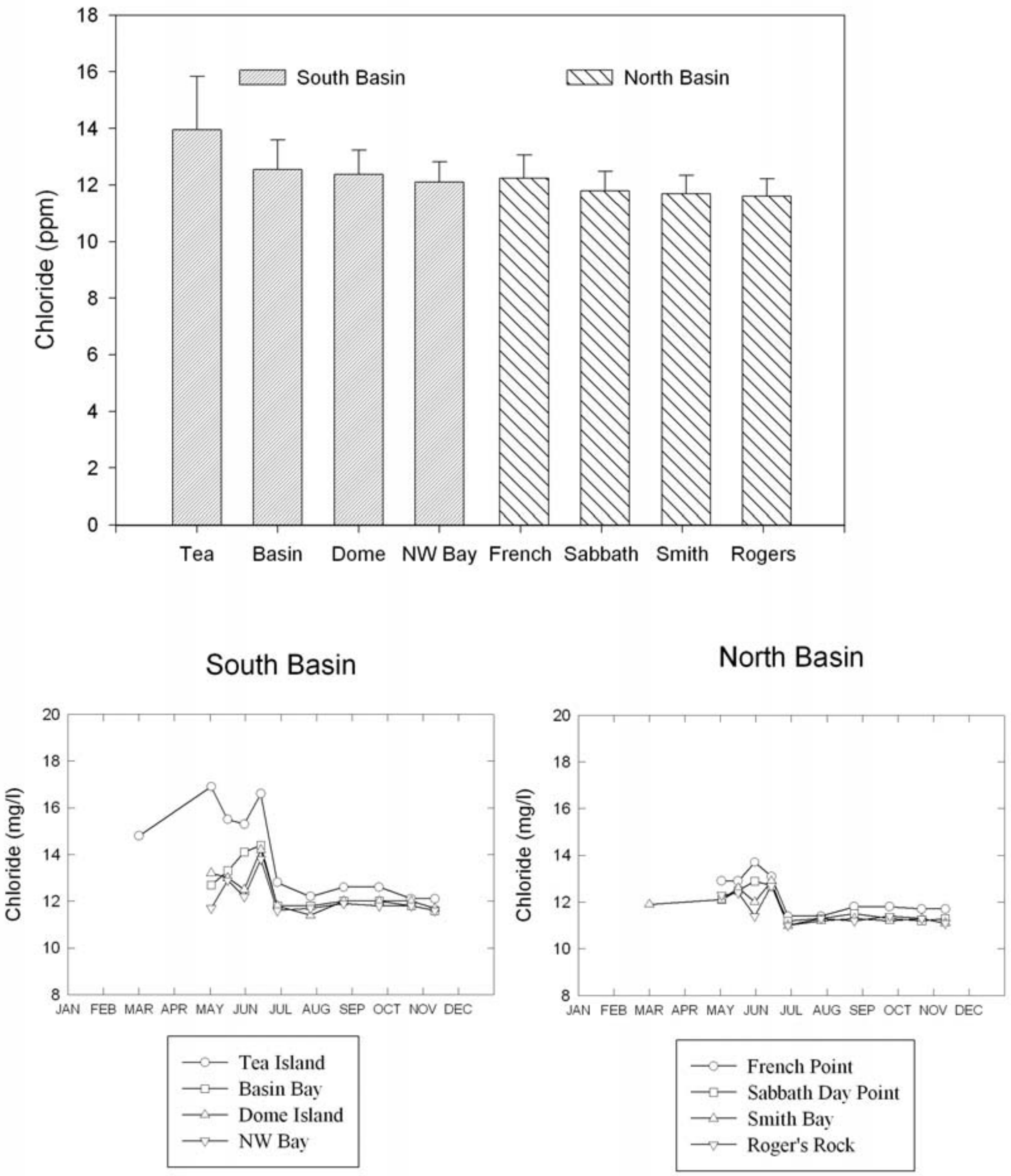


Figure 13. 2001 Average pH for mid-lake sites in Lake George, NY. Average and seasonal data by site.

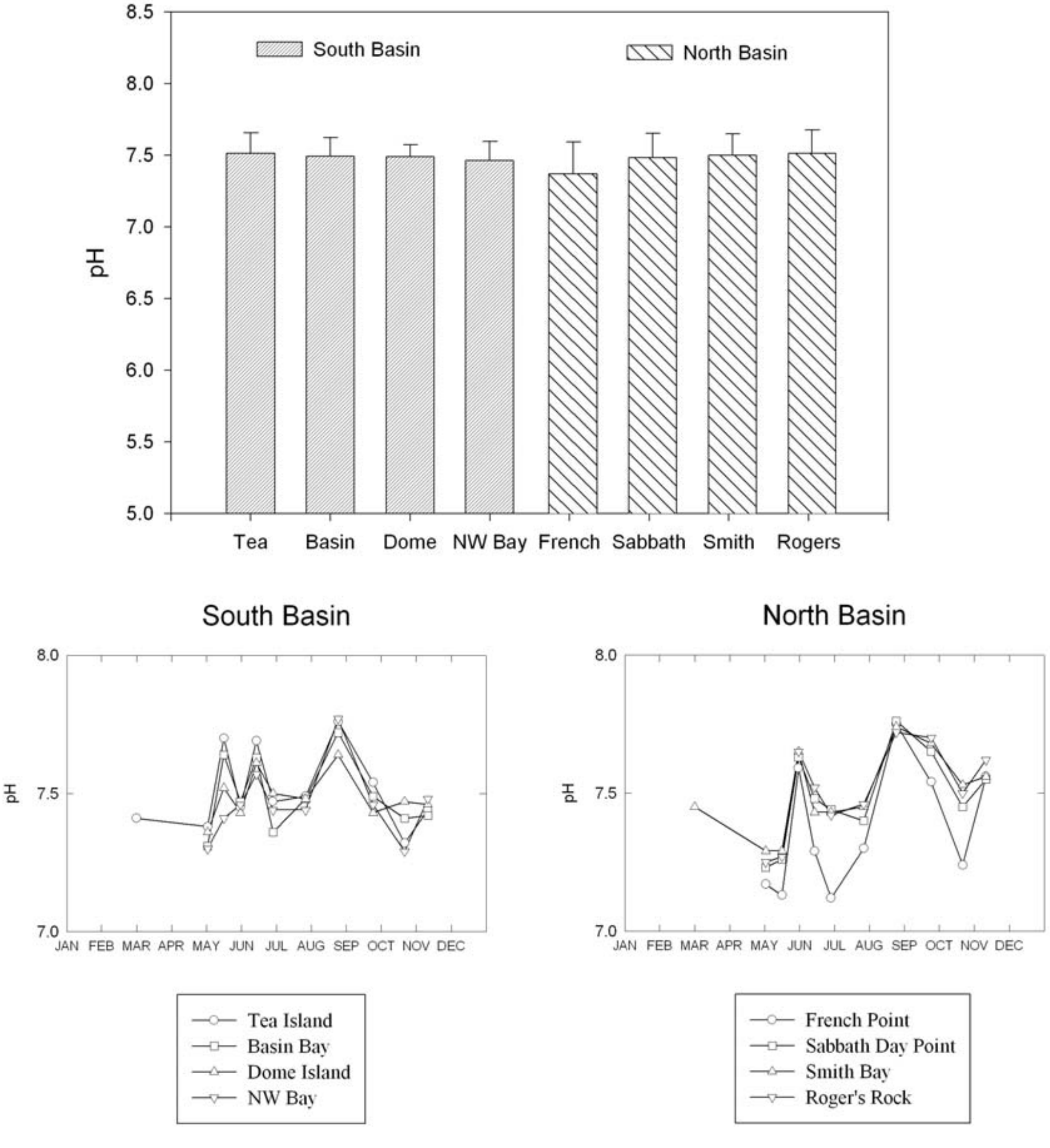


Figure 14. 2001 Ratio of Total Nitrogen to Total Phosphorus data for mid-lake sites in Lake George, NY. Average and seasonal data by site.

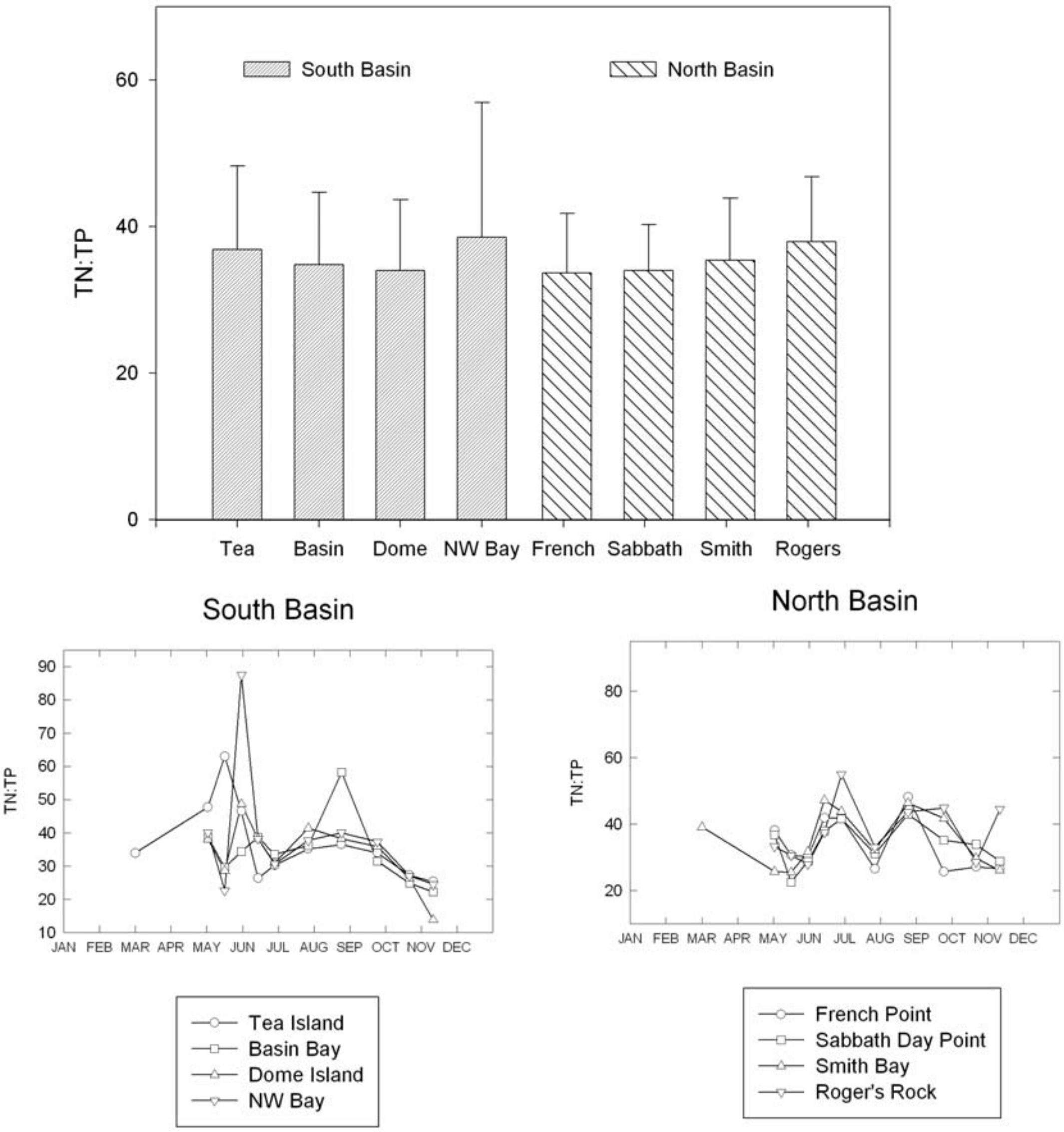


**Figure 16. Ratio of Silica to Total Phosphorus data for
mid-lake sites in Lake George, NY.
Average and seasonal data by site.**

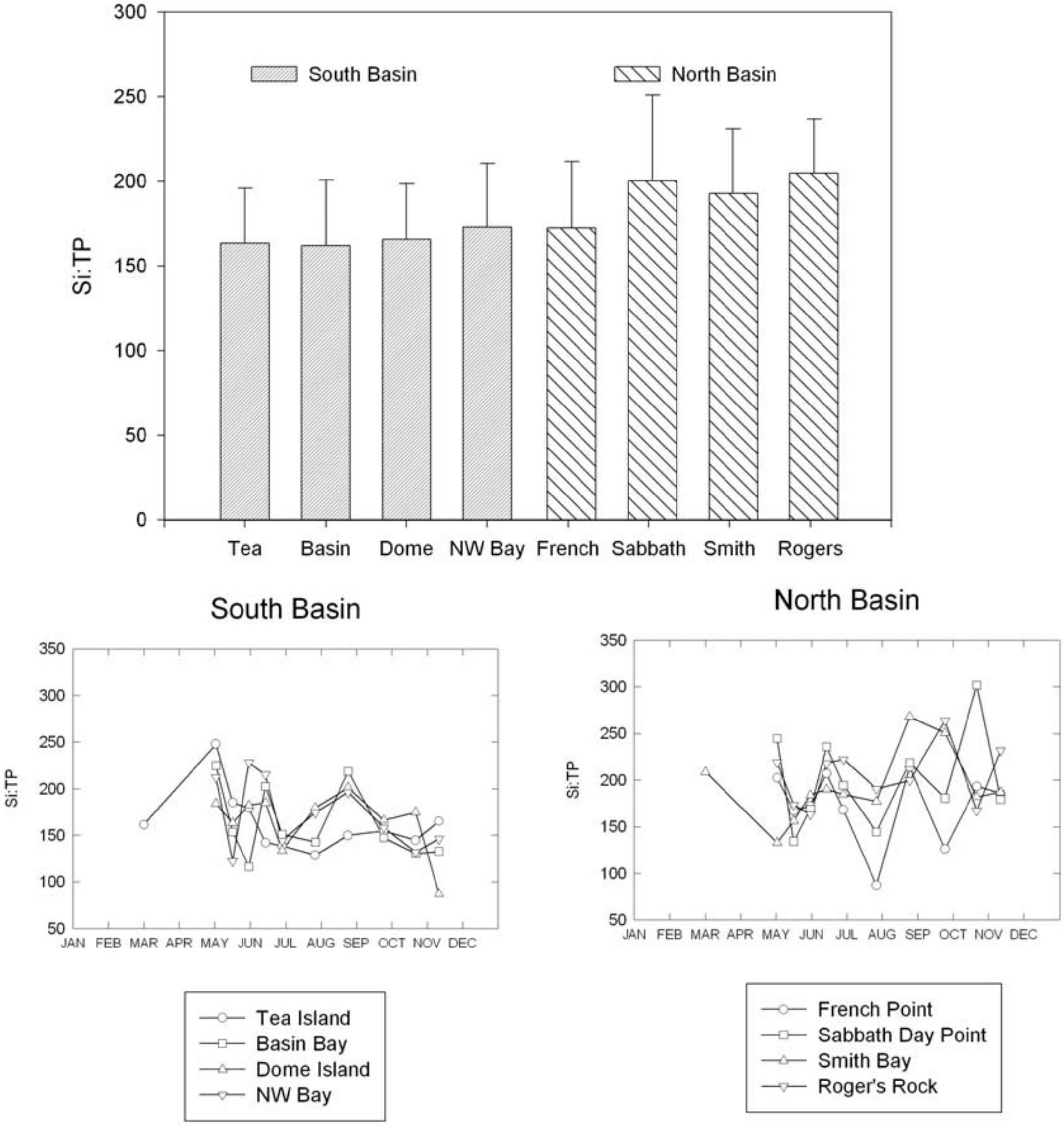


Figure 18. Dissolved Oxygen Profiles for the South Basin of Lake George, NY in 2001.

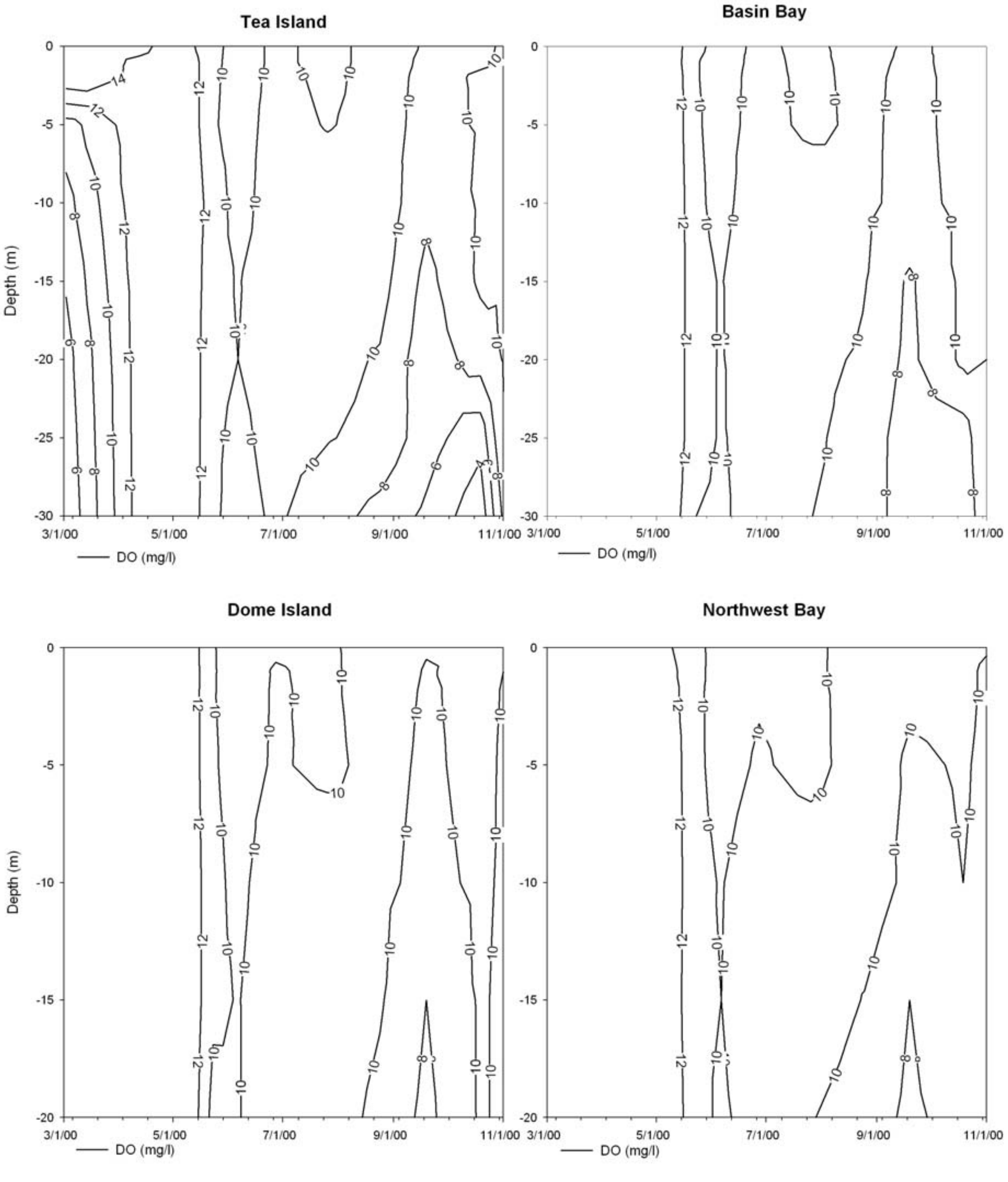


Figure 19. Dissolved Oxygen Profiles for the North Basin of Lake George, NY in 2001.

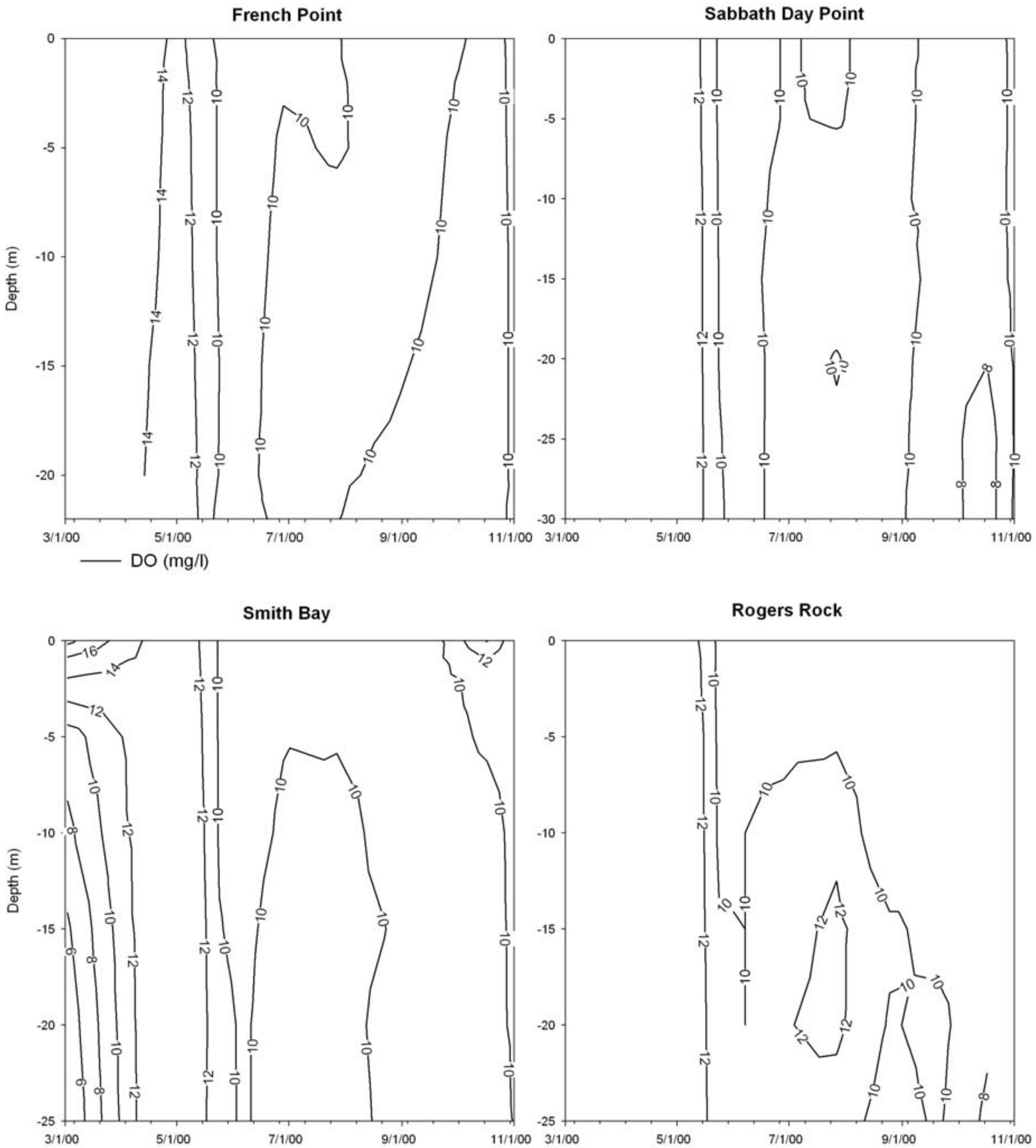


Figure 20. Monthly Precipitation at Cedar Lane, Lake George Village

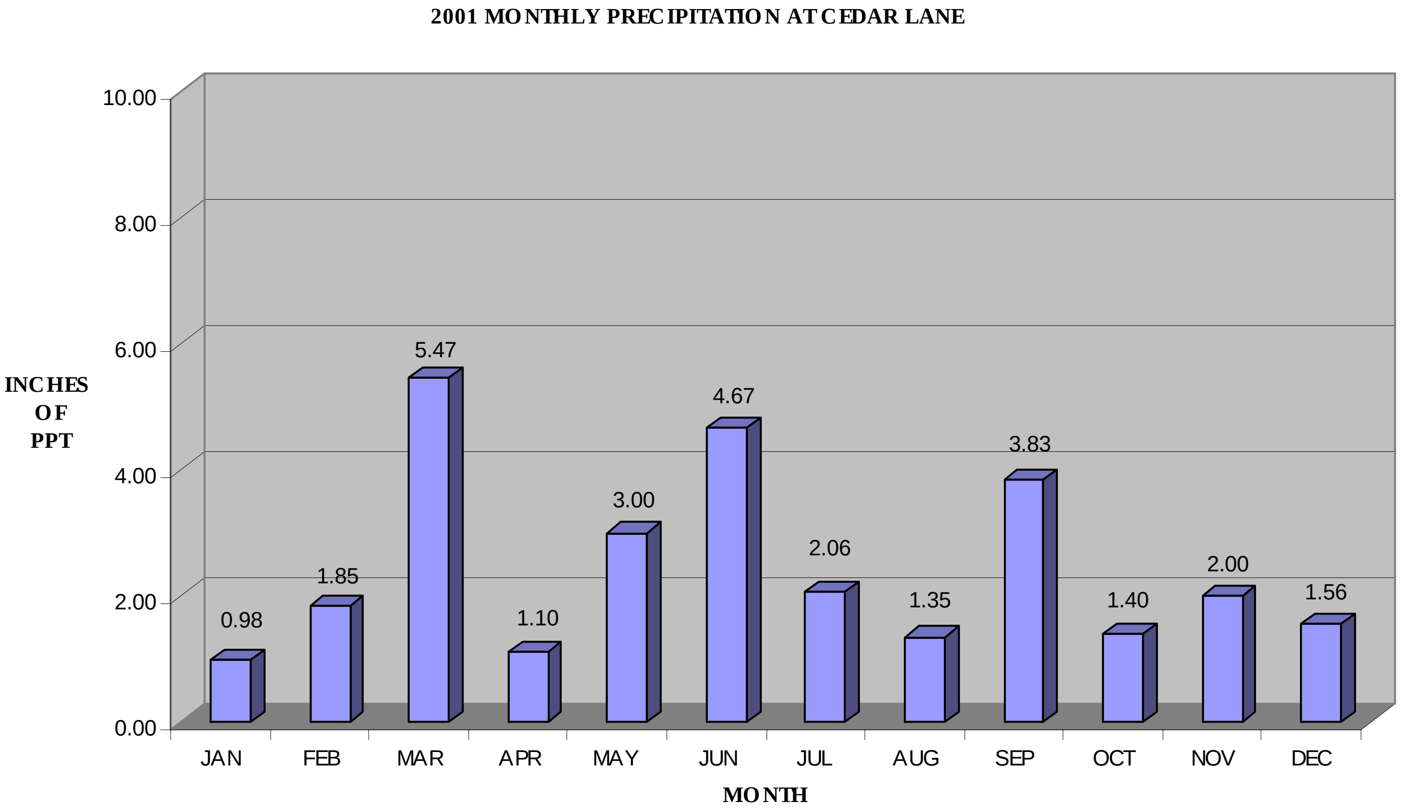


Figure 21. Total Annual Precipitation at Cedar Lane, Lake George Village

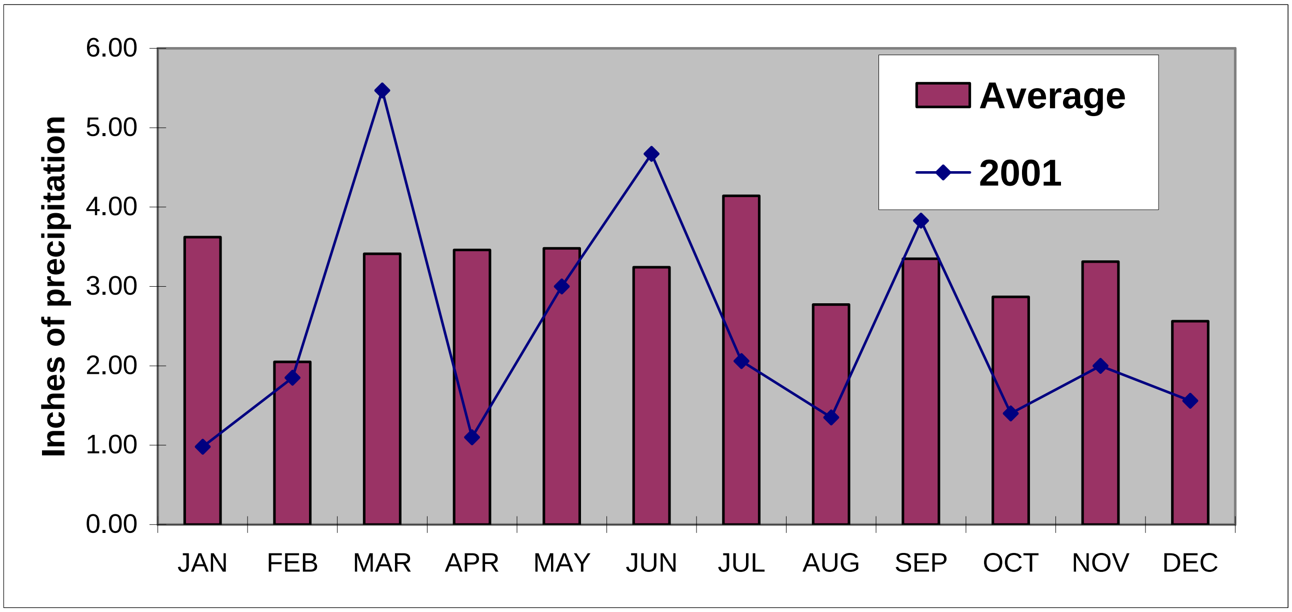


Figure 22. 2001 Calcium averages for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

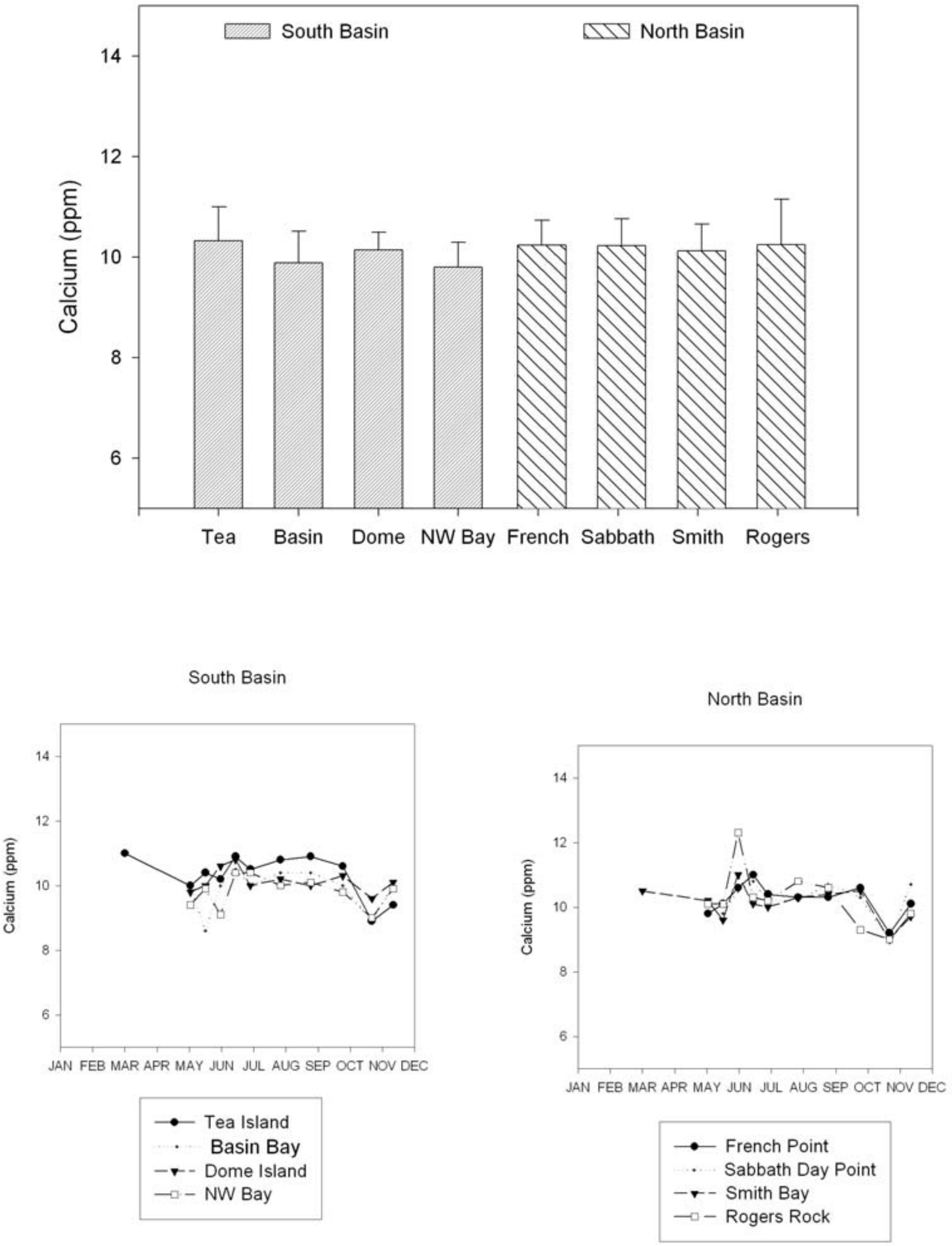
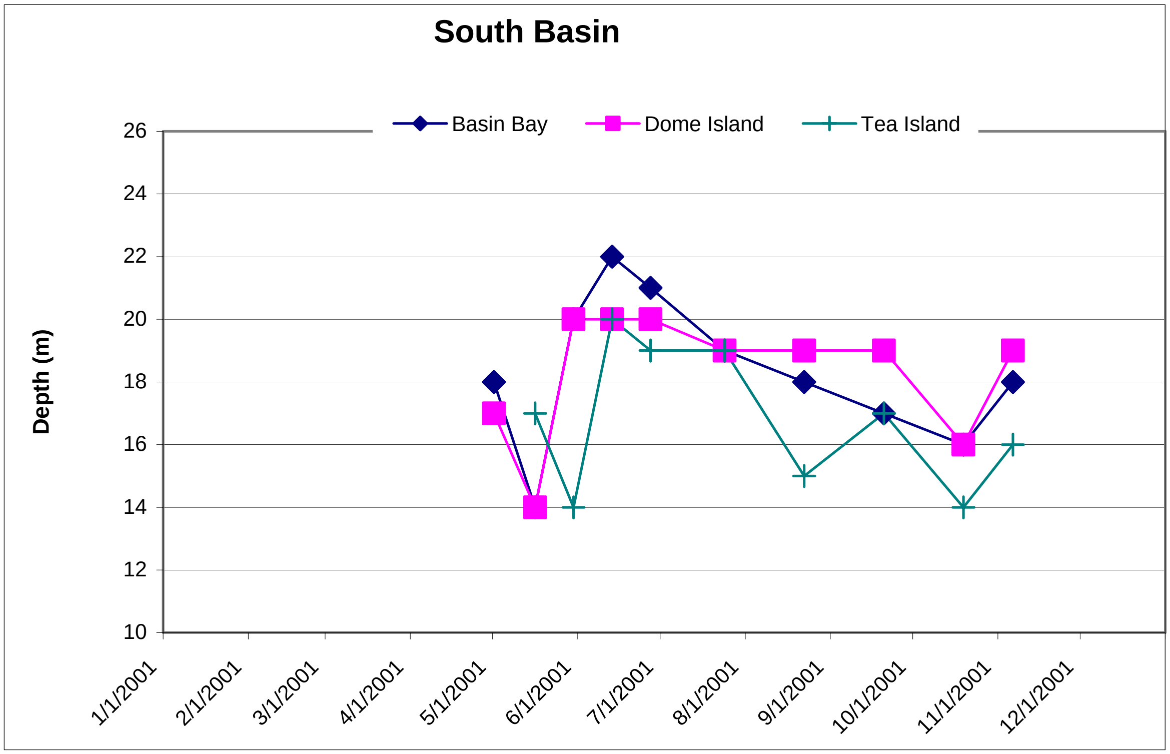
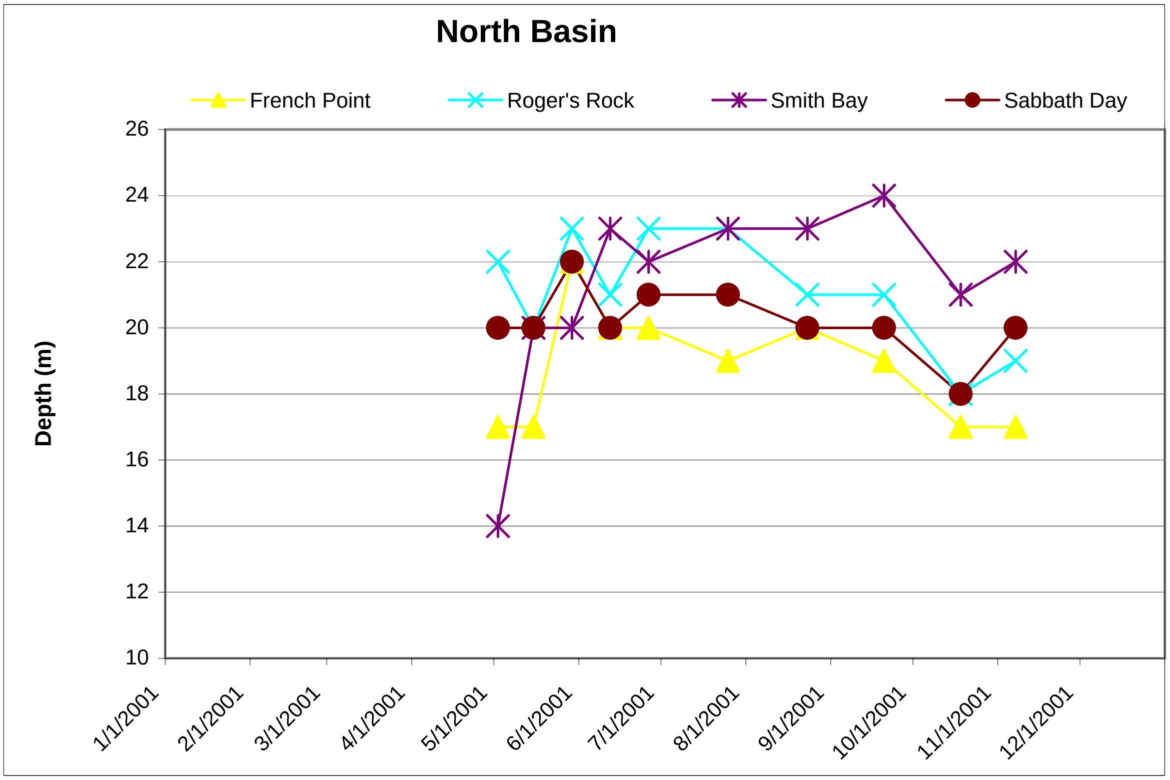


Figure 23. Depth at which 1% of surface light is present in the water column in Lake George, NY in 2001.





APPENDIX B. ANALYTICAL METHODS

Analyte	*Method*	*Instrument*
pH	Electrometric	Orion, Model 231
Specific Conductance	Wheatstone Bridge type meter (EPA Method 120.1)	Fisher Digital Conductivity Meter
Alkalinity	Titrimetric – pH 4.5 (EPA Method 310.1)	Orion, Model 231
Chloride	Ion Chromatograph (EPA Method 300)	LaChat 8000 Series - Ion Chromatograph
Chlorophyll & Pheophytin	Fluorometric (Standard Methods 10200)	Turner, Model 10-AU
Nitrate	Ion Chromatograph (EPA Method 300)	LaChat 8000 Series - Ion Chromatograph
Ammonia	Phenate Method (Standard Methods 4500-NH_3 F.)	Spectronics Genesys 5
Soluble Reactive Silica	Molybdate Reactive (Standard Methods 4500E)	Technicon Autoanalyzer II
Sulfate	Ion Chromatograph (EPA Method 300)	LaChat 8000 Series - Ion Chromatograph
Total & Total Soluble Phosphorus	Colorimetric – Persulfate Oxidation (EPA Method 365.2)	Spectronics Genesys 5
Molybdate Reactive Phosphorus (OP)	Colorimetric (EPA Method 365.2)	Spectronics Genesys 5
Total Nitrogen	Colorimetric – Persulfate Oxidation (Langner & Hendrix, 1982	Spectronics Genesys 5
Major Cations & Metals	Atomic Absorption Spectroscopy – Flame Standard Methods 3111	Perkin Elmer PE 5000

EPA Methods listed in this table are derived from: US EPA, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Cincinnati, OH.
Standard Methods for the Examination of Water and Wastewater, 20th ed. (1998). APHA, AWWA, & WEF. Washington, DC.
Langner, C.L. and P.F. Hendrix. 1982. Evaluation of a persulfate digestion method for particulate nitrogen and phosphorus. *Water Research 16: 1451-1454.*