

Conesus Lake Limnology 2009

Water Quality of USDA Monitored Watersheds Internal Hypolimnetic Phosphorus Loading Lake Chemistry Status of the Zooplankton Community

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Executive Summary

1. During the summer of 2009, Conesus Lake monitoring conducted by The College at Brockport determined the current status of the health of the lake to determine if any changes (improvement or further degradation) had occurred. To accomplish this goal, the following were completed: a trophic state assessment of the lake, an estimate of the internal loading of the lake's phosphorus budget, an estimate of phosphorus loading from streams, an evaluation of long-term trends in lake chemistry, an evaluation of the walleye stocking program on lake zooplankton, and the continued long-term evaluation of nutrient and soil losses from eight agricultural subwatersheds. The growth of weeds and algae in selected nearshore areas were evaluated and is reported elsewhere (Bosch 2010).
2. The now completed USDA study (Makarewicz *et al.* 2009, Bosch *et al.* 2009 a and b, Simon and Makarewicz 2009 a and b, Lewis and Makarewicz 2009) demonstrated that traditionally accepted management practices where introduced by the farming community clearly led to major improvements in stream and nearshore water quality and to major improvements in aesthetic appeal to lake landowners and homeowners as reductions in bacteria, algae, and weeds (macrophytes) were observed. This approach should be expanded to other watersheds with the assistance of County Soil and Water Conservation District or by the development of a TMDL strategy for each subwatershed.
3. Monitoring of the USDA streams (Graywood Gully, Cottonwood Gully, Long Point Gully, Sand Point Gully, Southwest Creek, North McMillan Creek, Sutton Point Gully, and North Gully) continued during the summer of 2009. The development of this data base as a tool for evaluation of the health of these watersheds is of considerable value in determining if management practices are being maintained since the USDA project ended and in determining if new land use practices may be affecting water quality. Thus the complete stream data set provides a picture of the status of the environmental health of these watersheds since 2002.
4. After several years of a general decrease in concentrations of various nutrients from managed watersheds that led to major improvements in water quality, major increases in nutrients were observed during the summer of 2009. At Graywood Gully for example, concentrations of soil (TSS), total phosphorus (TP), soluble reactive phosphorus (SRP), total Kjeldahl nitrogen (TKN), and nitrate increased in the stream water. Only sodium was observed to decrease from the previous year. At Cottonwood Gully, after a 5-year decrease, nitrate concentration (NO₃+NO₂) increased to levels not observed since 2003. Total Kjeldahl Nitrogen also showed a slight increase since 2008. Similar increases were observed in the Southwest, Sand Point, North Gully, Sutton Point and Long Point subwatersheds. These increases in nutrient losses from these subwatersheds could be interpreted as a failure to

maintain proper management plans. However, North McMillan Creek, which is the least impacted of the Conesus Lake watersheds studied in the USDA project, also exhibited major increases in TP, SRP, TSS, and TKN. A visual inspection of this watershed in summer of 2009 ruled out any major changes in land use. Although the increases observed may be related to new or changing farming practices, we are not able to rule out that the significant rainfalls in the spring and early summer of 2009 are not the cause. A limitation of the approach taken in 2008 and 2009 was that discharge was not measured as it was in the USDA study. Concentration of analytes is a function of discharge from streams; that is, as discharge increases, concentrations increase as more material is washed from the land and more material is dissolved. The observed increases could simply be due to the higher than usual rainfalls in May and especially June. For example, the daily rate of precipitation in June was twice the rate for any other previous year since 2002. May precipitation was the highest since 2003.

5. Lake chemistry was monitored from May to mid-August 2009. Total phosphorus (TP) provides an estimate of the total amount of phosphorus potentially available to aquatic plants. In 2009 average epilimnetic TP concentration was 20.9 $\mu\text{g P/L}$ ranging from a low of 11.0 (May 26) to a high of 39.8 $\mu\text{g P/L}$ (June 17). In fact, since 1985 average epilimnetic concentrations of TP in Conesus Lake surpassed the NYSDEC Ambient Water Quality Guideline of 20 $\mu\text{g P/L}$. With depth, concentrations of TP increased in the hypolimnion on 14 July 2009 as anaerobic conditions began to develop with thermal stratification. By 28 July and into August of 2009 total phosphorus concentrations reached almost 600 $\mu\text{g P/L}$ in the hypolimnion. Since 1985 there is no discernible trend, upward or downward, of summer average epilimnetic TP concentrations.
6. Offshore chlorophyll *a* provides an estimate of algal abundance in lakes. Generally in phosphorus-limited lakes, algal abundance increases with increasing levels of phosphorus in the water column. Epilimnetic chlorophyll *a* concentrations in the summer of 2009 ranged from 2.2 $\mu\text{g/L}$ in May to 8.6 $\mu\text{g/L}$ on 30 June 2009 with an average of 5.9 $\mu\text{g/L}$. Since 1985, average summer concentrations are quite variable (range 4.3 to 14.7 $\mu\text{g/L}$) with no obvious trend. Lakes, such as Conesus Lake, with a chlorophyll range in the 4.3 to 14.7 $\mu\text{g/L}$ are generally classified as eutrophic.
7. Nitrate concentrations were generally very low (<0.05 mg/L) in Conesus Lake in 2009 at all depths and is one of the reasons why Cyanobacteria likely predominate in offshore waters of the lake during the summer.
8. Total Kjeldahl nitrogen averaged 558 $\mu\text{g/L}$ in the epilimnion with a range of 227 to 1,375 $\mu\text{g/L}$. Concentrations were similar in the metalimnion (12 m, 606 $\mu\text{g/L}$) and hypolimnion (18 m, 623 $\mu\text{g/L}$) during the summer of 2009. Total Kjeldahl nitrogen concentrations were generally slightly higher in the streams.
9. Sodium is a component of deicing salt, which is used heavily during the winter on roads in the Conesus Lake watershed. Since 1985 there is a clear trend of

increasing salt in the waters of Conesus Lake. The current average summer concentration of sodium is 24.63 mg/L in the epilimnion of Conesus Lake. This is an increase of ~ 10 mg/L of sodium in the past 25 years. Whether or not this is a health issue is currently being debated by the US EPA.

10. At Conesus Lake during summer stratification, the hypolimnion became anoxic in early July with elevated hypolimnetic concentrations of phosphorus evident by 14 July 2009. For example, in mid-May TP concentration at 15 m was 13.6 µg P/L and not significantly different from the epilimnion at a concentration of 12.0 µg P/L. By late August, TP maximum concentrations in the hypolimnion reached 55 µg/L, almost 40 times higher than the epilimnion. This increase in phosphorus was the result of reducing conditions in the hypolimnion that allowed insoluble manganese and iron phosphates in the sediment to become soluble and move into the water column. On an annual basis, the sediments released 8,043 kg of phosphorus to Conesus Lake in 2009 or 8.7 mg P/m²/day. This areal internal loading falls within the range of release rates for many lakes of the world (range 6 to 18 mg P/m²/d, average 12.9 mg P/m²/d).
11. Carlson's TSI is used to assess the trophic state of a given lake by analyzing summer TP concentrations and Chl-*a* concentrations and by measuring summer secchi disk depth. Based on the average Chl-*a* and summer TP concentrations and secchi disk readings for the entire 1985-2009 period, a mesotrophic/eutrophic status for Conesus Lake is suggested based on the Carlson Index. Consideration of the trend data for transparency, chlorophyll, and TP concentrations but also of the trophic status values observed during the 1985-2009 period suggests there are no trends toward improvement of the lake's trophic status.
12. One of the adverse impacts of the proliferation of alewife in Conesus Lake is the extirpation of the larger-bodied zooplankton, such as *Daphnia* sp, which are effective grazers of the lake's phytoplankton. Biomanipulation is the deliberate alteration of an ecosystem by adding or removing species, especially predators. Unfortunately, there has been no significant change in the zooplankton community in the last twenty years despite the NYDEC walleye stocking program. *Daphnia* abundance (<3.04/L) and biomass (<1 mg/m³) is still low while the overall size (length) of the zooplankton community is still less than ¼ of the size in 1972.

Recommendations

1. The follow-up monitoring of the USDA study creeks should be continued. The County has a unique data base that now extends over a 7-year period. Such a data base provides an opportunity to determine if water quality conditions are improving or deteriorating in eight subwatersheds of Conesus Lake monitored during the USDA project. These data provide an opportunity to critically evaluate land use

practices in watersheds and could be used to provide direction to management practices in these watersheds as part of the Conesus Lake Watershed Plan.

2. The increase in nutrient loss from all of the USDA watersheds during the summer of 2009 suggests that the approach taken of using concentration data only to evaluate temporal trends is fraught with some danger. Starting with 2002, the summer data should be evaluated within the context of discharge or at least weighted for the effect of high rainfall/discharge on nutrient concentrations. Calculation of the marginal means using the covariate discharge as weighting factor in a statistical analysis titled analysis of covariance should work (Makarewicz *et al.* 2009). This was not done in 2008 and 2009 because of the high cost of collecting the discharge data continuously. At a minimum, discharge should be collected for the days of sampling. It is possible to go back to the 2002 to 2007 data and recalculate discharge for each sampling day. It may also be possible for 2008 and 2009. This should neutralize the impact of discharge and allow better interpretation of what is happening in the Conesus subwatersheds.
3. A lake that is oligotrophic is biologically unproductive with high transparency and low nutrient concentrations while a eutrophic lake is biologically productive with low transparency and high nutrient concentrations. A mesotrophic lake is a lake with characteristics intermediate of oligotrophic and eutrophic. With time, soil particles and nutrients from the watershed are gradually added to the lake, increasing concentrations of limiting nutrients such as phosphorus. Biotic productivity increases with the higher nutrient concentrations, sedimentation of dying plankton increases, and transparency of the lake decreases accordingly. This process is natural and is called eutrophication. However, the actions of humans in a lake's watershed can increase the loss of soils and nutrients from the watershed into the lake. This cultural eutrophication accelerates the natural process often leading to deteriorating water quality. Reducing cultural effects by decreasing the rate of eutrophication and improving water quality is the goal of many environmental agencies concerned with the health of lakes. Phosphorus is generally realized as the limiting nutrient controlling algal growth in most freshwater systems. In freshwater lakes, the most effective means of reducing productivity is usually obtained by decreasing algal growth through the reduction of phosphorus inputs.

In Conesus Lake, two major sources of phosphorus exist: phosphorus released from the watershed that is generally a function of land use, and phosphorus released from sediments as a result of anoxic conditions during the summer. The amount released from the eight USDA watersheds monitored over a period of time is ~ 2,103.8 kg P/year. This represents about one half of the major subwatersheds of Conesus Lake. If we assume the losses from the other major unmonitored watersheds are similar, this would raise the amount of phosphorus loss from these subwatersheds to ~4, 200 kg/P year. However, this estimate of loading to the lake does not account for rivulets, other small streams, and a major stream - the inlet. On an annual basis, the maximum potential phosphorus that "may" be released to the lake from the hypolimnion is 8,047 kg P/ year. However, not all of the phosphorus that is released

from the hypolimnion is transferred to the entire water column with fall mixing. With oxygenation of the deeper waters of what was the hypolimnion, some of the phosphorus will precipitate back into the sediments as oxides of iron and manganese. A long-term strategy of focusing efforts on reducing losses from the watershed through management practices is suggested. Even with the application of alum to curtail sediment release, the application will likely last only 10 to 15 years, especially if the source of much of the material, the watershed, is not curtailed.

4. Since there has not been a resurgence of *Daphnia* populations in Conesus Lake, a review of the walleye stocking program may shed some light on why this program has not been successful.

Introduction

Among the recommendations of the Conesus Lake Watershed Plan, adopted in 2003, was a commitment to an annual monitoring program of the lake and its watershed. Tracking water quality and habitat conditions throughout the watershed is a means to evaluate the effectiveness of control measures as the plan's recommendations are implemented. Monitoring within the lake and watershed is broadly organized on a three-year cycle: in-lake monitoring, watershed-wide monitoring, and detailed monitoring of target subwatersheds. Although this broad sequence has been modified to respond to funding opportunities over the years, the annual monitoring program continues to gather data from both the lake and the tributary streams.

The priorities outlined by the Conesus Lake Watershed Council in its annual work plan (Conesus Lake Watershed Management Plan 2009 Work Program) included:

- (1) assessing the effectiveness of the walleye stocking program on controlling the alewife population, and
- (2) updating the estimated phosphorus budget for Conesus Lake.

The results of the 2009 monitoring presented in this document includes components that address each of these two priorities. In addition, monitoring updated the trophic state assessment of Conesus Lake, updated the estimate of internal loading component of the lake's phosphorus budget, evaluated the walleye stocking program, monitored the growth of weeds and algae in selected nearshore areas, and continued the long-term dataset for eight agricultural subwatersheds.

The objectives are as follows:

Objective 1: Evaluate whether walleye stocking has been effective in controlling alewife

One of the adverse impacts of the proliferation of alewife in Conesus Lake is the extirpation of the larger-bodied zooplankton, e.g. *Daphnia* sp, which are effective grazers of the lake's phytoplankton. Stocking walleye, which are a predator of the alewife that reduce large-bodied zooplankton, is one measure to reduce phytoplankton

and improve the lake's water clarity. This analysis, which was last completed in 1993, documents the species composition, relative abundance, and size structure of the zooplankton community. Examining the zooplankton community composition in 2009 provides another indicator of whether and to what extent the Conesus Lake food web has changed. This investigation is timed to complement the NYSDEC fishery survey planned for 2009.

Objective 2: Assess the trophic state of Conesus Lake

Trophic state, or the level of productivity of a lake, may be assessed through indicator parameters that measure nutrient concentration and algal abundance. For phosphorus-limited systems such as Conesus Lake, trophic state was evaluated using total phosphorus, chlorophyll-a, and Secchi disk transparency measurements.

Objective 3: Update the estimate of internal loading component of the lake's phosphorus budget

The watershed is the ultimate source of phosphorus to Conesus Lake. Phosphorus enters the lake through its tributary streams or runoff from nearshore areas. Land use has a large impact on phosphorus export from the watershed, as documented in the USDA-funded project (Makarewicz *et al.* 2009). Phosphorus cycles through the lake ecosystem, becoming incorporated into biomass of algae, plants, and animals. Eventually, this biological material settles out of the water and becomes incorporated into the sediments. Lake sediments may release phosphorus via the iron/manganese cycle when the supply of dissolved oxygen in the water overlying the sediments becomes depleted by microbial activity. In Conesus Lake, deeper waters routinely become depleted of dissolved oxygen during the summer. Oxygen depletion is caused by an imbalance between supply and demand; lower waters are isolated from the atmosphere during summer and microorganisms consume oxygen as they break down organic material. The most recent estimate of the potential contribution of internal loading from sediments to the lake's phosphorus budget was completed in 2004.

Objective 4: Continue the long-term monitoring program in agricultural subwatersheds

The eight USDA streams (Graywood Gully, Cottonwood Gully, Long Point Gully, Sand Point Gully, Southwest Creek, North McMillan Creek, North Gully, and Sutton Point Gully) were monitored to further develop the data base as a tool for evaluation of the health of these watersheds, to determine if management practices were maintained after the USDA project ended, and to determine if new land use practices that may be affecting water quality have been adopted. This unique data set provides a picture of the current status of the environmental health of these watersheds.

Objective 5: Determine whether diversion of North Gully has resulted in reductions in macrophyte and metaphyton biomass in McPhersons Cove

Plant growth in McPhersons Cove has been monitored for seven summer seasons since 2002, including 2008 sampling funded by FL-LOWPA allocation from the Livingston County Planning Department. Both milfoil biomass and metaphyton cover have been consistently high in the cove over the period of monitoring. The rerouting of the North Gully outflow presents an excellent opportunity to test this particular management practice and to examine the influence of streams on local plant growth. A before-and-after study alone would not provide a robust answer to this question because it is difficult to differentiate between local trends and lake-wide annual trends. As part of the 2008 Conesus Lake monitoring program, three sites, including McPhersons Cove, were monitored for metaphyton and macrophyte biomass. The other two sites were Sand Point and Sutton Point, both part of the USDA monitoring program until 2007. There is a 7-year record for all three sites. These data will be reported elsewhere by Dr. Sid Bosch of SUNY Geneseo.

Methods

For both the lake and the stream sites, samples were taken every Tuesday morning from 19 May to 18 August 2009 irregardless of stream stage height; that is, water samples were taken on a Tuesday during hydrometeorologic events or nonevents. Stream samples were taken at the former USDA monitoring sites (Makarewicz *et al.*

2009) at the base of the Graywood Gully, Long Point Gully, Sand Point Gully, Cottonwood Gully, Sutton Point Gully, North Gully, and the North McMillan Creek sub-watersheds. Lake samples were taken at the deepest point in south basin of Conesus Lake (N 42° 46.784', W 77° 43.068')(Figure 1). Water samples were taken, preserved, and analyzed using approved standard methods (USEPA 1979, APHA 1999).

Stream samples were analyzed for TP (APHA Method 4500-P-F), TKN (USEPA Method 351.2), NO₃+ NO₂ (APHA Method 4500-NO₃-F), and TSS (APHA Method 2540D). Lake samples were analyzed for TP and measured biweekly at 0, 3, 6, 9, 12, and 15 m. Except for TSS, analyses were performed on a Technicon AutoAnalyser II. Method Detection limits were as follows: SRP (0.48 µg P/L), TP (0.38 µg P/L), NO₂+ NO₃ (0.005 mg N/L), TKN (0.15 µg N/L), and TSS (0.2 mg/L). Sample water for dissolved nutrient analysis (SRP, NO₃+ NO₂) was filtered immediately on site with 0.45-µm MCI Magna Nylon 66 membrane filters and held at 4°C until analysis the following day. Weekly lake chlorophyll-a (2-m tube composite) was measured fluorometrically using a Turner Model 111 Fluorometer. Approximately 1-L aliquots were filtered through glass fiber filters and extracted with 90% alkaline acetone. Extracted samples were centrifuged and measured fluorometrically (Wetzel and Likens 2000). The secchi disk depth was determined using a black and white 20-cm disk. Dissolved oxygen and temperature were measured with a Model DS5 Hydrolab at each meter of water depth.

Along with water samples, zooplankton were collected using a vertical (15 m to the surface) zooplankton tow (½-meter diameter plankton net, 63-µm mesh net) equipped with a General Oceanics flowmeter to correct for the volume filtered. Samples were preserved with 70% ethanol. From each sample, a 1-mL subsample was withdrawn using a Hensen-Stemple pipette from a well-mixed sample and transferred to a Sedgwick-Rafter counting cell. All zooplankton were identified and the number of individuals and eggs per species enumerated using a phase contrast microscope at 100X; species identification of copepods and *Daphnia* were confirmed at 200X or 400X. Length measurements were made on the first 20 individuals of each species encountered per sample. Zooplankton taxonomy largely followed Balcer *et al.* (1984); other keys consulted included Edmondson (1959), Ruttner-Kolisko (1974), and Brooks

(1957). The volume of each rotifer species was computed using the geometrical shape that most closely resembled the species (Downing and Rigler 1984). Assuming a specific gravity of one, volume was converted to fresh weight and to dry weight assuming a ratio of dry to wet weight of 0.1 (Doohan 1973) for all rotifer species except *Asplanchna* spp. A dry weight / wet weight ratio of 0.039 was used for *Asplanchna* spp. (Dumont *et al.* 1975). The dry weight of Crustacea was calculated using the length – weight relationships found in Downing and Rigler (1984).

Quality Control:

All water samples were analyzed at the Water Chemistry Laboratory at The College at Brockport, State University of New York (NELAC – EPA Lab Code # NY01449) within 24 h of collection. In general, this program includes biannual proficiency audits, annual inspections and documentation of all samples, reagents and equipment under good laboratory practices. All quality control (QC) measures are assessed and evaluated on an on-going basis. As required by NELAC and New York's ELAP certification process, method blanks, duplicate samples, laboratory control samples, and matrix spikes are performed at a frequency of one per batch of 20 or fewer samples. Field blanks (events and nonevents) are routinely collected and analyzed. Analytical data generated with QC samples that fall within prescribed acceptance limits indicate the test method was in control. For example, QC limits for laboratory control samples and matrix spikes are based on the historical mean recovery plus or minus three standard deviations. QC limits for duplicate samples are based on the historical mean relative percent difference plus or minus three standard deviations. Data generated with QC samples that fall outside QC limits indicate the test method was out of control. These data are considered suspect and the corresponding samples are reanalyzed. As part of the NELAC certification, the lab participates semi-annually in proficiency testing program (blind audits, Table 1) for each category of ELAP approval. If the lab fails the proficiency audit for an analyte, the lab director is required to identify the source and correct the problem to the certification agency.

Results and Discussion

Stream Watershed Monitoring (USDA Watersheds)

Starting in September of 2002, the Conesus Lake Watershed Project monitored the chemistry of stream water in several creeks of the Conesus Lake watershed (Makarewicz *et al.* 2009). Six small, predominantly agricultural (>70%) watersheds (<325 ha) in the Conesus Lake catchment of New York State were selected to test the impact of Best Management Practices (BMPs) on mitigation of nonpoint nutrient sources and soil loss from farms to downstream aquatic systems. Two other watersheds were added later in the study for a total of eight. The streams were monitored for the nutrients total phosphorus (TP), soluble reactive phosphorus (SRP), and nitrate. These are all measures that indicate how much “fertilizer” is in the water. Total Kjeldahl nitrogen (TKN) provides an indication of the amount of organic matter, such as manure, that is present in the water. Total suspended solids (TSS) provided a measure of the amount of erosion either from stream banks or from upland areas. Sodium is a measure of how much salt is in the water. Increases in these concentrations over a period of time would indicate that materials are being lost from the watersheds as a result of land use practices. Decreases in these concentrations would suggest improvements within a watershed; that is, materials are being kept within the watershed.

Over a 5-year period, intensive stream water monitoring and analysis of covariance provided estimates of marginal means of concentration and loading for each year weighted by covariate discharge (Makarewicz *et al.* 2009). In general, significant reductions in TP), SRP), nitrate+nitrite (NO_3+NO_2), TKN, and TSS concentration and flux occurred by the second and third years of implementation. At Graywood Gully for example, where Whole Farm Planning was practiced and a myriad of structural and cultural BMPs were introduced, we observed the greatest percent reduction (average = 55.8%, range 47% to 65%) and the largest number of significant reductions in analytes (4 out of 5). In general, both structural and cultural BMPs were observed to have profound effects on nutrient and soil loss. Where fields were left fallow or planted in a vegetative type crop (alfalfa), reductions, especially in NO_3+NO_3 , were observed. Where

structural implementation occurred, reductions in total fractions were particularly evident. Where both were applied, major reductions in nutrients and soil occurred. Taking significant portions of the watersheds out of crop production or removing dairy cows had a similar effect; nutrients and soil were maintained on the watershed, and significant reductions in nutrient and soil loads and concentrations to downstream systems were evident.

Interestingly, management practices resulted in reductions in nutrients and soil delivered to downstream systems and have had an effect on abundance of nuisance species of nearshore filamentous algae, weeds, and bacterial communities in the nearshore of Conesus Lake. Comparisons of Pre-BMP to the Post-BMP periods at Cottonwood and Graywood indicate that algal cover was statistically lower than Pre-BMP abundance in 8 of 11 sample years (72.7%) (Bosch *et al.* 2009a). At sites downstream from subwatersheds where no extensive changes in management were implemented by landowners, percent cover of filamentous algae was lower than Pre-BMP levels in only 3 of 12 sample years (25%)(Bosch *et al.* 2009a). Similarly, in macrophyte beds downstream from managed subwatersheds, quadrat biomass decreased by 30-50% within 1 or 2 years of BMPs implementation and was statistically lower than Pre-BMP values in 7 of 11 sample years (Bosch *et al.* 2009b). Also, Shuskey *et al.* (2009) suggest that growth of rooted macrophytes decreased as foliar uptake of nutrients decreased as a result of the decrease in available nutrients in the water. In the three macrophyte beds where minimal or no BMPs were introduced, biomass was statistically indistinguishable from Pre-BMP values in 12 experimental sample years.

The reduction in organic-bound phosphorus loss, due to management practices, from the watershed to the nearshore of the lake may play a pivotal role in the observed reduction in growth and biomass of macrophytes (Noll *et al.* 2009). Lastly, microbial populations declined in the nearshore below managed watersheds. For example, over the 5-year study period, a major decrease in bacterial levels in nonevent Graywood Gully stream water was evident after management practices were implemented. *Escherichia coli* levels dropped more than 10 fold to levels significantly below the 235

CFU/100 mL EPA Designated Bathing Beach Standard, while the yearly maximum for *Enterococcus* dropped by a factor 2.5 (Simon and Makarewicz 2009a and b).

The eight USDA streams (Graywood Gully, Cottonwood Gully, Long Point Gully, Sand Point Gully, Southwest Creek, North McMillan Creek, North Gully, and Sutton Point Gully) were monitored to further develop the data base as a tool for evaluation of the health of these watersheds, to determine if management practices were maintained after the USDA project ended, and to determine if new land use practices that may be affecting water quality have been adopted. Unlike the USDA project which monitored streams during the entire year, current monitoring of the streams, because of cost restrictions, was limited to the summer period (May through August). Also the annual 2003 to 2007 data set of Makarewicz *et al.* (2009) (Table 2) was selected for the same summer period to allow for comparisons to the summer 2008 and 2009 data collected. Since Makarewicz *et al.* (2009) generally took samples on every Tuesday of the year, the 2008 and 2009 data are directly comparable, as samples were taken on Tuesday during the summer of 2008 and 2009. The Makarewicz *et al.* (2009) event data, which was taken based on rainfall amount and occurred on random dates, was not included in the data in Table 2. Also the data presented in Table 2 is not adjusted for discharge from each creek as Makarewicz *et al.* (2009) did in his analysis. Nevertheless, the data set developed in summer 2008 and 2009 does provide a trend analysis over time of the status of each watershed. What follows is a watershed by watershed review.

Graywood Gully (Table 2, Fig. 2): The Maxwell Farm occurs in this watershed and a myriad of BMPs were introduced here. In the Graywood Gully watershed where row crops and dairy farming were present, application of a full spectrum of management practices (fertilizer reduction, cover crops, contour strips, reduction in fall and winter manure spreading, various grass filters for runoff from bunker storage of silage and milk house wastes, cows and heifers fenced from the creek and pond) were implemented. Reductions in the limiting nutrient phosphorus (whether it be the dissolved fraction or the total fraction) decreased by over 50% since the implementation of BMPs. The loss of soil from the land has also decreased by ~ 50% and NO_3+NO_2 by 75%, while organic

nitrogen as TKN decreased by 40%. Clearly, management practices have led to a decrease in the amount of soil and nutrients being lost from the land and a reduction of such being delivered to Conesus Lake. After the USDA project had ended, this reduction observed from 2003 to 2007 was maintained into 2008 for NO_3+NO_2 , TKN and TSS, but there appeared to be a slight increase in TP and SRP in 2008. In 2009, concentrations of TSS, TP, SRP, TKN, and NO_3+NO_2 increased in Graywood Gully stream water. Only sodium was observed to decrease from the previous year.

Sand Point Gully (Table 2, Fig. 3): At Sand Point Gully rotational grazing pens and water troughs were installed, and cattle were fenced out of the creek starting in May of 2003. Two gully plugs and tiles were also installed in a small portion of the watershed in November 2002 prior to the beginning of this project. We did not expect a large impact of management practices (rotational grazing and the “gully plugs”) here, especially since the major management area accounted for less than 9.5% of the entire watershed. Also, manure-spreading operations continued in large portions of the watershed throughout the study (P. Kanouse, Personal Communication, Livingston County Soil and Water Conservation District), which theoretically could cause elevated levels of NO_3+NO_2 and TP. Despite these expectations, a significant 44% reduction in NO_3+NO_2 concentration was observed (Table 2) by 2004 with no further significant changes over the study period, except for 2008. In 2009, NO_3+NO_2 levels increased by over 100% from the previous year. A slight increase in TKN was also observed. A reduction in other analytes, with the exception of sodium, was not observed. Discussion on why the decrease in NO_3+NO_2 may have occurred may be found in Makarewicz *et al.* (2009).

Long Point Gully (Table 2, Fig. 4): Dairy cattle were removed from the Long Point Gully watershed in 2003, and a 37% reduction (76.7 ha) in crop acreage occurred by 2004. Here major reductions in NO_3+NO_2 (42%), TP (36%), and SRP (53%) concentrations were observed by 2007, 3 years after removal of cropland from production (Table 2). As expected, removing land from crop production reduced nonpoint nutrient sources and led to major reductions of nutrients from the watershed. Somewhat surprisingly, concentrations of all parameters, except nitrate and TP,

increased dramatically in the summer of 2008. For example, SRP values had been steadily falling from ~40 µg/L in 2003 to ~15 µg/L in 2007. In 2008, SRP concentrations jumped back to 44.8 µg/L and remained high in 2009, exceeding concentrations observed in 2003. In 2009, NO₃+NO₂ levels were ~25% higher than from 2005 to 2008. Some type of new land use activities may have occurred in this watershed starting in the summer of 2008. There are many possible reasons for this and could be simply a new crop planted in the watershed.

Cottonwood Gully (Table 2, Fig. 5): In Cottonwood Gully where row crops predominate, BMPs were limited to two: construction of three water and sediment control basins (gully plugs) and strip cropping designed to retain soils. Previous to BMP introduction in this small watershed (98.8 ha), soil loss was high and conservatively estimated in the 1990s at 130 tons (metric) per year. As in Graywood Gully, significant impacts from management practices were observed in the second year after introduction of BMPs. Unlike Graywood Gully, reduction of soil and nutrients was recorded for only three of five analytes (TKN, TSS, and NO₃+NO₂). With the exception of TSS (71% reduction), the magnitude of reduction was low relative to Graywood Gully [e.g., NO₃ concentration: 32% (Cottonwood) versus 58% (Graywood)]. This trend was maintained into 2008 but not in 2009. In 2009 TP, SRP, TSS, and sodium concentrations remained similar to previous years. However, NO₃+NO₂, after a 5-year decrease, increased to levels not observed since 2004. Total Kjeldahl Nitrogen also showed a slight increase since in 2009.

Sutton Point Gully (Table 2, Fig. 6): Significant reductions in NO₃ (39%), TSS (72%), and TKN (33%) occurred at Sutton Point (Table 2) within 1, 3, and 4 years, respectively, after 2003. No physical infrastructure improvements were implemented in this watershed until 2007 when gully plugs were added. However, a significant and increasing portion of the watershed has been placed in alfalfa/grass production since 2003 (37% in 2005 to 60.3 % in 2007). As in Cottonwood Gully, the conversion of portions of this watershed to a long-term vegetative type crop (alfalfa-grass hay), a cultural BMP, would indicate that no nitrogen fertilizer was added to these fields (N.

Herendeen, Personal Communication, Cornell Cooperative Extension). Also during this period, manure slurry was not added to fields (P. Kanouse, Personal Communication, Livingston County Soil and Water Conservation District). Both practices, reduction in manure spreading and the establishment of increasing acreage of a vegetative crop, likely led to the observed decrease in NO_3+NO_2 and TKN to the downstream system. These reductions were maintained into 2008 and 2009 with the exception of TKN and SRP. With SRP and TKN, significant increases were observed in 2009.

Southwest Gully (Table 2, Fig. 7): This creek was not reported on by Makarewicz *et al.* (2009). Inspection of Table 2 suggests that major reductions in NO_3+NO_2 , TSS, and TKN occurred over the 7-year period. This may be related to the construction of a manure pit within this watershed by the USDA project. However in 2009, major increases in TP (~ 20%), SRP (~50%), and TKN (~ 90%) were observed from the previous year.

North Gully (Table 2, Fig. 8): North Gully served as a reference watershed for macrophyte studies of Bosch *et al.* (2009 a). Sampling began here in 2004, rather than 2002, and was taken in a somewhat different procedure. Water samples were taken once per week as with the other streams, but there was no autosampler taking event samples or measuring flow continuously. Thus samples represent the conditions on any given day and certainly miss many of the hydrometeorologic events. As with many of the other Conesus creeks, increased concentrations of various analytes were observed in 2009 compared to previous years. Total phosphorus, SRP, sodium, and TSS all increased. For example, a 200% increase in TSS was observed, going from ~5 mg/L (2004 to 2007) to 15 mg/L in 2009.

North McMillan Creek (Table 2, Fig. 9): This watershed was the reference watershed for the USDA Study. No BMPs were introduced here. No significant changes were observed in stream concentrations for any of the parameters from 2003 to 2008. However in 2009, major increases in TP, SRP, TSS, and TKN occurred. Of all the subwatersheds of Conesus Lake, this is the least impacted by humankind (Makarewicz

et al. 2009). These increases in concentrations of particulate fractions, such as TP, TKN and TSS, suggest that the increases observed are related to above average rainfall in May and June of the summer of 2009 (Fig. 15). In June 2009 for example, rainfall was twice as high as in any other year from 2003 to 2008. Besides land use being a factor in determining stream concentrations, increased rainfall will carry more materials from the watershed and dissolve more soil increasing stream concentrations.

In summary, where management practices were implemented, major decreases in losses of nutrients and soil from various watersheds were realized; that is, soil and nutrients were being maintained on these watersheds and not being lost to Conesus Lake. In general, these reductions observed from 2003 to 2007 were maintained into 2008 after the USDA project had ended. The exception was Long Point Gully where major increases in phosphorus (SRP and TP), soils (TSS), and organic nitrogen (TKN) were observed. In 2009, major increases in nitrogen compounds were observed in several watersheds. This may be related to new or changing farming practices. However, we cannot rule out that the significant rainfalls in the spring and early summer of 2009 are not the cause. The amount of precipitation in June was twice the amount for any other previous year since 2002 (Fig. 15). May precipitation was the highest since 2003. A limitation of the approach taken in 2008 and 2009 was that discharge was not measured as it was in the USDA study. Concentration of analytes is a function of discharge from streams; that is, as discharge increases, concentrations increase as more material is washed from the land or more material is dissolved. With discharge measurements, a statistical procedure called Analysis of Covariance ANCOVA, may be used to factor out this effect. This was successfully done in the USDA study (Makarewicz *et al.* 2009). If monitoring of the streams continues, we recommend that discharge measurements and ANCOVA analysis be performed.

Lake Chemistry

Phosphorus (Table 3)

Total phosphorus (TP) provides an estimate of the total amount of phosphorus potentially available to aquatic plants. In 2009, the average epilimnetic TP concentration was 20.9 µg P/L ranging from a low of 11.0 (May 26, Fig. 10) to a high of 39.8 µg P/L (June 17, Fig. 11). In fact, since 1985, average epilimnetic concentrations of TP in Conesus Lake surpassed the NYSDEC Ambient Water Quality Guideline of 20 µg P/L (Fig. 16). With depth, concentrations of TP increased in the hypolimnion on 14 July 2009 (Fig. 14) as anaerobic conditions began to develop with thermal stratification (Fig. 12). By 28 July and into August of 2009 (Fig. 14), TP concentrations reached almost 600 µg P/L in the hypolimnion. Since 1985 there is no discernible trend of summer average TP concentrations (Fig. 16).

Soluble reactive phosphorus (SRP) represents a soluble fraction of phosphorus, phosphate ion that is readily taken up by phytoplankton and macrophytes and is generally considered the limiting factor to plant growth in lakes in New York. During this period, epilimnetic SRP ranged from <0.62 to 14.0 µg P/L in the epilimnion (Table 3). Hypolimnetic SRP concentrations reached almost 600 µg P/L by August when SRP was moving out of the sediment into the hypolimnion during periods of anoxia.

Chlorophyll-a (Table 3)

Chlorophyll *a* provides an estimate of algal abundance in lakes. Generally in phosphorus-limited lakes, algal abundance increases with increasing levels of phosphorus in the water column. Epilimnetic chlorophyll *a* concentrations in the summer of 2009 ranged from 2.2 µg/L in May to 8.6 µg/L on 30 June 2009 with an average of 5.9 µg/L. Since 1985, average summer concentrations are quite variable (range 4.3 to 14.7 µg/L) with no obvious trend. Lakes, such as Conesus Lake, with a chlorophyll range in the 4.3 to 14.7 µg/L since 1985, are generally classified as eutrophic (Table 7).

Nitrate and Total Kjeldahl Nitrogen (Table 3):

Nitrate concentrations were generally very low (<0.05 mg/L) in Conesus Lake in 2009 at all depths (Table 3). This is in contrast with the stream concentrations that generally average well above 1 mg/L (Table 2). The reason for the low NO₃+NO₂ levels in the

lake is due to uptake of NO_3+NO_2 by algae for photosynthesis. Low levels of NO_3+NO_2 tend to favor the growth of nuisance algae such as blue-green algae (Cyanobacteria) that have the capability of utilizing other atmospheric sources of nitrogen. Cyanobacteria are often predominant in Conesus Lake during mid and late summer. There is a suggestion that NO_3+NO_2 levels may be increasing slightly (Fig. 16).

Total Kjeldahl nitrogen averaged 558 $\mu\text{g/L}$ in the epilimnion with a range of 227 to 1,375 $\mu\text{g/L}$. Average concentrations were similar in the metalimnion (12 m, 606 $\mu\text{g/L}$) and hypolimnion (18 m, 623 $\mu\text{g/L}$) during the summer of 2009 (Table 3). Total Kjeldahl nitrogen concentrations were generally slightly higher in the streams (Table 2).

Sodium

Sodium is a component of deicing salt, which is used heavily during the winter on roads in the Conesus Lake watershed. Since 1985 there is a clear trend of increasing salt in the waters of Conesus. The average summer concentration of sodium is 24.63 mg/L in the epilimnion of Conesus Lakes. This is an increase of ~ 10 mg/L of sodium in the past 25 years (Fig. 16). Whether or not this is a health issue is currently being debated by the US EPA. This low level of concern is compounded by the legitimate criticisms of EPA's 20 milligrams per liter (mg/L) Drinking Water Equivalency Level (DWEL or guidance level) for sodium. EPA believes this guidance level for sodium needs updating and is probably low. If a health benchmark for drinking water were established using current information and current drinking water health assessment procedures, it would likely be higher.

Internal (hypolimnetic) Phosphorus Loading

During stratification, lakes with anoxic hypolimnia often accumulate TP in the hypolimnion (Nurnberg 1984). That high concentration of reduced substances is usually present in the hypolimnion under such conditions suggests that much of this phosphorus is released from the anoxic sediment surface, through redox reactions (Nurnberg 1984). In fact, laboratory release experiments have also suggested that under anoxic conditions, lake sediments will release significant amounts of phosphorus

into the water column (Nurnberg 1984). If this surplus of hypolimnetic phosphorus is transported vertically to the euphotic zone, it may stimulate algal growth (Cooke *et al.* 1977).

At Conesus Lake, TP concentrations were monitored biweekly throughout the water column from 19 May 2009 to 18 August 2009. During summer stratification, the hypolimnion became anoxic in early July (Fig. 12) with elevated hypolimnetic concentrations of phosphorus evident by 14 July 2009 (Fig. 14). For example, in mid-May TP concentration at 15 m was 13.6 $\mu\text{g P/L}$ and not significantly different from the epilimnion at a concentration of 12.0 $\mu\text{g P/L}$. By late August, TP maximum concentrations in the hypolimnion reached 558 $\mu\text{g/L}$ - almost 40 times higher than the epilimnion. This phosphorus is the result of reducing conditions in the hypolimnion that allow insoluble manganese and iron phosphates in the sediment to become soluble and move into the water column. On an annual basis, the sediments contributed 8,043 kg of phosphorus to Conesus Lake in 2009 (Tables 4 and 5) or 8.7 $\text{mg P/m}^2/\text{day}$. This areal internal loading falls within the range of release rates for many lakes of the world (range 6 to 18 $\text{mg P/m}^2/\text{d}$, average 12.9 $\text{mg P/m}^2/\text{d}$, Table 6). For example, sediment P release rates for Sodus Bay are reported as 6.3 $\text{mg P/m}^2/\text{d}$ (White *et al.* 2002).

On an annual basis, the maximum potential phosphorus that may be released to the lake from the hypolimnion is 8,047 kg P/year. The amount released from the subwatersheds that we have data for is ~ 2,103.8 kg P/year. This represents about one half of the major subwatersheds of Conesus Lake. If we assume the losses from the unmonitored watersheds are similar, this would raise the amount of phosphorus loss from these subwatersheds to ~4, 200 kgP/year. This is a conservative number as we have no idea of the amount of P lost from each of the other streams, rivulets, and storm drains. It would appear that the amount of phosphorus released from the hypolimnion represents the major source of phosphorus to the lake. This conclusion is likely to be erroneous. Not all of the phosphorus that is released from the hypolimnion is transferred to the entire water column with fall mixing. With oxygenation of the deeper waters of what was the hypolimnion, some of the phosphorus will precipitate back into

the sediments as oxides of iron and manganese. Efforts to reduce phosphorus inputs to Conesus Lake should focus on reducing losses from the watershed.

Trophic Status Index (TSI)

Carlson's TSI is used to assess the trophic state of a given lake by analyzing summer TP concentrations and Chl-*a* concentrations and by measuring summer secchi disk depth. This index is one of several that can be used to evaluate the trophic status of a lake; that is, what is the overall productivity of the lake. Based on the average Chl-*a* and summer TP concentrations and secchi disk readings for the entire 1985-2009 period, Carlson's total TSI generally averaged 50 (Table 9) for TP and chlorophyll and ~ 45 for secchi disk, suggesting a mesotrophic/eutrophic status for the lake. The conclusion of a mesotrophic/eutrophic status was reinforced by considering the general relationship of lake productivity with phosphorus, transparency, and chlorophyll. Consideration, not only of the trend data for transparency and chlorophyll and TP concentrations (Fig. 16) but also of the trophic status values (Table 9) observed during the 1985-2009 period suggests there are no trends toward improvement of the lake's trophic status.

Zooplankton

One of the adverse impacts of the proliferation of alewife in Conesus Lake is the extirpation of the larger-bodied zooplankton, such as *Daphnia* sp, which are effective grazers of the lake's phytoplankton. Biomanipulation is the deliberate alteration of an ecosystem by adding or removing species, especially predators. In Conesus Lake, the stocking of walleye by NYSDEC has been underway for many years with two objectives: to increase the population of fishable walleye and to reduce the number of alewife in the lake. If alewife populations are reduced, it is believed that the large *Daphnia* populations that once existed in Conesus Lake may return to historic levels and then graze and reduce down the high phytoplankton levels in the lake (Makarewicz 2001). Unfortunately, there has been no significant change in the zooplankton community in the last twenty years (Table 10). *Daphnia* abundance (<3.04/L) and biomass (<1 mg/m³)(Table 1) is still low while the overall size (length) of the zooplankton community

is still less than $\frac{1}{4}$ of the size in 1972 (Table 1). A review of the walleye stocking program may shed some light on why this program has not been successful.

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**Table 1. Proficiency audit of the Water Quality Laboratory at The College at Brockport.
WADSWORTH CENTER
NEW YORK STATE DEPARTMENT OF HEALTH
ENVIRONMENTAL LABORATORY APPROVAL PROGRAM**

Proficiency Test Report

Lab 11439 SUNY BROCKPORT EPA Lab ID NY01449
 WATER LAB LENNON HALL
 BROCKPORT, NY 14420
 Shipment: 320 Non Potable Water Chemistry
 Shipment Date: 20-Jan-2009

<u>Analyte</u>	<u>Sample ID</u>	<u>Result</u>	<u>Mean/Target</u>	<u>Acceptance Limits</u>	<u>Method</u>	<u>Score</u>
Approval Category : Non Potable Water						
Sample: Residue						
Solids, Total Suspended 198 passed out of 207 reported results.	2002	85.1	85.8	70.4 - 95.3	SM18-20 2540D (97)	Satisfactory
Sample: Organic Nutrients						
Kjeldahl Nitrogen, Total 89 passed out of 89 reported results.	2004	27.4	29.3	19.3 – 37.6	EPA 351.2 Rev. 2.0	Satisfactory
Phosphorus, Total 98 passed out of 106 reported results.	2004	9.00	8.62	7.13 – 10.2	SM18-20 4500-PF	Satisfactory
Sample: Inorganic Nutrients						
Nitrate (as N) 119 passed out of 120 reported results.	2007	27.98	27.1	21.1 – 32.7	SM18-20 4500-NO3 F (00)	Satisfactory
Orthophosphate (as P) 90 passed out of 97 reported results.	2007	3.00	2.94	2.58 – 3.51	SM18-20 4500-PF	Satisfactory
Sample: Minerals II						
Sodium, Total 80 passed out of 81 reported results.	2037	72.9	67.0	56.9 – 76.9	SM 18-20 3111B (99)	Satisfactory
Sample: Nitrite						
Nitrite as N 107 passed out of 111 reported results.	2041	2.89	2.87	2.43 – 3.31	SM 18-20 4500-NO2 B	Satisfactory

Table 2. Average summer concentration (May through September only) of stream water draining the Graywood, Sand Point, Long Point, Sutton Point, Southwest, North Gully, Cottonwood, and North McMillan Creek watersheds of Conesus Lake. Data from 2003 to 2007 are derived from the annual data of Makarewicz *et al.* 2009. See text for further explanation.

	Year	TP ($\mu\text{g P/L}$)		Nitrate (mg N/L)		TSS (mg/L)		TKN ($\mu\text{g N/L}$)		Sodium (mg/L)		SRP ($\mu\text{g P/L}$)	
		Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean
Graywood	2003	247.9	71.5	8.09	1.21	8.8	1.4	539	42	65.53	5.15	116.6	15.4
	2004	241.9	25.2	8.14	1.20	14.8	2.7	558	35	52.58	2.12	120.8	13.1
	2005	163.3	10.6	3.63	.40	9.1	2.4	555	54	59.04	4.67	104.7	8.9
	2006	173.8	19.7	1.87	.19	7.1	1.5	384	52	70.72	4.82	105.5	13.5
	2007	96.3	21.1	2.22	.31	5.3	1.2	376	77	99.58	10.98	59.2	13.3
	2008	123.8	19.9	1.21	.31	5.4	1.0	303	44	102.03	5.26	99.1	16.2
	2009	236.9	43.1	3.79	1.26	19.4	4.6	768	135	60.38	3.85	171.5	36.0
Sand Point	2003	59.6	4.2	2.00	.50	5.5	1.3	569	75	44.01	3.38	39.2	5.0
	2004	111.4	44.4	.97	.13	46.8	41.1	719	217	23.74	1.72	37.0	9.1
	2005	75.5	8.7	1.65	.36	5.0	1.6	466	76	19.48	.95	50.3	6.8
	2006	86.8	13.5	1.17	.14	3.8	.6	539	104	16.95	.87	43.5	4.5
	2007	70.4	8.4	1.57	.66	2.5	.3	477	59	17.75	1.13	48.5	8.0
	2008	79.6	3.6	0.66	.04	4.5	1.1	505	40	21.48	1.83	54.3	4.0
	2009	80.4	8.4	2.44	0.80	15.8	90.9	654	90	24.52	2.28	50.3	4.3
Long Point	2003	102.3	22.6	4.99	.97	10.6	4.4	775	116	58.65	2.16	39.7	7.1
	2004	219.4	129.3	4.41	1.11	132.6	124.0	832	199	33.04	2.89	40.4	7.7
	2005	69.8	17.8	2.58	.58	8.7	4.2	568	54	31.04	1.09	34.4	8.5
	2006	60.7	14.9	2.23	.55	8.1	3.8	552	95	40.61	2.08	29.5	7.7
	2007	41.0	15.3	2.40	.96	3.4	.7	515	90	36.20	3.91	14.8	8.3
	2008	75.7	15.5	1.97	0.31	16.5	13.1	771	265	57.75	3.75	44.8	7.9
	2009	50.3	10.3	3.85	0.98	4.8	3.5	489	78	38.42	2.61	33.2	5.6

	Year	TP ($\mu\text{g P/L}$)		Nitrate (mg N/L)		TSS (mg/L)		TKN ($\mu\text{g N/L}$)		Sodium (mg/L)		SRP ($\mu\text{g P/L}$)	
		Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean	Mean	Standard Error of Mean
Sutton Point	2003	45.5	4.7	1.93	.36	11.6	3.2	415	50	24.51	1.30	28.4	2.6
	2004	216.6	160.6	1.15	.10	13.7	7.3	413	56	18.09	1.37	26.5	3.7
	2005	46.6	5.0	1.28	.26	4.2	.7	318	38	15.87	.62	30.9	3.9
	2006	48.6	2.9	.98	.09	2.8	.9	352	86	21.14	1.18	28.9	2.9
	2007	38.0	3.2	1.57	.21	1.0	.1	305	83	19.40	1.21	25.0	4.1
	2008	46.6	2.1	1.32	.28	3.7	1.1	221	36	18.51	1.65	31.2	3.0
	2009	47.4	3.2	1.09	.10	5.3	2.1	483	85	28.82	1.31	35.9	2.2
Cottonwood	2003	68.0	6.0	2.83	.48	3.6	1.1	468	65	37.97	3.26	51.1	5.7
	2004	143.2	66.0	2.35	.60	69.4	58.3	568	86	18.16	1.01	53.0	6.6
	2005	97.3	23.3	2.30	.44	10.5	4.5	424	38	17.48	.50	57.5	6.0
	2006	68.8	6.4	1.64	.17	1.0	.3	393	37	21.46	.75	43.4	3.9
	2007	63.8	3.5	1.48	.13	2.5	.8	433	76	19.27	.33	45.8	3.7
	2008	84.7	9.9	1.12	.13	2.6	.8	381	46	25.02	2.34	57.7	3.9
	2009	72.5	3.7	2.79	0.28	3.9	1.2	518	82	23.43	1.07	58.8	3.2
Southwest	2003	83.2	5.0	3.54	.74	5.7	1.5	1054	527	37.01	1.26	63.1	7.2
	2004	179.1	47.9	1.63	.24	46.2	34.6	796	204	30.01	1.52	78.1	10.2
	2005	124.2	7.7	1.28	.39	10.8	3.5	486	61	32.28	1.02	69.1	7.7
	2006	97.9	6.4	1.03	.17	4.6	1.7	456	63	44.95	1.85	61.8	4.9
	2007	116.1	10.3	1.09	.11	7.1	3.6	469	100	35.02	.56	76.4	5.0
	2008	100.4	3.6	1.17	.14	3.0	0.8	297	33	45.50	2.67	69.5	5.3
	2009	127.6	8.5	1.17	0.10	8.9	4.3	633	76	46.08	2.81	100.5	7.5
North McMillan	2003	10.9	2.3	.26	.05	2.7	1.3	265	41	35.05	1.77	4.4	.6
	2004	39.6	26.6	.14	.02	33.3	30.0	365	85	28.36	2.02	5.1	1.4
	2005	11.4	2.0	.24	.03	3.5	.8	276	39	30.04	.99	4.8	.6
	2006	10.5	1.5	.13	.03	1.7	.5	229	30	36.63	.65	3.7	.9
	2007	7.6	.9	.14	.02	2.0	.5	246	64	36.63	1.04	2.5	.3
	2008	13.8	7.0	.11	.02	2.3	.4	220	34	50.72	1.17	2.9	.5
	2009	27.4	8.8	.13	.01	70.3	67.1	455	96	36.90	2.16	9.1	4.3

Table 3. Conesus Lake water chemistry at the deepest point in the South Basin. Chl a= Chlorophyll-a (0-3m integrated, TP =Total Phosphorus, TKN=Total Kjeldahl Nitrogen, SRP=Soluble Reactive Phosphorus .

Conesus Lake	Chl -a	TP	Nitrate	TKN	Sodium	SRP	Turbidity
Depth (0m)	(µg P/L)	(µg P/L)	(mg N/L)	(µg N/L)	(mg/L)	(µg P/L)	(NTU)
5/19/2009	2.2	12.0	0.12	435	19.27	2.5	2.4
5/26/2009	2.3	11.0	0.02	268	17.67	4.3	1.95
6/3/2009	3.3	14.5	0.03	292	25.27	1.2	0.78
6/9/2009	5.5	14.5	0.03	850	28.65	<0.62	1.36
6/17/2009	6.0	39.8	0.06	465	23.25	2.1	0.91
6/24/2009	8.5	29.2	0.04	772	29.05	0.8	1.18
6/30/2009	8.6	22.3	<0.04	550	28.11	6.9	2.49
7/7/2009	5.4	20.6	<0.04	391	28.70	1.1	1.36
7/14/2009	6.9	29.2	<0.04	379	25.52	<0.62	1.84
7/22/2009	5.3	20.2	<0.04	1374	24.32	14.0	2.42
7/28/2009	7.1	25.6	ND	672	16.94	5.5	1.04
8/4/2009	6.8	22.8	0.04	227	24.77	1.0	2.79
8/11/2009	7.6	14.2	0.04	509	26.67	<0.62	1.34
8/18/2009	6.4	16.2	<0.04	623	26.66	1.7	1.89
Average	5.8	20.9	0.04	557.6	24.6	3.7	1.7
	Date	TP	Nitrate	TKN	Sodium	SRP	Turbidity
Depth 9m	Collected	(µg P/L)	(mg N/L)	(µg N/L)	(mg/L)	(µg P/L)	(NTU)
	5/19/2009	15.2	0.10	469	17.69	2.0	2.57
	5/26/2009	11.6	0.02	478	17.69	3.7	0.85
	6/3/2009	19.4	0.03	478	27.90	1.2	1.83
	6/9/2009	26.5	0.02	741	26.06	<0.62	2.76
	6/17/2009	28.6	0.06	465	23.48	<0.62	1.16
	6/24/2009	15.7	0.04	518	29.95	<0.62	0.92
	6/30/2009	15.4	0.08	497	28.44	5.0	1.92
	7/7/2009	26.3	<0.04	986	29.55	1.1	2.14
	7/14/2009	32.3	<0.04	374	26.06	1.9	1.97
	7/22/2009	39.7	<0.04	1198	23.70	35.9	4.73
	7/28/2009	21.6	ND	648	24.59	11.3	1.78
	8/4/2009	21.6	0.04	613	26.59	9.3	2.96
	8/11/2009	22.5	0.04	441	25.41	4.9	3.43
	8/18/2009	69.0	<0.04	488	27.05	50.8	3.77
Average		26.1	0.04	599.5	25.3	11.6	2.3

Table 3. Continued							
Depth	Date	TP	Nitrate	TKN	Sodium	SRP	Turbidity
18m	Collected	($\mu\text{g P/L}$)	(mg N/L)	($\mu\text{g N/L}$)	(mg/L)	($\mu\text{g P/L}$)	(NTU)
	5/19/2009	14.1	0.11	550	18.22	1.8	4.79
	5/26/2009	19.3	0.05	409	21.79	3.2	3.75
	6/3/2009	19.4	0.06	566	26.56	1.9	6.75
	6/9/2009	21.0	0.03	730	27.93	2.2	2.67
	6/17/2009	32.0	0.09	634	22.69	5.6	1.86
	6/24/2009	26.9	0.04	772	28.89	<0.62	0.81
	6/30/2009	45.5	0.02	666	27.91	21.0	3.48
	7/7/2009	54.9	<0.04	692	30.15	36.4	1.99
	7/14/2009	136.9	<0.04	483	25.82	98.2	3.14
	7/22/2009	397.2	<0.04	648	21.34	50.8	13.4
	7/28/2009	542.3	0.04	441	24.70	248.3	12.9
	8/4/2009	519.4	ND	368	25.86	502.5	16.5
	8/11/2009	557.5	0.04	646	26.81	557.5	9.83
	8/18/2009	258.6	<0.04	1118	26.92	210.3	5.03
		188.9	0.05	623	25.4	133.8	6.20

19 May Depth (m)	TP (μg P/L)	Section Depth (m)	Volume ($\text{m}^3 \times 10^6$)	TP (kg P)
0	12.0	0 - 1.5	18.27	219.2
2	21.1	1.5 -3.5	31.90	673.1
6	13.1	3.5 - 7.5	29.50	386.5
9	15.2	7.5 - 10.5	27.44	417.1
12	12.0	10.5-13.5	19.03	228.4
15	13.6	13.5-16.5	13.07	177.8
18	19.0	16.5-20	4.25	80.8
Total				2,183
Total 9-18m				904

18 August Depth (m)	TP (μg P/L)	Section Depth (m)	Volume ($\text{m}^3 \times 10^6$)	TP (kg P)
0	16.2	0 - 1.5	18.27	296.0
3	26.1	1.5 -3.5	31.90	832.6
6	25.5	3.5 - 7.5	29.50	752.3
9	69.0	7.5 - 10.5	27.44	1893.4
12	201.1	10.5-13.5	19.03	3826.9
15	162.8	13.5-16.5	13.07	2127.8
18	258.6	16.5-20	4.25	1099.1
Total				10,828
Total 9-18m				8947

Table 4. Concentration and amount of total phosphorus (TP) in various depth strata of Conesus Lake on 19 May and 18 August 2009. Based on the Savard hypsographic curve.

	TP
Hypolimnion P 5/18/2009 (kg P)	904
Hypolimnion P 8/14/2009 (kg P)	8947
Hypolimnion P increase (kg P)	8043
Time period (days)	92
Phosphorus Release Rate (kg P/day)	87.4
Area _{Hypolimnion} (km ²)	10.0
Areal Phosphorus Release Rate (mg P/m ² /day)	8.74

Table 5. Phosphorus release rates and Total Phosphorus (TP) content of the hypolimnion for Conesus Lake. The August hypolimnion was defined by the temperature vs. depth curve as being below 9 meters of depth (see Figure 13).

Lake	Release Rate (mg P/m ² /d)
Shagawa	12.1
Mendota	10.8
West Twin	6.5
East Twin	6.0
Erie	7.4
White Lake	19.0
Barten Broad	9.6
Alderfen Broad	20.0
Baldeggersee	9.7
Rotsee	28.0
Norrviken	9.2
Bergundasjoen	24.5
Esrom	11.5
Byoesjoen	20.0
Magog	13.5
Sodus Bay	6.3
Mean	13.4
Conesus 2009	8.7

Table 6. Estimates of phosphorus release rates from lakes of the world with anoxic hypolimnions. Release rates are calculated in a manner similar to this study. Negative release rates indicate absorption of phosphorus by sediment. Data are reproduced from Nurnberg (1984) and White et al. (2002).

	Epilimnetic Total Phosphorus ($\mu\text{g P/L}$)	Annual Total Phosphorus ($\mu\text{g P/L}$)	Chl <i>a</i> ($\mu\text{g/L}$)	Secchi Disk (m)
Oligotrophic	5-10	3.0-17.7	0.3- 4.5	5.4-28.3
Mesotrophic	10-30	10.9-95.6	3-11.0	1.5-8.1
Eutrophic	30-100	16.0-386	3-78.0	0.8-7.0
Hypereutrophic	>100	750-1200	100-150	0.4-0.5
Conesus Lake (2009)				

Table 7. General relationship of lake productivity in relation to phosphorus, nitrogen, transparency and chlorophyll *a*. Adapted from Wetzel (2001).

	Annual Phosphorus Load (kg P/ year)					
	2002	2003	2004	2005	2006	Average
	1	2	3	4	5	
Cottonwood	92.7	124.4	202.6	54.0	131.5	121.0
Graywood	79.1	502.4	266.2	51.7	145.6	209.0
Long Point	255.2	232.7	609.7	248.6	177.9	304.8
North McMillan	643.3	1402.3	678.2	183.7	1032.1	787.9
Sand Point	151.6	113.9	139.4	44.7	68.5	103.6
Southwest	207.9	157.0	349.1	180.1	130.0	204.8
Sutton Point	9.4	49.8	37.1	14.3	23.8	26.9
North Gully			190.4	88.9	758.1	345.8
Eagle Point				63.9	90.0	77.0
					Sum	2103.8

Table 8. Annual loss of phosphorus from nine tributaries of Conesus Lake. Except for North Gully and Eagle Point, losses are based on hourly measurement and event responsive water sampling (Makarewicz *et al.* 2009). North Gully and Eagle Point are based on approximately 52 weekly measurements and grab samples taken on each sampling date.

Carlson's TSI			
	TP	Chl-a	Secchi
1985	53.5	45.4	43.4
1988	49.7	52.0	43.6
1991	47.9	52.2	45.6
1993	53.0	55.4	48.0
1996	48.2	54.0	44.0
1999	48.1	52.3	ND
2000 -SB	46.0	53.7	ND
2000 -NB	48.0	56.3	ND
2003	53.0	ND	ND
2004	52.0	49.6	47.6
2009	48.0	47.9	45.0
Average	49.8	51.9	45.3

Table 9. Values for Carlson's Trophic Status Index (TSI) from 1985 to 2009 for the south (SB, 1985 to 2000) and south basin (NB, 2000 to 2009). In 2000 the trophic index was calculated for both the south and north basins. ND=No data.

	1972	1985	1988	1991	1993	1996	1999	2004	2009
Zooplankton Biomass (mg/m ³)									
Crustacea	228	182	99	99	71	216	81	57	105
Calanoida	30	7	0	0	0	0.1	0	0	0
Cladocera	146	62	84	59	40	94	42	29	44
Daphnia spp.	87	23	3	0	1	3	0.1	1	1
Rotifera (ind/L)	NA	567	1235	795	461	846	855	310	139
Zooplankton Length (mm)									
Crustacea	1.03	0.47	0.29	0.28	0.32	0.34	0.29	0.20	0.24
Crustacea+Rofifera	0.6	0.23	0.18	0.16	0.18	0.19	0.12	0.20	0.24

Table 10. Summary of zooplankton data collected from 1972 to 2009 in Conesus Lake. NA=Not available. Values represent the average for the May through September period, unless stated otherwise. See Makarewicz (2001) for information on data collected in 1972, 1985 and 1988.

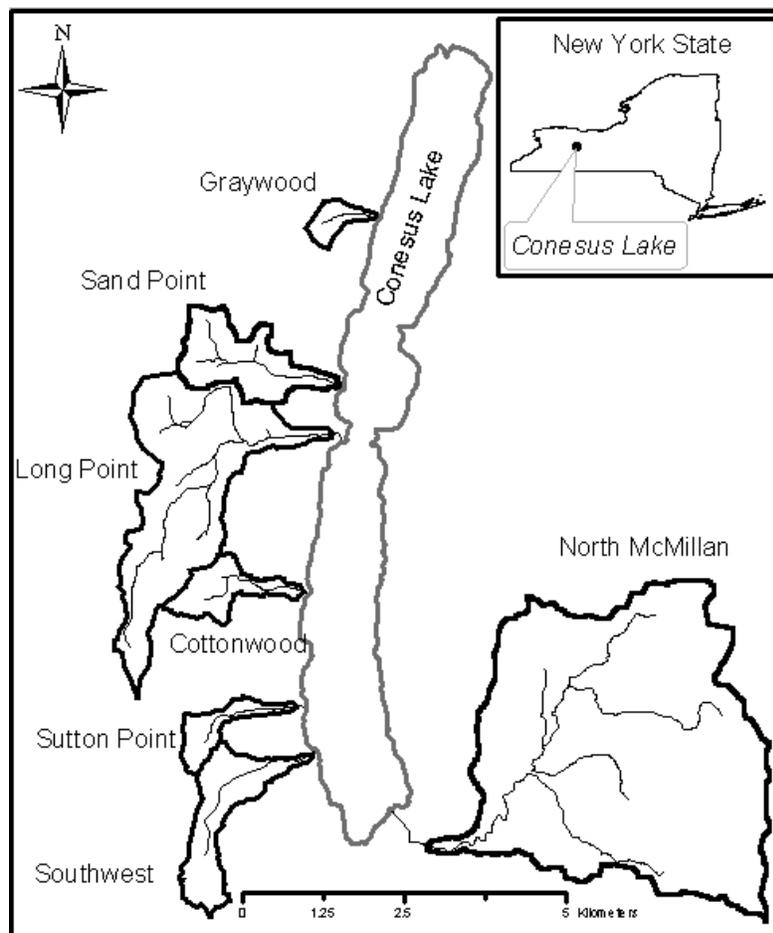


Figure 1. USDA sampling sites of Makarewicz (2009) sampled during the summer of 2008.

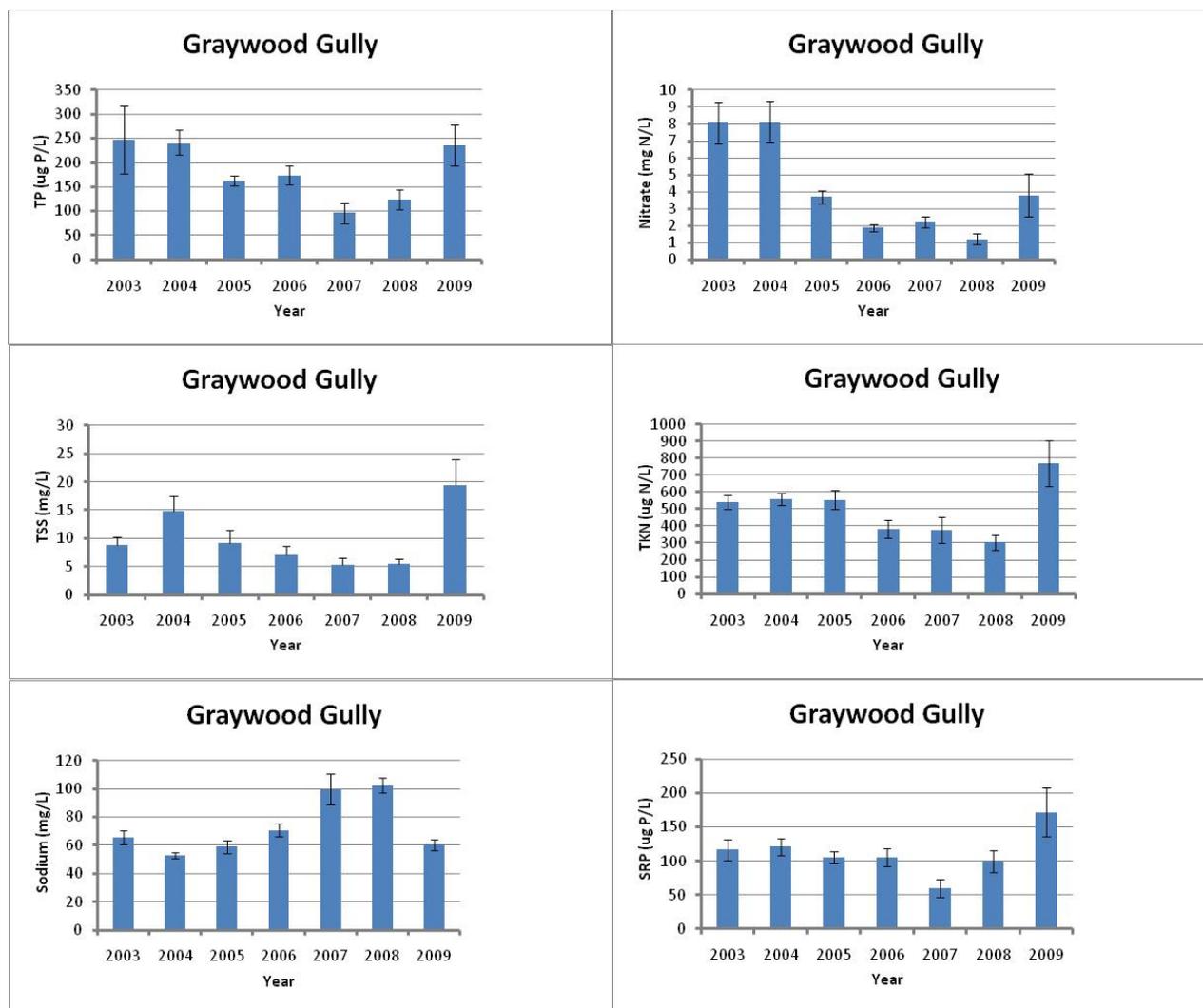


Figure 2. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) in Graywood Gully from 2003 to 2009. S.E.=standard error.

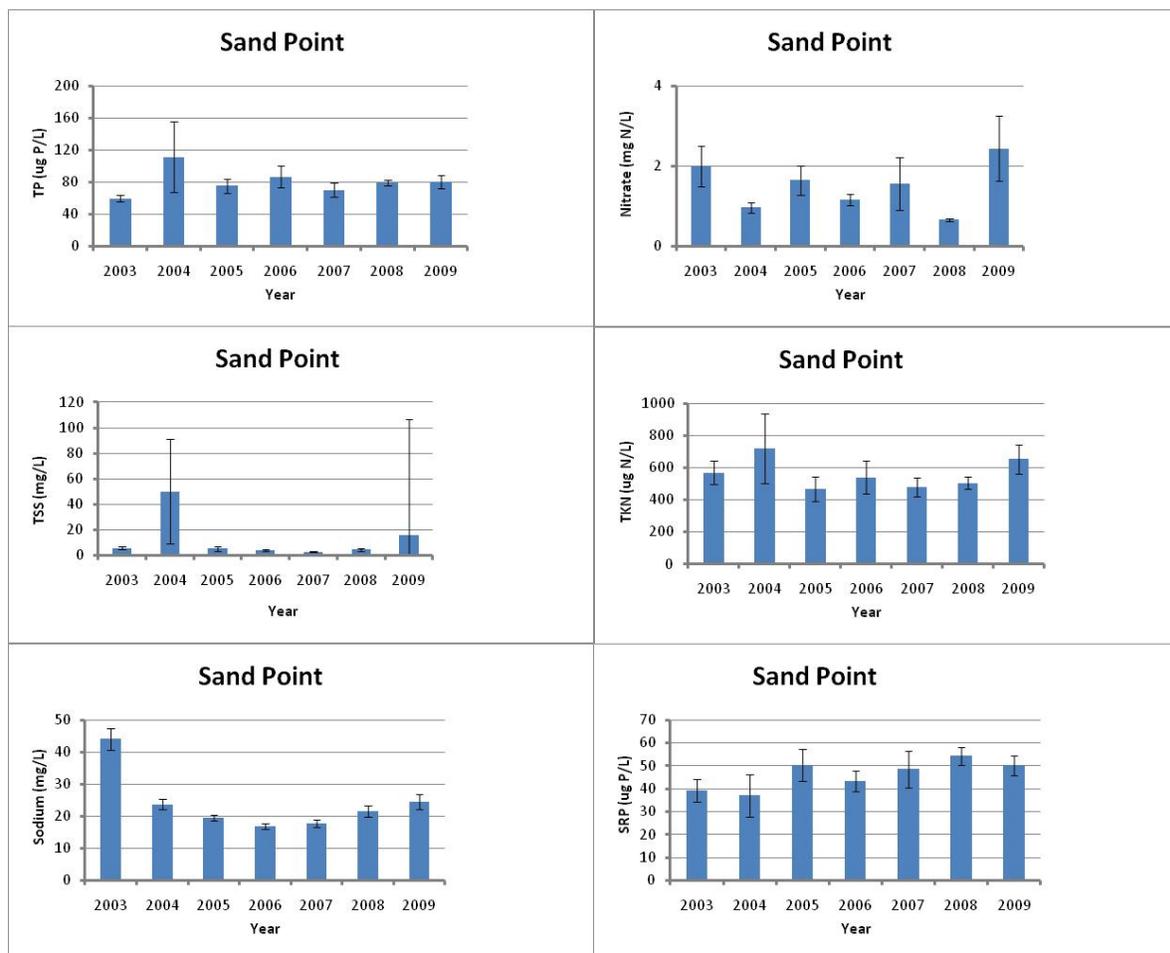


Figure 3. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at Sand Point Gully from 2003 to 2009. S.E.=standard error.

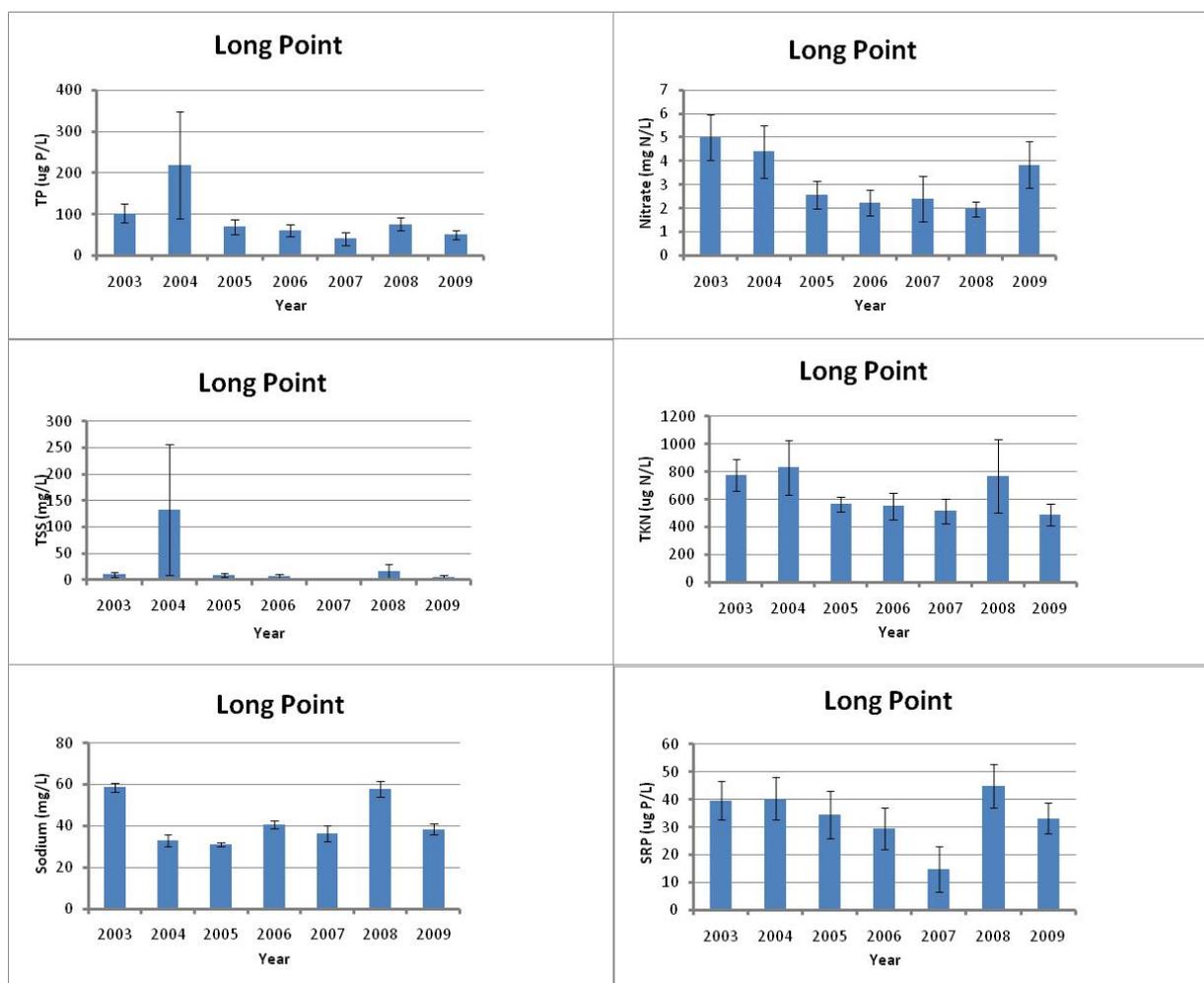


Figure 4. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at Long Point Gully from 2003 to 2009. S.E.=standard error.

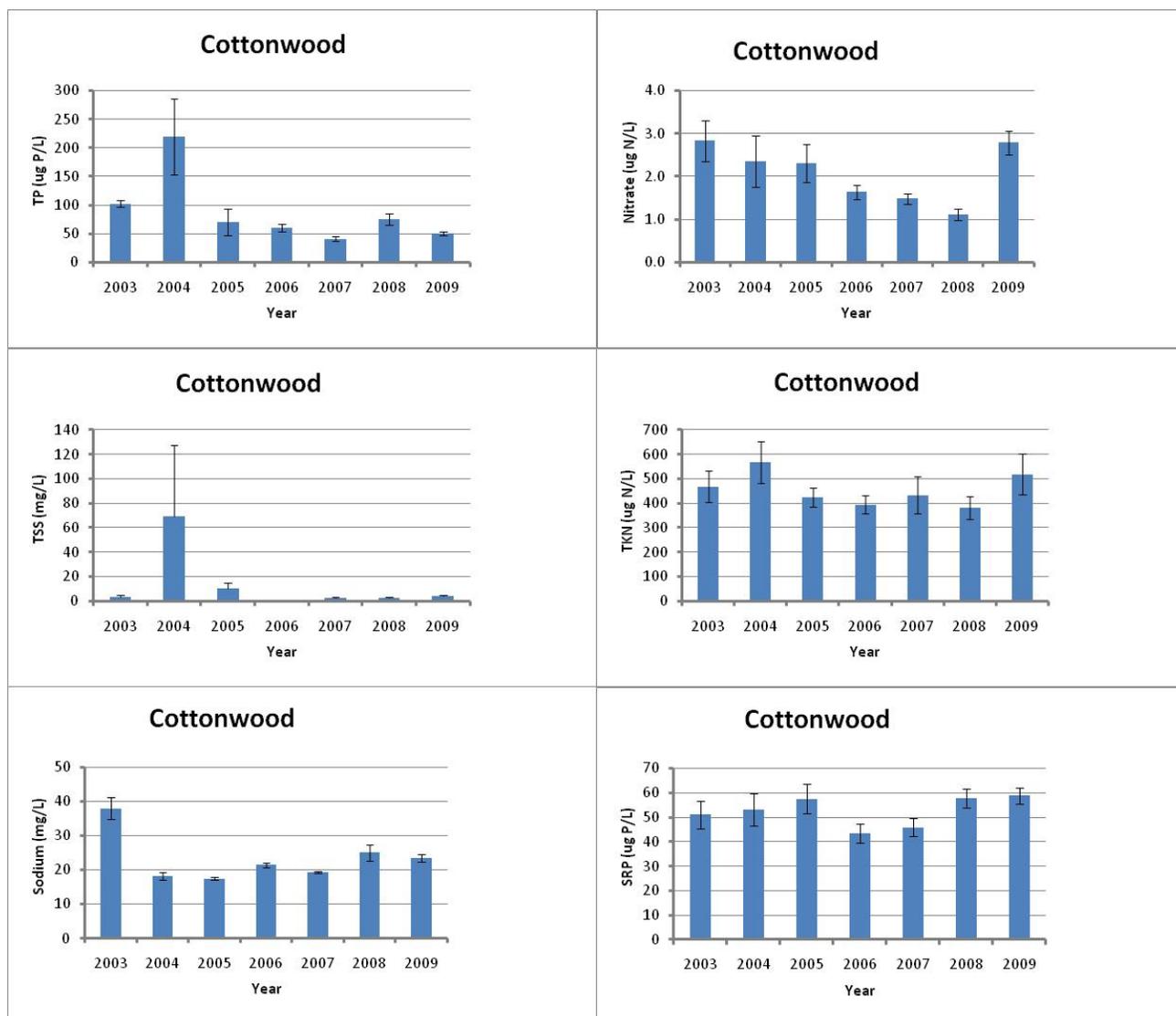


Figure 5. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at Cottonwood Creek from 2003 to 2009. S.E.=standard error.

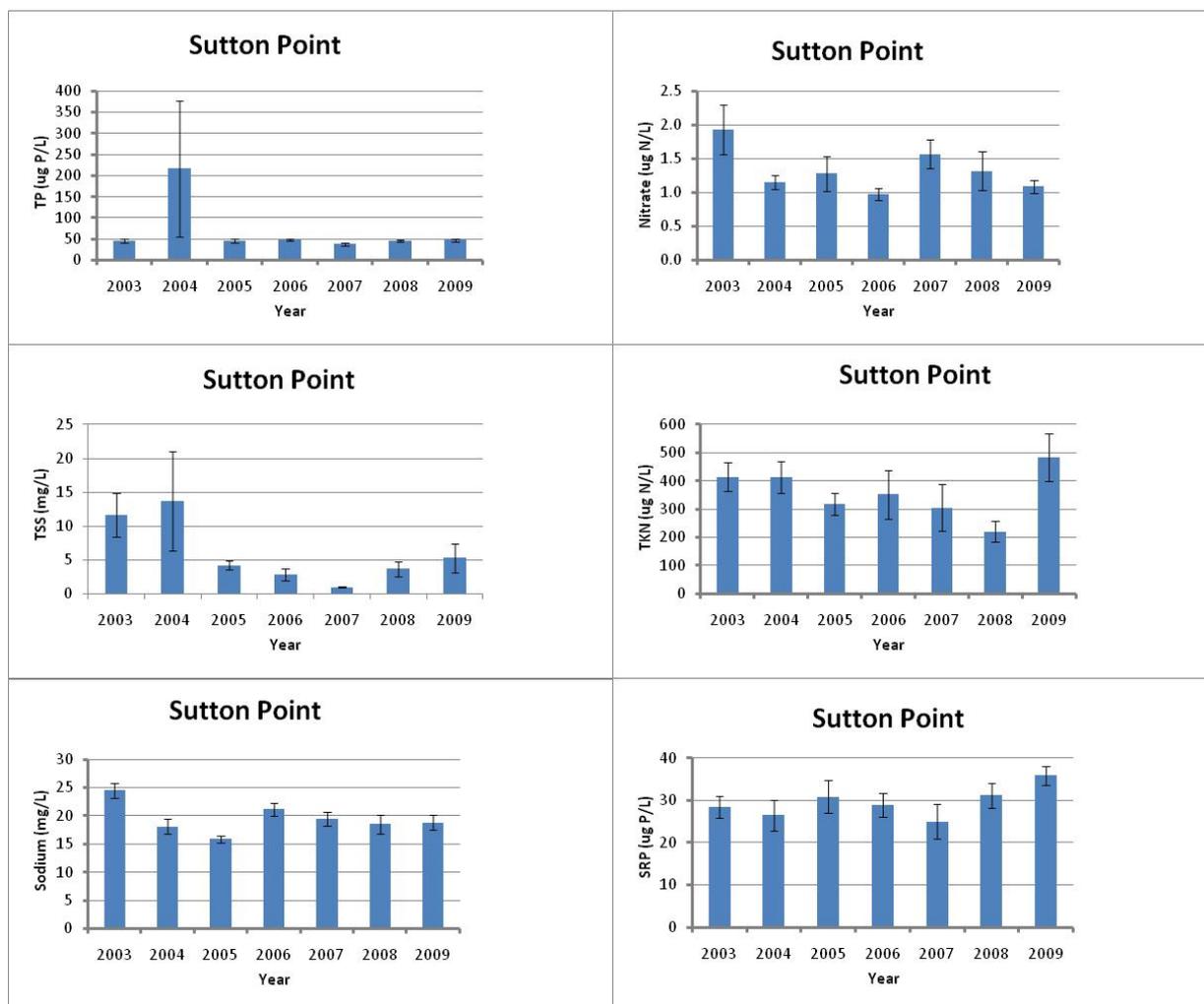


Figure 6. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at Sutton Point from 2003 to 2009. S.E.=standard error.

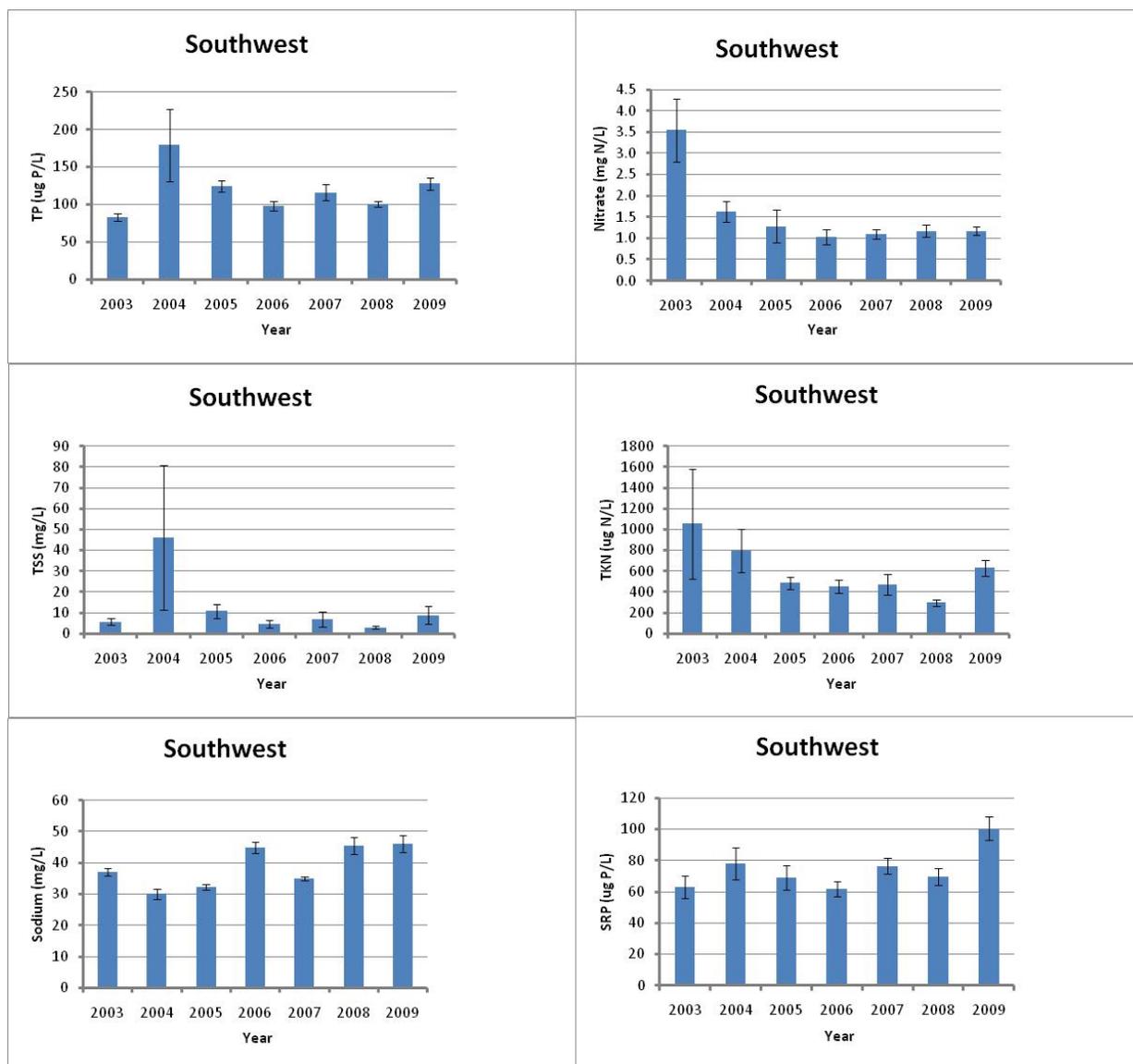


Figure 7. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at Southwest Gully from 2003 to 2009. S.E.=standard error.

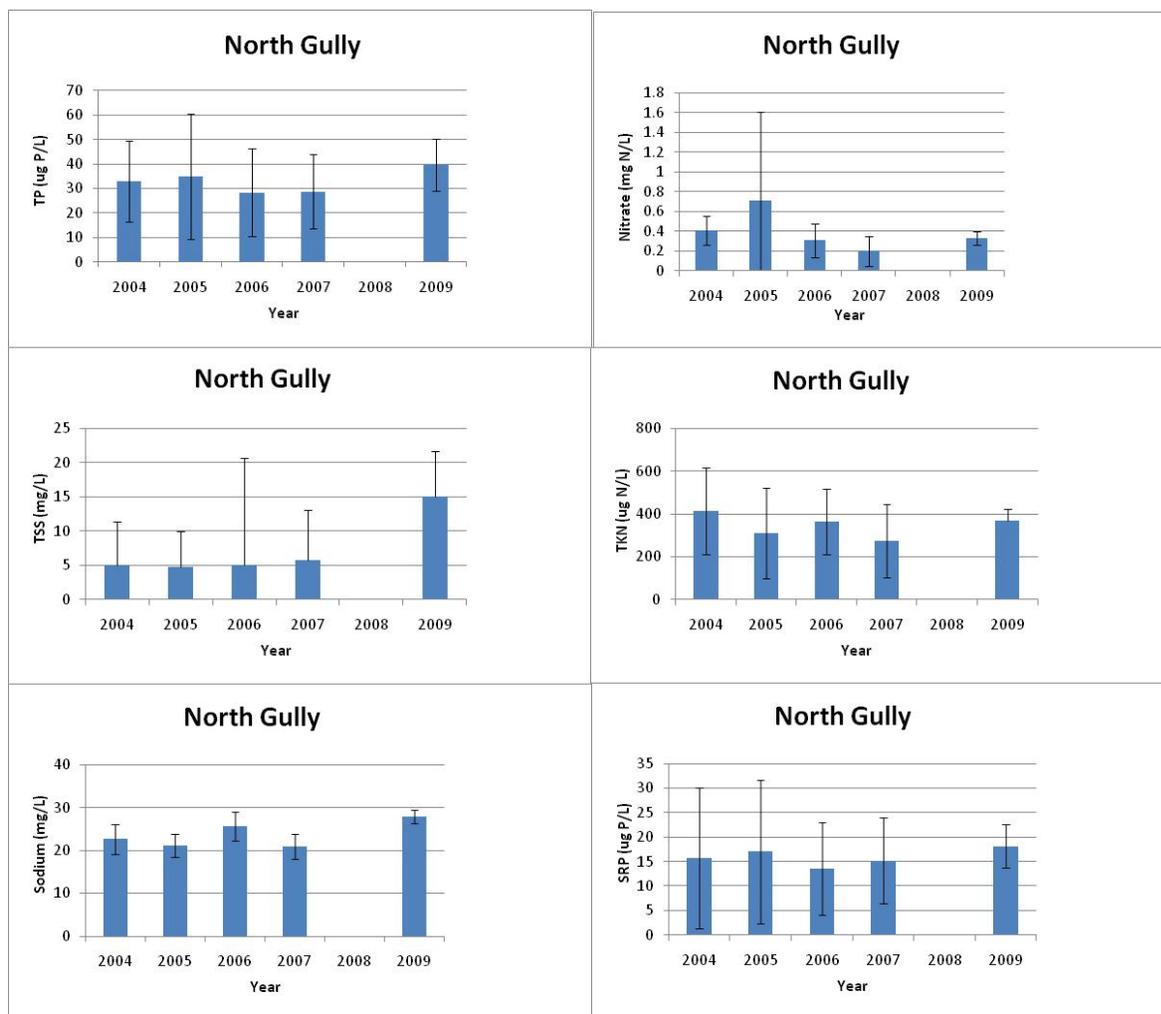


Figure 8. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at North Gully from 2003 to 2009. S.E.=standard error.

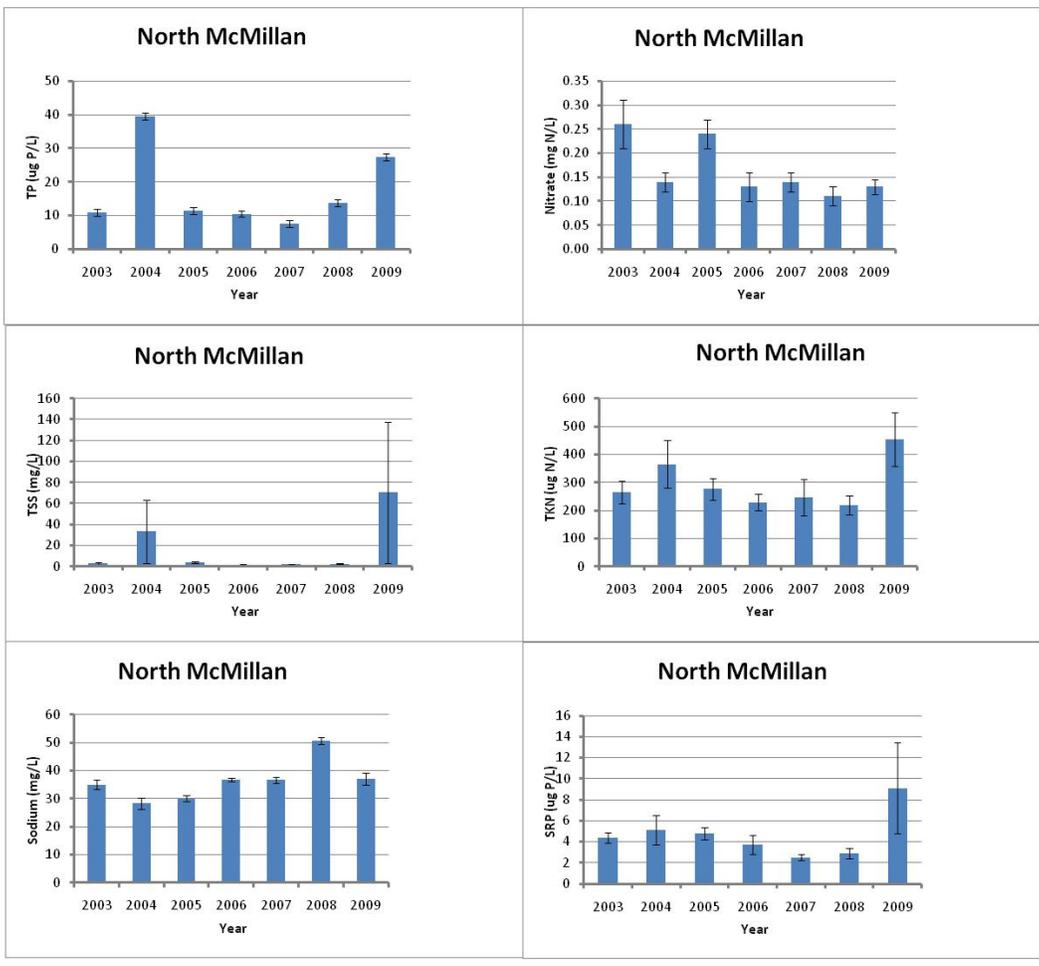


Figure 9. Average (\pm SE) concentrations (May through August) of total phosphorus (TP), nitrate, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), sodium, and soluble reactive phosphorus (SRP) at North McMillan Creek from 2003 to 2009. S.E.=standard error.

Figure 10. Profiles of temperature, dissolved oxygen, chlorophyll-a and pH of the north basin at the deepest location in Conesus Lake, May 2009.

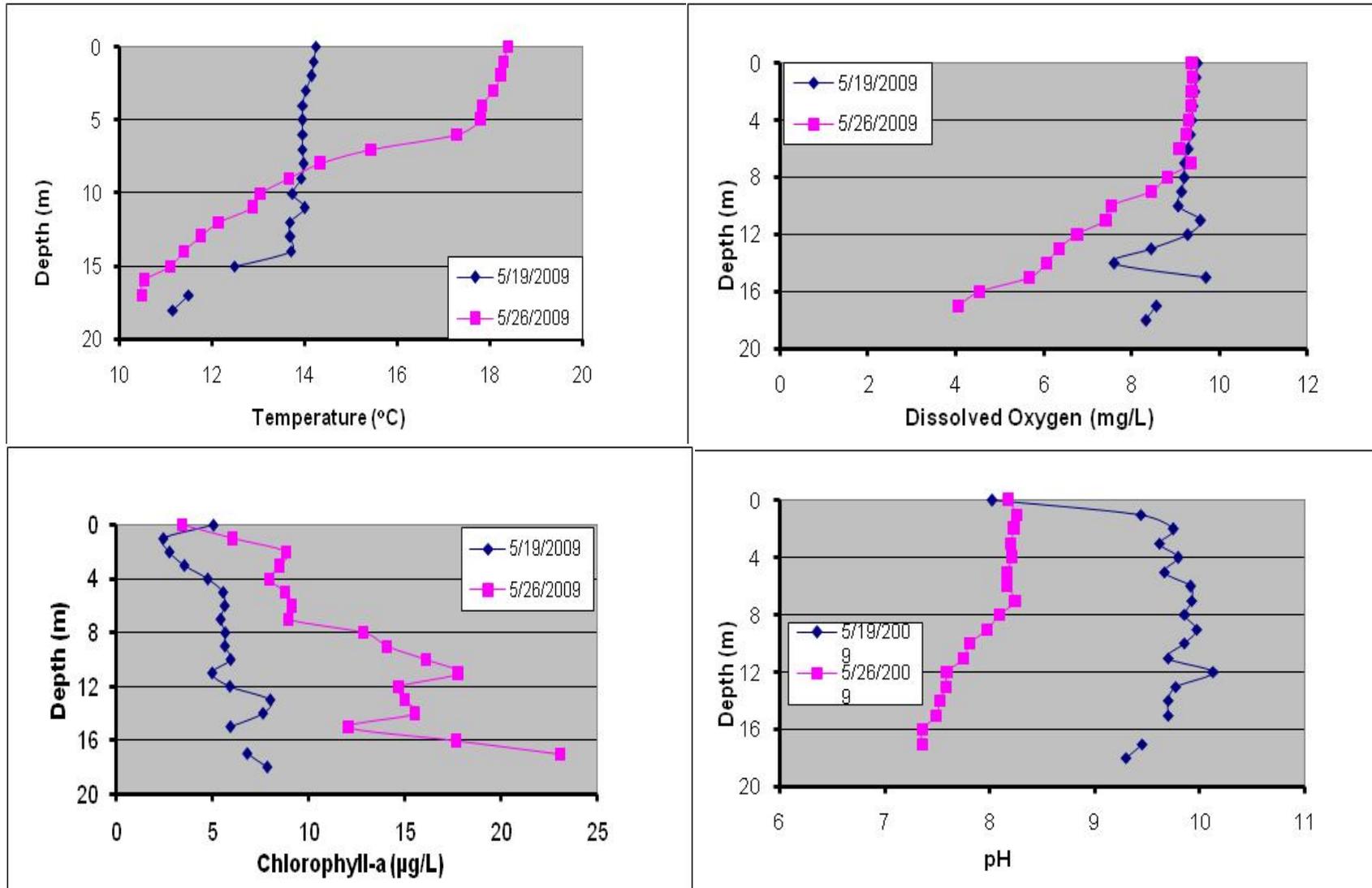


Figure 11. Profiles of temperature, dissolved oxygen, chlorophyll-a and pH of the north basin at the deepest location in Conesus Lake, June 2009.

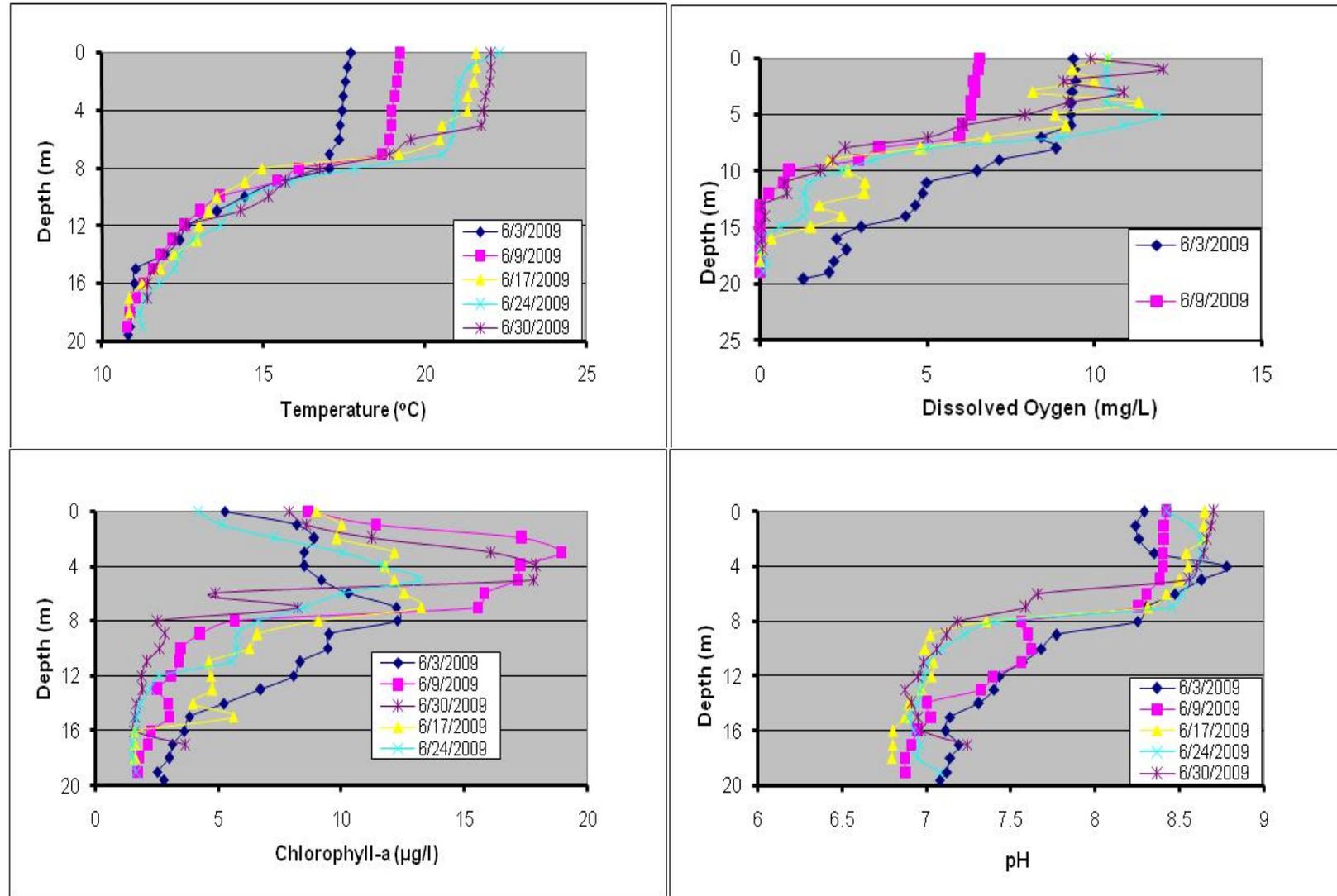


Figure 12. Profiles of temperature, dissolved oxygen, chlorophyll-a and pH of the north basin at the deepest location in Conesus Lake, July 2009.

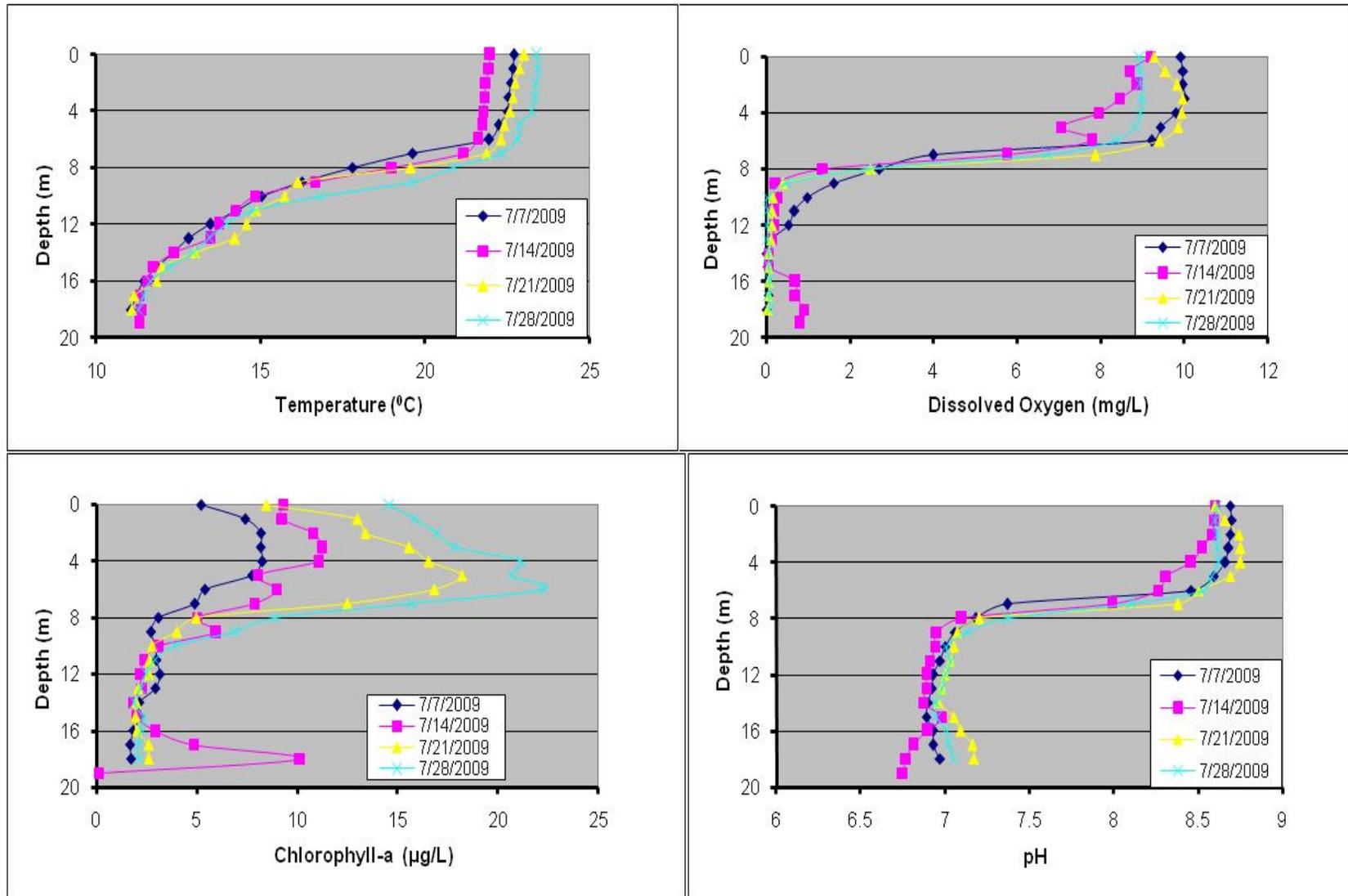


Figure 13. Profiles of temperature, dissolved oxygen, chlorophyll-a and pH of the north basin at the deepest location in Conesus Lake, August 2009.

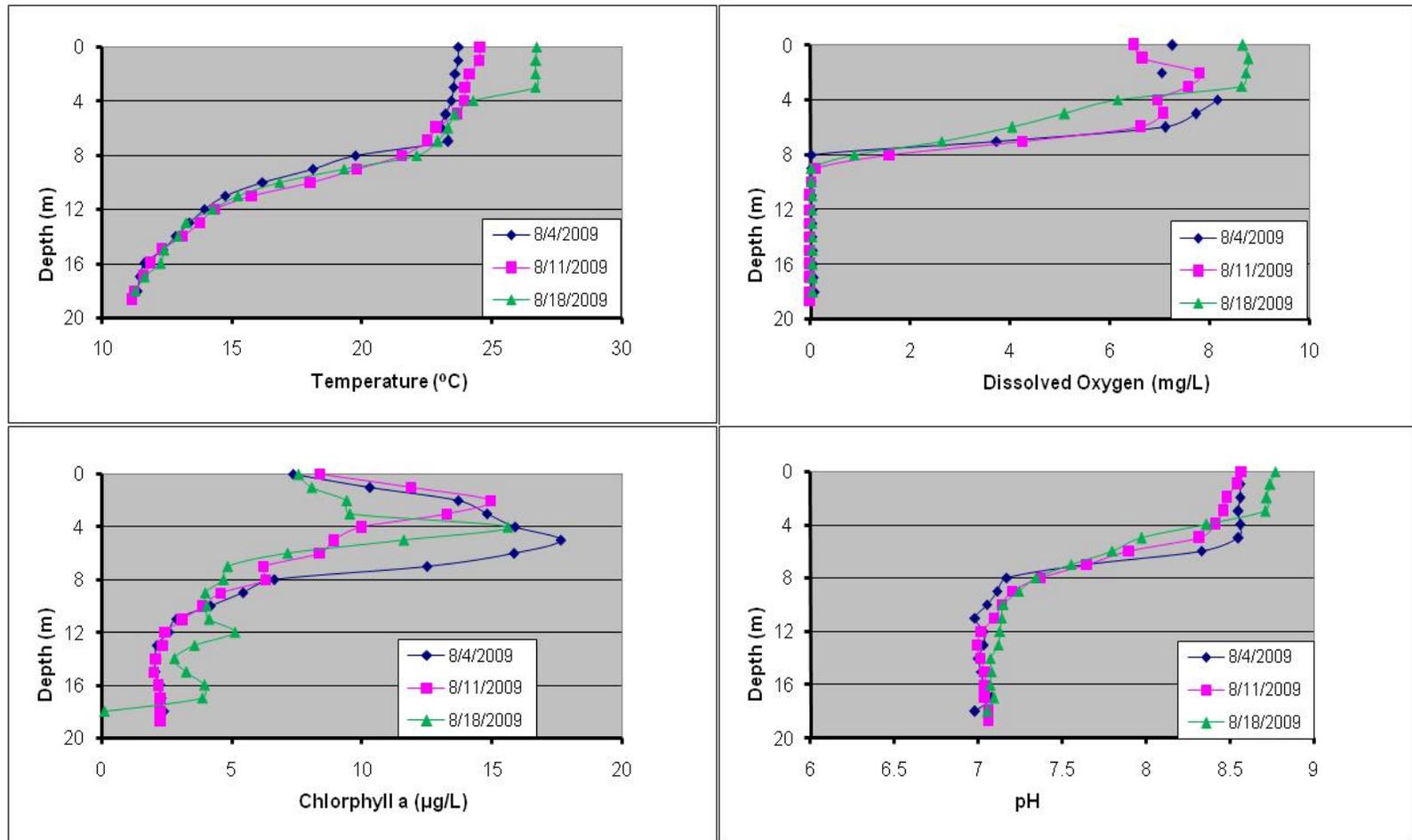
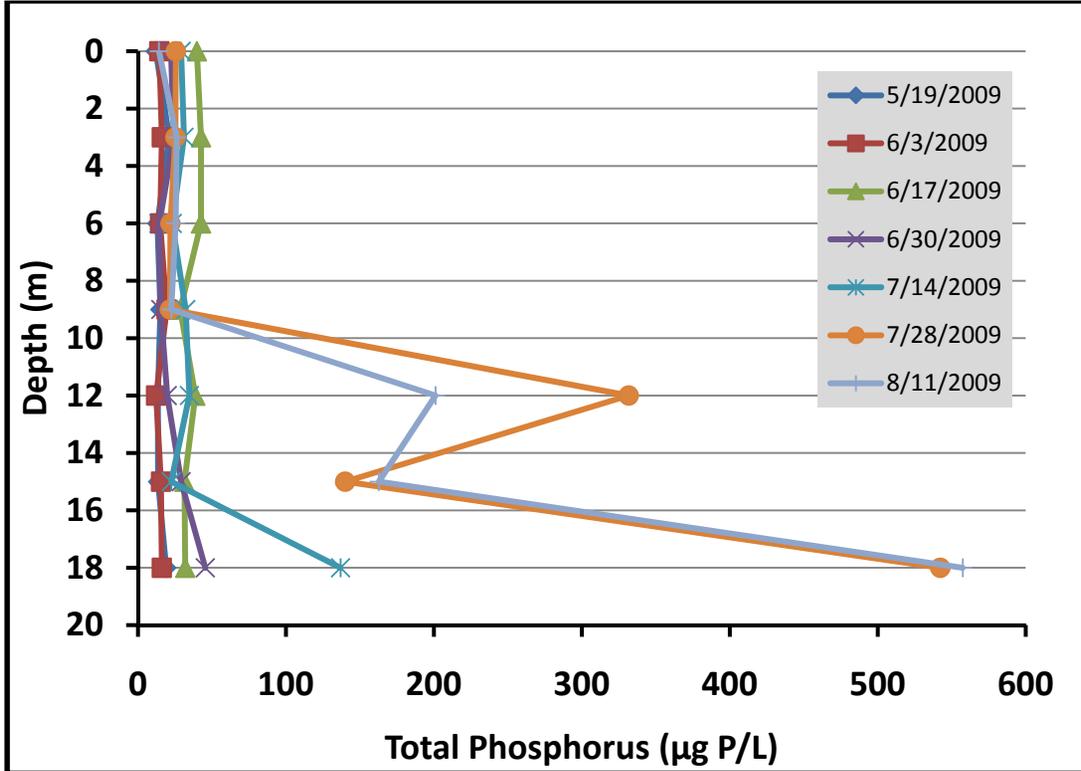


Figure 14. Total phosphorus versus depth during the summer 2009. Samples were taken in the north basin at the deepest locations in Conesus Lake.



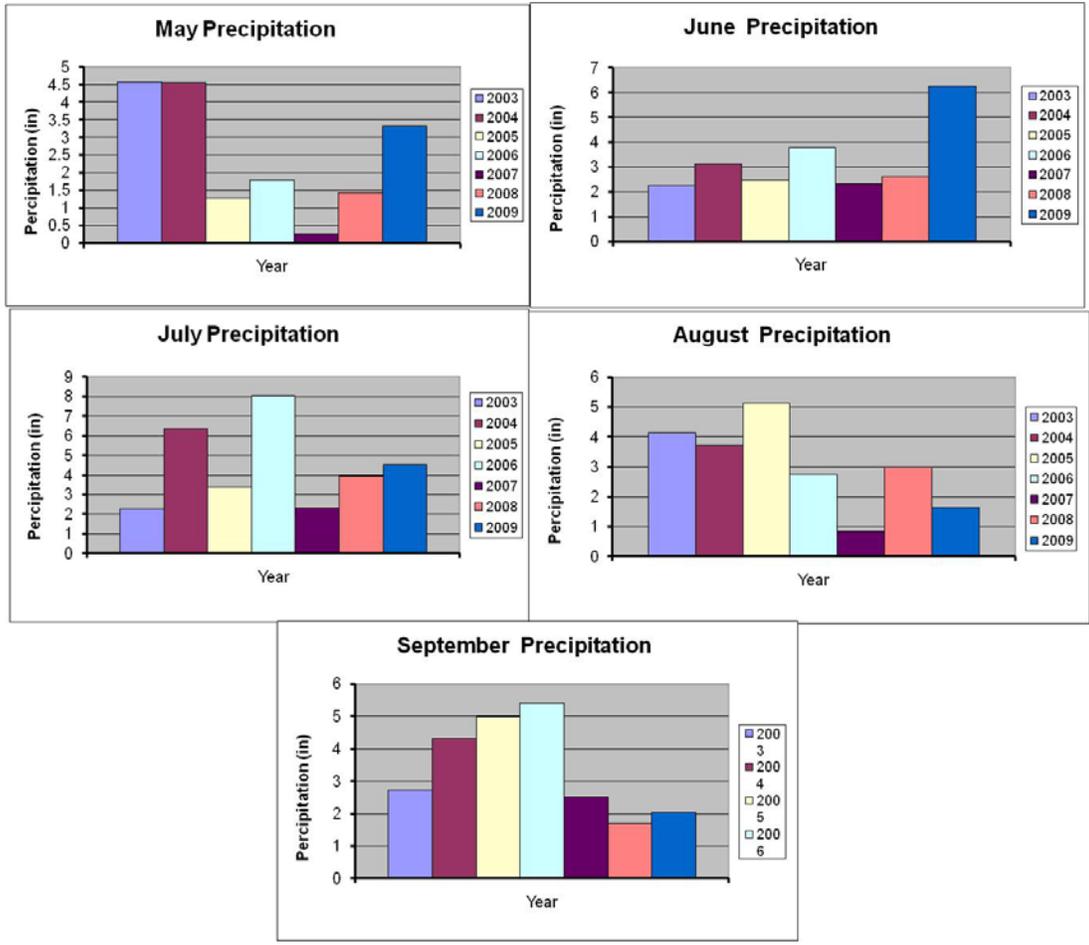


Figure 15. Monthly rainfall during the summer of 2009. Data from the National Weather Service in Rochester, NY (2009).

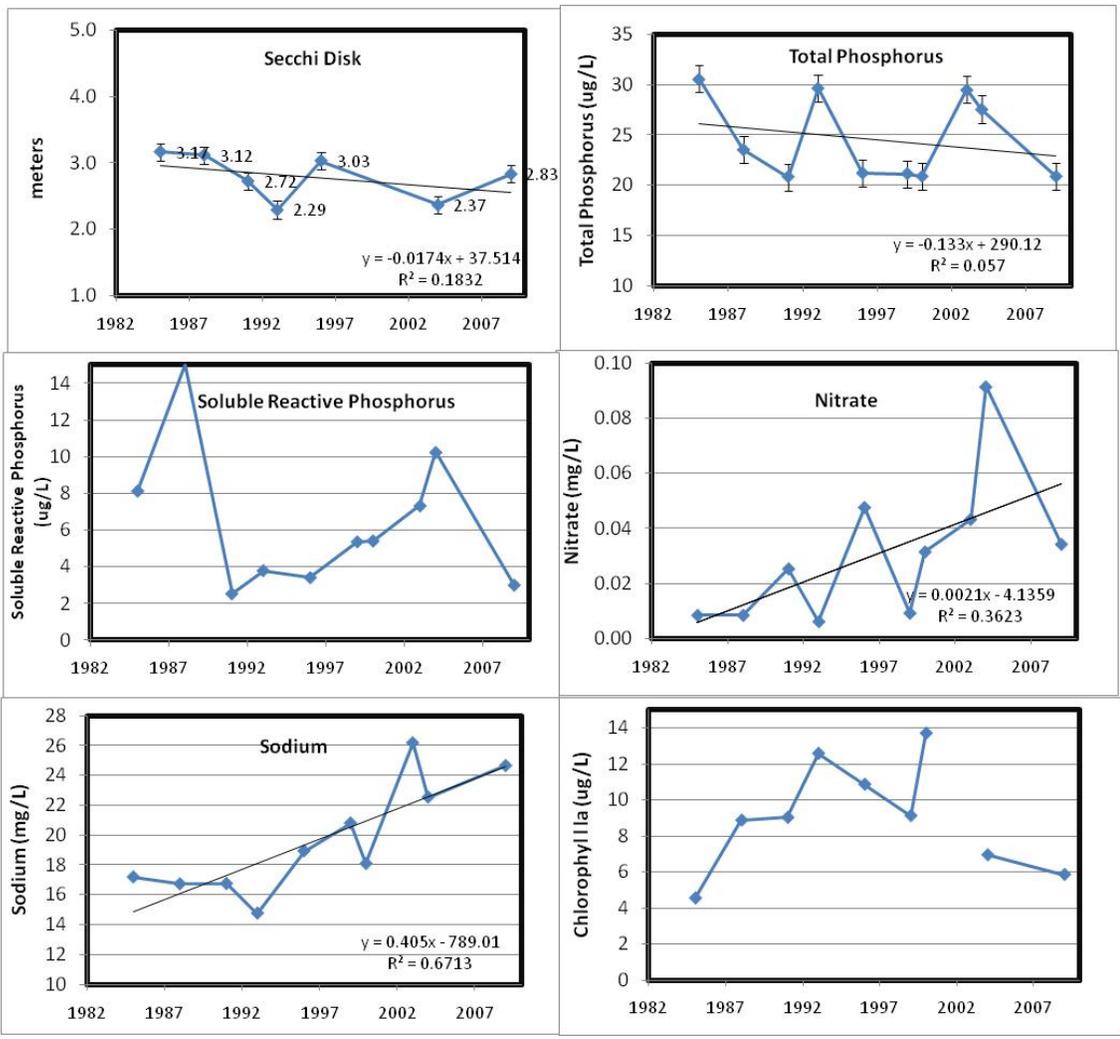


Figure 16. Trends in transparency (secchi disk), total phosphorus, soluble reactive phosphorus, nitrate, sodium and chlorophyll concentration from 1985 to 2009, Conesus Lake.

Appendices. Zooplankton data 2009

Table A. Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 19 May 2009.

Conesus Lake 19 May 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	282	38.96	23.94
Copepoda			
Copepod nauplius	195	17.82	7.13
Cyclopoida			
Cyclopoid copepodid	585	39.72	24.90
Weighted Crustacea Average	391	Total	96.50
96.50			55.96
Rotifera			
<i>Ascomorpha</i> sp.	117	0.51	0.01
<i>Asplanchna priodonta</i>	471	4.58	4.30
<i>Conochilis unicornis</i>	73	9.17	0.06
<i>Filinia longiseta</i>	153	6.87	0.20
<i>Keratella cochlearis</i>	111	29.28	0.16
<i>Keratella crassa</i>	190	8.66	1.38
<i>Keratella earlinae</i>	172	126.55	14.77
<i>Keratella quadrata</i>	145	3.82	0.27
<i>Notholca acuminata</i>	224	0.76	0.03
<i>Polyarthra dolichoptera</i>	120	0.76	0.04
<i>Polyarthra major</i>	156	0.51	0.06
<i>Polyarthra remata</i>	95	10.19	0.27
<i>Polyarthra vulgaris</i>	131	3.82	0.26
<i>Synchaeta</i> sp.	148	22.92	0.52
<i>Trichocerca multicroinis</i>	179	2.55	0.33
Weighted Rotifera Average	159	Total	230.95
230.95			22.65
Weighted Sample Average	227	Total	327.45
327.45			78.62

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 26 May 2009.

Conesus Lake 26 May 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	280	26.81	16.19
Copepoda			
Copepod nauplius	215	44.08	17.63
Cyclopoida			
Cyclopoid copepodid	553	10.83	5.44
Weighted Crustacea Average	281	Total 82	39
Rotifera			
<i>Asplanchna priodonta</i>	548	13.15	19.36
<i>Conochilis unicornis</i>	117	4.64	0.04
<i>Filinia longiseta</i>	156	0.77	0.02
<i>Keratella cochlearis</i>	114	13.15	0.08
<i>Keratella crassa</i>	192	7.73	1.26
<i>Keratella earlinae</i>	176	75.01	9.49
<i>Keratella quadrata</i>	151	1.55	0.12
<i>Polyarthra dolichoptera</i>	97	6.19	0.18
<i>Polyarthra major</i>	156	0.77	0.09
<i>Polyarthra remata</i>	87	22.43	0.46
<i>Polyarthra vulgaris</i>	122	5.41	0.30
<i>Synchaeta</i> sp.	158	5.41	0.15
<i>Trichocerca multicornis</i>	176	2.32	0.23
Weighted Rotifera Average	182	Total 158.53	31.79
Weighted Sample Average	216	Total 240.25	71.06

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 3 June 2009.

Conesus Lake 3 June 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	309	34.92	27.01
Copepoda			
Copepod nauplius	257	9.60	3.84
Cyclopoida			
Cyclopoid copepodid	587	24.81	15.71
<i>Diacyclops thomasi</i>	932	0.20	0.79
Weighted Cyclopoida Average	589	Total	25.01
			47.35
Weighted Crustacea Average	403	Total	69.53
			47.35
Rotifera			
<i>Asplanchna priodonta</i>	599	7.76	14.96
<i>Conochilis unicornis</i>	143	5.72	0.12
<i>Filinia longiseta</i>	142	3.17	0.07
<i>Kellicottia longispina</i>	130	0.31	0.00
<i>Keratella cochlearis</i>	109	11.03	0.06
<i>Keratella crassa</i>	200	0.61	0.11
<i>Keratella earlinae</i>	178	17.66	2.29
<i>Keratella quadrata</i>	151	1.94	0.16
<i>Polyarthra dolichoptera</i>	104	0.41	0.02
<i>Polyarthra major</i>	160	0.20	0.03
<i>Polyarthra remata</i>	92	6.23	0.15
<i>Polyarthra vulgaris</i>	117	6.74	0.33
<i>Synchaeta</i> sp.	215	10.31	0.72
<i>Trichocerca multigrinis</i>	198	3.37	0.42
Weighted Rotifera Average	199	Total	75.45
			19.44
Weighted Sample Average	297	Total	144.98
			66.79

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 9 June 2009.

Conesus Lake 9 June 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	265	42.29	22.09
Copepoda			
Copepod nauplius	218	12.52	5.01
Cyclopoida			
Cyclopoid copepodid	681	15.61	17.84
Weighted Crustacea Average	349	70.43	44.94
Rotifera			
<i>Asplanchna priodonta</i>	560	6.18	9.74
<i>Conochilis unicornis</i>	100	1.63	0.02
<i>Filinia longiseta</i>	136	0.98	0.02
<i>Keratella cochlearis</i>	108	5.04	0.03
<i>Keratella crassa</i>	200	0.98	0.18
<i>Keratella earlinae</i>	173	19.03	2.28
<i>Keratella quadrata</i>	148	3.58	0.27
<i>Ploesoma hudsonii</i>	406	0.16	0.11
<i>Polyarthra dolichoptera</i>	78	0.16	0.00
<i>Polyarthra major</i>	164	1.30	0.18
<i>Polyarthra remata</i>	94	4.23	0.11
<i>Polyarthra vulgaris</i>	128	20.66	1.33
<i>Synchaeta</i> sp.	201	2.28	0.13
<i>Trichocerca multicornis</i>	181	16.75	1.73
Weighted Rotifera Average	183	Total	82.95
Weighted Sample Average	259	Total	153.38
			61.06

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 17 June 2009.

Conesus Lake 17 June 2009	Mean Length (µm)		Abundance (#/L)	Biomass (µg/L)
Cladocera				
<i>Bosmina longirostris</i>	280		141.24	84.68
<i>Ceriodaphnia</i> sp.	325		0.75	0.37
Weighted Cladocera Average	280	Total	141.99	85.05
Copepoda				
Copepod nauplius	200		9.47	3.79
Cyclopoida				
Cyclopoid copepodid	644		16.44	15.04
<i>Mesocyclops edax</i>	946		0.75	3.16
Weighted Cyclopoida Average	657	Total	17.19	18.20
Weighted Crustacea Average	314	Total	168.64	107.03
Rotifera				
<i>Ascomorpha</i> sp.	156		0.25	0.01
<i>Asplanchna priodonta</i>	594		1.25	2.35
<i>Conochilis unicornis</i>	106		6.97	0.10
<i>Filinia longiseta</i>	136		0.75	0.02
<i>Kellicottia longispina</i>	117		0.50	0.00
<i>Keratella cochlearis</i>	117		1.49	0.01
<i>Keratella crassa</i>	197		1.99	0.35
<i>Keratella earlinae</i>	173		8.72	1.05
<i>Keratella quadrata</i>	150		5.98	0.46
<i>Polyarthra dolichoptera</i>	105		0.50	0.02
<i>Polyarthra eurypta</i>	140		0.25	0.02
<i>Polyarthra major</i>	167		9.22	1.32
<i>Polyarthra remata</i>	100		8.97	0.27
<i>Polyarthra vulgaris</i>	134		80.21	5.97
<i>Trichocerca multicornis</i>	167		33.88	3.04
Weighted Rotifera Average	147	Total	160.92	14.99
Weighted Sample Average	232	Total	329.56	122.03

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 24 June 2009.

Conesus Lake 24 June 2009	Mean Length (µm)		Abundance (#/L)	Biomass (µg/L)
Cladocera				
<i>Bosmina longirostris</i>	276		133.58	77.57
<i>Ceriodaphnia</i> sp.	328		7.23	3.66
Weighted Cladocera Average	279	Total	140.81	81.23
Copepoda				
Copepod nauplius	241		35.39	14.16
Cyclopoida				
Cyclopoid copepodid	644		16.75	15.32
<i>Acanthocyclops vernalis</i>	923		1.14	8.17
<i>Mesocyclops edax</i>	898		3.04	10.46
Weighted Cyclopoida Average	696	Total	20.93	33.95
Weighted Crustacea Average	316	Total	197.14	129.34
Rotifera				
<i>Asplanchna priodonta</i>	549		4.19	6.22
<i>Conochilis unicornis</i>	98		15.98	0.19
<i>Kellicottia longispina</i>	133		1.52	0.02
<i>Keratella crassa</i>	178		1.52	0.20
<i>Keratella earlinae</i>	172		10.66	1.24
<i>Keratella quadrata</i>	138		3.04	0.19
<i>Polyarthra eurypta</i>	195		0.38	0.09
<i>Polyarthra major</i>	176		63.56	10.72
<i>Polyarthra remata</i>	100		28.54	0.87
<i>Polyarthra vulgaris</i>	119		114.55	5.88
<i>Trichocerca multicornis</i>	162		12.94	1.13
Weighted Rotifera Average	142	Total	256.89	26.75
Weighted Sample Average	217	Total	454.02	156.09

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 30 June 2009.

Conesus Lake 30 June 2009	Mean Length (µm)		Abundance (#/L)	Biomass (µg/L)
Cladocera				
<i>Bosmina longirostris</i>	301		43.60	31.52
<i>Ceriodaphnia</i> sp.	402		5.38	5.15
Weighted Cladocera Average	312	Total	48.98	36.66
Copepoda				
Copepod nauplius	232		6.27	2.51
Cyclopoida				
Cyclopoid copepodid	775		15.83	30.21
<i>Mesocyclops edax</i>	921		2.99	11.34
Weighted Cyclopoida Average	798	Total	18.81	41.55
Weighted Crustacea Average	429	Total	74.06	80.73
Rotifera				
<i>Asplanchna priodonta</i>	580		7.17	12.56
<i>Conochilis unicornis</i>	119		54.05	0.72
<i>Keratella cochlearis</i>	101		0.60	0.00
<i>Keratella crassa</i>	179		4.18	0.56
<i>Keratella earlinae</i>	173		4.18	0.50
<i>Keratella quadrata</i>	151		4.48	0.36
<i>Polyarthra major</i>	167		2.99	0.43
<i>Polyarthra remata</i>	103		14.63	0.49
<i>Polyarthra vulgaris</i>	131		41.81	2.90
<i>Trichocerca multicroinis</i>	101		11.35	1.80
Weighted Rotifera Average	147	Total	145.44	20.32
Weighted Sample Average	242	Total	219.50	101.05

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 7 July 2009.

Conesus Lake 7 July 2009	Mean Length (µm)		Abundance (#/L)	Biomass (µg/L)
Cladocera				
<i>Bosmina longirostris</i>	282		76.32	46.73
<i>Ceriodaphnia</i> sp.	336		13.78	7.53
<i>Daphnia retrocurva</i>	647		2.65	2.84
Weighted Cladocera Average	300	Total	92.75	57.10
Copepoda				
Copepod nauplius	240		14.31	5.72
Cyclopoida				
Cyclopoid copepodid	688		17.23	20.59
<i>Mesocyclops edax</i>	867		3.98	11.89
Weighted Cyclopoida Average	722	Total	21.20	32.48
Weighted Crustacea Average	363	Total	128.26	95.31
Rotifera				
<i>Asplanchna priodonta</i>	487		1.59	1.64
<i>Conochilis unicornis</i>	89		76.06	0.68
<i>Filinia longiseta</i>	133		0.27	0.00
<i>Kellicottia longispina</i>	122		0.80	0.01
<i>Keratella cochlearis</i>	101		0.80	0.00
<i>Keratella crassa</i>	192		7.95	1.30
<i>Keratella earlinae</i>	179		1.59	0.21
<i>Keratella quadrata</i>	150		1.86	0.14
<i>Polyarthra major</i>	168		3.71	0.55
<i>Polyarthra remata</i>	94		6.89	0.17
<i>Polyarthra vulgaris</i>	128		29.42	1.90
<i>Trichocerca multicroinis</i>	168		1.86	0.16
Weighted Rotifera Average	114	Total	132.77	6.77
Weighted Sample Average	237	Total	261.03	102.08

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 14 July 2009.

Conesus Lake 14 July 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	305	38.40	28.58
<i>Ceriodaphnia</i> sp.	347	21.16	12.75
<i>Daphnia retrocurva</i>	646	2.35	2.51
Weighted Cladocera Average	332	Total 61.91	43.83
Copepoda			
Copepod nauplius	259	19.59	7.84
Cyclopoida			
Cyclopoid copepodid	770	12.15	22.63
<i>Mesocyclops edax</i>	911	4.31	15.67
Weighted Cyclopoida Average	807	Total 16.46	38.31
Weighted Crustacea Average	397	Total 97.95	89.98
Rotifera			
<i>Asplanchna priodonta</i>	560	1.96	3.09
<i>Conochilis unicornis</i>	119	103.05	1.36
<i>Gastropus</i> sp.	138	1.57	0.08
<i>Keratella cochlearis</i>	103	1.57	0.01
<i>Keratella crassa</i>	184	3.92	0.56
<i>Keratella earlinae</i>	176	1.96	0.25
<i>Keratella quadrata</i>	151	1.96	0.16
<i>Polyarthra eurypta</i>	193	3.13	0.75
<i>Polyarthra major</i>	165	5.09	0.71
<i>Polyarthra remata</i>	105	6.27	0.22
<i>Polyarthra vulgaris</i>	123	15.67	0.90
<i>Trichocerca multicornis</i>	140	0.78	0.05
Weighted Rotifera Average	131	Total 146.93	8.15
Weighted Sample Average	237	Total 244.88	98.12

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 22 July 2009.

Conesus Lake 22 July 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	293	28.55	19.18
<i>Ceriodaphnia</i> sp.	389	32.27	27.99
<i>Daphnia retrocurva</i>	671	1.24	1.49
Weighted Cladocera Average	350	Total	62.06
62.06			48.65
Copepoda			
Copepod nauplius	218	10.86	4.34
Cyclopoida			
Cyclopoid copepodid	649	11.79	11.13
<i>Mesocyclops edax</i>	881	1.24	3.96
Weighted Cyclopoida Average	671	Total	13.03
13.03			15.08
Weighted Crustacea Average	382	Total	85.95
85.95			68.08
Rotifera			
<i>Asplanchna priodonta</i>	569	0.93	1.54
<i>Conochilis unicornis</i>	94	12.10	0.09
<i>Kellicottia longispina</i>	117	0.31	0.00
<i>Keratella cochlearis</i>	101	0.62	0.00
<i>Keratella crassa</i>	183	8.07	1.13
<i>Keratella earlinae</i>	187	0.62	0.09
<i>Keratella quadrata</i>	148	0.31	0.02
<i>Polyarthra eurypta</i>	192	2.17	0.51
<i>Polyarthra major</i>	161	0.93	0.12
<i>Polyarthra remata</i>	94	1.24	0.03
<i>Polyarthra vulgaris</i>	117	5.27	0.26
<i>Trichocerca multicornis</i>	168	0.62	0.05
Weighted Rotifera Average	145	Total	33.20
33.20			3.86
Weighted Sample Average	316	Total	119.15
119.15			71.94

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 28 July 2009.

Conesus Lake 28 July 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	303	57.77	42.31
<i>Ceriodaphnia</i> sp.	360	53.00	36.06
<i>Daphnia retrocurva</i>	642	3.04	3.18
Weighted Cladocera Average	339	Total 113.81	81.54
Copepoda			
Copepod nauplius	220	39.96	15.99
Cyclopoida			
Cyclopoid copepodid	664	34.32	35.51
<i>Mesocyclops edax</i>	844	3.48	9.34
Weighted Cyclopoida Average	680	Total 37.79	44.85
Weighted Crustacea Average	381	Total 191.57	142.38
Rotifera			
<i>Asplanchna priodonta</i>	499	0.43	0.48
<i>Conochilis unicornis</i>	120	139.01	1.86
<i>Gastropus</i> sp.	133	3.04	0.14
<i>Keratella cochlearis</i>	104	1.74	0.01
<i>Keratella crassa</i>	178	19.11	2.48
<i>Keratella earlinae</i>	176	2.61	0.33
<i>Polyarthra eurypta</i>	179	2.17	0.41
<i>Polyarthra major</i>	183	1.74	0.33
<i>Polyarthra remata</i>	100	3.91	0.12
<i>Polyarthra vulgaris</i>	122	9.99	0.55
<i>Trichocerca multicroinis</i>	162	4.78	0.42
Weighted Rotifera Average	130	Total 188.53	7.15
Weighted Sample Average	256	Total 380.09	149.52

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 4 August 2009.

Conesus Lake 4 August 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	311	37.30	29.22
<i>Ceriodaphnia</i> sp.	354	15.91	10.25
Weighted Cladocera Average	324	Total 53.21	39.47
Copepoda			
Copepod nauplius	227	12.43	4.97
Cyclopoida			
Cyclopoid copepodid	617	11.19	8.66
<i>Mesocyclops edax</i>	880	1.24	3.93
Weighted Cyclopoida Average	643	Total 12.43	12.60
Weighted Crustacea Average	359	Total 78.07	57.04
Rotifera			
<i>Asplanchna priodonta</i>	523	0.25	0.32
<i>Conochilis unicornis</i>	90	181.25	1.58
<i>Gastropus</i> sp.	133	0.25	0.01
<i>Kellicottia bostoniensis</i>	86	0.25	0.00
<i>Kellicottia longispina</i>	123	0.99	0.01
<i>Keratella cochlearis</i>	105	1.24	0.01
<i>Keratella crassa</i>	183	2.24	0.31
<i>Keratella earlinae</i>	164	0.25	0.03
<i>Keratella quadrata</i>	140	0.25	0.02
<i>Polyarthra eurypta</i>	181	2.49	0.49
<i>Polyarthra major</i>	161	4.48	0.57
<i>Polyarthra vulgaris</i>	122	5.47	0.30
<i>Trichocerca multigrinis</i>	179	0.25	0.02
Weighted Rotifera Average	96	Total 199.65	3.66
Weighted Sample Average	170	Total 277.73	60.70

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 11 August 2009.

Conesus Lake 11 August 2009	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	294	25.50	17.30
<i>Ceriodaphnia</i> sp.	307	20.89	8.61
<i>Daphnia retrocurva</i>	573	1.77	1.29
Weighted Cladocera Average	310	Total 48.16	27.21
Copepoda			
Copepod nauplius	244	7.44	2.97
Cyclopoida			
Cyclopoid copepodid	670	7.08	7.61
<i>Mesocyclops edax</i>	831	0.71	1.78
Weighted Cyclopoida Average	685	Total 7.79	9.39
Weighted Crustacea Average	348	Total 63.39	39.57
Rotifera			
<i>Asplanchna priodonta</i>	390	0.35	0.19
<i>Conochilis unicornis</i>	94	60.20	0.44
<i>Kellicottia longispina</i>	120	3.54	0.03
<i>Keratella cochlearis</i>	107	1.42	0.01
<i>Keratella crassa</i>	186	2.12	0.31
<i>Keratella earlinae</i>	187	0.35	0.05
<i>Polyarthra eurypta</i>	164	0.71	0.10
<i>Polyarthra major</i>	166	1.42	0.20
<i>Polyarthra remata</i>	90	1.77	0.04
<i>Polyarthra vulgaris</i>	122	4.60	0.26
<i>Pompolyx sulcata</i>	111	2.48	0.05
<i>Trichocerca multigrinis</i>	172	0.71	0.07
Weighted Rotifera Average	104	Total 79.68	1.74
Weighted Sample Average	212	Total 143.06	41.31

Table A (cont.). Abundance, biomass (dry weight) and mean length of Conesus Lake zooplankton, 18 August 2009.

Conesus Lake 18 August	Mean Length (µm)	Abundance (#/L)	Biomass (µg/L)
Cladocera			
<i>Bosmina longirostris</i>	280	24.58	14.84
<i>Ceriodaphnia</i> sp.	362	24.86	17.20
<i>Daphnia retrocurva</i>	819	0.28	0.62
Weighted Cladocera Average	324	Total 49.71	32.66
Copepoda			
Copepod nauplius	227	4.69	1.88
Cyclopoida			
Cyclopoid copepodid	652	8.29	8.01
<i>Mesocyclops edax</i>	836	2.49	6.43
Weighted Cyclopoida Average	695	Total 10.77	14.44
Weighted Crustacea Average	379	Total 65.18	48.98
Rotifera			
<i>Asplanchna priodonta</i>	543	0.83	1.19
<i>Conochilis unicornis</i>	109	22.92	0.29
<i>Kellicottia bostoniensis</i>	94	0.28	0.00
<i>Kellicottia longispina</i>	125	0.55	0.00
<i>Keratella cochlearis</i>	107	1.10	0.01
<i>Keratella crassa</i>	179	4.69	0.63
<i>Keratella earlinae</i>	172	0.55	0.06
<i>Polyarthra eurypta</i>	186	2.49	0.52
<i>Polyarthra major</i>	158	5.52	0.67
<i>Polyarthra remata</i>	101	3.04	0.10
<i>Polyarthra vulgaris</i>	115	5.52	0.26
<i>Pompolyx sulcata</i>	105	1.10	0.02
<i>Trichocerca multigrinis</i>	156	4.14	0.34
Weighted Rotifera Average	135	Total 52.75	4.09
Weighted Sample Average	270	Total 117.92	53.07