Darrin Fresh Water Institute

A Research Center of Rensselaer Polytechnic Institute

REPORT ON THE LAKE GEORGE

OFFSHORE CHEMICAL MONITORING PROGRAM

2007

Submitted to

The FUND for Lake George

by

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March 2008

DFWI Tech. Report # 2008-6

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Executive Summary

The Offshore Chemical Monitoring Program is largely an open-water testing program. That is, the sites selected are 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. 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 25 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.

As in past years, major changes in chemical and physical parameters of the epilimnetic (surface) 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 southernmost site (Tea Island). This site has continued to show near anaerobic conditions in the deep waters (hypolimnion) beneath the thermocline 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 2007 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, was completed in 2001. The conclusions of this report stress that although urbanized lands only account for 5% of the land area in the basin, they account for 43% of the phosphorus loading to the lake via surface runoff. Continuing efforts to incorporate stormwater management into any and all construction within the basin is critical. 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. Heavy rains in June of 2007, causing widespread erosion, particularly in the Bolton Landing area, affected the composition of various components in 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 elevated for a longer period of time in the spring due to the runoff caused by the increased precipitation. Higher phosphorus levels provide more 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 2007. These differences generally indicated poorer water quality in the southern, more urbanized portion of the lake. The ultimate consequences of human activity in the basin will be demonstrated through continued long-term monitoring of the sites contained within this program.

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 25 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 259 discrete samples were collected from 12 individual sampling locations throughout the lake for the 2007 Lake George Offshore Chemical Monitoring Program. A map showing the sampling sites is presented in Figure 1. Winter sample collection “through-the-ice” was conducted on March 14, 2007. Biweekly sampling commenced in May, and continued through mid-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 2007 sampling season.

Table 1. Offshore sampling dates for the 2007 sampling season.

March	14	August	8-9
May	1-2	September	5-6
May	16-17	October	2-3
May	30-31	October	30-31
June	13-14	November	14-15
July	10-11		

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 (ppm) or micrograms (ppb) 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. Precipitation data is based on records from the NYS Department of Environmental Conservation monitoring site (Cedar Lane) located in Lake George Village. This site was selected due to its presence within the Lake George basin. Average precipitation values used in this report for the Lake George watershed reflect the results of this monitoring site since 1992 (Table 3). In 2007 a total of 38.7 inches of precipitation fell on Lake George, representing below average (40.3 inches) rainfall. Seven months were above average for precipitation. In

June and August, only a small fraction of the average rainfall was recorded. Winter snowpack (January thru March) was very limited resulting in little Spring runoff, however heavy rains in April produced runoff events.

Table 3. Precipitation records for the Lake George basin in 2007 (Sutherland et al., 2007).

Precipitation Records for NYS DEC Cedar Lane Station		
Month	**Precipitation (inches)**	**1992 – 2007 Average Precipitation (inches)**
January	3.63	3.19
February	1.54	2.11
March	3.24	3.02
April	5.39	3.74
May	1.61	3.88
June	0.68	4.17
July	5.27	4.25
August	1.67	3.11
September	4.00	3.71
October	3.63	3.63
November	4.02	3.47
December	3.97	3.03
Total	***38.65***	***40.30***

RESULTS and DISCUSSION

Thermocline

Typical for many northern temperate lakes, two periods of thermal stratification (dimictic) are observed in Lake George. During the winter months, inverse thermal stratification occurred, with near zero temperatures at the lake surface, increasing to approximately 4^{o}C near the lake bottom in water depths in excess of 20 meters. This phenomena was observed at the Smith Bay and Tea Island sites during March. In the Spring of the year, April and May, near isothermal conditions existed throughout the lake. By late-June, a thermocline was established at all sites between 8 and 17 meters. By July, a thermocline was well established at a depth of approximately 10 meters throughout the lake. In August, the thermocline or metalimnion covered from 10 to 13 meters depth. By September, the thermocline had begun to move deeper, as deep as 13 meters in the south to 14 meters in the north. During the early October sampling (October 2nd and 3rd) all stations still exhibited thermal stratification. A vestige of thermal and chemical stratification was present in late October in depths greater than 25 meters, however a thermocline was not present at any of the sampling sites. The final sampling in November showed no thermal stratification in the lake. The period and configuration of thermal stratification in 2007 was typical for the Lake George basin.

Transparency

Water clarity or transparency is recorded in two ways, Secchi disk and submarine photometer. Lake George Secchi transparency data is displayed in Figure 2 and Table 4. As reported for previous years' data, a trend toward increasing transparency on a south to north axis was observed. In the south basin the mean Secchi transparency was 8.9 ± 1.6 m (SD), and in the north basin the mean Secchi transparency was 9.5 ± 1.3 m (SD). Lake-wide, the mean Secchi transparency was 9.2 ± 1.5 m (SD).

Table 4. Mean annual Secchi transparencies for the open water monitoring sites in 2007 (n=12). Sites are listed in order from south to north.

Site	Secchi Depth (m)	Standard Deviation
Tea Island	8.9	1.2
Basin Bay	8.6	1.6
Dome Island	8.7	1.4
Northwest Bay	9.3	2.0
French Point	9.6	1.1
Sabbath Day Point	9.7	1.2
Smith Bay	9.9	1.7
Rogers Rock	8.9	0.9

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 compensation depths for the lake were typical at 10 to 15 meters. Light transmission (transparency) was greatest lake-wide in late May with an average compensation depth of 21 meters across the lake. Compensation depth (1% of surface light transmission) declined to 19 meters by the end of June, and slowly began to fall for the rest of the summer season. A difference was noted in the compensation depth from south to north, with the lowest values at Tea Island, and the highest at Roger's Rock. Typically, south basin seasonal averages were approximately 2-3 meters less than the seasonal averages for the north basin, except in the fall when compensation depths were very similar between basins. Lake-wide, the compensation depth averaged 19.1 meters for 2007 (Figure 3).

Dissolved Oxygen

As discussed in previous years' reports, the deep basin (hypolimnion) at the southern terminus of the lake has shown substantial declines of dissolved oxygen in the deeper waters during the late summer. Depletion of oxygen in hypolimnetic waters is characteristic of a more enriched or mesotrophic lake condition, rather than oligotrophic, the typical designation for Lake George. The near-sediment waters at Tea Island showed declining saturation levels, below 80%

saturation, as early as July. A steady decline continued through the end of summer stratification in late October, with dissolved oxygen levels in the near-sediment waters as low as 28% of saturation (3.2 mg/l). Following overturn in November dissolved oxygen values once again approached saturation. Dissolved oxygen concentrations in hypolimnetic waters at the adjacent Basin Bay sampling site remained greater than 6.5 mg/l (61% saturation) over the same period at comparable depths. At a site of comparable depth in the north basin (Sabbath Day Point), levels of dissolved oxygen never fell below 75% of saturation for that same timeframe. Dissolved oxygen concentrations for each site in 2007 can be found in Figures 4 and 5 of Appendix A.

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 necessary nutrients. Phosphorus is measured as three different forms: total phosphorus (TP), total soluble phosphorus (TSP), and soluble reactive or 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 6. Typically, 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 photosynthetic zone (surface waters) and can often cause phytoplankton blooms in the fall.

Mean concentrations varied at the open water sites from 3.0 ± 0.6 μg P/l at Rogers Rock in the north basin to 4.2 ± 0.6 μg P/l at Tea Island in the south basin. The lake-wide epilimnetic mean TP concentration was 3.7 ± 0.9 μg P/l, with a south basin mean value of 3.8 ± 0.9 μg P/l and a north basin mean value of 3.4 ± 0.8 μg P/l. Historically, higher values are seen in the southern basin. Similar results are seen for average TP values in the near-shore waters (Figure 7). 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 near-shore sites (Figure 7) 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 7.8 ± 1.2 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. Waters released from the wetland often cause the water in Warner Bay to take on a brown color as a result of dissolved organic compounds. This is a common occurrence in freshwater wetland systems.

The deep-water (hypolimnetic) sampling areas (Figure 8) 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 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 has historically shown the most marked increase of P where levels reached 6.9 μg P/l in October, just prior to fall destratification and 5.6 μg P/l in November following destratification. This has been the case at T30 since severe oxygen depletion (< 5 mg/l) was first observed in 1985. At the French Point sampling station, upwelling of hypolimnetic waters has been suggested by a number of authors. Future investigations are necessary to reconcile the elevated phosphorus levels reported at this location in 2007.

Total soluble phosphorus (TFP) levels for the open water and near-shore sites followed much the same seasonal trends as TP only at lesser values. The lake-wide epilimnetic mean TFP concentration was 1.7 ± 0.6 μg P/l, with a south basin mean value of 1.8 ± 0.5 μg P/l and a north basin mean value of 1.7 ± 0.6 μg P/l. 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.

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. Epilimnetic samples from the open water sites ranged from undetectable (< 1.0 μg P/l) to 4.6 μg P/l for the 2007 sampling season. Tea Island produced the highest average epilimnetic (1.3 ± 0.4 μg P/l) and hypolimnetic (1.8 ± 1.1 μg P/l) OP concentration during the 2007 sampling season.

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 2007 the average was 2.0 ± 0.8 (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, incorporating both soluble and bound forms of nitrogen, are also recorded for all samples.

The seasonal fluctuations of nitrate in the Lake George surface waters are usually quite predictable, with nitrate concentration 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 9 shows this pattern development for all the surface water sites during 2007. The greatest levels of NO_3 were seen at Tea Island 30 m and Lake George Village at various dates throughout the sampling season, ranging from 0.01 to 0.09 mg N/l at the highest levels. Basin Bay and Sabbath Day Point also measured somewhat higher levels in the deep waters in late summer (0.03 – 0.05 mg N/l). The majority of sampling stations produced nitrate values were above the detection limit in March and early May. Nitrate concentrations for sites in the south basin generally exceeded levels for comparable sites in the north basin. Nitrate levels began to decrease in early April 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 in the south basin continued to show measurable levels for NO_3 for the rest of the sampling season.

For most open water sites in 2007, the ammonia levels were rarely above the limit of detection (0.01 mg N/l). Some of the deeper sites exhibited slightly elevated levels of ammonia during various sampling dates throughout the year. The greatest level of ammonia in the lake, 0.08 mg/l, was recorded at the Warner Bay site in March.

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 0.06 to 0.39 mg N/l (Figure 10) with the lake-wide epilimnetic average 0.14 ± 0.03 (SD) mg N/l. Epilimnetic mean total nitrogen values for the south and north basins were 0.14 ± 0.03 and 0.12 ± 0.03 mg N/l, respectively. Maximum concentrations were observed at Warner Bay in October. Total nitrogen values followed seasonal trends similar to those described for total phosphorus. An increase of TN values was observed in late Spring and possibly related to heavier than normal rainfall in late May.

Chlorophyll *a*

Figure 11 gives the average chlorophyll measurements for the open water sites. Tea Island recorded the greatest average chlorophyll for the open water sites with 1.7 ± 0.4 (SD) μg/l and Rogers Rock the least with 1.3 ± 0.4 (SD) μg/l. The Lake George epilimnetic average for chlorophyll was 1.4 ± 0.4 (SD) μg/l in 2007. There is a general trend of decreasing chlorophyll concentrations 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 levels throughout the year. The pattern of chlorophyll 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 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 photosynthetic zone of the lake. This availability of nutrients is reflected in the fall increase of chlorophyll 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 12) as chlorophyll 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 large spike in the late fall possibly associated with heavy rainfall in October. Warner Bay experienced a large increase in the summer months before returning to lower levels in September for the rest of the year. This may be due to the heavy volumes of rain in June of 2007, which probably caused a high influx of nutrients into the bay from the adjacent wetland. 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.

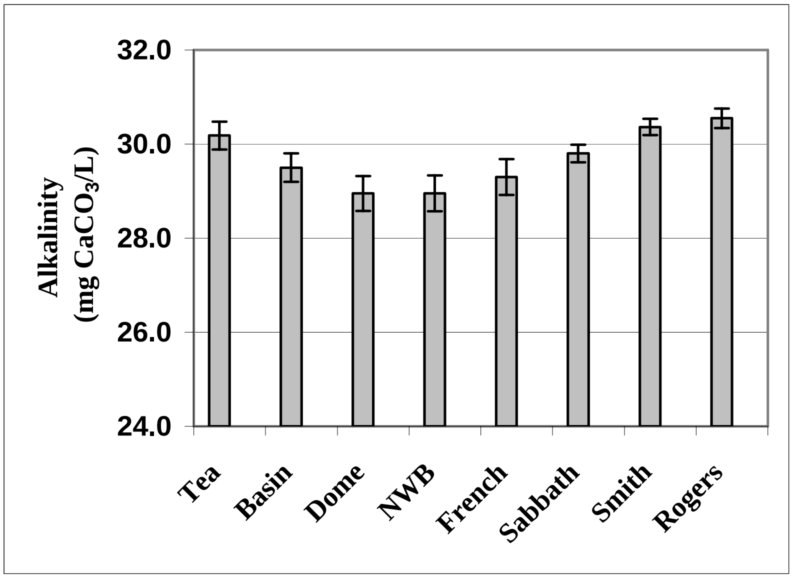
Average silica levels in the open waters of Lake George are similar throughout the lake, ranging from an average low at Rogers Rock of 0.83 mg Si/l to a high of 1.02 mg Si/l at Tea Island. The Lake George epilimnetic average for soluble silica was 0.92 ± 0.16 (SD) mg/l in 2007. Near-shore sites did not differ substantially from their open-water counterparts, with Hearts Bay averaging the lowest at 0.87 mg Si/l and Warner Bay recording the highest average for the lake in 2007 with 1.24 mg Si/l. There are distinct and predictable fluctuations of SiO_2 on a seasonal basis (Figure 13). Peaks in SiO_2 concentrations occur in the spring when inputs from groundwater and surface runoff are greatest. As the spring 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 early 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. Late June levels of silica in Northwest Bay were elevated as a result of the severe June storm.

Chloride

The levels of chloride in the waters of Lake George generally vary with season. Figure 14 shows levels of chloride present in all surface waters throughout the year. A spring peak is observed at the Tea Island site, 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 (17.3 mg Cl/l), Warner Bay (16.1 mg Cl/l) and Tea Island (15.9 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 in the south basin recorded levels of 14.3 and 14.6 mg Cl/l, respectively. Typically, the southern basin shows greater levels of chloride than the northern basin. These differences may be attributable to stormwater runoff from the urbanized portion of the Lake George basin. In the north basin, open water sites averaged 14.1 mg Cl/l. The Lake George epilimnetic average for chloride was 14.5 ± 0.8 (SD) mg/l in 2007.

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 (see plot above). The mean alkalinity, lake wide, was 29.7 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. The average specific conductance for all open water sites was 123.2 ± 3.8 µmhos during 2007. The waters of the south basin show somewhat greater average specific conductance (124.7 ± 4.5 µmhos) than the north basin (121.6 ± 2.1 µmhos). The greatest measurements were recorded in the surface waters at Lake George Village, where the average specific conductance was 135.5 ± 12.0 µmhos. The waters of the north basin showed lower average measurements ranging from 120 to 132 µmhos, with near-shore values similar to open lake values.

pH

The pH measurements for all surface waters are shown in Figure 15. 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 epilimnetic pH value at all sites for 2007 was 7.66.

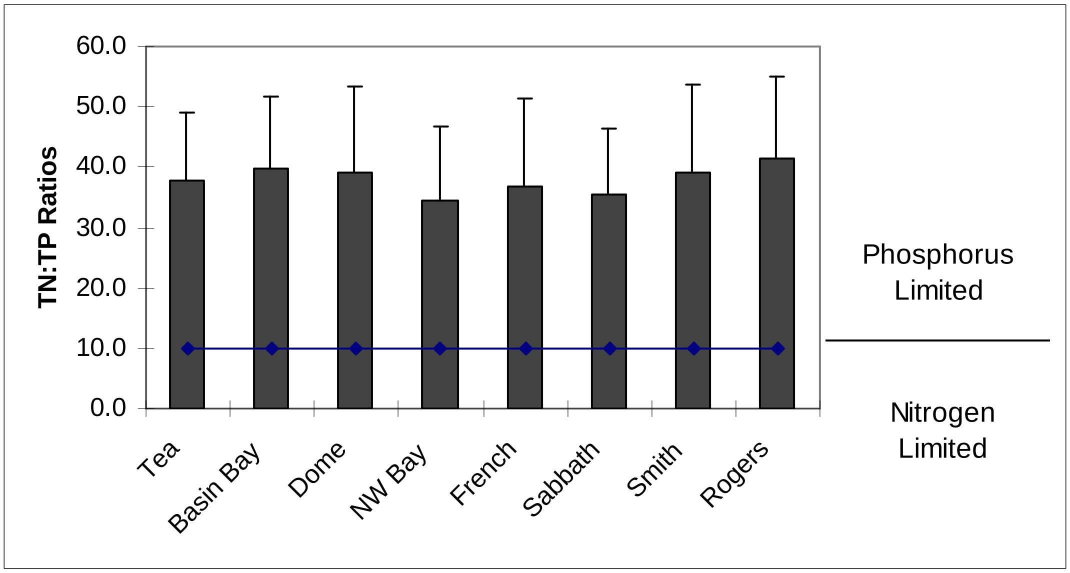
Calcium

Lake-wide, Lake George epilimnetic calcium concentrations averaged 12.4 ± 1.0 (SD) mg/l. Sampling station averages ranged from 11.8 – 12.8 mg/l Ca. Calcium levels lake-wide remained relatively constant throughout the sampling period, with the exception of slightly higher concentrations in early spring (Figure 16). 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. Recent investigations of the 128 known tributaries to Lake George shed some light on the occurrence of zebra mussels in Lake George. A number of the streams tributary to the lake periodically have calcium levels much greater than the lake waters, creating ephemeral microhabitats where they enter the lake. Two of the four discrete zebra mussels colonies recorded to date in Lake George are found associated with these enhanced sources of calcium.

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 ranged between 14 and 59. 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 17). 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 2007 data (Figures 17 &18) support this supposition. 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 18. Ratios of total nitrogen to total phosphorus for mid-lake sites.
Error bars are 1 Standard Deviation.

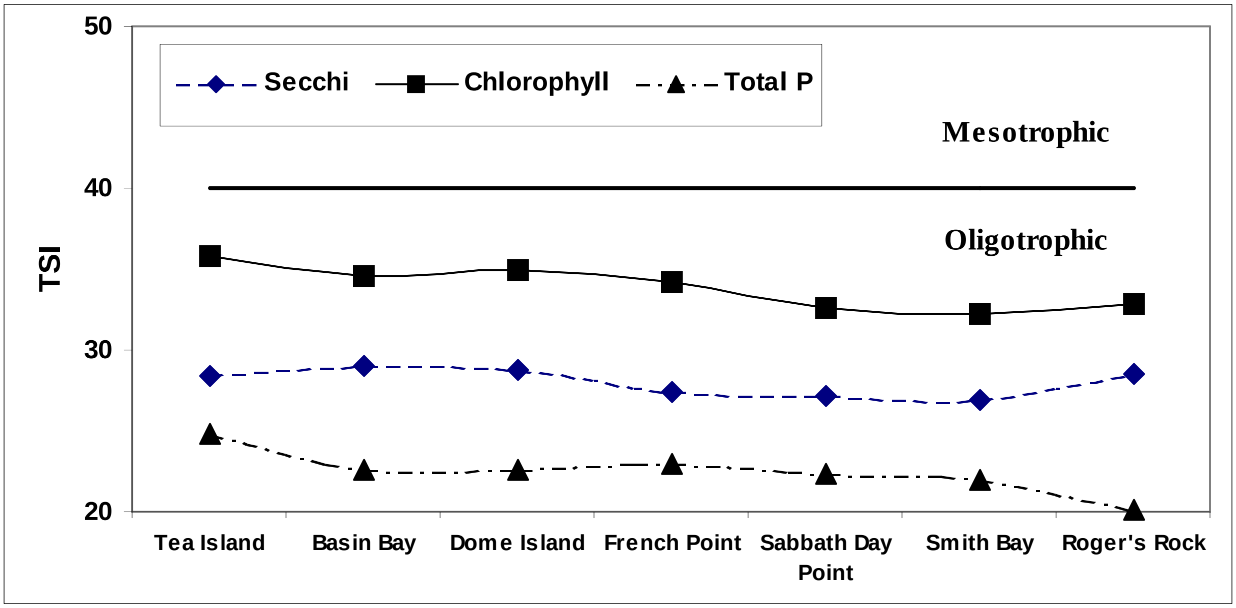


Silica limitation has also been suggested as a controlling factor for phytoplankton speciation and abundance. Lake-wide, epilimnetic Si:P ratios ranged from a low of 74 at Huletts Landing to a high of 407 at Warner Bay. In the south basin open water sites, ratio averages ranged from 240 at Tea Island to 275 at Dome Island (Figure 19). In the north basin, the range was 249 at French Point to 282 at Rogers Rock. There were no occasions where the epilimnetic Si:P ratios for mid-lake samples were less than 100, a level considered to limit diatom growth. The lowest Si:P ratios were recorded at Warner Bay with an annual average of 146 in 2007.

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 110 (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 20 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 20. 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 2007 Chemical Monitoring Program on Lake George marked the 27th 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:11.0 mg/l chloride, 4.54 μg/l total phosphorus, and 1.43 μg/l 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 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. Applying these rates, predicted concentrations for 2007 were: 14.5 mg/l chloride, 4.3 μg/l total phosphorus, and 2.21 μg/l total chlorophyll. The actual observed values for these analytes in 2007 were: 14.6 mg/l chloride, 3.7 μg/l total phosphorus, and 1.43 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. More importantly, not only has the chloride concentration more than doubled in the last 25 years, but the annualized rate of change of chloride (0.46 mg/l/yr) continues to increase.

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 Tiffini Burlingame, Charles Szablewski and Brett D'Arco for their aid in data collection and analysis. Robert Bombard provided the 1992-2007 precipitation volume data used in the report.

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APPENDIX A: FIGURES

Figure 1. Location of the Offshore Program sampling sites.

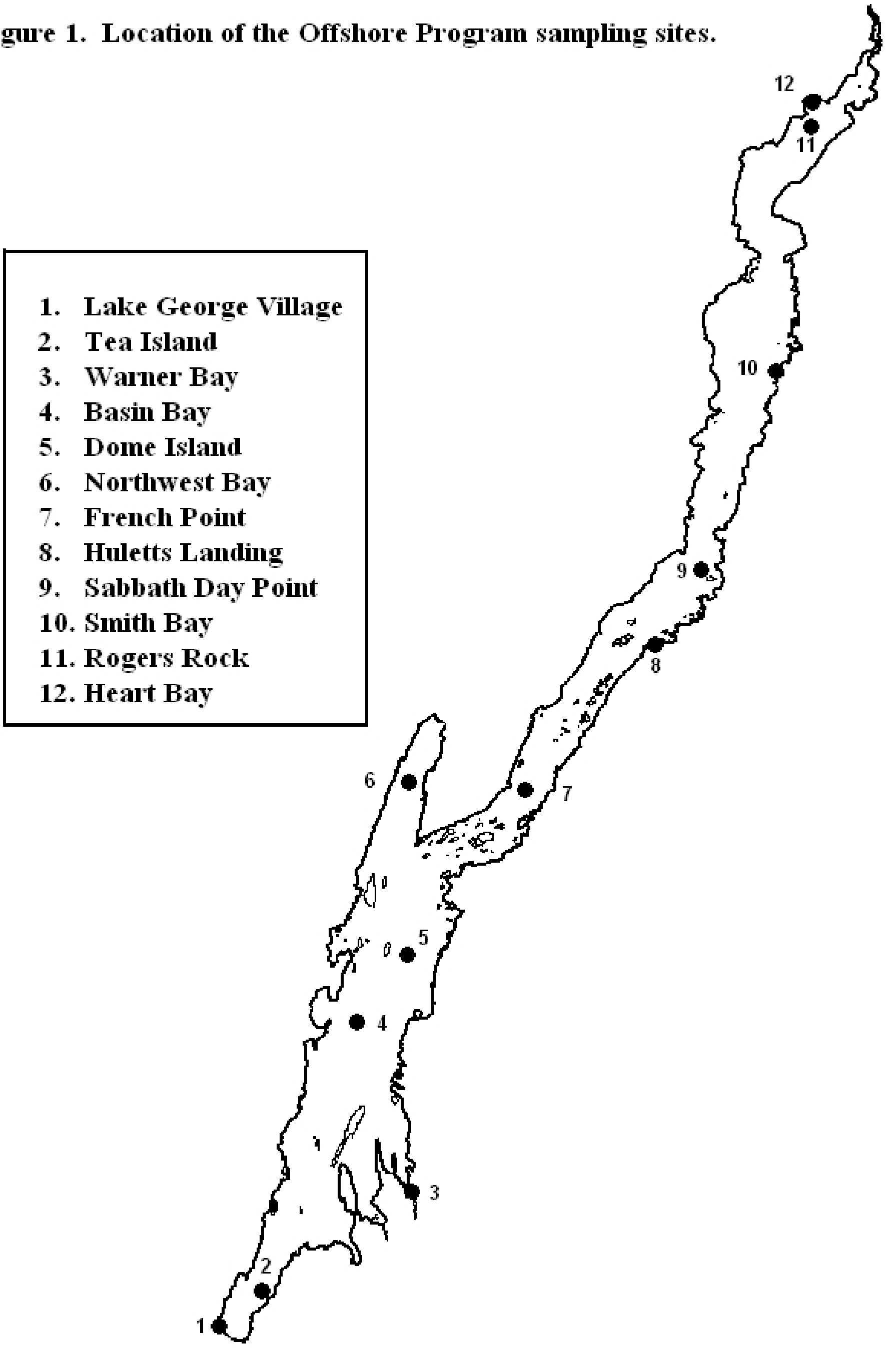


Figure 2. 2007 Average Secchi Transparencies for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

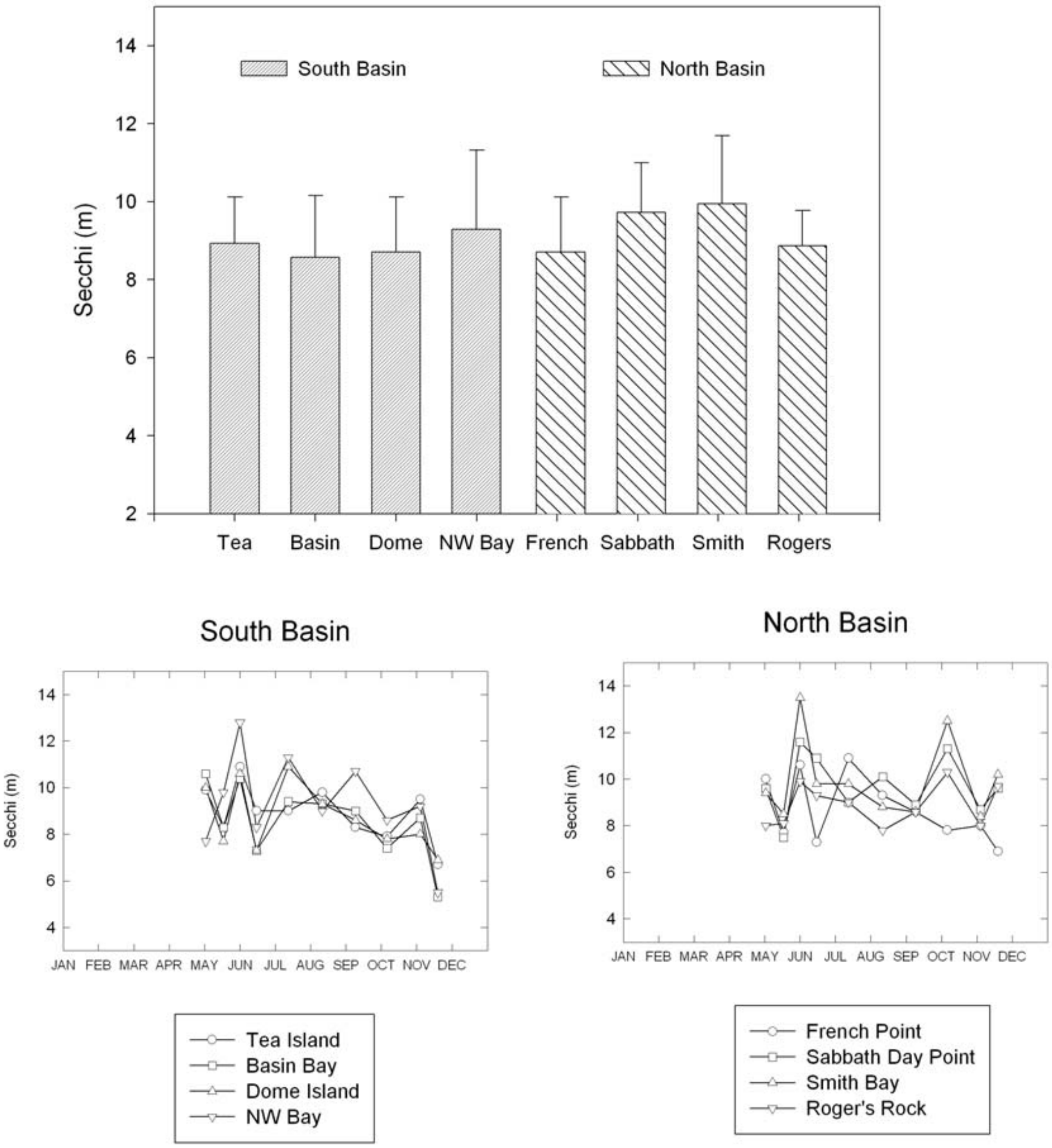
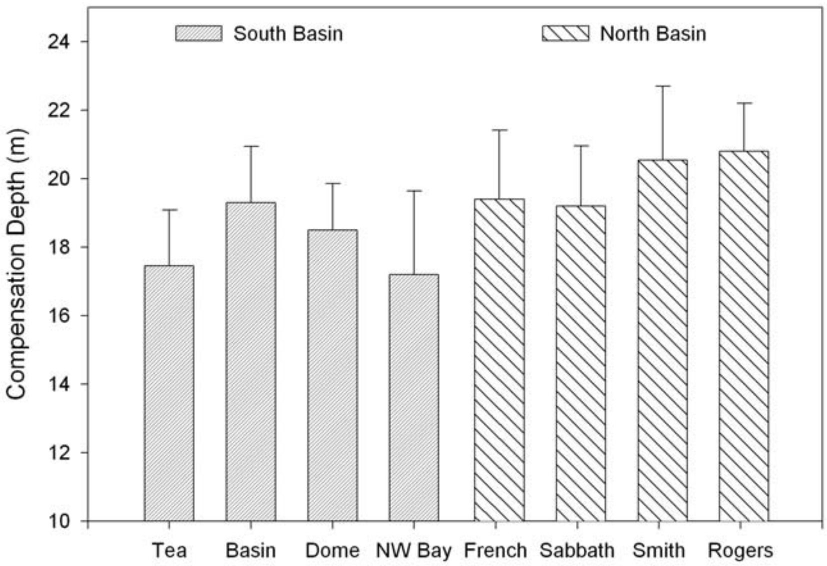
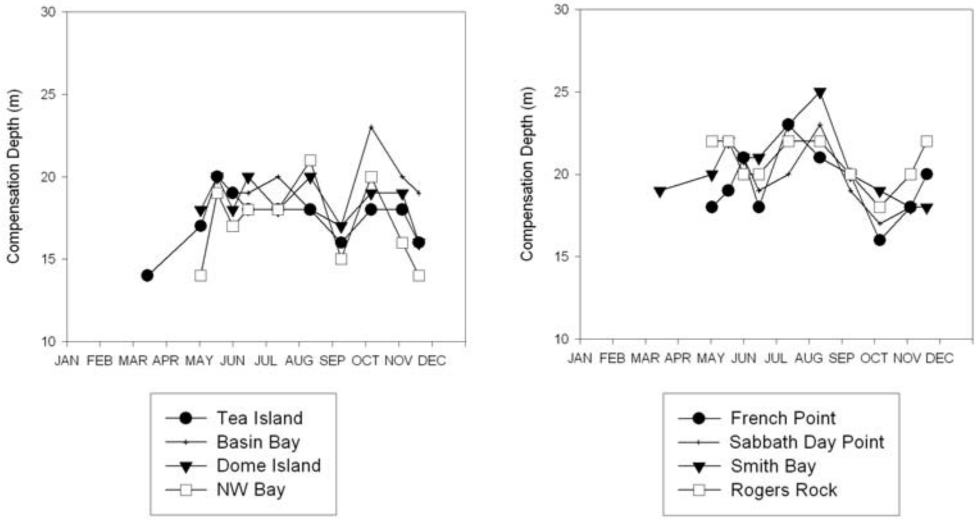


Figure 3. 2007 Compensation depth averages for all mid-lake sites in Lake George, NY. Average and seasonal data by site.





South Basin **North Basin**

Figure 4. Dissolved Oxygen Profiles for the South Basin of Lake George, NY in 2007.

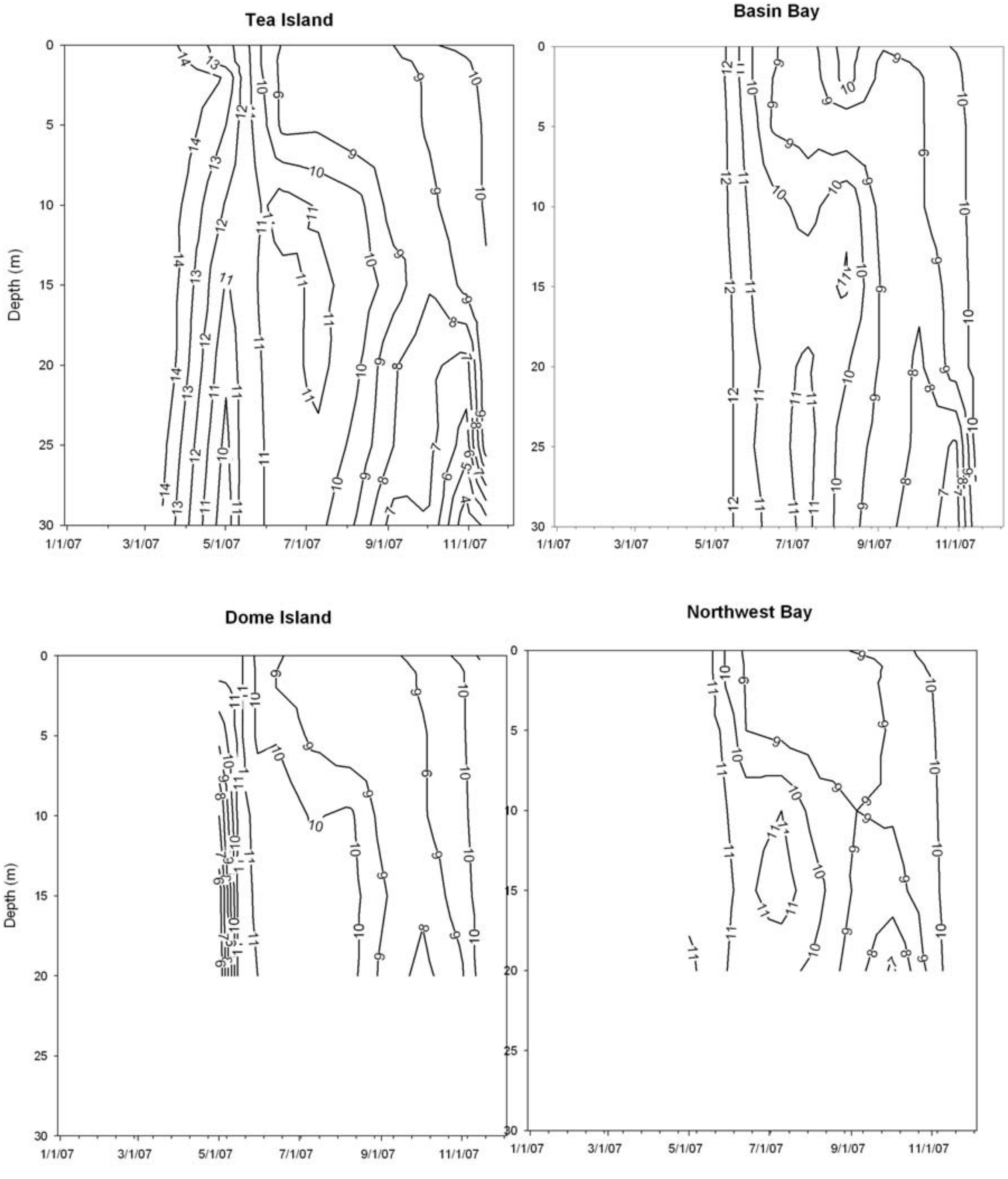
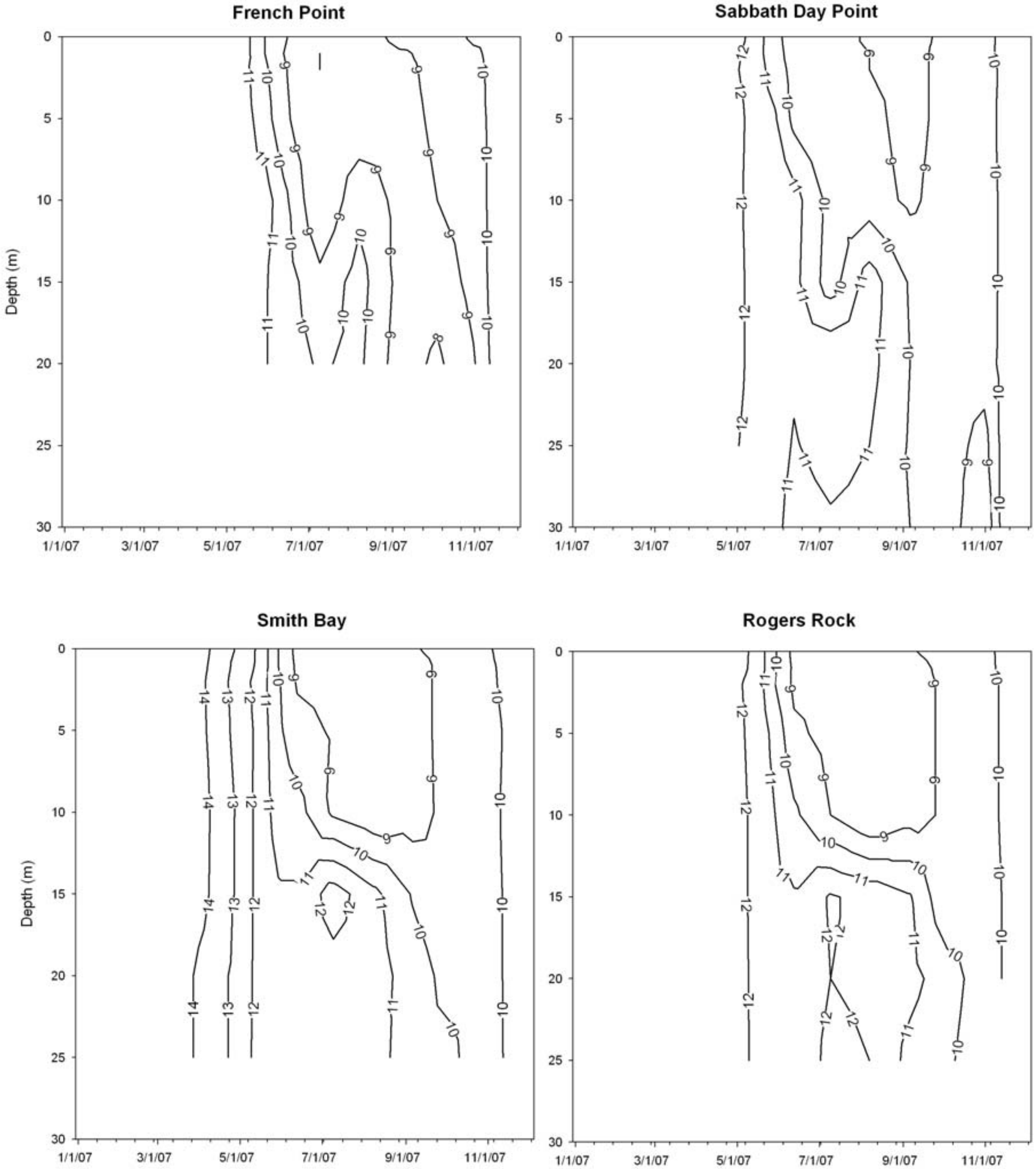


Figure 5. Dissolved Oxygen Profiles for the North Basin of Lake George, NY in 2007.


French Point

Sabbath Day Point

Smith Bay

Rogers Rock

Figure 6. 2007 Average Total Phosphorus concentrations for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

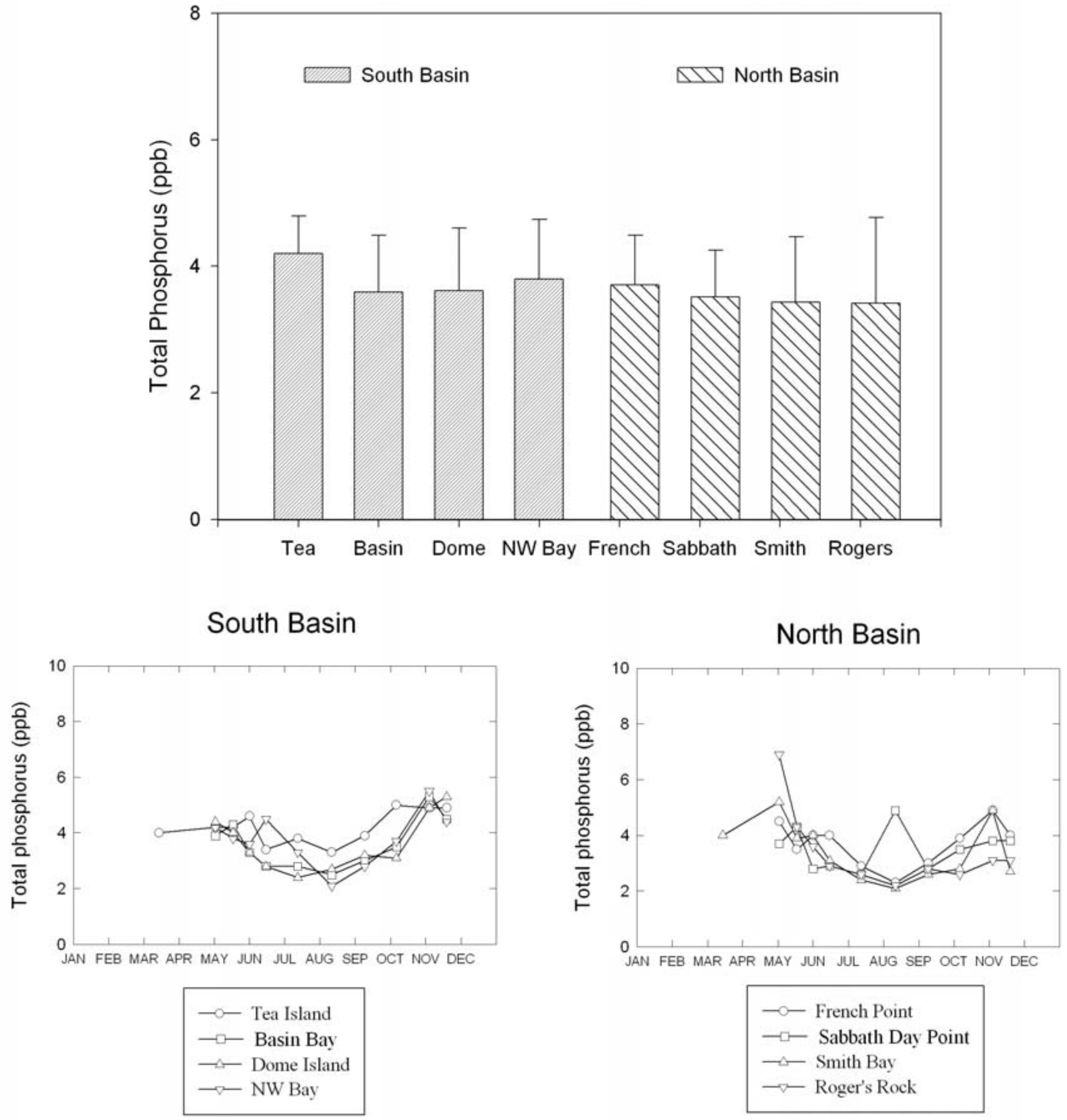


Figure 7. 2007 Average Total Phosphorus data for all near-shore sites in Lake George, NY. Average and seasonal data by site.

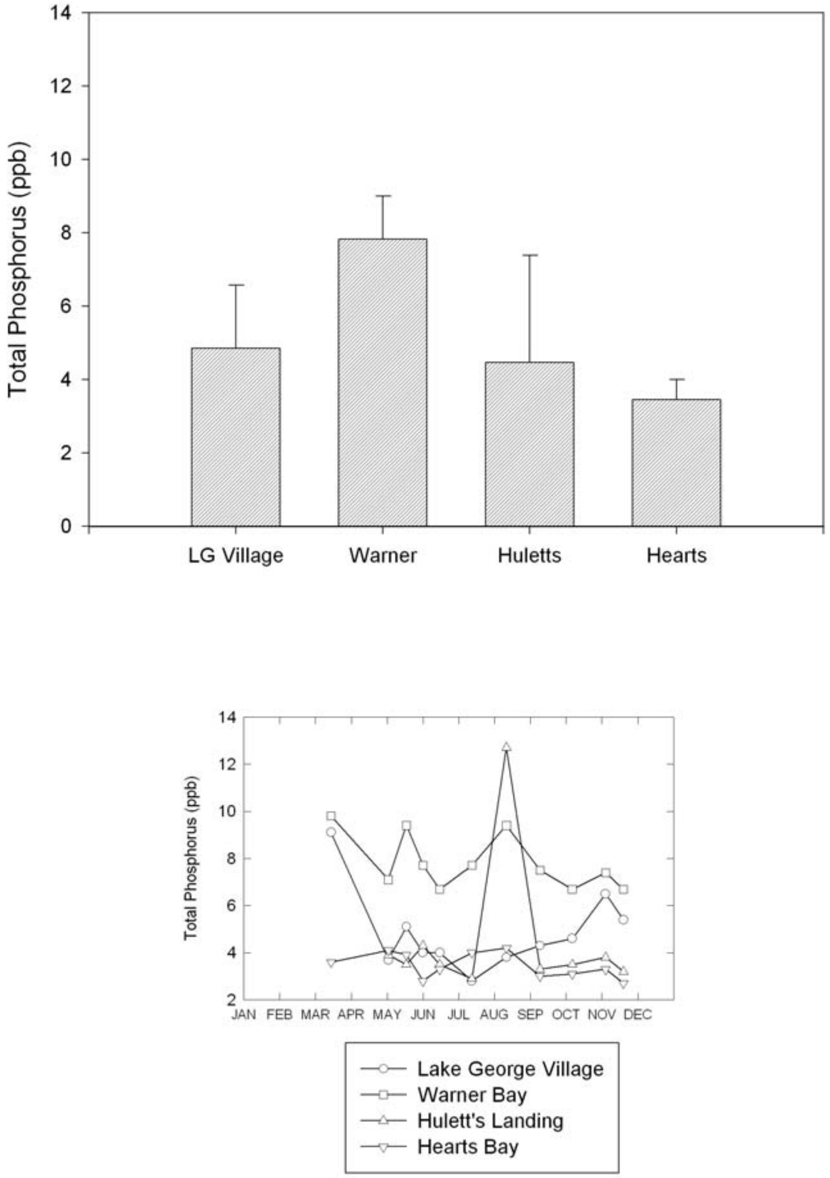


Figure 8. 2007 Average Total Phosphorus concentrations for all hypolimnetic sites in Lake George, NY. Average and seasonal data by site.

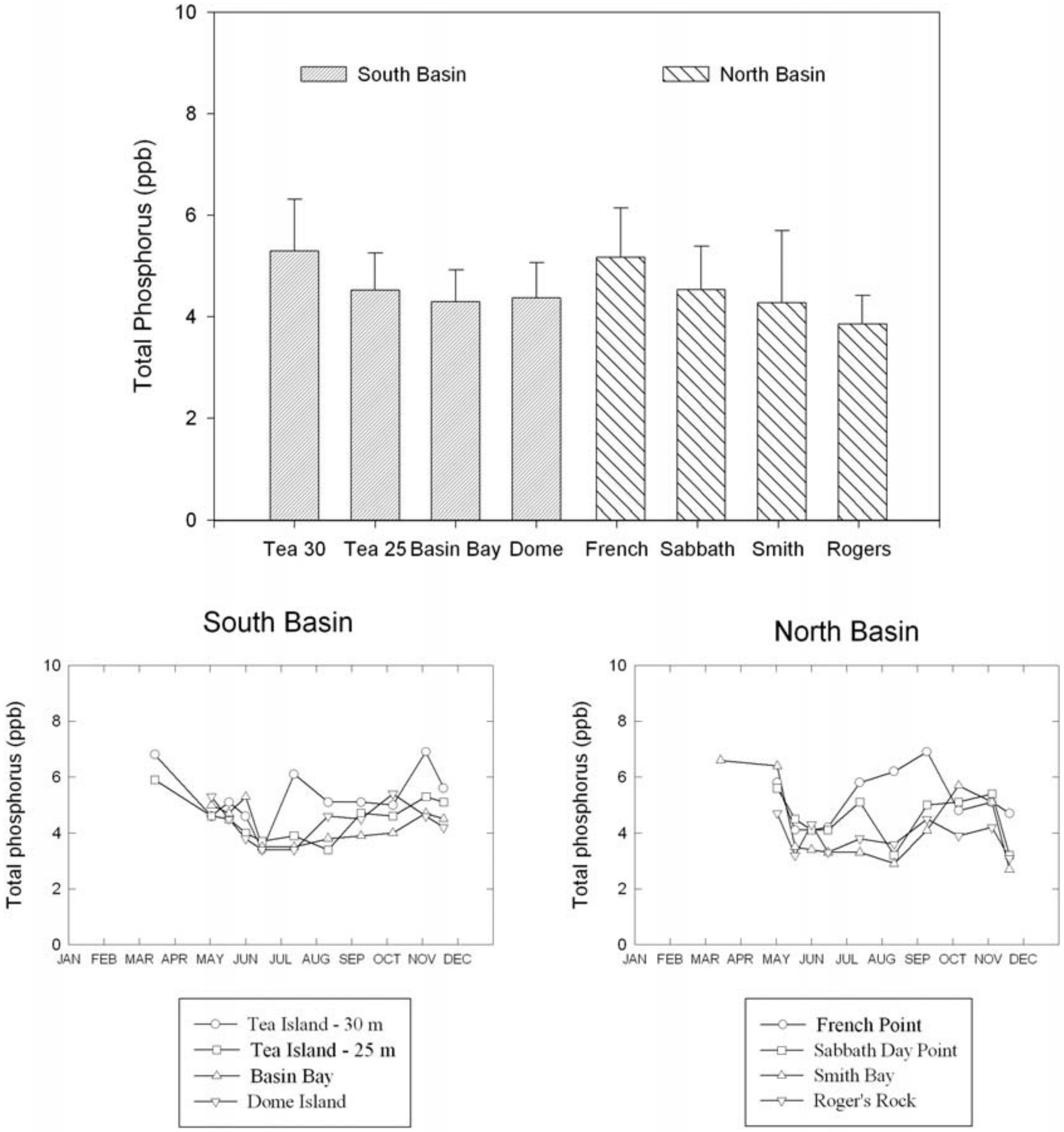


Figure 9. 2007 Average Nitrate concentrations for mid-lake sites in Lake George, NY. Average and seasonal data by site.

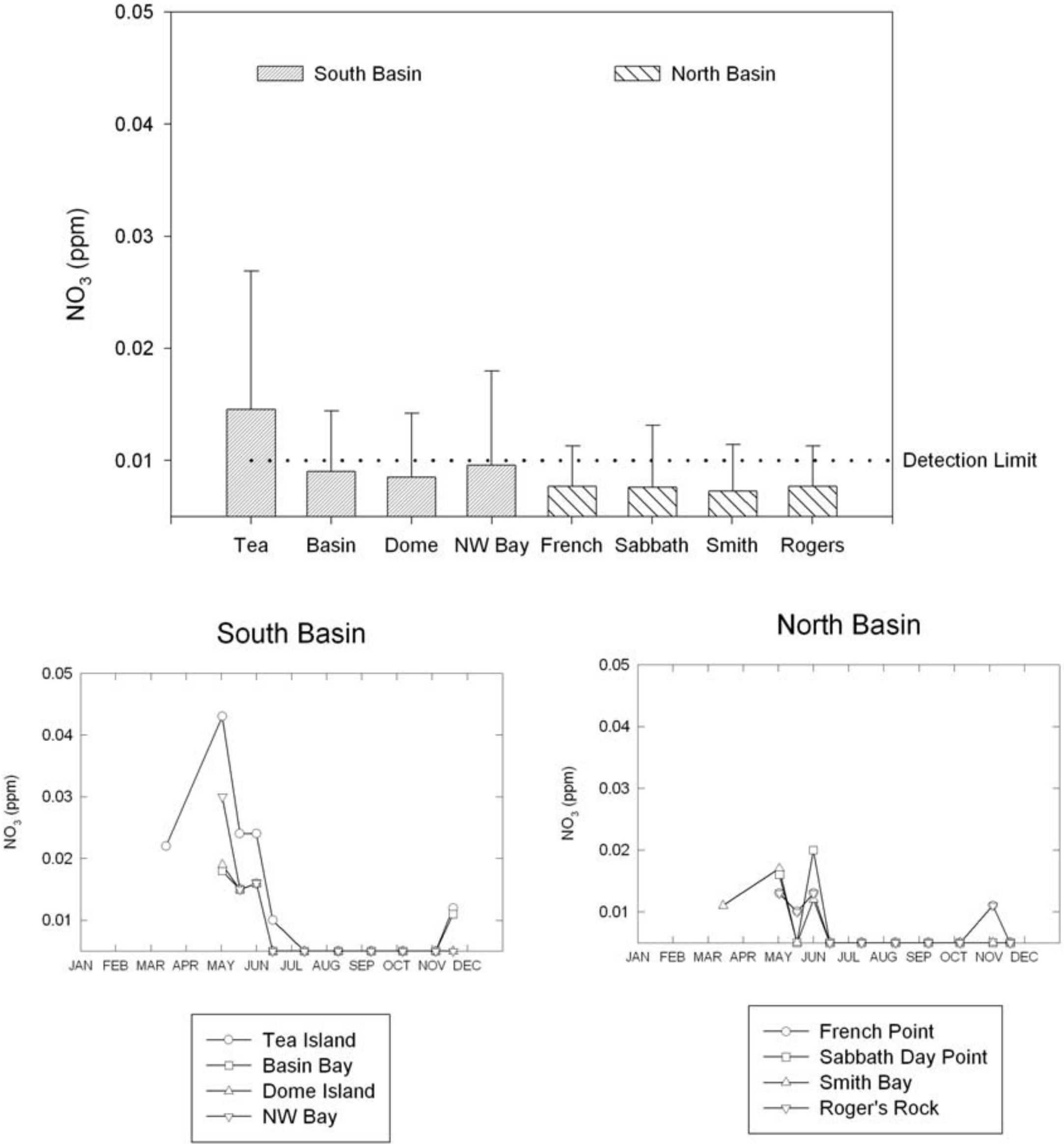


Figure 10. 2007 Average Total Nitrogen concentrations for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

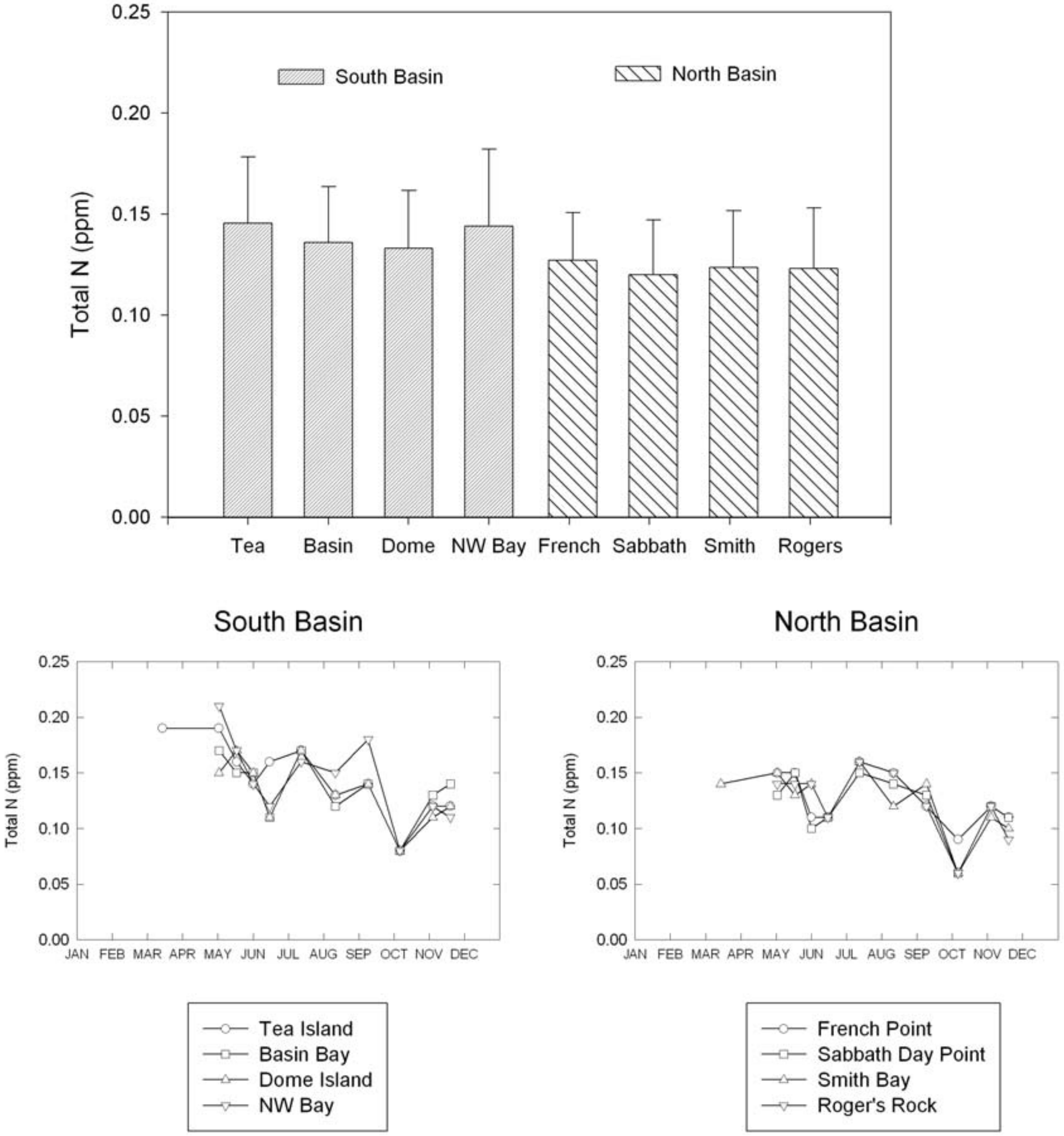
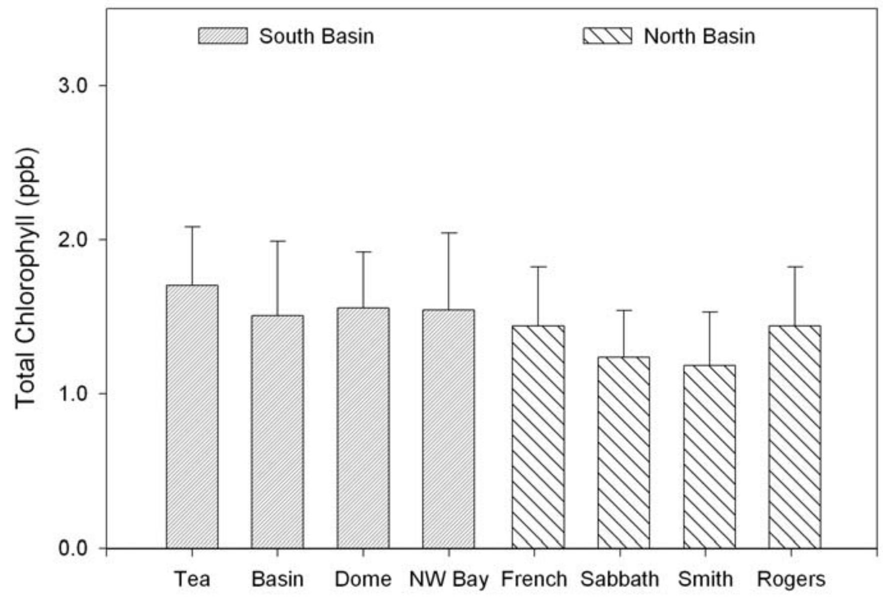


Figure 11. 2007 Average Total Chlorophyll concentrations for all mid-lake sites in Lake George, NY.
Average and seasonal data by site.



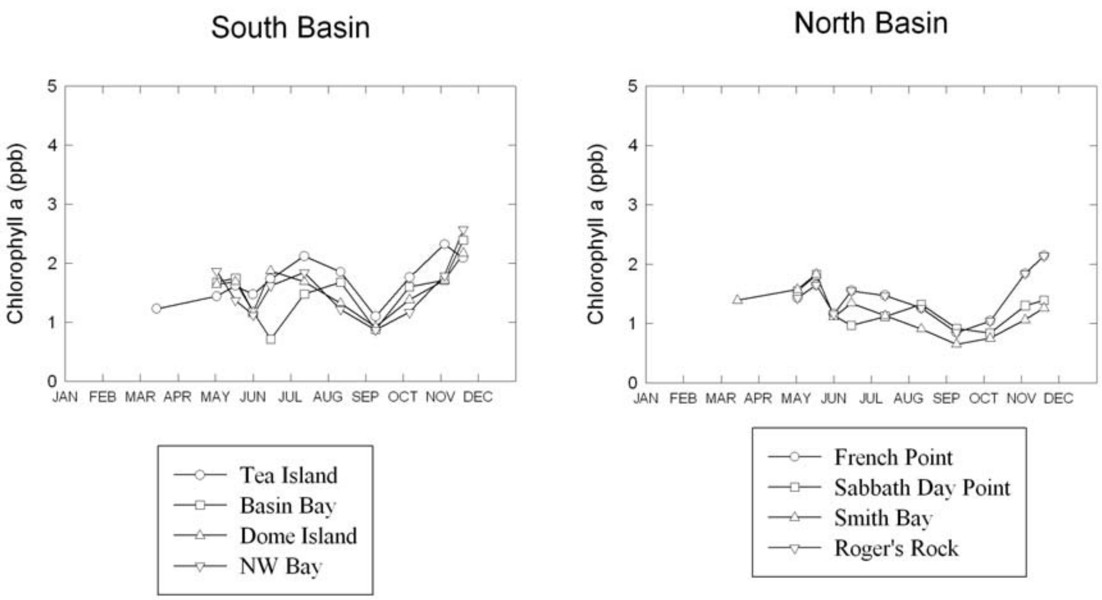


Figure 12. 2007 Average Total Chlorophyll data for all near-shore sites in Lake George, NY. Average and seasonal data by site.

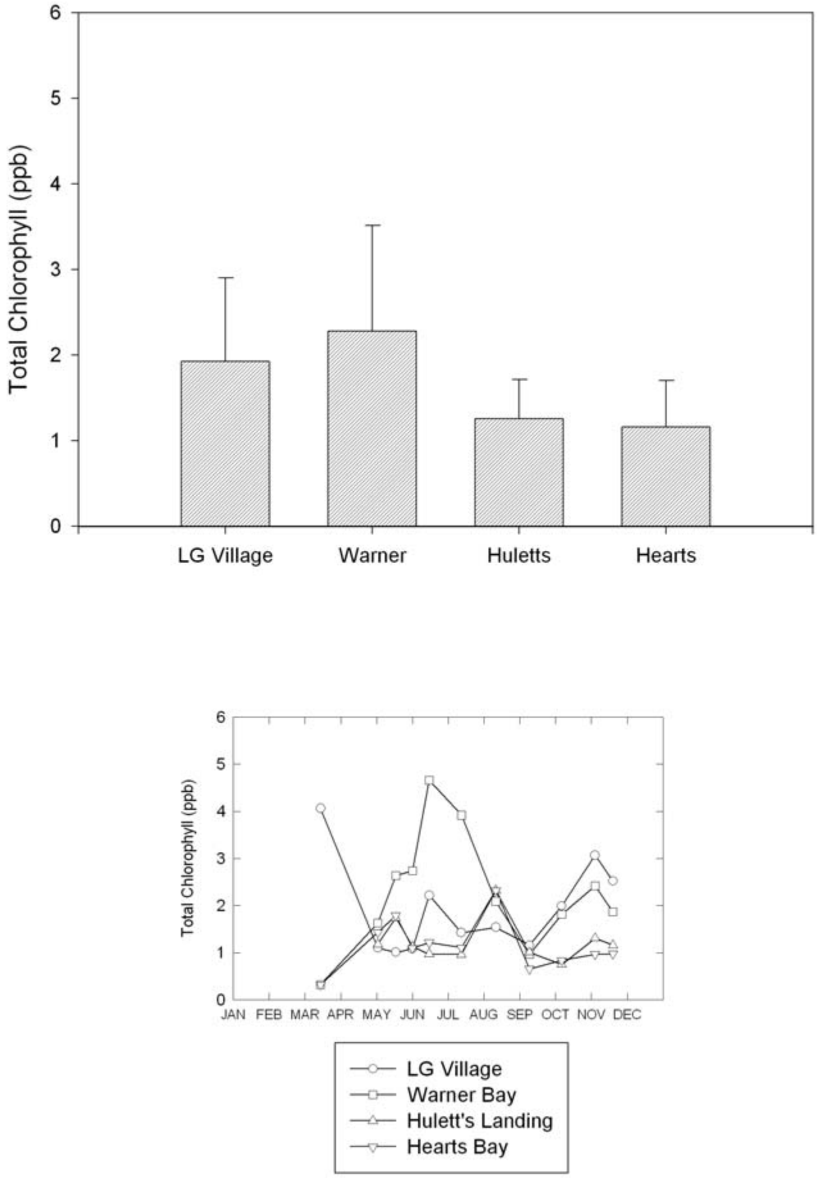


Figure 13. 2007 Average Soluble Silica concentrations for all mid-lake sites in Lake George, NY.
Average and seasonal data by site.

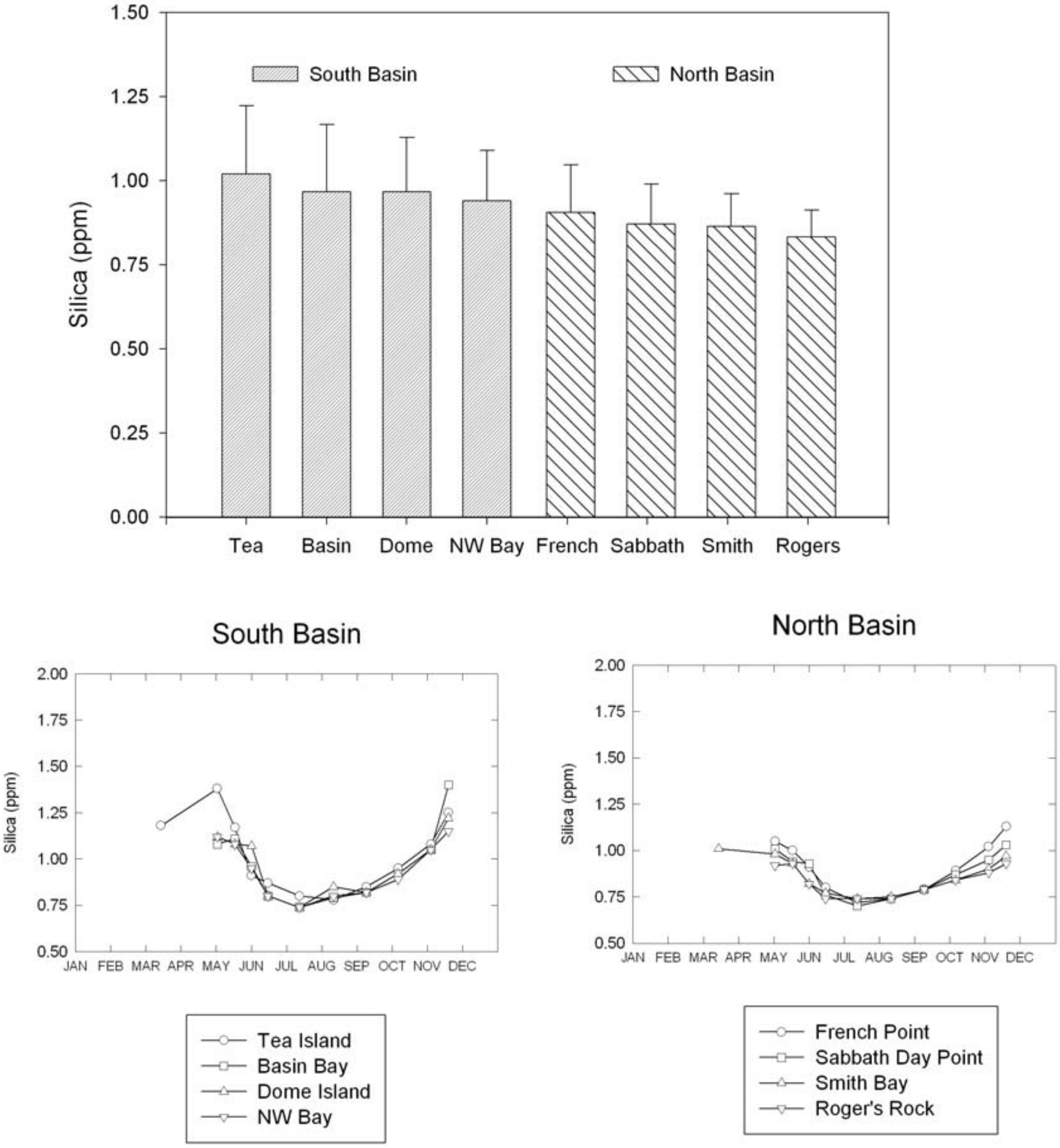


Figure 14. 2007 Average Chloride concentrations for mid-lake sites in Lake George, NY.
Average and seasonal data by site.

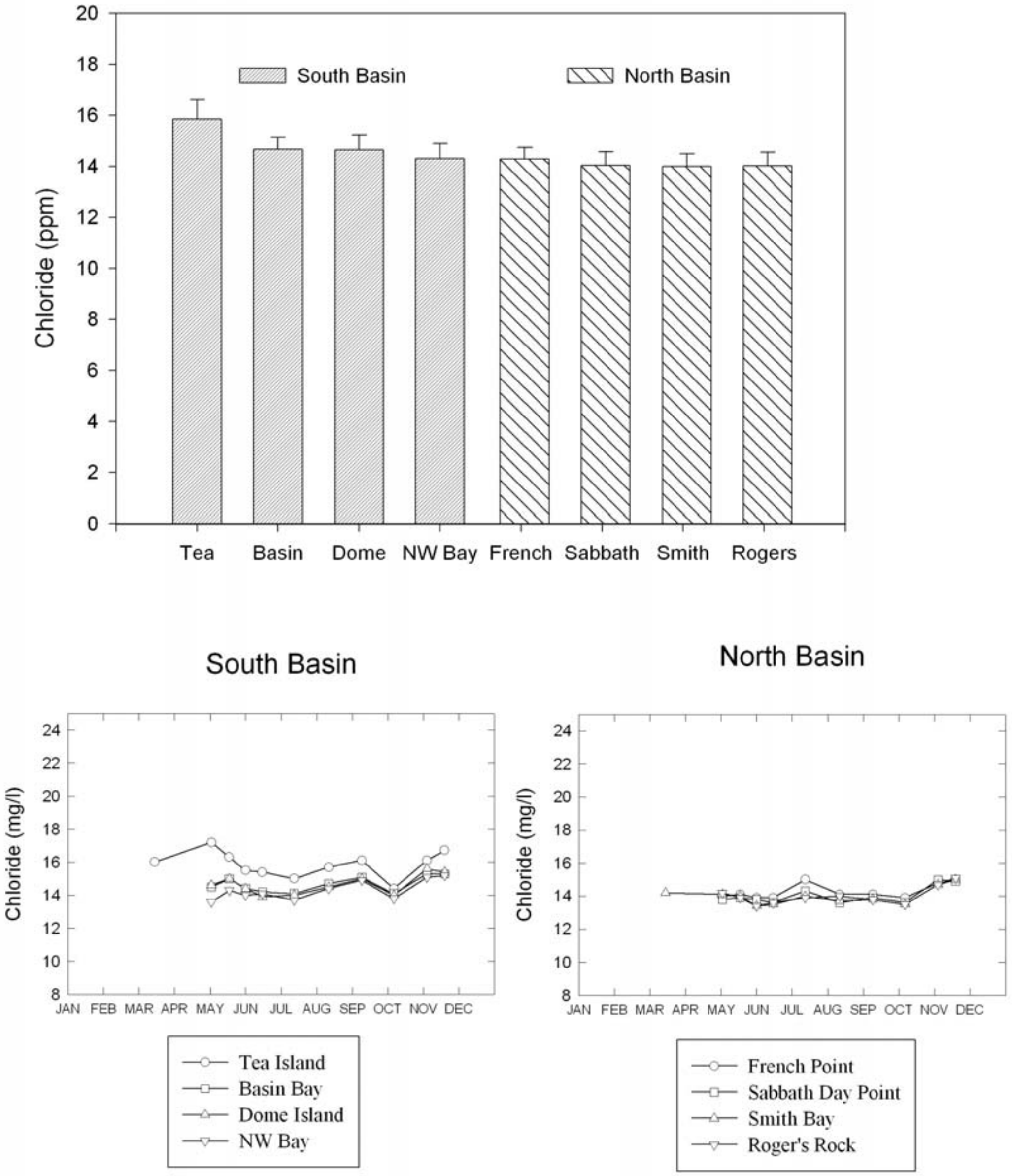


Figure 15. 2007 Average pH for mid-lake sites in Lake George, NY. Average and seasonal data by site.

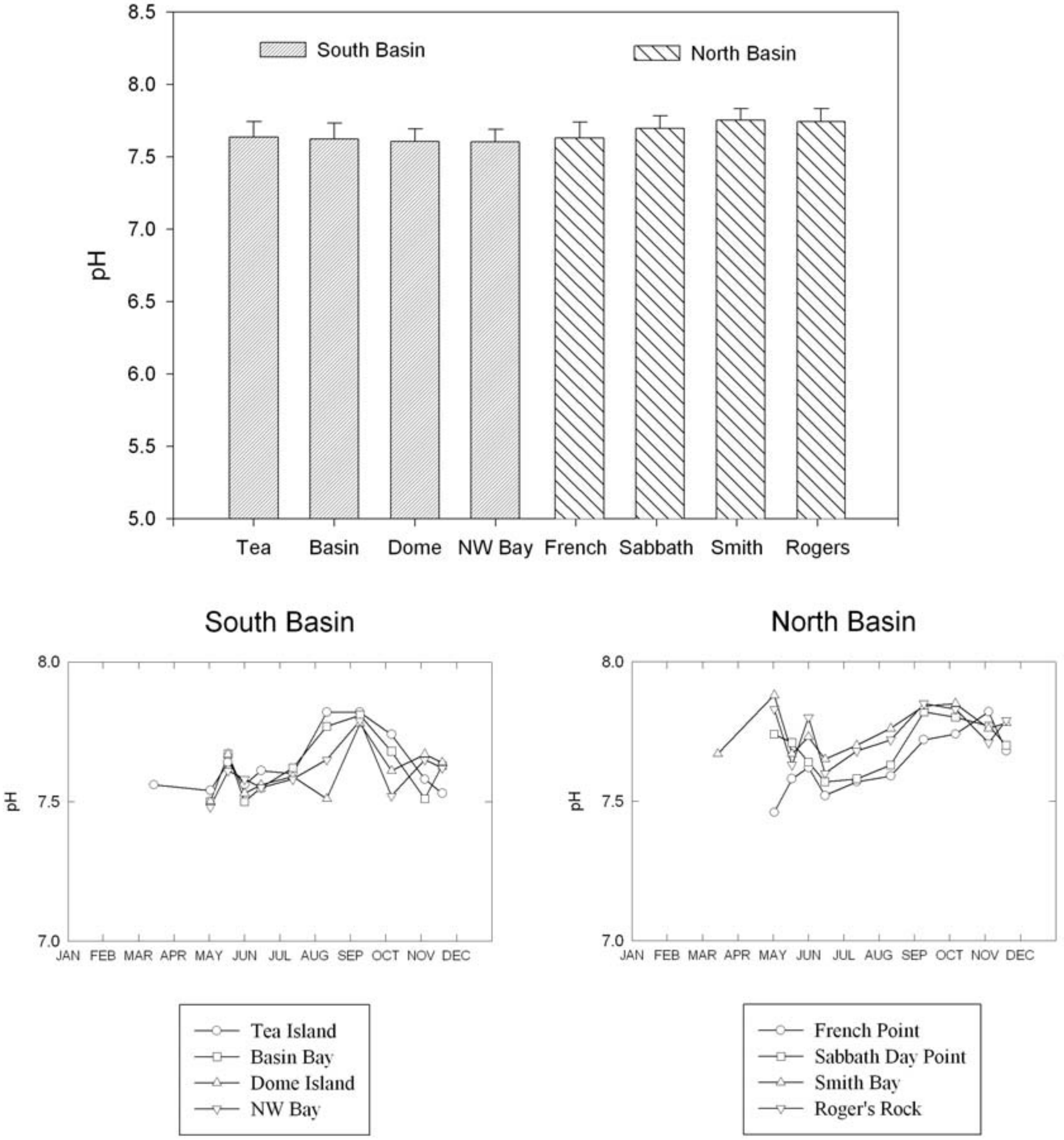


Figure 16. 2007 Calcium averages for all mid-lake sites in Lake George, NY. Average and seasonal data by site.

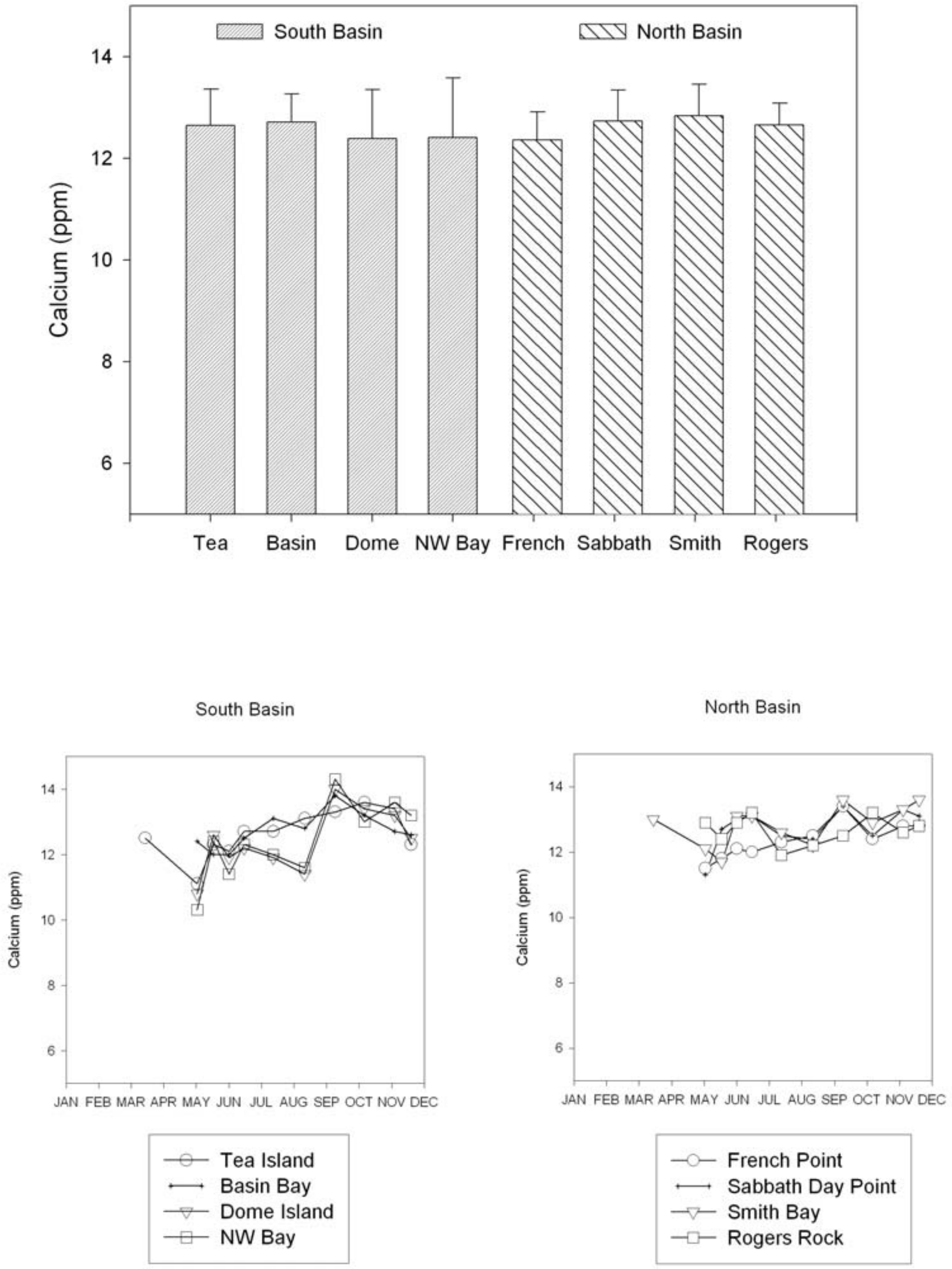


Figure 17. 2007 Ratio of Total Nitrogen to Total Phosphorus data for mid-lake sites in Lake George, NY. Average and seasonal data by site.

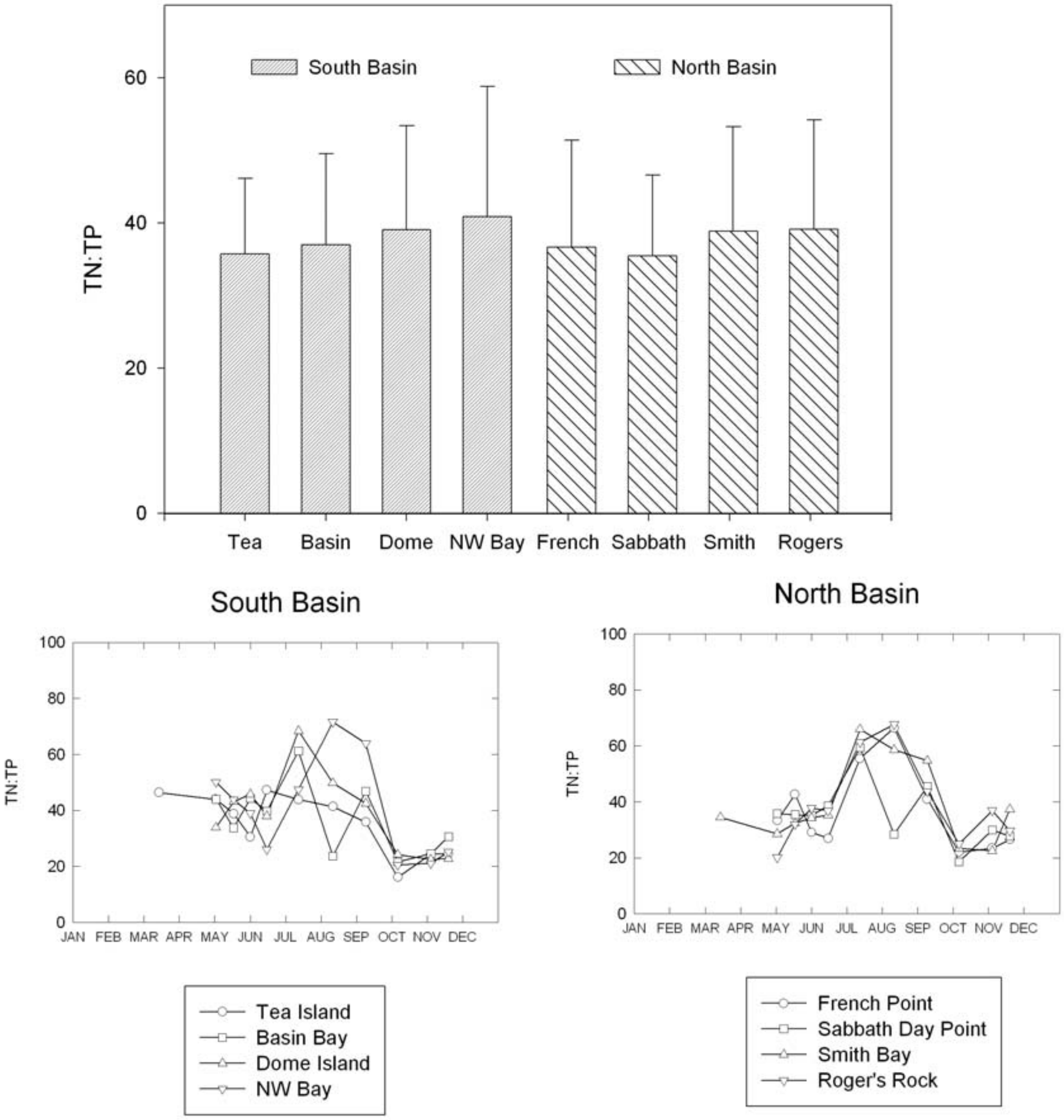
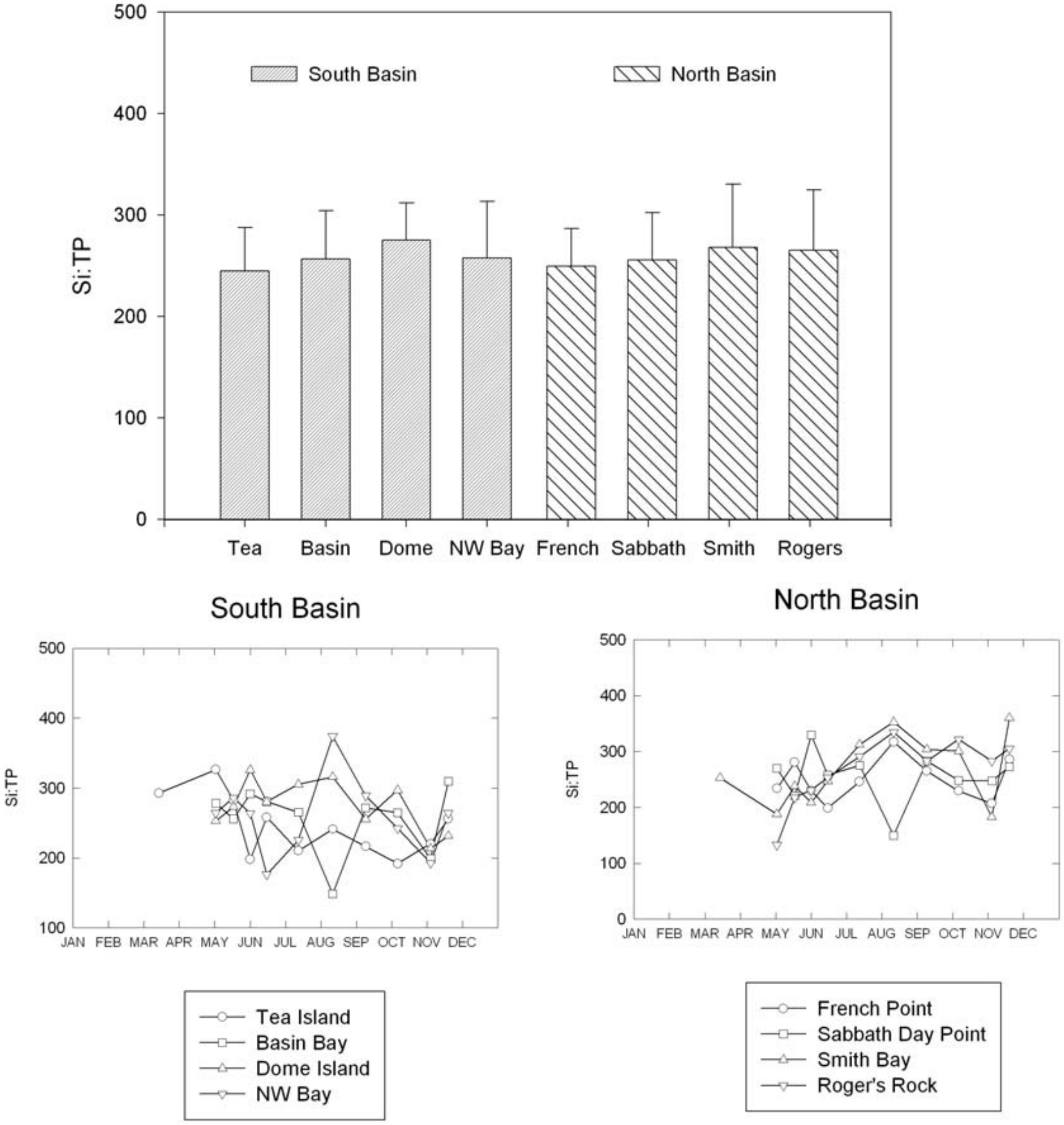


Figure 19. Ratio of Silica to Total Phosphorus data for mid-lake sites in Lake George, NY. Average and seasonal data by site.



APPENDIX B. ANALYTICAL METHODS

Analyte	*Method*	*Instrument*
pH	Electrometric (Standard Methods 4500-H^+)	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 4500-SiO_2 E.)	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 (Ca, Mg, Na, K, Mn, Fe)	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.

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