4-1991

Chemical Analysis and Nutrient Loading of Streams Entering Conesus Lake, N.Y with sections on I. Status of Conesus Lake I I. Crayfish as Control Agents of Macrophytes

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Repository Citation

Makarewicz, Joseph C.; Lewis, Theodore W.; Dilcher, Ronald C.; Letson, Michael; and Puckett, Norma L., "Chemical Analysis and Nutrient Loading of Streams Entering Conesus Lake, N.Y with sections on I. Status of Conesus Lake I I. Crayfish as Control Agents of Macrophytes" (1991). *Technical Reports*. 111.
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CHEMICAL ANALYSIS AND NUTRIENT LOADING OF STREAMS ENTERING CONESUS LAKE, N.Y

with sections on
I. Status of Conesus Lake
II. Crayfish as Control Agents of Macrophytes

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Prepared for the

Livingston County Planning Department
Mt. Morris, N.Y.

April, 1991

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EXECUTIVE SUMMARY

WATERSHED ANALYSIS AND NUTRIENT LOADING

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1. Sampling sites on the eleven major tributaries entering Conesus Lake (Densmore, Hanna's, Long Point South McMillan, North McMillan, North Gully, South Gully, Wilkins, Sand Point Gully, Inlet, No Name Creek) were monitored weekly for 52 weeks (6 March 1990 - 26 February 1991) for 20 chemical and physical parameters including stream discharge.
2. 69.2% of the water discharged into Conesus Lake is from three creeks (North McMillan, South McMillan and the Inlet) located at the south end of the lake. Seasonal discharge was variable but highest (76 to 87%) during the winter and spring.
3. Watershed losses of sodium and chloride, major constituents of deicing salt, were above normal during the study period in two streams. Annual concentrations of sodium and chloride were significantly higher in Hanna's (53.1 mg Na/L, 86.9 mg Cl/L) and Wilkins Creeks (97.0 mg/L, 158.1 mg/L) than in the other streams (mean = 19.0 mg Na/L, 36.2 mg Cl/L). The watersheds of these two creeks delivered the largest amount of sodium per unit area of watershed to the lake (49%). Sixty nine to 88% of the salt (as sodium) enters the Lake in the winter and spring when deicing salt is applied to roads. Large deicing salt piles are maintained in these watersheds for road use during the winter. The cause of the high concentrations of sodium and

chloride in Hanna's Creek was demonstrated in 1985 as due to poor storage of winter deicing salt at the New York State Department of Transportation garage located in this watershed. The high concentrations of salt in Wilkins Creek were due to deicing salt usage within the Village of Livonia and/or poor storage of deicing salt at the Livonia Town Garage. Wilkins and Hanna's Creeks are undoubtedly contributing to the slow but clear trend of increasing salt (Na and Cl) concentration in Conesus Lake.

4. The average lake sodium concentration in 1985 and in 1988 was 17 mg/L; a 30% increase in 15 years. Excessive sodium in human diets is a proven health hazard, affecting blood pressure (hypertension) and aggravating cardiovascular, kidney and liver diseases. The New York State Sanitary Code advises that water containing more than 20 mg/L of sodium should not be used for drinking by those on severely restricted diets. It follows that Conesus Lake water suppliers may be required to notify consumers that the sodium concentration is 20 mg/L or higher in the near future.
5. Many chemical parameters in Conesus Lake are influenced by discharge from tributaries. Phosphorus is an element required for plant growth, whether on land or in the water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or over-production of lakes. Phosphorus may enter from the watershed as a result of sewage disposal and heavy fertilizer use. Watersheds, drained by streams with high phosphorus concentrations, are potentially the cause of increased phytoplankton and macrophyte (weed) production. Hanna's (74.6 μg P/L), "No Name" Creek (77.8 μg P/L), North Gully (65.9 μg P/L), Wilkins (74.9 μg P/L) and Long Point Gully (53.2 μg P/L) had significantly higher total phosphorus than other streams (mean = 28.1 μg P/L) draining into Conesus Lake.

Similarly, nitrate and TKN concentrations were exceedingly high at Long Point Gully (3.99 mg N/L and 538 μg N/L), "No Name" (4.48 μg N/L and 621 μg N/L) and Sand Point Creeks (1.17 mg N/L and 513 μg N/L) compared to the other creeks (mean = 0.60 mg N/L and 439 μg N/L).

6. Of the eleven creeks monitored annually, South McMillan Creek was the major contributor of nutrients to Conesus Lake accounting for 27%, 32% and 39% of the total phosphorus, total nitrogen and total suspended solids, respectively, entering Conesus Lake. North McMillan Creek had the second highest loading of total phosphorus (17%), total nitrogen (23%) and suspended solids (26%). These two creeks accounted for 44% and 65% of the total phosphorus and total suspended solids, respectively, entering Conesus Lake. Most of the phosphorus and total suspended solids enters during precipitation events. For example in South McMillan Creek, 41% of the total phosphorus and 82% of the total suspended solids entered during eight events. Thus, it is not surprising that an extensive macrophyte community exists at the mouth of South McMillan and McMillan Creeks, which extends well into the Creek. These two watersheds are logical candidates for a nutrient control program.

7. The high input of nitrates occurring in other watersheds perhaps reflects different land use patterns. The watersheds of Long Point Gully, the Inlet and North McMillan Creek were the major contributors of the nitrate to Conesus Lake accounting for 21%, 17% and 17%, respectively, or 55% of the total nitrate load. Approximately 50% of the nitrate load entered during the winter. It is important to note that the relative load of nitrate per unit area of land is considerably higher for Long Point Gully, "No Name",

Hanna's and South Gully, which are all watersheds having a high percentage of land in croplands (>40%, average = 70.8%). This suggests a land use, agriculture, that is contributing to the nutrient load of the lake. These watersheds are candidates for a best management practice (BMP).

8. Based on the total stream phosphorus loading and chlorophyll data that we have collected for Conesus Lake and its tributaries, Conesus Lake falls into the mesotrophic category of bodies of water. That is to say, Conesus Lake is a productive body of water.

MACROPHYTES (WEEDS)

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1. The large number of samples taken (126) from a number (6) of locations will provide baseline for determining whether or not the "weed problem" is improving or getting worse in the future. Seventeen species of macrophytes were observed in Conesus Lake. The dominant plant, accounting for over 45% of the plant biomass at four of the six sites sampled, was *Myriophyllum* spp. This same species was the second most important macrophyte at "No Name" Creek (30% of the biomass) and at the "North End" (20% of the plant biomass) of the lake. At the "North End" of the lake, *Chara* sp. accounted for over 60% of the biomass, while at "No Name" Creek *Potamogeton* sp. represented nearly 50% of the plant biomass.
2. Macrophyte biomass ranged from 105 g/m^2 at Cottonwood Creek to a high of 338 g/m^2 at the "South End" of the lake. In general, biomass was highest at the "South End" and at the "North End" of the lake. The high biomass at the "South End" probably

reflects the high total input of nutrients from South and North McMillan Creeks and the Inlet. The high biomass at the "North End" of the Lake may reflect relatively high nutrient inputs from Hanna's and Wilkins Creek. The high plant biomass in McPherson's Cove and Long Point perhaps reflects the influence of nearby creeks.

STATUS OF CONESUS LAKE

1. Conesus Lake was sampled for chemistry and biological parameters from May, 1988 to October 1988. Conesus Lake water quality changed little over the 1985-1988 period: except for those water quality criteria in which algae and small-size zooplankton were involved. Turbidity, chlorophyll a, pH and SRP have increased significantly within the epilimnion -the area of highest biologic activity from 1985 to 1988.
2. The 1988 zooplankton assemblage were smaller in size, having a weighted mean length of 0.18 mm compared to a 1985 weighted mean length of 0.23 mm and a 1972-73 mean length of 0.60 mm. Ninety-eight percent of the 1988 zooplankton were less than 0.35 mm in size, and 93% of the crustacean zooplankton were less than 0.35 mm. Zooplankton biomass had decreased in 1988 to one-half the biomass of 1985.
3. The 1985 zooplankton were a **Rotifera-Eucopepoda** (calanoid and cyclopoids)-**Cladocera** community. By 1988 the community changed to **Rotifera-Cladocera-Eucopepoda** (cyclopoids). The disappearence of the large calanoid **Eucopepoda** *Diaptomus* and the appearance of *Eucyclops agilis* and *Macrocyclops albidus*, were unexpected in the pelagic waters of Conesus Lake.

4. From 1985 to 1988, yellow perch increased 30%, walleye increased 8%, small mouth bass increased 3%, pike remained unchanged and alewife decreased 41%. The 1988 yellow perch consisted of jack perch and healthy smaller perch, with two sizes, 160-179 mm and 260-279 mm, being predominant. Alewife decreased in weight from 1985 to 1988, weighing 32-119 gm and 16-40 gm, respectively. The decline of the planktivore population by 12% since 1985 was most likely caused by a lack of a forage base for the planktivores, especially the alewifes.

5. In 1988 the Conesus Lake alewife fed on *Mesocyclops edax* 99% of the time, preferring *M. edax* that were 1.0 mm or greater in size. Those *M. edax* which were 1.0 mm or larger in size constituted only 0.016% of the total zooplankton community suggesting that they may be suffering from a dwindling food base.

6. Attempts at biomanipulation in Conesus Lake have been frustrating. Walleye sac fry have been planted at a density of 5000 per acre since the early 1980's, but they have not survived. A stocking program of 65,000 walleye fingerlings per year began in 1985, but a cage study that accompanied the 1988 stocking indicated there was an overall 81.2% cage mortality of fingerlings. Handling difficulties and shipping of the fingerlings seemed to overstress the fish. Thus, the survival of walleye fingerlings that were stocked in Conesus Lake from 1985 through 1988 has been low.

6. What is evident is that the walleye introduction to Conesus Lake has not had an effect on zooplankton, phytoplankton and turbidity as expected. In fact, turbidity has increased since 1985. However, the reason for this lack of success of the biological control is rather straight forward. There have been difficulties in the restocking program of walleyes. Thus predator control of alewifes has not had ample time to

work in Conesus Lake.

CRAYFISH CONTROL OF WEEDS

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1. Crayfish significantly decreased macrophyte biomass in all experiments. However, only the crayfish levels, that exceeded 140-150 g/m^2, significantly decreased macrophyte biomass. The rate of crayfish grazing, in cages where significant decreases in macrophyte biomass occurred, averaged 0.012 g of macrophytes consumed/crawfish/m^2/day.
2. A crayfish biomass value of 140 g/m^2 in Conesus Lake corresponds to 88 crawfish/m^2 or about 880,000 crayfish/ha (356,275 crawfish/acre).
3. The research completed certainly suggests crayfish may be an effective biological control of macrophytes. However, crayfish were protected from their predators including fish, birds, mammals and man in this study. Further experimental work should be conducted to evaluate crayfish grazing with the presence of predators.
4. The economics of using crayfish as control agents of macrophytes are not strong. At the densities required to reduce macrophyte biomass, the cost of crayfish is high. The cost for 1000 crayfish is $65, while the cost for 50,000 would be $2750. Thus control weeds by crayfish is possible but the cost would appear to be prohibitedly high for a single acre.

RECOMMENDATIONS

1. More detailed studies of Hanna's, "No Name" and Long Point Creeks are required to determine actual sources of nitrates, total kjeldahl nitrogen and phosphorus within these watersheds. These creeks are contributing nutrients at a much greater rate than similar sized watersheds.
2. A literature study on what types of best management practices could be successfully used in the Conesus Lake watershed should be undertaken.
3. A nutrient control program or best management practice (BMP) should be initiated on South McMillan and North McMillan Creeks. These two watersheds contribute almost 50% of the phosphorus to the lake.
4. Losses of de-icing salt from the Wilkins and Hanna's Creek need to be managed better. There has been a significant increase in sodium levels within the lake that is approaching levels considered to be of concern to those on restricted diets.
5. Three watersheds (Inlet, South and North McMillan) represent over 50% of the watershed of Conesus Lake. Much of this area is unsewered and relatively undeveloped, especially the Inlet watershed. In the future, unmanaged development in these watersheds could have significant effects on water quality and perhaps macrophyte production. Development and/or enforcement of zoning codes within these watersheds is an important consideration for the future.

6. If macrophyte control is truly desireable and the need immediate, consideration should be given to use of the sterile grass carp after careful consideration of environmental impact on the lake.
7. Sample Conesus Lake for water chemistry and the zooplankton community in 1991. DEC plans a gill net census of Conesus Lake every three years, which would be 1991.

INTRODUCTION

A program of research was developed at the State University of New York at Brockport's Department of Biological Sciences to investigate the causes of decreasing water transparency and increased salt levels in some streams draining into Conesus Lake and to identify watersheds and sources of fertilizers that may be polluting the lake and causing increased abundance of "weeds". It has been supported by New York State, Livingston County, the Villages of Avon and Geneseo and the Town of Livonia and many private citizens. The thrust of the research has been to gather and synthesize information necessary to determine the physical capabilities of Conesus Lake to maintain its aesthetic character, its use as a water supply, and its ability to continue to serve as the symbol of the region.

Phase 1 started in 1985 with the goal to identify the causes of the decrease in water "clearness" or the increase in turbidity of the Lake water. The higher turbidity was of concern to the New York State Department of Health because turbidity for the first time was exceeding the New York State's Guidelines on Drinking Water. The high turbidity may eventually require the construction of new water treatment plants. Results from this work suggest that the high turbidity was correlated with the accidental introduction of a new fish, the alewife or sawbelly, into the Lake. Detailed information was also gathered concerning the water quality of Conesus Lake to ascertain its status and fragility.

The final report can be found at Drake Library on the SUNY Brockport campus and at the Town of Livonia or Village of Geneseo and Avon Offices.

In response to public concern created by an abundance of nuisance weeds (i.e. macrophytes) within Conesus Lake, the Conesus Lake Aquatic Weeds Strategy (CLAWS) was initiated by the Livingston County Planning Department in 1990 to develop long-term management strategies for Conesus Lake. CLAWS took a two-pronged approach: a short-term weed harvesting program to remove weeds and a long-term research program to identify the cause of the weed problem.

Phase 2 was begun during the summer of 1990 in an attempt to relieve the immediate problem of an abundance of "weeds". A weed harvesting machine was purchased by the County through the Soil and Water Conservation District to physically remove nuisance weeds from designated areas of the lake. Recognizing that weed cutting is, at best a short-term answer analogous to cutting a grass lawn, a third phase was simultaneously instituted to attempt to find a long-term solution to the weed problem.

Phase 3 also began in 1990 and was scheduled for completion in 1992. Because of budget cuts at the state level, only one year of the full project will be completed by the spring of 1991. Phase 3 is to fully describe the amount of water entering the lake and its quality. With this information, it will be possible to calculate the runoff of nutrients from the land, correlate that with the water quality in the lake and project what effects additional future development will have on water quality. This approach may also identify problem watersheds; i.e. watersheds that are polluting the Lake. Once these areas are defined, attempts to control runoff through "Best Management Practices" could be instituted. Best Management Practices are methods of regulating and controlling pollutants in water running off the watershed into streams and into lakes such as applying mulch to recently stripped land for construction or contour plowing.

Phase 4 is to send the information to local planning agencies so that they may use it to prepare legislation that will facilitate the goals of the plan. When levels of nutrient loading that cannot be exceeded without jeopardizing water quality are identified, local planners will be able to develop regulations to maintain an intensity of land use that will not allow nutrient runoff to exceed those levels. Working with the Soil Conservation Service and Agricultural Stabilization and Conservation Services, Best Management Practices (BMP's) such as farmyard improvement or nutrient management plans could be suggested for implementation to protect lake resources as well as rendering an economic advantage to participating farmers. A whole host of alternatives or combinations of methodologies are available to address those problems, but they are expensive. The acquiring of funds from federal or other non-local sources to help implement these actions is also an important part of the on-going program.

Objectives of the current study (Phase 3) were:

1. To seasonally monitor eleven of the streams entering Conesus Lake for selected chemical parameters for an annual cycle;
2. To develop seasonal and annual nutrient loads for phosphorus, nitrate, total kjeldahl nitrogen, total suspended solids and sodium for each stream to identify problem watersheds;
3. To develop baseline data on macrophyte (weeds) biomass at various locations within Conesus Lake;
4. To obtain fish and zooplankton data to evaluate any effects due to biomanipulation (i.e. addition of walleye);
5. To characterize the environmental status and water quality of Conesus Lake. Has the lake turbidity improved with the increased stocking of walleyes? and;
6. To test and evaluate crayfish as a biological control of "weeds".

Study Site

Conesus Lake is the westernmost of the Finger Lakes. The lake and its accompanying watershed are part of the drainage basin of the Genesee River which originates in Pennsylvania and travels 140 miles before emptying into Lake Ontario north of Rochester. It is one of the area's important natural resources. Besides providing excellent fishing, swimming and boating, Conesus Lake provides drinking water for Avon, Geneseo and Lakeville. The Conesus Lake watershed is believed to be home to as many as 10,000 people during the summer months. Conesus Lake's watershed is relatively large (70 square miles of watershed) with a major portion of it existing south of the lake (Fig. 1). This portion of the watershed is not sewered. A complete discussion of the history, biology and limnology may be found in "Lakes of New York State" (Bloomfield 1978) and the "The Diamonds are Dancing: A History of Conesus Lake" (Anderson 1976)

METHODS

General

Stream water samples were collected and stream height was measured weekly at all stream sites from 1 March 1990 to 28 February 1991. Sites were chosen, above the influence of Conesus Lake, for ease of access (i.e. closeness to a bridge or culvert for gaging purposes)(Fig. 2). Precipitation events were monitored hourly at South McMillan Creek with an Isco Sequential Sampler.

Water and zooplankton samples from Conesus Lake were collected biweekly from May to November in 1988 (Fig. 2). Water samples were taken with a Van Dorn bottle (non-metallic) at depths of 1, 8 and 12m. Water temperature was measured at meter intervals with a thermistor thermometer.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All filtration units and other processing apparatus were cleaned routinely with phosphate-free RBS. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (EPA 1979) or Standard Methods for the Analysis of Water and Wastewater (APHA 1989). Sample water for dissolved nutrient analyses (SRP, nitrate + nitrite) was filtered immediately with 0.45 μm MCI Magma Nylon 66 membrane filters and held at 4°C until analysis. Analyses of pH, alkalinity, specific conductance, turbidity and dissolved oxygen were completed within two hours of collection. Subsequent analyses were always completed within 24 hours of collection.

Statistics were performed on a PRIME 9955 mini-computer using MINITAB and SPSSx software packages.

Water Chemistry

Chlorophyll a: Chlorophyll a was measured with a fluorometer following the method of Wetzel and Likens (1979)

Turbidity: Turbidity was measured with a Turner nephelometric turbidimeter within four hours after sample collection. When analyzing cold water samples, care was taken to avoid condensation on the outside of the sample tube or gas bubble formation within the tube.

Specific Conductance: A Thomas Model 275 Conductivity Meter was used to measure conductivity. Results were corrected to 25°C.

pH: Analyses were made by electrode using the Beckman 45 meter standardized daily using two buffers (4 and 9). pH was measured as soon as possible following sample collection.

Dissolved Oxygen: Dissolved oxygen analyses were made using the modified Winkler method (APHA 1989). Samples were fixed in the field and transported to the laboratory for final titration.

Total Alkalinity: Alkalinity was estimated within two hours of collection by titrating with standard H_2SO_4 to a pH end point of 4.5.

Nitrate + Nitrite: Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (EPA 1979).

Total Phosphorus: The persulfate digestion procedure was used prior to analysis by the automated (Technicon Autoanalyser) colorimetric ascorbic acid method (APHA 1989).

Soluble Reactive Phosphorus: Analysis was performed using the automated (Technicon) colorimetric ascorbic acid method (APHA 1989).

Total Kjeldahl Nitrogen: Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were performed:
1. In the sodium salicylate-sodium nitroprusside solution, sodium nitroferri-cyanide (0.4g) replaced the concentrated nitroprusside stock solution.
2. The reservoir of the autoanalyser was filled with 0.2M H_2SO_4 instead of distilled water.
3. Other reagents were made fresh prior to each analysis.

Total Suspended Solids: APHA (1989) Method 2540D was employed for this analysis.

Chloride: Analyses were performed using the mercuric nitrate method (APHA 1985).

Metals: Calcium, magnesium, sodium and potassium were determined by atomic absorption spectrophotometry (Perkin-Elmer 3030) (APHA 1985).

Physical Measurements

Temperature: Stream and Lake temperatures were measured with a calibrated mercury thermometer and a Whitney thermistor, respectively.

Stream Height: Stream height was determined weekly by measurements of the distance from the surface of the stream to a standard location on the overlying bridge or culvert. Continuous readings of stage height were taken at South McMillan Creek using an ISCO pressure detector. Stream area for various stream heights was calculated by planimetry. A line was fit to the values for stream area by polynomial interpolation, which allowed stream cross-sectional area to be estimated for all sampling dates based on stream heights.

Stream Velocity: Stream velocity was measured either in the culvert or within the cement channel of a bridge (Chow 1964). Measurements were at equally spaced locations at each station on all sampling dates with a Gurley Meter.

Watershed Area: Areas used in the loading calculations were obtained by planimetry from USGS topography maps. Watershed areas were not the whole area of the watershed but were the area of the watershed upstream from the sampling point. Boundaries of each sub-watershed have been determined and have been incorporated into the Graphic Information System (GIS) of the Livingston County Health Department by their personnel (Fig. 1).

Biological Measurements - Lake

Zooplankton: Zooplankton were sampled with a Wisconsin net (0.5m-diameter, 80μm-mesh net) equipped with a calibrated flow meter. Vertical tows were from 1m off the bottom to the surface (depth = 18m). Zooplankton were narcotized with tonic water and preserved in 5% formalin. Three counts of each sample made with a Sedgewick-Rafter cell. Cyclopoids were identified and counted separately under a dissecting scope. Identifications follow Ward and Whipple (1965) and Stemberger (1979). Where possible, up to 50 length measurements per sampling date were made of each species of Crustacea observed (10 for Rotifera).

Fish: Fish were sampled with multi-filament experimental nylon gill nets (1.5, 2.0, 2.5, 3.0, 4.0 and 5.0" stretch mesh, [1"=2.54cm]) hung full on polyfoam float and lead-core bottom lines that fish the bottom 2.6m of water. A total of nine randomly selected gill net sets were made in 1985 and again in 1988. Nets (100m long) were fished overnight in water ranging from 5 to 11 m total depth with the deepest end set in water containing at least 5 mg/L of dissolved oxygen. All fish captured were identified to species and enumerated according to the mesh size of capture. Sex, maturity, age, weight and length were determined. Fifteen alewife stomachs were slit and preserved with 95% ethanol for diet analysis. The percent composition of food was calculated following Neilsen and Johnson (1983) and Ricker (1971). Unless stated otherwise, all ANOVA's were evaluated with a significance level of $P = 0.05$.

Macrophytes (Weeds): The aquatic macrophytes in Conesus Lake were sampled at six sites [McPherson Point (1400m transect), North End (2000m), Long Point (1000m), Cottonwood Cove - "No Name Creek" (600m), South End (1600m) and McPherson Cove (1400m)] during the period 15 through 17 August 1990 and on 25 August 1990 (Fig. 2) (also see Appendix A for a complete description of all macrophyte sampling sites). At each site, triplicate samples were taken at 200m intervals along a depth contour of 1m. At each 200-m interval a metal hoop (0.25 m^2) was tossed three times and all macrophytes within the hoop were removed with a trowel, placed in a labelled plastic bag and returned to the canoe, where the bag was again labelled with an internal card.

All samples were immediately frozen for storage pending cleaning and weighing. Subsequently, as time permitted during the fall, individual samples were rinsed over a white enamel pan, in water, while in a 1.0mm sieve. Pebbles, sand, snails and other animals and detrital material were washed or picked away. By floatation, in situ plant material that got washed through the sieve was recaptured. The washed plant material then was placed in a large shallow white pan, in water, and individual plants (or their parts) were separated by genus (or species if requisite structures were present). This second separation also served as a final wash; the macrophytes then were rebagged, labelled and refrozen until they could be dewatered and weighed.

During that cleaning and weighing process, one of the three replicates from each collection station was identified and sorted by genus (and species where that was possible). Those samples sorted by genus were weighed and reported by genus. Although only one replicate from each sampling site was dry-weighed by genus, a list was kept of genera found in each replicate. Weeds were dried and weighed after reaching constant weight at 105^{o}C

Crayfish Experiments

To evaluate the grazing effect of crawfish on macrophytes during a period of active macrophytic growth three experiments were designed.

The first experiment (Pre-established, 7 July - 31 July, 1989) was designed to evaluate the crawfish grazing ability before the macrophytes were established, prior to the annual summer growth period of macrophytes. This experiment was terminated two weeks after a luxuriant growth of macrophytes developed in the lake and in the control cages. The second experiment (Post-established, 4 August - 31 August, 1989), was designed to evaluate the effectiveness of crawfish grazing on an established community of macrophytes. The third experiment (Continuous, 7 July - 31 August, 1989) evaluated macrophytic growth in the presence of crawfish over the entire summer.

Eighteen cylindrical cages constructed of 6.3 mm mesh hard-ware cloth were placed into a 4x3 random block design in the northern most end of Conesus Lake: six cages for the Continuous phase and twelve for the Pre-established phase. The edge of each cage was buried below the surface of the sediment and anchored into place with stakes and a metal fence post. Cage dimensions were .56 m in diameter x 1.5 m in height (area of crawfish grazing = .25 m^{2}). The cylindrical construction of the cages proved to be resistant to the occasional heavy wave action that occurred. All experiments were conducted at the northern end of Conesus Lake in approximately .5 to 1.0 meters of water.

The crawfish were purchased and placed in acclimation cages for 24 hours prior to introduction into experimental cages. The selection of the crawfish, *Orconectes immunis*, was based on its ability to survive in a lake habitat, and that it is a native species to New York State. Basic biological data was taken (sex, length, weight) on each crawfish before and after completion of each experimental time period (Pennak 1959). Length was taken from the anterior tip of the rostrum to the posterior tip of the abdomen with the uropods turned in towards the telson (Dean 1969). Each crawfish's wet weight was determined by placing them into a weighing vessel on a triple beam balance.

In the Pre- and Post-established experiments, four different levels of crawfish biomass were used: 0.0 g/m^{2} (control), 40-48 g/m^{2} (level 1), 140-150 g/m^{2} (level 2), and 240-250 g/m^{2} (level 3). Each biomass level of crawfish was replicated (n=3). The Continuous experiment was set up with three control cages (crawfish biomass of 0.0 g/m^{2}) and three experimental cages (crawfish biomass same as a level 2 in both the Pre and Post-established phases).

Macrophytes were harvested from both the crawfish and control cages by placing a steel hoop inside the cage to mark the location of the cage, removing the cage and harvesting the macrophytes within the hoop (above surface portions only). All macrophytes were placed in plastic bags and frozen until wet weight, dry weight (105°c), and ash free dry weight (ignition for 6 hrs at 550°c) was determined (APHA 1989, Westlake 1963, Vollenweider 1969).

Quality Control

Quality Assurance Internal Quality Control: Multiple sample control charts (APHA 1985) were constructed for each parameter analyzed, except oxygen and total suspended solids. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run. Frequency of instrument calibration is indicated in Table 1. Table 2 provides a summary of the quality assurance data.

External Quality Control: Biannually, reference solutions were obtained from The USEPA EMSL Laboratory in Cincinnati, Ohio and from the U.S. Geological Survey Resource Division's Standard Reference Sample Project and placed into the analysis stream. In all cases, analyses fell within the standard error of the control sample provided (Table 3). The mean rating for the USGS reference solutions was 3.0 (Table 4), which represents a rating value of very good.

Table 1. Frequency of Calibration of Reagents or Instruments

Instrument	Standard / Recalibration
Turbidity	Polymer standards weekly
YSI Conductivity Bridge	KCL standards weekly
pH meter	Standards weekly
Alkalinity	$NaCO_3$ quarterly
Dissolved Oxygen	Biniodate quarterly
Technicon-Nitrate Nitrite	Stock standards weekly
Technicon-TP	Stock standards weekly
Technicon-SRP	Stock standards weekly
Technicon-TKN	Stock standards each analysis
Chloride	Stock standards weekly
Atomic Absorption Spectrophotometer	Stock standards weekly

Table 2. Summary of quality assurance data from the water quality laboratory at SUNY Brockport, Brockport, N.Y. May, 1990 - April, 1991. SRP = Soluble reactive phosphorus, TKN = Total kjeldahl nitrogen, R.E.=Relative Error, S.D.=Standard Deviation, C.V.=Coefficient of Variation, C.I.=Confidence Interval. Values in mg/L unless otherwise noted.

		Number of Samples	True Value	Mean	Standard Deviation	Coefficient of Variation	95% Confidence Interval	Relative Error %
POTASSIUM	A	31	1.01	0.99	0.050	0.049	0.89-1.09	1.9
	B	21	5.00	4.99	0.13	0.027	4.73-5.26	0.1
SODIUM	A	28	10.00	9.96	0.36	0.036	9.24-16.40	0.4
	B	24	40.00	39.61	0.94	0.024	37.73-30.71	1.0
MAGNESIUM	A	38	10.00	10.03	0.15	0.015	9.73-10.33	0.3
	B	14	15.00	15.67	0.36	0.024	14.94-16.40	4.3
CALCIUM	A	29	30.00	30.03	0.34	0.011	29.35-30.71	0.1
	B	23	80.00	80.15	1.06	0.013	78.03-82.27	0.2
NITRATE	A	26	0.40	0.39	0.03	0.067	0.34-0.45	1.6
	B	26	1.60	1.61	0.07	0.045	1.47-1.75	0.6
SRP µg P/L	A	23	4.96	4.18	1.03	0.208	2.12-6.25	18.5
TP µg P/L	A	23	24.80	25.31	2.59	0.105	20.12-30.50	2.0
	B	29	37.20	37.34	3.27	0.088	30.79-43.89	0.4
COND µmhos/cm		52	717.00	715.08	3.68	0.005	707.71-722.44	0.3
pH	A	30	4.01	4.01	0.05	0.013	3.91-4.11	0.0
	B	22	9.18	9.18	0.07	0.007	9.05-9.31	0.0
ALKALINITY		52	75.51	75.27	0.90	0.012	73.47-77.08	0.31
CHLORIDE	B	52	27.93	27.14	2.96	0.106	21.23-33.06	2.9
TURBIDITY		52	0.46	0.46	0.05	0.100	0.36-0.55	0.89
SULFATE	A	27	20.00	18.64	1.06	0.053	16.52-20.76	7.3
NTU	B	25	30.00	28.14	1.83	0.061	24.47-31.80	6.6
TKN µg N/L		48	1.50	1.44	0.15	0.103	1.13-1.75	4.1

Table 3. Results of the semi-annual interlaboratory testing program of the Environmental Protection Agency performed by SUNY Brockport. Reference samples are Minerals - WP1188/1288, Nutrient - WP1188 and Turbidity - WS289.

MINERALS	EPA MEAN	95% C.I.	SUNY VALUE
pH	6.01	5.91-6.11	6.06
CALCIUM	20.37	18.3-22.5	20.15
MAGNESIUM	5.00	4.44-5.56	5.13
SODIUM	20.0	17.8-23.5	19.53
POTASSIUM	4.94	4.17-5.71	5.17
TOTAL ALKALINITY	20.3	17.5-24.5	22.42
SULFATE	19.71	15.3-22.5	20.5
CHLORIDE	52.0	48.2-55.4	51.28
SPECIFIC CONDUCTANCE	279	258-300	271
NUTRIENTS			
NO_2+NO_3	1.99	1.71-2.27	1.96
ORTHOPHOSPHATE	0.39	0.31-0.47	0.39
TOTAL-PHOSPHATE	1.53	1.30-1.76	1.53
TOTAL KJELDAHL NITROGEN	4.95	4.07-5.83	4.79
TURBIDITY			
HIGH	5.00	4.26-5.62	5.05
LOW	1.05	0.81-1.29	1.05

Table 4. Results of the semi-annual interlaboratory testing program (February, 1991) of the U.S. Geological Survey performed by SUNY Brockport. The USGS Rating is as follows: 0 (poor), 1 (questionable), 2 (satisfactory), 3 (good), 4 (excellent). The reference samples analysed were titled "Nutrients" and "Major Constituents".

Parameter	Reported	Most Probable Value	USGS Rating
Calcium	45.9	41.2	0
Potassium	5.06	4.90	4
Magnesium	9.10	9.7	2
Sodium	58.2	64.3	0
Total Phosphorus	0.190	0.190	4
Specific Conductance	1466	1477	4
Soluble Reactive Phosphorus	0.150	0.152	4
pH	2.75	2.74	4
Sulfate	24.4	25.0	4
Alkalinity	37	38.0	4
Chloride	199	208	2
Total Kjeldahl nitrogen	0.100	0.254	3
Nitrate	0.32	0.34	4

RESULTS AND DISCUSSION

Crayfish As Biological Control Agents of "Weeds"

Aquatic macrophytes are both a nuisance and benefit to an ecosystem (Nichols 1986). A macrophyte crop with a diverse species assemblage is an important stabilizing condition in aquatic ecosystems providing cover for fish, a constant oxygen supply, and food for select aquatic animals (Forest 1986, Moore 1987). Yet excess aquatic macrophytes are also considered to have a detrimental effect on water quality standards, impede recreation, and cause concern to municipal water users (Peverly and Johnson 1987).

Mechanisms for the control of aquatic macrophytes include water level manipulations, use of harvesters, herbicides, dragging, floating platforms to reduce light, sediment covers (Moore 1987), and biological controls (Peverly and Johnson 1987, Seagrave 1988, Leslie 1987); biological controls include insects, snails, mammals, fish and invertebrate such as crawfish (Peverly and Johnson 1987).

Crawfish are considered an omnivorous animal (Groves 1985; Crocker and Barr 1968; Pennak 1953; Chidester 1912) but do show a preference for submerged aquatic plants (Dean 1969; Tack 1941; Flint and Goldman 1975, Seagrave 1988), suggesting that these organisms could be viable controlling agents for submerged aquatic macrophytes. Dean (1969) observed that macrophytes were controlled when high densities of the crawfish *Orconectes causeyi* occurred. Similarly, Flint and Goldman (1975) have shown that the crawfish *Pacifastacus leniusculus* do graze on certain macrophytes. These results suggest that crawfish, in sufficient numbers, may control submerged aquatic macrophytes.

Crayfish are present in Conesus Lake, but local residents report that abundance has diminished since the 60s'. Based on these reports and the scientific literature, there was justification to evaluate whether addition of crayfish would be a solution to current "weed" problems in Conesus Lake.

The northern end of Conesus Lake was the site selected for an inclusion-exclusion experiment to determine the effectiveness of the crawfish *Orconectes immunis* as a submerged aquatic macrophyte grazer. The macrophytes prevalent in Conesus Lake, *Chara, Ceratophyllum, Elodea, Heterantera, Myriophyllum* and various *Potamogeton* spp., are some of the same species preferred by crawfish (Forest 1977; Dean 1969).

The research reported here experimentally evaluated the ability of the crawfish *Orconectes immunis* to graze submerged aquatic macrophytes. Two questions were addressed:

1) At what density do the crawfish need to be stocked to control macrophytes; and
2) At what time should crawfish be placed into the ecosystem for maximum control.

Discussion: Crayfish significantly decreased macrophyte biomass in all experiments. Crayfish levels of 140-150 g/m^2 or higher significantly decreased macrophyte biomass in both the Pre-established and the Continous experiments (Table 5 and 6). It took a level of 240-250 g crayfish/m^2 to significantly reduce an established macrophyte bed (Table 7). The rate of crayfish grazing, in cages where significant decreases in macrophyte biomass occurred, averaged 0.012 g of macrophytes consumed/crawfish/m^2/day.

Throughout the study period, crawfish survival averaged 88% (range=85-90%), with an average increase in weight and length of 1.4 g/crawfish and 0.5 cm/crawfish, respectively. As would be expected, lowest weight gain in crawfish biomass occurred at the highest stocking densities. Water quality was not significantly different between cages and the lake.

Table 5. Results of crawfish grazing on macrophytes in the pre-established experiment. Level I = 40-48 g of crawfish/m^2; Level II = 140-150 g of crawfish/m^2; Level III = 240-250 g of crawfish/m^2; Control has no crawfish; Lake refers to macrophytes biomass in the lake outside of the cages.

	Macrophyte Biomass (ash-free weight in g/m^2)	
REP 1	REP 2	REP 3
38.19	22.22	14.41
6.61	3.16	30.40
0.00	0.00	0.00
0.00	0.00	0.00
9.45	37.03	48.92

* Significantly different amounts of macrophytes compared to controls at $P=.05$, one-tailed t-test.

Biological control of macrophytes is possible when crawfish levels are at least 240 g/m^2, in a well established macrophyte community, and 140 g/m^2 in a pre-established early summer macrophyte community. Flint and Goldman (1975) reported a much lower level of crawfish biomass (69 g/m^2) as a minimum to reduce macrophyte biomass by *Pacifastacus leniusculus* in Lake Tahoe. Lake Tahoe is an oligotrophic lake while Conesus is mesotrophic. Thus, this difference in ability to graze macrophytes may be due to enhanced growth of macrophytes in a mesotrophic lake and the presence of a larger crawfish in Lake Tahoe than the ones used in this experiment. A crawfish biomass value of 140 g/m^2 in Conesus Lake corresponds to 88 crawfish/m^2 or about 880,000 crawfish/ha or (356,275 crawfish/acre).

Table 6. Results of crawfish grazing on macrophytes in the continuous experiment. Level II = 140-150 g of crawfish/m^2; Control has no crawfish; Lake refers to macrophytes biomass in the lake outside of the cages.

	Macrophyte Biomass (ash-free weight in g/m^2)		
	REP 1	REP 2	REP 3
CONTROL	36.21	36.63	49.19
LEVEL II*	0.00	0.00	0.00
LAKE	44.56	27.74	64.77

* Significantly different amounts of macrophytes compared to controls at P=.05, one-tailed t-test.

Table 7. Result of crawfish grazing on macrophytes in the post-established experiment. Level I = 40-48 g of crawfish/m^2; Level II = 140-150 g of crawfish/m^2; Level III = 240-250 g of crawfish/m^2; Control has no crawfish; Lake refers to macrophytes biomass in the lake outside of the cages.

	Macrophyte Biomass (ash-free weight in g/m^2)		
	REP 1	REP 2	REP 3
CONTROL	59.67	59.60	46.73
LEVEL I	75.14	39.69	72.16
LEVEL II	5.20	60.25	46.41
LEVEL III*	20.27	13.38	31.13
LAKE	70.78	46.24	49.66

* Significantly different amounts of macrophytes compared to controls at P=.05, one-tailed t-test.

Peverly and Johnson (1987) estimated that 1000 crawfish/acre are required to disrupt growth throughout a growing season in a predator free environment, which is considerably less than the 360,000 crawfish/acre required to provide total elimination of macrophytes in three weeks in Conesus Lake. Using the crawfish grazing rate observed in this study for 1000 crawfish/acre, a 25, 50 and 100% reduction in macrophyte biomass would occur in 2104, 4208, and 8417 days, respectively. Obviously, total reduction of macrophytes using this species is not possible within a growing season at 1000 crawfish/acre. The effect of changing the numbers of crawfish is inversely proportional to the number of days to achieve a certain level of reduction on any grazing area (Fig. 3). Therefore, the choice of reduction amount and area of grazing are important considerations prior to crawfish introduction.

When should the crawfish be placed in the ecosystem for maximum effect? The experimental results suggest control is achieved with less crawfish when the macrophytes are not well established; that is, early in the growing season. However, elimination of macrophytes early in the growing season will remove cover for the crawfish and potentially make them susceptible to predation. Any removal of the crawfish by predation would decrease their ability to control macrophytes and hinder further control in subsequent years.

One of the most researched, and promising, of the biological controls of weed masses is that of the grass carp (*Ctenopharyngodon idella*). The grass carp, a native of the river systems of Asia, is a highly effective grazer of submerged aquatic macrophytes (Bauer and Willis 1990; Lembi *et al.* 1978; Leslie *et al.* 1983; Woltman and Goetke 1985;). It has been shown that the stocking of 15-25 grass carp per metric ton of macrophytes resulted in complete elimination of macrophytes in less than one year (Leslie *et al.* 1987). Leslie *et al.*(1987) also suggests that a stocking rate of 2 grass carp per metric ton of macrophytes would control macrophytes if macrophytes are reduced prior to the introduction of the carp by other methods of control.

Nevertheless, there are advantages of using crawfish over the grass carp. Advantages include: 1) an exotic species would not be introduced into the lake ecosystem, 2) the non-selective nature of the crawfish to a plant diet while the grass carp exhibits selectivity of plants, 3) the crawfish may not have the side effects on the ecosystem that the grass carp has, such as increases in turbidity and nutrients, and 4) the crawfish could provide a food source for a number of other species, not just large predators as is the case for the grass carp.

There are also disadvantages of using the crawfish over the grass carp. Disadvantages include: 1) the amount of crawfish needed to control macrophytes compared to estimates of 15-40 grass carp/acre (Woltman and Goetke 1985), 2) the more crawfish the greater the cost of procurement, 3) the potential for predation on the crawfish due to high densities, and 4) low biomasses of crawfish may enhance the growth of the macrophytes.

At the densities required to reduce macrophyte biomass, the initial cost of crawfish is high. The cost for 1000 crawfish is $65, while the cost for 50,000 would be $2750. However, it may be feasible to utilize crawfish for the purpose of macrophyte control because no other cost is associated with their use and it may only take the initial introduction for years of macrophyte control. This is unlike other controls that require regular maintenance, as is the case with mechanical harvesters and periodic application of herbicides.

The research completed suggests crawfish may be an effective biological control of macrophytes. However, during the study period, crawfish were protected from their predators (fish, birds, mammals and man). Further experimental work may be warranted to evaluate crawfish introduction over larger areas and with no protection from predators. Long-term studies would determine if larger populations of crawfish could be sustained and what their effects on macrophytes would be.

Why are crawfish not found in Conesus Lake in sufficient numbers to provide some macrophyte control? Anecdotal evidence from local people suggest that crawfish were present in large numbers in Conesus Lake in the past. At present, we have no suggestion as to cause for this apparent decrease in crawfish abundance in Conesus Lake. Possible reasons for a decrease include increased predation and loss of habitat. However, a major predator in the lake, the walleye, has decreased in recent years (Puckett 1989). Similarly, the luxuriant macrophte growth would suggest considerable cover from predators.

STATUS OF CONESUS LAKE

Conesus is rated as a Class AA lake (NYSDEC 1987) and has had a reputation as being an excellent walleye and jack (yellow) perch fishery. The New York State Department of Environmental Conservation (DEC) has managed four game fish within its waters: northern pike (*Esox lucius*); largemouth bass (*Micropterus salmoides*); rainbow trout (*Salmo gairdnerii*); and walleye (*Stizostedion vitreum vitreum*) (Abraham 1975). During the early 1970's, complaints that the walleye fishery had collapsed prompted DEC to estimate walleye abundance. Results confirmed that walleye had decreased in numbers, from a 1966 estimate of 12,000 individuals down to a 1975 estimate of 9614 (Abraham 1975). By 1986, the walleye population had dropped to 1850 (Abraham 1986).

Reasons have been sought for the walleye decline. One suggestion is that Rebel and Rapala lures in the late 1960's led to overfishing. Lack of a suitable spawning habitat due to human activities (additional shoreline construction) and/or lack of mature egg-laying females may also have been causes for the collapse of the fishery. While a one year class failure of a piscivore can be alarming, several consecutive year class failures can have a devastating effect upon the fishery.

The decline of the walleye played a role in the proliferation of an obligate planktivore in Conesus Lake. During the late 1970's, *Alosa pseudoharengus*, commonly known as a sawbelly or alewife (Scott and Crossman 1973), was introduced into the lake. With fewer top level predators, like the walleye, the alewife was able to populate the lake. Anglers reported that alewife were caught during the 1983 ice fishing season. By the spring of 1984 an alewife die-off occurred and fall gill netting revealed alewife cohorts from 1981, 1982 and 1983. These fish were large and robust (49-135 gm) (Abraham 1988).

Intense predation by alewives (*A. pseudoharengus* and *A. aestivalis*), yellow perch (*Perca flavescens*), and bloaters (*Coregoni hoyi*) is known to alter the next lower trophic level by decreasing the abundance of large size (1.0 mm or greater) zooplankton thereby allowing an increase in the numbers of small size (less than 1.0 mm) zooplankton (Brooks and Dodson 1965; Brooks 1968; Morsell and Norden 1968; Wells 1970; Evans and Jude 1986). Loss of the larger herbivorous zooplankton allows algae (Lynch and Shapiro 1981; Elser et al. 1988), chlorophyll a (Andersson et al. 1978), and turbidity (Elliott et al. 1983) to increase.

Turbidity has been recorded daily at the water treatment plants along Conesus Lake shores. Since the late 1970's, turbidity levels at the Avon water treatment plant have gradually risen from a 1977 mean of 0.85 NTU to a mean of 1.5 NTU in 1988 (Fig. 4). A study, done by Makarewicz (1986) reported that Conesus Lake had significant increases in turbidity ($P < 0.001$) since the introduction of the alewife. The Makarewicz (1986) study also confirmed the loss of a large (> 1.0 mm) and efficient herbivorous zooplankton, *Daphnia pulex*. Historically, *D. pulex* had been dominant in Conesus Lake since 1910. *D. pulex* made up 87% of the biomass of the zooplankton and had been collected on every sampling day between June 1972 and August 1973 (Chamberlain 1975). As recent as 1983, *D. pulex* (mean length of 1.3 mm and 22.6 individuals/liter) was observed in Conesus Lake (Abraham 1988). Thereafter, no *D. pulex* were collected.

By 1985, Conesus Lake was experiencing low piscivore abundance and high planktivore numbers. Ninety percent of the fish gill netted in 1985 by DEC were planktivores (Fig. 5). Attempts to increase piscivore mass were begun when DEC stocked 15.9 million walleye sac fry per year in the early 1980's; in 1985, they began stocking 3-5 cm walleye fingerlings at a rate of 65,000 per year. By increasing the biomass at the top trophic level (stocking of 65,000 walleye fingerlings), the planktivores should decrease in biomass, zooplankton should increase in biomass, algal biomass would decrease and result in lower chlorophyll *a* and turbidity readings (Carpenter *et al.* 1985). Has the stocking of these 3-5 cm fingerlings helped improve the Conesus Lake water quality and has it helped increase the biomass of the zooplankton community?

Results

Water Chemistry A historical summary of water chemistry is presented in Table 8. Conductivity, Na^+ and Cl^- have increased since the 60's due to the heavy usage of deicing salt in this region during the winter and spring (Makarewicz 1986). Total phosphorus has not changed significantly from 1969 to 1988 (Table 9). Epilimnetic soluble reactive phosphorus was not significantly different from 1972-73 to 1985 but increased significantly from 1985 to 1988 (Table 9). Turbidity has steadily increased from 1984 to 1988 after eight years of no significant change (Fig. 4).

Chlorophyll Chlorophyll *a* in 1973 and 1985 was not significantly different (Table 9). The increase in chlorophyll from 1985 to 1988 occurred in the spring and early summer (Fig. 6).

Zooplankton Rotifer abundance in 1988 was twice the 1985 density (Table 10). Also, the number of rotifer species observed increased to 22 in 1988 with the addition of at least six new species: *Lecane* spp., *Brachionus* spp., *Collotheca* spp., *Ploesoma* spp., *Polyarthra euryptera* and *Hexarthra mira.* One species observed in 1985, *Keratella crassa,* was not observed in 1988. Relative abundance changed dramatically from 1985 to 1988. The five most abundant rotifers in 1988 were: *Polyarthra major* increasing ten-fold since 1985; *Keratella cochlearis* increasing seven-fold; *Synchaeta* sp. increasing twelve-fold; *Polyarthra vulgaris* increasing eight-fold; and *Ploesoma sp.* increasing 100% from 1985 (Table 10). The 1985 rank order was *Conochilus unicornis, Kellicottia longispina, Kellicottia bostonensis*, *Asplanchna priodonta,* and *Keratella quadrata* (Table 10).

As in 1985, the dominant cladoceran in 1988 continued to be *Bosmina longirostris*. However, average abundance increased from 32.6 individuals/L in 1985 to 133.4 individuals/L in 1988. *Ceriodaphnia reticulata* displaced *Daphnia retrocurva* as the codominant Cladocera, increasing fourteen-fold since 1985. While increasing in abundance, these codominants decreased in size from 1985 (*B. longirostris* = 0.32 mm; *C. reticulata* = 0.39 mm) to 1988 (*B. longirostris* = 0.26 mm; *C. reticulata* = 0.32 mm). Only twelve *Daphnia*,(*D. retrocurva* or *D. galeata mendotae*), were captured during the 1988 sampling period representing only 0.08% of the zooplankton abundance compared to 1.27% in 1985. Chydorids, not observed in 1985, were the third most important Cladocera group in 1988.

Three major shifts occurred within the Copepoda of Conesus Lake from 1985 to 1988: 1) the calanoid copepod *Diaptomus* disappeared from the lake; 2) the relative abundance of *Cyclops bicuspidatus thomasi* decreased from 12.3% of the crustacean abundance in 1985 to 0.20% in 1988; and 3) four new cyclopoid species, two pelagic species (*Cyclops vernalis, Tropocyclops prasinus mexicanus*) and two littoral species

(*Eucyclops agilis* and *Macrocyclops albidus*) appeared in the pelagic zone. *E. agilis* was observed in mid-June, mid-July and September, while *M. albidus* appeared in early October. Abundance of *E. agilis* and *M. albidus* was low (Table 10).

Table 8. Historical summary of chemical and physical parameters for Conesus Lake. N.D. = not detectable. The 1973 nitrate-N measurements are integrated samples from the upper 10 meters while the remaining 1973 parameters were taken from surface and bottom samples on 22 April, 17 July and 28 August. The 1985 sampling period was for one year. Samples of 1988 were collected 1 May through 31 October. Values are mg/L unless noted otherwise.

Year		pH	Conduct-ivity µmhos/cm	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Trans-parency (m)	CL^{-}	SO$_4^{--}$	NO$_3^{-}$-N	Alkali-inity
1910[1]								6.3	11.3		100	
Before 1963[2]		7.7	309	40	11	9.4		6.4	13	31	0.239	108.2
1971[3]	epilimnion	8.4		44					27.1		0.051	99.8
	hypolimnion	7.7		53					27.4		0.008	107.9
1972[4]		8.1	339					4.7			0.02-0.04	118
1973[5]		8.2	330	41	13.2	12.2	2.6	3.5	29.4	27.8	0.046-0.145	118
1985	epilimnion	8.1	369	39	12	17	2.6	3.1	29.2	24.4	N.D.-0.040	117.0
	metalimnion	8.0	372	39	12	17	2.6		29.1	24.7	N.D.-0.069	117.5
	hypolimnion	7.9	377	40	12	17	2.6		29.0	25.2	N.D.-0.062	121.0
1988	epilimnion	8.4	381	33	11.2	16.7	2.2	3.1	30.2	23.7	N.D.- .09	113.4
	metalimnion	8.2	381	35	11.5	16.3	2.1		30.9	23.2	N.D.- .09	116.8
	hypolimnion	7.7	392	36	11.3	15.9	2.1		30.2	22.7	N.D.- .06	124.4

[1] Birge and Juday(1914)
[2] Berg(1966)
[3] Forest et al (1978)
[4] USEPA (1974)
[5] Mills (1975)

Fish

Gill netting of 1988 sports fish revealed a 30% increase in yellow perch, an 8% increase in walleye, a 3% increase in small mouth bass, a 41% decrease in alewife and no change for pike since 1985 (Table 11, Fig. 5). Alewifes were the most abundant species collected in 1985 but were surpassed by yellow perch and walleye in 1988 (Table 11). The planktivores comprise 78% of the 1988 gill net catch compared to 90% in 1985. Alewife weighed between 16-40 grams in 1988 compared to weights of 32-119 grams in 1985 (Abraham 1988). Yellow perch were predominantly of two sizes, 160-179 mm and 260-279 mm, and were healthy individuals. Several jack perch were netted. Walleye, jack perch and pike exuded alewife from their stomachs.

Table 9. Summary of selected biological and chemical data from 1972, 1985 and 1988, Conesus Lake. Data represent the May through October period, unless stated otherwise.

	1972	1985	1988
Mean Zooplankton Biomass (mg/m^3)			
Crustacea	228[a]	182	99
Cyclopoida	52	113	15
Calanoida	30	7	0
Cladocera	146	62	84
Daphnia spp.	87	23	3
Mean Zooplankton Length (mm)			
Crustacea	1.03	0.52	0.29
All zooplankton (including rotifers)	0.60	0.23	0.18
Phytoplankton (ug/L)			
Chlorophyll *a*	3.4[c]	3.8[d]	7.3[d]
Chemistry (ug/L)			
Total phosphorus	23[e]	26.5	23.5
Soluble reactive phosphorus	4.4[b]	5.8[d]	13.5[d]

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[a] The 1972-73 biomass estimates represent the weighted mean for June through October of 1972 and for May through August of 1973. The 1972-73 zooplankton data were not corrected for net efficiency. We applied a net efficiency of 77.3% to the 1972-73 data based on our 1985 data. Because a 150um mesh net was used in 1972 (80um net in 1973), the 1972-73 biomass estimates are believed to be conservative (graphical accuracy, Chamberlain 1975). Copepod nauplii are not included in the biomass estimates.

[b] 1972 data of Oglesby *et al* (1978). Data represent the stratification period: May 31 to September 26.

[c] 1972 data of Mills (1975). Data represent the stratification period: May 31 to September 26.

[d] Means are for the period May 25 to September 31.

[e] 1969 data of Stewart and Markello (1974). Graphical accuracy for the May through October period.

Table 10. Rank abundance within each taxonomic group for Conesus Lake zooplankton, May-October 1985 and May-October 1988. N.O.= not observed.

1985			1988		
	#/Liter	Percent		#/Liter	Percent
CLADOCERA			**CLADOCERA**		
Bosmina longirostris	32.6	4.57	*Bosmina longirostris*	133.4	9.19
Daphnia retrocurva	7.5	1.06	*Ceriodaphnia reticulata*	27.0	1.86
Eubosmina coregoni	3.8	0.53	*Chydoridae*	1.3	0.09
Diaphanosoma birgei	2.5	0.36	*Diaphanosoma birgei*	.5	0.04
D. galeata mendotae	1.5	0.21	*Daphnia retrocurva*	.5	0.04
Ceriodaphnia reticulata	1.8	0.26	*D. galeata mendotae*	.5	0.04
Chydoridae	N.O.	N.O.	*Eubosmina coregoni*	.5	0.04
	49.9	7.00		163.8	11.29
EUCOPEPODA			**EUCOPEPODA**		
Copepoda nauplii	51.1	7.17	*Copepoda* nauplii	37.5	2.58
C. bicuspidatus thomasi	17.8	2.50	*Cyclopoid*-copepodite	5.0	0.35
Cyclopoid-copepodite	13.4	1.88	*Mesocyclops edax*	3.5	0.25
Mesocyclops edax	12.9	1.82	*Cyclops vernalis*	1.1	0.08
Diaptomus pallidus	1.5	0.22	*T. prasinus mexicanus*	1.1	0.08
Cyclops vernalis	N.O.	N.O.	*C. bicuspidatus thomasi*	.4	0.03
Eucyclops agilis	N.O.	N.O.	*Macrocyclops albidus*	.2	0.02
T. prasinus mexicanus	N.O.	N.O.	*Eucyclops agilis*	.1	0.01
Macrocyclops albidus	N.O.	N.O.	*Diaptomus pallidus*	N.O.	N.O.
	97.1	13.59		49.1	3.39
ROTIFERA			**ROTIFERA**		
Conochilus unicornis	108.7	15.24	*Polyarthra major*	233.3	16.07
Kellicottia longispina	83.4	11.69	*Keratella cochlearis*	174.5	12.02
Kellicottia bostoniensis	79.2	11.10	*Synchaeta sp.*	151.9	10.47
Asplanchna priodonta	63.7	8.92	*Polyarthra vulgaris*	128.4	8.85
Keratella quadrata	53.8	7.55	*Ploesoma sp.*	105.4	7.26
Polyarthra dolichoptera	31.7	4.44	*Conochilus unicornis*	102.5	7.06
Pompholyx sp.	27.5	3.88	*Polyarthra remata*	94.6	6.52
Polyarthra major	24.6	3.45	*Hexarthra mira*	83.5	5.76
Keratella cochlearis	23.7	3.32	*Polyarthra euryptera*	38.7	2.67
Polyarthra vulgaris	16.3	2.30	*Polyarthra dolichoptera*	28.9	1.99
Polyarthra remata	13.9	1.95	*Keratella quadrata*	19.8	1.37
Synchaeta sp.	12.8	1.80	*Kellicottia bostoniensis*	16.4	1.13
Keratella crassa	9.0	1.26	*Trichocerca multicrinis*	12.2	0.84
Trichocerca multicrinis	6.6	0.93	*Ascomorpha sp.*	11.6	0.80
Keratella hiemalis	6.1	0.85	*Collotheca sp.*	10.3	0.71
Ascomorpha sp.	4.4	0.63	*Pompholyx sp.*	6.7	0.47
Notholca acuminata	.6	0.10	*Keratella hiemalis*	5.8	0.40
Brachionus sp.	N.O.	N.O.	*Asplanchna priodonta*	4.3	0.30
Collotheca sp.	N.O.	N.O.	*Kellicottia longispina*	3.4	0.24
Ploesoma sp.	N.O.	N.O.	*Notholca acuminata*	1.0	0.07
Polyarthra euryptera	N.O.	N.O.	*Brachionus sp.*	.9	0.07
Hexarthra mira	N.O.	N.O.	*Lecane sp.*	.3	0.02
Lecane sp.	N.O.	N.O.	*Keratella crassa*	N.O.	N.O.
	566.8	79.41		1235.3	85.10
Ostracoda	N.O.	N.O.	*Ostracoda*	3.1	0.22

Table 11. Catch per lift (CPL) in experimental gill nets fished in Conesus Lake during 1985 and 1988. ** Significantly different at P<0.05. * Significantly different at P<0.10.

Species	1985	1988
Alewife (*Alosa pseudoharengus*)	45.1	7.3**
Yellow perch (*Perca flavescens*)	33.1	45.4
White sucker (*Catastomus commersoni*)	4.9	4.4
Walleye (*Stizostediom vitreum vitreum*)	3.3	7.8*
Smallmouth bass (*Micropterus dolomieui*)	3.6	5.0
Rock bass (*Ambloplites rupestris*)	3.9	3.1
Pumpkinseed (*Lepomis gibbosus*)	3.3	3.6
Brown bullhead (*Ictalurus nebulous*)	2.6	3.9
Carp (*Cyprinus carpio*)	1.7	0.9
Northern pike (*Esox lucius*)	1.0	1.1
Bluegill (*Lepomis macrochirus*)	0.9	0.3

DISCUSSION

Fish Abundance of a top level predator, the walleye (Stizostedion vitreum vitreum), decreased from a high of 12,000 individuals in 1966, to 9,614 individuals in 1975, to 1,850 individuals by 1985 in Conesus Lake (Abraham 1989). Lack of suitable spawning habitat due to shoreline construction, overfishing and consequently, the lack of mature egg-laying females are possible causes for the collapse of the fishery (Abraham 1989). Coincidental with the decline of the walleye in Conesus Lake was the proliferation of an obligate planktivore, *Alosa pseudoharengus* (Abraham 1988). During the late 1970's (probably 1978 or 79), the alewife was accidentally introduced and became established in the lake. The first alewife die-off occurred in the spring of 1984. These fish were large and robust (49-135 gm) and similar in weight to the 1985 fish (32-119 gm).

The decrease in alewife relative abundance and weight observed by 1988 may be related to availability of food and/or vulnerability to the sampling gear. The mean length (1988 - 0.26mm) of the dominant *B. longirostris* in Conesus Lake, may be the minimum size that a 130 mm alewife (the 1988 mean length of alewife in Conesus Lake) can capture (MacNeill 1989). Stomach analyses of Conesus' alewife support this idea. Even though *B. longirostris* and Copepoda nauplii represented 82% of the crustacean abundance in the water column, alewife were selectively feeding on large *Mesocyclops edax* (99% of the identifiable stomach contents and only 0.25% of the total zooplankton abundance).

Abraham (1989) suggests the decrease in relative abundance of the alewife is apparent and not real and due to bias in the sampling gear. The condition factor (k) (Everhart and Youngs 1981), a measure of plumpness of a fish, was significantly lower in 1988 (0.60) than 1985 (1.05). In addition, most alewife were captured in the smallest mesh

(1.5") in the 1988 sampling; whereas in the 1985 netting, alewives were caught in both the 1.5" and 2.0" mesh net suggesting that the slender 1988 alewives may not have been caught in the smallest mesh gill net in 1988.

Zooplankton The 1985 and 1988 (post-alewife introduction) zooplankton species composition represents a significant change since 1973 (pre-alewife). In 1973 Chamberlain (1975) described Conesus Lake as dominated by *Daphnia pulex*, *Conochilus unicornis* and *Cyclops bicuspidatus*. The overwhelming dominance of *D. pulex* in 1973 is impressive. It was the dominant cladoceran (numerical basis) on each of the 50 sampling days throughout the year. Abundances reached as high as 36 individuals/L in the summer and 13 individuals/L in December. As a result of the introduction of the alewife into Conesus Lake in 1978-79, the cladoceran community changed and was dominated by the small *Bosmina longirostris* by 1985. *Daphnia retrocurva* was the second most important Cladocera while *D. galeata mendotae* was somewhat rare in 1985 (Table 10): the last *D. pulex* being observed in 1983 (Table 12). *Cyclops bicuspidatus* and *Conochilus unicornis* were the dominant Copepoda and Rotifera in 1985, as in 1973.

With continued size-selective feeding by the alewife, further changes in the zooplankton community were observed by 1988. *B. longirostris* and *Ceriodaphnia reticulata* were codominant in 1988, while the 1985 codominant *D. retrocurva* was rare in 1988 (Table 10). As in 1985, *D. pulex* was not present in the lake. A large Copepoda, *Diaptomus pallidus* (length = ~1 mm), present in 1985 but with a reduced abundance compared to 1973, was completely eliminated by 1988 - nine years after the introduction of alewife. Similarly, abundance and size of *Cyclops bicuspidatus thomasi* decreased from 1985 (12.3% of the Crustacea abundance; mean length of 0.92 mm) to 1988 (0.20% of the

Crustacea abundance; mean length of 0.72 mm) (Table 9). Wells (1970) reported similar losses of the largest cladocerans, calanoids and the largest cyclopoid copepod (*M. edax*) from the waters of southeastern Lake Michigan when alewifes increased.

In general, weighted mean length of the Crustacea progressively decreased from 1.03 mm in 1972 (pre-alewife) to 0.52 mm in 1985 down to 0.29 mm in 1988 (Table 9). Even the dominant and small crustacaean *Bosmina longirostris* decreased in average size (0.32 mm in 1985 to 0.26 mm in 1988). By 1988, 98% of the crustacean community was less than 0.35 mm in length (Fig. 7). Conesus Lake is a classic example of size-selective predation by planktivorous fish that has resulted in a shift in prey composition to smaller zooplankton. Many experimental and field studies have documented similar size-related effects on zooplankton community structure (See McQueen *et al* 1989 for a review).

The increase in abundance of rotifers (Table 10) in Conesus Lake is consistent with both the indirect and direct evidence that suggests that rotifers are more prevalent in the absence of exploitative and interference competition from *Daphnia* (Gilbert 1988). Similarly, the increase in ambient soluble reactive phosphorus (Table 9) appears to be a size-related consequence. Since the excretion of phosphorus by zooplankton is inversely proportional to body size (Peters 1975), a reduction in average size of the zooplankton community induced by size-selective predation may influence community excretion rates. Henry (1985) tested this hypothesis and experimentally demonstrated that phosphorus release rates were higher in zooplankton communities dominated by smaller zooplankton than those dominated by larger ones. Similarly in Conesus Lake, the increase in SRP from 1972 to 1985 to 1988 was associated with a decrease in zooplankton body size (Table 9).

Trophic Interactions Various classification schemes indicate that Conesus Lake is a eutrophic lake (Mills 1975). Even so, chlorophyll levels prior to the introduction of alewife (1978-79) were much lower than those expected, based on ambient winter total phosphorus concentrations. Oglesby and Schaffner's (1978) regression model (Chl = 0.574 [T] - 2.90), $r^2 = 0.82$, where T = winter total phosphorus levels) derived from data on 16 Finger Lakes of New York, including Conesus Lake, predicted summer chlorophyll levels 29% higher (7.2 mg/m^3) than observed (5.6 mg/m^3) in 1973. The lower chlorophyll levels were apparently maintained by the presence and dominance (biomass) of the large-bodied Cladocera, *Daphnia pulex* (Forest *et al.* 1978). The abundant population of *D. pulex* prior to 1978 was maintained by low size-selective predation pressure from planktivores (mostly yellow perch). By 1988, when *Daphnia* was essentially nonexistent after 8 to 10 years of alewife predation, the actual summer chlorophyll level was 7.3 mg/m^3 comparable to the 7.2 mg/m^3 predicted by the Oglesby/Schaffner model further suggesting that zooplankton, perhaps *Daphnia*, was controlling chlorophyll levels.

Table 12. Abundance of *Daphnia pulex* in Conesus Lake from 1982 to 1988. Values are in #/L.

1982 (May)	1983 (August)	1984 (August)	1985 (May-Oct.)	1988 (May-Oct.)
21.1	22.6	0	0	0

Soluble reactive phosphorus (SRP) is higher throughout the summer of 1988 compared to 1985 (Fig. 8) and possibly is the cause of the higher chlorophyll observed in 1988. If elevated SRP was the cause of the higher chlorophyll, we would expect a high, relatively constant chlorophyll throughout the summer reflecting the high constant SRP; if zooplankton grazing was not a factor. This is not what was observed. Even though SRP was high and constant, chlorophyll varied, being higher in May and June of 1988 compared to the rest of the year and compared to June and July of 1985.

The lower chlorophyll in late June of 1988 was associated with a bloom of *Bosmina longirostris* (Fig. 9), while the high chlorophyll observed in May and June of 1988 was inversely correlated with total zooplankton biomass (Fig. 9). During May and June of 1985, when chlorophyll was low, total zooplankton biomass was high (Fig. 9). The major difference in zooplankton biomass between the 1985 and 1988 period was a >98% decrease in the biomass of *Cyclops bicuspidatus thomasi* and all *Daphnia* species by 1988. These results suggest that the high chlorophyll levels observed in June and July of 1988 are due to the disappearance of *Daphnia* and *C. bicuspidatus thomasi*. *Daphnia* is an efficient filter feeder, while *C. bicuspidatus thomasi* is a raptorial feeder generally associated with predation on zooplankton (McQueen 1969) but is omnivorous. For example, McNaught (1980) observed *Cyclops bicuspidatus thomasi* to have a high assimilation efficiency of nannoplankton and net plankton in Lake Huron.

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The Top-down:Bottom-up model predicts that in a eutrophic lake with an established population of a large-bodied zooplankton, such as *Daphnia pulex*, decimation of the large-bodied cladoceran by size-selective feeding of a planktivore should result in an increase in phytoplankton biomass. The Conesus Lake data support this corollary of the TD:BU model (Table 9). However, the data from Conesus Lake, do not rule out the possibility that the lower biomass of a cyclopoid during June and July led to increased chlorophyll levels. Similarly, McNaught (1980) concluded that immature stages of copepods were the most effective grazers in Lake Huron, including nauplii and calanoid and cyclopoid copepods.

With decreasing intersummer zooplankton biomass, there was an increase in summer chlorophyll *a* concentrations; that is, a negative correlation (r=-0.98 , n=3) existed between the intersummer chlorophyll and zooplankton biomass. Admittedly, more interannual data points are desirable. However, the similarity in summer total phosphorus concentration between years (Table 9) suggests the changes in chlorophyll observed are not due to bottom-up effects. Together these results suggest that trophic level biomass at the primary producer level can and is controlled by a top-down effect under the conditions described for Conesus Lake. These data are consistent with predictions made by the top down:bottom-up model, and the implication is that in Conesus Lake, the trophic cascade does not uncouple or is not dampened out at the zooplankton - phytoplankton link.

BIOMANIPULATION

What is evident is that the walleye introduction to Conesus Lake has not had an effect on zooplankton, phytoplankton and turbidity as expected. In fact, turbidity has increased since 1985. However, the reason for this of lack of success of the biological control is rather straight forward. There have been difficulties in the restocking program of walleyes. Thus predator control of alewifes has not had ample time to work in Conesus Lake.

Attempts at biomanipulation in Conesus Lake have been frustrating. Walleye sac fry have been planted at a density of 5000 per acre since the early 1980's, but they have not survived. A stocking program of 65,000 walleye fingerlings per year began in 1985, but a cage study that accompanied the 1988 stocking indicated there was an overall 81.2% cage mortality of fingerlings. Handling difficulties and shipping of the fingerlings seemed to overstress the fish (Abraham 1988). Thus, the walleye fingerlings that were stocked in Conesus Lake from 1985 through 1988 have not survived. Talks with other fishery managers revealed that stocking these small (3 - 5 cm) fingerlings have never created a fishery in New York State (Abraham 1988).

The two New York State lakes which have had successful stocking programs, Silver Lake and Canadarago Lake, were stocked with larger (8.9 - 15 cm) fingerlings (Abraham 1988). In August 1988, the entire state's allottment (7500) of 10.16 cm fin-clipped walleye fingerlings went into Conesus Lake. A caged study indicated there were no deaths of these larger walleye. This stocking appears to have the potential of increasing piscivore biomass within Conesus Lake.

Another problem that can affect biomanipulation are aquatic weeds (macrophytes). Macrophyte beds have expanded in the last seven years at Conesus Lake. Kerfoot (1974) contends that a standing crop of fry will increase in proportion to the development of littoral vegetation. Thus, the planktivorous fry and young-of-the-year have perfect conditions to hide from predators along Conesus Lake's shoreline.

Suggestions of further work and areas of investigation for Conesus Lake

1. Implement a moratorium on all walleye fishing for two years. This would help establish the 7500 (10.16 cm) walleye fingerlings stocked August 1988. With such a low food base now present in the lake for the alewifes, a die-off is likely and the newly stocked walleye would have a better chance to impede future alewife growth.
2. Sample Conesus Lake for water chemistry and the zooplankton community in 1991. DEC plans a gill net census of Conesus Lake every three years, which would be 1991.

BASELINE DATA ON MACROPHYTES (WEEDS)

The large number of samples taken from several locations will provide a good baseline for determining whether or not the "weed problem" is improving or getting worse. Macrophyte biomass ranged from 105 g/m^2 at "No Name" Creek at Cottonwood Point to a high of 338 g/m^2 at the "South End" of the lake (Table 13). In general, biomass was highest at the "South End" and at the "North End" of the lake. The high biomass of weeds at the "South End" of the lake probably reflects the high total input of nutrients from South and North McMillan Creeks and the Inlet. The high biomass at the "North End" of the Lake may reflect relatively high nutrient inputs from Hanna's and Wilkins Creek. The high plant biomass in McPherson's Cove and Long Point perhaps reflects the influence of nearby creeks (Fig. 10).

At least seventeen species of macrophytes were observed in Conesus Lake (See Fig. 11). The dominant plant, accounting for over 45% of the plant biomass at four of the six sites sampled, was *Myriophyllum* sp. This same species was the second most important macrophyte at "No Name" Creek (30% of the biomass) and at the "North End" (20% of the plant biomass) of the lake. At the "North End" of the lake, *Chara* sp. accounted for over 60% of the biomass, while at "No Name" Creek *Potamogeton* sp. represented nearly 50% of the plant biomass.

CONESUS LAKE TRIBUTARY DATA

Stream Height and Discharge

The relationship between stream height and cross-sectional area of the stream at a given stream height are presented in Fig. 12-15.

Based on the seasonal velocity measurements, the relationship between stream discharge and surface height (i.e. rating curve) is presented for each stream in Figures 16-19. The equations developed from the rating curves predicting discharge at each site are given in Table 14. Correlation coefficients (r^2), exceed 0.80 indicating a good fit of the actual discharge measurements to the fitted regression line; i.e, we are able to predict stream velocity with a fair degree of precision. The correlation between discharge at South McMillan and discharge at all other creeks was above 0.71 (r^2). This suggested that the use of South McMillan Creek as a base station for instantaneous measurements of discharge and their application to other creeks within the Conesus Lake watershed would be successful. Predictive equations for daily discharges of all Conesus Lake tributaries based on our continuous recording of stage height at South McMillan are presented in Table 15.

Table 13. Average biomass (dry weight) of macrophytes at selected sites in Conesus Lake.

	Number of Samples	Mean Biomass g/m^2	Standard Error
South End	27	338	47
North End	33	226	37.5
McPherson Cove	21	196	22.1
Long Point	18	156	14.1
McPherson Point	24	123	18.2
Cottonwood Creek	12	105	33.4

The mean daily discharge values (m^3/day) in descending order were North McMillan (45,297), South McMillan (36,389), Inlet (22,751), Hanna's (14,265), North Gully (7,768), Wilkens (5,836), Long Point Gully (5,761), Densmore (5,374), South Gully (3,817), "No Name" (2,892) and Sand Point (922) (Table 16 and 17). 69.2% of the water discharged into Conesus Lake is from three Creeks (North McMillan, South McMillan and the Inlet) located at the south end of the lake. As expected, seasonal discharge is variable but highest (76 to 87%) during the winter and spring (Fig. 20 and 21).

Table 14. Equations predicting discharge rates in Conesus Lake tributaries. D = Discharge (CFS), H = Height in inches (except South McMillan where H = feet). Height is the distance from the surface of the stream to a fixed stable point at the top of the culvert pipe or top of the bridge over the stream. With South McMillan, H = the actual depth of the stream in feet.

Densmore	$D = 338.51145 - 15.67578H + 0.18145H^2$
Hanna's	$D = 452.43671 - 4.98733H$
Inlet	$D = 82.70729 - 1.58561H + 0.00258H^2$
Long Point Gully	$D = 348.06749 - 4.09912H + 0.00172H^2$
No Name	$D = 21{,}227.62160 - 589.40420H + 4.09140H^2$
North Gully	$D = 808.47136 - 20.55887H + 0.13069H^2$
North McMillan	$D = 3665.94883 - 91.90387H + 0.57596H^2$
South Gully	$D = -229.13079 + 39.01106H - 1.65942H^2$
Sand Point Gully	$D = 954.32175 - 29.13339H + 0.22233H^2$
South McMillan	$D = 98.28480 - 280.83739H + 274.78542H^2 - 11.54605H^3 + 18.77287$
Wilkins	$D = 2{,}043.31813 - 49.566965H + 0.30064H^2$

Chemistry

General - The water chemistry of the streams draining sub-watersheds of Conesus Lake often reflects usage within that watershed and thus is instructive. Annual means for stream water chemistry data are presented in Tables 16 and 17. There are small differences, probably insignificant, between watersheds for some chemical and physical parameters, such as temperature, pH, potassium and perhaps dissolved oxygen. For other chemical parameters, such as alkalinity, magnesium, calcium and sulfate, the differences observed are often small and when they are large, probably reflect differences in soil conditions.

Table 15. Equations predicting daily discharge rates for Conesus Lake tributaries based on continuous discharges measured at South McMillan Creek. D = Discharge (Cubic Feet per Second - CFS), X = Discharge at South McMillan Creek in CFS.

Densmore	$D = 0.1539X - 0.1009$	$r^2 = 0.87$
Hanna's	$D = 0.3810X + 0.4696$	$r^2 = 0.83$
Inlet	$D = 0.5638X + 0.8913$	$r^2 = 0.88$
Long Point Gully	$D = 0.1466X + 0.3639$	$r^2 = 0.78$
No Name	$D = 0.000158X^2 + 0.03360X - 0.0987$	$r^2 = 0.81$
North Gully	$D = 0.2705X - 1.1139$	$r^2 = 0.74$
North McMillan	$D = 1.3386X - 1.6392$	$r^2 = 0.87$
South Gully	$D = 0.1156X - 0.1876$	$r^2 = 0.86$
Sand Point Gully	$D = 0.0296X - 0.0810$	$r^2 = 0.71$
Wilkin's	$D = 0.1523X - 0.1155$	$r^2 = 0.91$

Sodium, Chloride and Conductivity - Annual concentrations of sodium and chloride are significantly higher in Hanna's (53.1 mg Na/L, 86.9 mg Cl/L) and Wilkins Creeks (97.0 mg

Na/L, 158.1 mg Cl/L) compared to other streams in the watershed (mean = 19.0 mg Na/L, 36.2 mg Cl/L) (Fig. 22). These high concentrations reflect high use or poor storage of deicing salts within these watersheds. The cause of the high concentrations of sodium and chloride in Hanna's Creek was demonstrated back in 1985 (Makarewicz 1986) as due to poor storage of winter deicing salt at the New York State Department of Transportation garage located in this watershed. The high concentrations of salt in Wilkins Creek, a watershed with more miles of road, were due to deicing salt usage within the Town of Livonia (Fig. 23D) and/or poor storage of deing salt at the Livonia Town Garage. These two sources are undoubtedly contributing to the slow, but clear trend of increasing salt (Na and Cl) concentration in Conesus Lake (Table 17, Fig. 22). The high conductivity values, which are a measure of total ions, in part reflect the high sodium and chloride concentrations observed for these creeks.

Total Suspended Solids - Total suspended solids generally reflect the amount of materials being lost from a watershed. With more urban development of the watershed, the amount of materials lost from the watershed increased (Fig. 23A). More specifically, the streams draining the Wilkins and South McMillan watersheds had the highest concentration of total suspended solids (Tables 17). The high concentration of total suspended solids in South McMillan, a highly forested watershed, was due to road construction that occurred in this watershed during the sampling period.

Total Phosphorus and Soluble Reactive Phosphorus - Phosphorus is an element required for plant growth whether on land or in the water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or over-production of lakes. Within the Conesus Lake watershed, the concentration of total phosphorus decreased with increasing percentage of woodland in the watershed (Fig. 23B) or as the watersheds become more developed, for agricultural or other usage, the concentrations of phosphorus in the streams increased. Phosphorus may enter from the watershed as a result of sewage disposal and of heavy fertilizer use for lawns or agriculture. Watersheds that have streams with high phosphorus concentrations are potentially the cause of increased phytoplankton and macrophyte (weed) production. Hanna's (74.6 µg P/L), "No Name" Creek (77.8 µg P/L), North Gully (65.9 µg P/L), Wilkins (74.9 µg P/L) and Long Point Gully (53.2 µg P/L) have significantly higher total phosphorus concentration than other streams (mean = 28.1 µg P/L) draining into Conesus Lake (Tables 16 and 17, Fig. 24).

Nitrate and Total Kjeldahl Nitrogen (TKN) - Nitrate is found in fertilizer, while total kjeldahl nitrogen roughly represents the organic nitrogen present. Organic nitrogen would occur from sources such as sewage and animal manure. Nitrate and TKN concentrations were exceedingly high at Long Point Gully (3.99 mg N/L and 538 µg N/L), "No Name" (4.48 µg N/L and 621 µg N/L) and Sand Point Creeks (1.17 mg N/L and 513 µg N/L) compared to the other creeks (mean = 0.60 mg N/L and 439 µg N/L) (Tables 16 and 17, Fig. 25 and 26). In fact, the amount of TKN in the stream increased with the amount of acreage in cropland within the watershed (Fig. 23C).

Table 16. Summary of physical and chemical parameters (March 1990 - February 1991, n = 52) for Densmore, Hanna's, Inlet, Long Point and No Name Creeks. Values are the mean ± standard error. The range of values observed are in parentheses.

MEAN ± S.E.
(RANGE)

	Densmore	Hanna's	Inlet	Long Point	No Name
Temperature (Celsius)	7.4 ± 1.0 (0.0 - 19.0)	6.9 ± 1.1 (0.0 - 20.0)	8.7 ± 1.0 (0.0 - 19.0)	5.0 ± 0.9 (0.0 - 19.0)	4.7 ± 0.9 (0.0 - 18.0)
Watershed Area (ha)	647.5	717.5	4,475	622.5	415.0
Discharge (Cubic meters/day)	5,374 ± 685 (0 - 23,619)	14,265 ± 1792 (0 - 60,232)	22,751 ± 2522 (1,798 - 89,611)	5,761 ± 715 (0 - 23,624)	2,892 ± 644 (0 - 30,507)
pH	8.26 ± 0.04 (7.55 - 8.67)	8.22 ± 0.04 (7.75 - 8.92)	8.03 ± 0.04 (7.40 - 8.90)	8.46 ± 0.04 (7.85 - 9.21)	8.34 ± 0.03 (7.76 - 9.04)
Alkalinity (mg $CaCO_3$/L)	257.42 ± 5.86 (169.2 - 333.3)	185.66 ± 6.16 (65.8 - 323.3)	143.90 ± 6.56 (47.4 - 226.3)	201.30 ± 3.96 (141.5 - 230.8)	159.69 ± 3.60 (92.6 - 181.3)
Conductivity (µmhos/cm)	741 ± 17 (494 - 1049)	679 ± 30 (471 - 1314)	410 ± 17 (159 - 629)	620 ± 12 (475 - 781)	514 ± 14 (305 - 639)
Turbidity (NTU)	3.37 ± 1.35 (0.12 - 49.00)	3.85 ± 1.10 (0.49 - 40.60)	5.25 ± 1.40 (0.36 - 51.20)	2.64 ± 0.83 (0.26 - 21.70)	5.89 ± 2.44 (0.48 - 62.50)
Dissolved oxygen (mg/L)	10.9 ± 0.4 (4.7 - 15.3)	11.4 ± 0.4 (6.5 - 15.0)	10.5 ± 0.3 (5.0 - 14.5)	12.5 ± 0.2 (10.2 - 14.6)	12.1 ± 0.2 (8.8 - 14.4)
Calcium (mg/L)	82.58 ± 1.98 (58.94 - 118.62)	62.23 ± 1.55 (29.36 - 85.08)	49.76 ± 2.09 (17.29 - 81.50)	76.14 ± 1.83 (54.68 - 106.36)	63.24 ± 1.72 (35.72 - 76.04)
Magnesium (mg/L)	20.41 ± 0.55 (14.30 - 30.95)	14.53 ± 0.39 (5.39 - 18.86)	12.01 ± 0.50 (4.74 - 20.12)	18.17 ± 0.42 (13.07 - 24.66)	16.07 ± 0.41 (9.82 - 20.91)
Potassium (mg/L)	3.02 ± 0.11 (2.10 - 5.30)	3.55 ± 0.19 (2.36 - 7.69)	2.17 ± 0.08 (1.20 - 4.11)	3.82 ± 0.18 (2.80 - 8.78)	4.98 ± 0.24 (3.70 - 10.88)
Sodium (mg/L)	39.28 ± 1.11 (28.44 - 62.38)	53.05 ± 5.85 (21.68 - 170.54)	16.34 ± 0.51 (10.00 - 23.14)	20.49 ± 0.66 (14.52 - 29.46)	12.83 ± 0.25 (9.63 - 17.06)
Chloride (mg/L)	68.1 ± 2.6 (44.0 - 131.7)	86.9 ± 8.9 (37.2 - 255.6)	28.8 ± 0.9 (15.1 - 42.1)	47.2 ± 1.8 (29.6 - 67.6)	36.4 ± 1.0 (15.2 - 45.1)
Sulfate (mg/L)	35.7 ± 1.1 (21.3 - 52.9)	32.0 ± 1.5 (13.7 - 52.7)	32.8 ± 1.1 (13.0 - 49.8)	42.9 ± 1.3 (27.8 - 58.2)	41.9 ± 1.6 (13.1 - 60.2)
Total phosphorus (µg P/L)	32.9 ± 7.4 (6.9 - 282.0)	74.6 ± 8.6 (27.1 - 229.1)	28.2 ± 4.0 (4.2 - 133.1)	53.2 ± 4.3 (25.4 - 133.8)	77.8 ± 17.0 (19.4 - 615.0)
Soluble reactive phosphorus (µg P/L)	15.1 ± 4.0 (0.7 - 177.7)	44.0 ± 5.1 (10.0 - 140.4)	9.7 ± 2.5 (1.4 - 133.1)	39.9 ± 3.1 (14.4 - 90.1)	51.9 ± 3.6 (33.1 - 151.4)
Nitrate + nitrite (mg N/L)	0.60 ± 0.04 (0.18 - 1.47)	0.69 ± 0.05 (0.12 - 1.45)	0.81 ± 0.05 (0.10 - 1.70)	3.99 ± 0.30 (0.60 - 6.96)	4.48 ± 0.24 (2.07 - 8.26)
Total Kjeldahl nitrogen (µg N/L)	368.2 ± 44.3 (100.0 - 1710.0)	579.3 ± 59.6 (60.0 - 2200.0)	412.9 ± 46.8 (10.0 - 2020.0)	538.3 ± 36.9 (270.0 - 1200.0)	621.2 ± 70.6 (30.0 - 2500.0)
Total suspended solids (mg/L)	6.4 ± 2.1 (0.0 - 77.0)	7.4 ± 1.5 (0.1 - 48.0)	7.9 ± 2.6 (0.0 - 86.0)	4.0 ± 1.0 (0.0 - 29)	11.5 ± 5.4 (0.0 - 172.0)

Table 17. Summary of physical and chemical parameters (March 1990 - February 1991, n = 52) for North Gully, North McMillan, Sand Point Gully, South McMillan and Wilkins Creek. The range of values observed are in parentheses.

MEAN ± S.E.
(RANGE)

	North Gully	North McMillan	Sand Point Gully	South McMillan	South Gully	Wilkins
Temperature	7.9 ± 0.9	7.9 ± 1.0	8.5 ± 1.0	8.2 ± 1.0	7.3 ± 1.0	8.4 ± 0.9
(Celsius)	(0.0 - 19.0)	(0.0 - 19.0)	(0.0 - 19.0)	(0.0 - 19.0)	(0.0 - 19.0)	(0.0 - 19.0)
Watershed Area	735.0	2,045	325.0	2,687	345.0	690
Discharge	7,768 ± 1121	45,297 ± 5893	922 ± 126	36,389 ± 4,466	3,817 ± 506	5,836 ± 681
(Cubic meters/day)	(2 - 39,222)	(0 - 203,570)	(0 - 4,392)	(21 - 155,073)	(0 - 17,467)	(268 - 23,900)
pH	8.40 ± 0.02	8.39 ± 0.03	8.39 ± 0.03	8.01 ± 0.04	8.41 ± 0.03	8.32 ± 0.02
	(7.83 - 8.99)	(7.69 - 9.03)	(7.91 - 9.07)	(7.19 - 9.07)	(7.84 - 9.03)	(7.73 - 9.00)
Alkalinity	238.28 ± 4.35	148.94 ± 4.77	209.86 ± 3.52	63.49 ± 2.83	220.72 ± 4.99	250.03 ± 5.79
(mg $CaCO_3$/L)	(156.75 - 284.83)	(77.59 - 207.92)	(125.21 - 243.21)	(28.94 - 107.54)	(121.43 - 260.58)	(66.74 - 308.75)
Conductivity	556 ± 7	441 ± 15	541 ± 9	214 ± 8	538 ± 11	994 ± 53
(µmhos/cm)	(411 - 665)	(230 - 636)	(387 - 671)	(111 - 373)	(330 - 653)	(358 - 1807)
Turbidity	4.95 ± 1.74	7.26 ± 4.03	2.14 ± 0.66	12.69 ± 7.45	7.43 ± 2.86	4.63 ± 1.95
(NTU)	(0.25 - 74.80)	(0.08 - 197.80)	(0.14 - 27.80)	(0.47 - 376.40)	(0.24 - 97.80)	(0.35 - 99.70)
Dissolved oxygen	11.2 ± 0.3	11.6 ± 0.3	11.2 ± 0.3	11.4 ± 0.3	11.5 ± 0.3	10.9 ± 0.3
(mg/L)	(7.9 - 15.0)	(8.3 - 15.0)	(8.2 - 14.8)	(8.0 - 15.2)	(7.9 - 14.9)	(7.1 - 15.8)
Calcium	72.30 ± 1.33	47.11 ± 1.37	68.83 ± 1.64	23.15 ± 0.72	69.03 ± 1.56	79.49 ± 1.98
(mg/L)	(48.40 - 99.10)	(26.12 - 67.38)	(17.50 - 85.66)	(12.69 - 36.34)	(39.16 - 88.78)	(21.40 - 109.38)
Magnesium	18.62 ± 0.36	12.66 ± 0.41	17.91 ± 0.33	5.07 ± 0.16	17.91 ± 0.42	20.07 ± 0.69
(mg/L)	(12.94 - 23.29)	(6.96 - 18.85)	(10.73 - 21.71)	(3.01 - 7.13)	(10.46 - 22.68)	(3.76 - 27.90)
Potassium	2.89 ± 0.13	1.64 ± 0.08	2.33 ± 0.08	1.35 ± 0.08	2.30 ± 0.10	2.96 ± 0.15
(mg/L)	(1.98 - 6.71)	(1.11 - 4.46)	(1.61 - 4.34)	(0.64 - 3.99)	(1.58 - 4.96)	(1.26 - 5.59)
Sodium	15.44 ± 0.52	23.10 ± 1.04	14.98 ± 0.67	12.66 ± 0.59	15.85 ± 0.57	96.99 ± 9.17
(mg/L)	(9.55 - 23.93)	(12.51 - 44.07)	(7.48 - 26.75)	(7.40 - 35.97)	(8.53 - 29.66)	(33.62 - 258.10)
Chloride	25.8 ± 1.4	38.4 ± 1.8	29.8 ± 1.5	22.2 ± 1.1	29.3 ± 1.5	158.1 ± 14.8
(mg/L)	(2.0 - 41.8)	(20.8 - 67.0)	(13.5 - 61.6)	(12.0 - 69.2)	(3.8 - 54.7)	(53.3 - 412.1)
Sulfate	29.3 ± 0.9	27.5 ± 0.8	38.2 ± 1.0	16.1 ± 0.3	30.9 ± 0.9	28.42 ± 0.82
(mg/L)	(18.8 - 48.5)	(15.2 - 38.4)	(22.6 - 53.3)	(11.9 - 21.0)	(15.8 - 43.5)	(12.10 - 40.60)
Total phosphorus	65.9 ± 10.4	22.3 ± 8.2	45.1 ± 3.0	30.6 ± 6.3	36.5 ± 6.3	74.9 ± 25.7
(µg P/L)	(13.3 - 396.0)	(2.7 - 403.0)	(19.1 - 112.3)	(4.5 - 322.0)	(10.9 - 199.3)	(11.8 - 1334.0)
Soluble reactive	39.0 ± 4.8	6.0 ± 1.1	33.6 ± 2.5	10.6 ± 1.7	18.9 ± 1.9	24.5 ± 2.7
phosphorus (µg P/L)	(1.7 - 234.9)	(0.1 - 45.4)	(14.7 - 111.3)	(1.8 - 74.4)	(2.0 - 78.2)	(3.8 - 66.6)
Nitrate + nitrite	0.60 ± 0.05	0.36 ± 0.03	1.17 ± 0.11	0.31 ± 0.03	0.93 ± 0.09	0.46 ± 0.04
(mg N/L)	(0.00 - 1.21)	(0.00 - 0.82)	(0.13 - 4.44)	(0.00 - 1.60)	(0.07 - 2.11)	(0.00 - 1.03)
Total Kjeldahl	428.5 ± 44.9	389.2 ± 74.5	513.3 ± 41.8	460.2 ± 68.3	384.9 ± 43.9	483.7 ± 69.4
nitrogen (µg N/L)	(70.0 - 1730.0)	(10.0 - 3220.0)	(70.0 - 1730.0)	(30.0 - 2950.0)	(10.0 - 1230.0)	(70.0 - 2520.0)
Total suspended solids	17.3 ± 6.0	19.5 ± 12.9	4.0 ± 1.1	33.0 ± 20.9	11.9 ± 4.0	37.4 ± 25.4
(mg/L)	(0.2 - 224.0)	(0.0 - 640.0)	(0.0 - 41.0)	(0.0 - 1040.0)	(1.0 - 137.0)	(0.9 - 1276.0)

STREAM LOADING TO CONESUS LAKE:

Table 18 presents loadings (amount of material entering the lake per unit time) of total phosphorus, total kjeldahl nitrogen, nitrate, total suspended solids and sodium. The loading data presented include precipitation events but do not actual include chemistry measurements for events, except in the case of South McMillan Creek, where event chemistry was monitored. Thus the data presented may be an underestimate of loading. However, these data do provide a reasonable indication of loadings to the lake. Estimates of annual loadings can be derived by multiplying values from Table 18 by 365.

Sodium: Major losses of sodium from the watershed occurred during the study period (Table 18). Sodium is the major constituent of deicing salt. From 69% to 88% of the salt (as sodium) that enters the Lake occurs in the winter and spring when deicing salt is applied to roads (Fig. 27 and 28). Hanna's and Wilkins Creeks watersheds delivered the highest amount of sodium per unit area of watershed to the lake (Table 18). As mentioned previously, large deicing salt piles are maintained in these watersheds. Inlet, "No Name" and Sand Point Creeks, which had the lowest loading of sodium, are all watersheds that are either very large with little development (e.g. Inlet) or have small watersheds that have a minimal amount of major roads - a source of deicing salt.

Excessive sodium in human diets is a proven health hazard, affecting blood pressure (hypertension) and aggravating cardiovascular, kidney and liver diseases (Page 1978, Tuthill 1981). The New York State Sanitary Code (1981) advised that water containing more than 20 mg/L of sodium should not be used for drinking by those on severely restricted diets. The average lake sodium concentration was 17 mg/L in 1985 and 1988 (Makarewicz 1986). Since sodium levels have increased about 30% in 15 years, it follows that Conesus Lake water suppliers may be required to notify consumers that the soidum concentration is 20 mg/L or higher.

Total Suspended Solids:

The loss of suspended solids from a watershed is a measurement of loss of soil or erosion from a watershed. The watershed of South McMillan Creek (839 kg/d) has the greatest loss of suspended solids during the year followed by North McMillan Creek (566 kg/d)(Table 18). Similarly, when the loss of suspended solids is normalized for watershed area, these two creeks still have the greatest loss per unit area of land. Two other watersheds, Hanna's and North Gully, have a high loss of soil relative to the unit area of land. Thirty two to 54% of the suspended materials that are lost occur during the spring runoff period (Fig. 29 and 30). An opportunity may exist through better land management to minimize some of these losses from the watersheds and improve conditions in the Lake.

Nutrients:

Phosphorus and Total Kjeldahl Nitrogen - Annually, the watershed of South McMillan Creek was the major contributor of nutrients to Conesus Lake (Table 18) accounting for 25%, 23% and 39% of the total phosphorus, total nitrogen and total suspended solids, respectively, entering Conesus Lake. North McMillan Creek had the second highest loading of total phosphorus (17%), total nitrogen (23%) and suspended solids (26%).

However, Hanna's Creek, which had the third highest phosphorus loading to the lake (16), had the highest load of phosphorus per unit area (Fig. 31). As in the other

Creeks, over 70% of the phosphorus loading occurs in the winter and spring, the period of greatest discharge of water from the watershed (Fig. 33 and 34). This is also the period of greatest surface runoff due to snow melt and high spring rains. Precipitation events are also important. For example, eight precipitation events, mostly in the winter and spring, accounted for 25% of the water discharge, 41% of the total phosphorus and 82% of the total suspended solids lost during the year from South McMillan Creek. Thus land practices, such as manure spreading, plowing of fields, construction, etc. will have their greatest impact downstream. A phosphorus control program within these three watersheds would probably have the greatest impact on macrophytes and on water quality in the Lake. These three watersheds account for 57.5% of the phosphorus entering the lake (Fig. 31A). Similarly, these three watersheds deliver 60% of the organic nitrogen (Fig. 32). This suggests a source(s) of organic nitrogen in these watersheds. Since nitrogen can affect macrophyte growth and overall phytoplankton growth and thus water quality, a nitrogen and phosphorus control program in these watersheds should be considered.

Nitrate - Unlike total phosphorus and total kjeldahl nitrogen, the watersheds of Long Point Gully, the Inlet and North McMillan Creek were the major contributors of the nutrient, nitrate, to Conesus Lake (Table 18) accounting for 21%, 17% and 17%, respectively or 55% of the total nitrate load (Fig. 35). Approximately 50% of the nitrate load entered during the winter (Fig. 36 and 37). It is important to note that the relative load of nitrate per unit area of land is considerably higher for Long Point Gully, "No Name", Hanna's and South Gully, which are all watersheds having a high percentage of land in croplands (>40%, average = 70.8%) (Fig. 38). This suggests that a land use, agriculture, is contributing to the nutrient load of the lake. However, type of crops, tillage or fertilizer practices probably play a major role. For example, Densmore Creek has a high percentage in agriculture (70.7%) but contributes only 2.7% of the nitrate load to Conesus Lake.

The various creeks of the Irondequoit Bay watershed (Monroe County, NY.) have been identified as grossly polluted prior to remedial action (O'Brien and Gere 1983). Similarly, Northrup Creek (central Monroe County), which receives effluent from a sewage treatment plant, is known to be polluted and to posses a higher loading of phosphorus than creeks in the Irondequoit Bay watershed (Makarewicz 1988). A comparison of Conesus Lake tributaries to creeks entering Lake Ontario and Irondequoit Bay is instructive in identifying the relative condition of creeks entering Conesus Lake (Table 19). Compared to the suburban and urban watersheds of Monroe County, the tributaries of Conesus Lake contribute relatively small amounts of phosphorus. However, the low relative loadings of the Conesus Lake tributaries compared to Monroe County need to be viewed in perspective. The streams in portions of Monroe County are already degraded while the goal in Livingston County is to improve and maintain water quality in Conesus Lake and its tributaries. What we have to remember is that even with these relatively low nutrient loads to Conesus Lake, the lake is experiencing high productivity of phytoplankton and macrophytes. Furthermore, there are some streams that are approaching the level of loading in Monroe County. For example, the impact of Hanna's Creek on Conesus Lake is comparable to phosphorus loadings (areal basis) from a suburban watershed west of Rochester.

A major concern for the future is the large watersheds at the south end of Conesus Lake - Inlet, South McMillan and North McMillan. These three largely undeveloped and unsewered watersheds contain over 50% of drainage basin of Conesus Lake. With development, we can expect an increase in nutrient loss from these watersheds and perhaps discharge to Conesus Lake. If this were to happen, we can expect further decreases in water quality and increases in macrophytes (i.e. weeds) in the lake.

Thus management of the watershed becomes desireable. Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing nonpoint source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices which reduce surface runoff have been shown to decrease dramatically the magnitudes of sediment and chemical losses from land areas (Haith 1975).

Haith (1975) and the NYSDEC (1986) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other management practices include diversion terraces and ditches, stormwater detention ponds and infiltration pits. The relatively few days of high runoff required to export much of the annual water and nutrients from the Conesus Lake watershed implies the necessity of management practices designed to deal with the large volumes of water involved during intense runoff events. Changes in cropping and soil conservation practices, decreases in impervious services and provision of buffer areas along surface waterways will result in predictable changes in runoff quantities and qualities and hence nonpoint source pollution (Haith 1975).

Table 18. Average daily loadings for selected parameters of tributaries of Conesus Lake. A estimate of annual loading may be derived by multiplying by 365. TP = total phosphorus, TKN = Total Kjeldahl Nitrogen, NO_3 = nitrate, Na = sodium, TSS = Total suspended solids.

A	TP kg P/d	TKN kg N/D	NO_3 kg N/d	Na kg Na/d	TSS kg/d
DENSMORE	0.15	1.76	3.15	193	34
HANNA'S	0.83	7.28	10.81	562	88
INLET	0.56	16.36	20.14	322	279
LONG POINT	0.30	3.05	23.86	117	25
NO NAME	0.22	1.73	12.25	36	36
NORTH GULLY	0.58	2.71	6.43	135	151
NORTH MCMILLAN	0.89	11.53	19.47	873	566
SAND POINT	0.03	0.42	1.36	17	5
SOUTH GULLY	0.13	1.13	4.55	63	47
SOUTH MCMILLAN	1.29	11.19	10.73	436	839
WILKINS	0.25	2.61	3.36	353	101
TOTAL	5.23	49.79	116.12	3,106	2,171

B.	TP g P/ha/d	TKN g N/ha/d	NO_3 g N/ha/d	Na g Na/ha/d	TSS g/ha/d
DENSMORE	0.23	2.72	4.87	299	53
HANNA'S	1.16	10.15	15.07	783	122
INLET	0.13	1.42	4.50	72	62
LONG POINT	0.49	4.90	38.32	187	41
NO NAME	0.52	4.16	29.52	87	88
NORTH GULLY	0.79	3.69	8.75	183	205
NORTH MCMILLAN	0.43	5.64	9.52	426	277
SAND POINT	0.10	1.30	4.18	51	14
SOUTH GULLY	0.39	3.29	13.20	181	137
SOUTH MCMILLAN	0.48	4.16	3.99	162	312
WILKINS	0.36	3.78	4.88	512	146
TOTAL	5.07	45.23	136.8	2,945	1,456

Table 19. Comparison of phosphorus loading in subbasins of the Irondequoit Bay watershed to phosphorus loadings from Otis and Salmon Creeks. Irondequoit basin data are from Bannister and Burton (1979) and Peet, Burton, Baker et al. (1985). Other data are from Makarewicz and Lewis (1991).

Subbasin or Creek	Total Phosphorus Loading (Kg P/d)	Total Phosphorus Loading (g P/ha/d)
IRONDEQUOIT BAY		
Irondequoit Creek at Browncroft Blvd.		
1975-77 (pre-diversion)	220	5.6
1978-79 (post-diversion)	78	2.0
Irondequoit Creek at Blossom Road		
1979	85	2.3
1980	81	2.2
1981	36	1.0
1982	34	0.92
1983	23	0.62
1984	42	1.10
1985	28	0.76
LAKE ONTARIO		
Larkin Creek (1988-89)	2.2	0.70
Buttonwood Creek (1988-89)	3.6	1.58
Lower Northrup (1988-89)	12.4	4.24
Upper Northrup (1988-89)	3.4	3.23
Black Creek (1988-89)	1.4	0.60
Otis Creek (1989-90)	7.4	1.56
Salmon Creek (1989-90)	7.4	1.00
CONESUS LAKE (1991)		
Densmore	0.15	0.23
Hanna's	0.83	1.16
Inlet	0.56	0.13
Long Point Gully	0.30	0.49
No Name	0.22	0.52
North Gully	0.58	0.79
North McMillan	0.89	0.43
Sand Point Gully	0.03	0.10
South Gully	0.13	0.39
South McMillan	1.29	0.48
Wilkins	0.25	0.36

Table 20. Watershed land use and area. Conesus Lake watershed. Derived from 1984 Livingston County Soil and Water Conservation data. Idle refers to weeded fields that are not woodlands or are not being farmed. Other refers to urban, wetlands, gravel pits, etc.

	Croplands	Idle	Other	Pasture	Woodlands	Watershed Area (ha)
DENSMORE	70.7	0.0	2.7	1.5	25.1	647.5
HANNA'S	75.6	13.2	4.5	0.0	6.6	717.5
INLET	29.4	12.0	0.8	3.4	54.4	4475.0
LONG POINT	84.7	0.0	2.4	2.0	10.8	622.5
NO NAME	79.5	0.0	1.8	0.0	18.7	415.0
NORTH GULLY	46.6	23.1	3.4	1.0	25.9	735.0
N. McMILLAN	29.2	15.2	3.9	1.5	50.2	2045.0
SAND POINT	86.9	2.3	3.8	0.0	6.9	325.0
SOUTH GULLY	43.5	16.7	2.2	8.0	29.7	345.0
S. McMILLAN	25.9	5.2	1.6	4.7	62.7	2687.5
WILKINS	54.0	7.6	23.6	3.3	11.6	690.0

Table 20. Watershed land use and area. Conesus Lake watershed. Derived from 1984 Livingston County Soil and Water Conservation data. Idle refers to weeded fields that are not woodlands or are not being farmed. Other refers to urban, wetlands, gravel pits, etc.

	Croplands	Idle	Other	Pasture	Woodlands	Watershed Area (ha)
DENSMORE	70.7	0.0	2.7	1.5	25.1	647.5
HANNA'S	75.6	13.2	4.5	0.0	6.6	717.5
INLET	29.4	12.0	0.8	3.4	54.4	4475.0
LONG POINT	84.7	0.0	2.4	2.0	10.8	622.5
NO NAME	79.5	0.0	1.8	0.0	18.7	415.0
NORTH GULLY	46.6	23.1	3.4	1.0	25.9	735.0
N. McMILLAN	29.2	15.2	3.9	1.5	50.2	2045.0
SAND POINT	86.9	2.3	3.8	0.0	6.9	325.0
SOUTH GULLY	43.5	16.7	2.2	8.0	29.7	345.0
S. McMILLAN	25.9	5.2	1.6	4.7	62.7	2687.5
WILKINS	54.0	7.6	23.6	3.3	11.6	690.0

TROPHIC STATUS OF CONESUS LAKE

It is now well accepted that eutrophication of lakes depends on excessive discharge of phosphorus and nitrogen to inland waters. This concept, sometimes called the nutrient loading concept, implies that a quantifiable relationship exists between the amount of nutrients reaching a lake and its trophic status. Figure 39 presents the relationship of chlorophyll level to potential available phosphorus for some common upstate New York lakes and bays. Based on the phosphorus loading and chlorophyll data that we have collected for Conesus Lake and its tributaries, Conesus Lake falls into the mesotrophic category of bodies of water. That is to say, Conesus is a productive body of water. The low hypolimnetic oxygen levels during the summer also support this conclusion.

SUMMARY OF CONESUS LAKE WATER QUALITY

Based on the total stream phosphorus loading and chlorophyll data that we have collected for Conesus Lake and its tributaries, Conesus Lake falls into the mesotrophic category of bodies of water. That is to say, Conesus Lake is a productive body of water.

Many chemical parameters in Conesus Lake are influenced by discharge from tributaries. Phosphorus is an element required for plant growth, whether on land or in the water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or over production of lakes. Nitrate is another key nutrient often lost during the application of fertilizer to croplands. Hanna's (74.6 μg P/L), "No Name" Creek (77.8 μg P/L), North Gully (65.9 μg P/L), Wilkins (74.9 μg P/L) and Long Point Gully (53.2 μg P/L) have significantly higher total phosphorus than other streams (mean = 28.1 μg P/L) draining into Conesus Lake. Similarly, nitrate and TKN concentrations were exceedingly high at Long Point Gully (3.99 mg N/L and 538 μg N/L), "No Name" (4.48 μg N/L and 621 μg N/L) and Sand Point Creeks (1.17 mg N/L and 513 μg N/L) compared to the other creeks (mean = 0.60 mg N/L and 439 μg N/L). Phosphorus and nitrogen levels in streams were generally higher in watersheds with more acreage in croplands. Nitrate and phosphorus are found in fertilizer, while total kjeldahl nitrogen represents the organic nitrogen found water. Organic nitrogen would occur from sources such as sewage and animal manure.

The watershed with the greatest amount of development, Wilkins, had the greatest lost of suspended materials. The high concentration of total suspended solids in the largely forested South McMillan watershed was probably due to the road construction that occurred in portions of this watershed during the study period.

Of the eleven creeks monitored annually, South McMillan Creek was the major contributor of nutrients to Conesus Lake accounting for 25%, 23% and 39% of the total phosphorus, total nitrogen and total suspended solids, respectively, entering Conesus Lake. North McMillan Creek had the second highest loading of total phosphorus (17%) and total nitrogen (23%) and suspended solids (26%). These two creeks accounted for 44% and 65% of the total phosphorus and total suspended solids, respectively, entering Conesus Lake. Thus, it is not surprising that an extensive macrophyte community exists at the mouths of South McMillan and North McMillan Creeks, which extends well into the Lake. These two watersheds are logical candidates for a nutrient control program.

However, major inputs of nitrates occurring in other watersheds perhaps reflected different land use patterns. The watersheds of Long Point Gully, the Inlet and North McMillan Creek were the major contributors of the nitrate to Conesus Lake accounting for 21%, 17%

and 17%, respectively, or 55% of the total nitrate load. Approximately 50% of the nitrate load entered during the winter. It is important to note that the relative load of nitrate per unit area of land is considerably higher for Long Point Gully, "No Name", Hanna's and South Gully, which are all watersheds having a high percentage of land in croplands (>40%, average = 70.8%). This suggests that a land use, agriculture, is contributing to the nutrient load of the lake. These watersheds are candidates for a best management practice (BMP).

Major losses of sodium from the watershed occurred during the study period. Sodium is the major constituent of deicing salt. Annual concentrations of sodium and chloride are significantly higher in Hanna's (53.1 mg Na/L, 86.9 mg Cl/L) and Wilkins Creeks (97.0 mg/L, 158.1 mg/L) than in the other streams (mean = 19.0 mg Na/L, 36.2 mg Cl/L). From 69% to 88% of the salt (as sodium) that enters the Lake occurs in the winter and spring when deicing salt is applied to roads. Hanna's and Wilkins Creeks watersheds delivered the highest amount of sodium per unit area of watershed to the lake. As mentioned, large deicing salt piles are maintained in these watersheds. The cause of the high concentrations of sodium and chloride in Hanna's Creek was demonstrated in 1985 as due to poor storgae of winter deicing salt at the New York State Department of Transportation garage located in this watershed. The high concentrations of salt in Wilkins Creek were due to deicing salt usage within the Village of Livonia and/or poor storage of deicing salt at the Livonia Town Garage. These two sources are undoubtedly contributing to the slow, but clear trend of increasing salt (Na and Cl) concentration in Conesus Lake.

RECOMMENDATIONS

1. More detailed studies of Hanna's, "No Name" and Long Point Creeks are required to determine actual sources of nitrates, total kjeldahl nitrogen and phosphorus within these watersheds. They are contributing nutrients at a much greater rate than similar sized watersheds.

2. A literature study on what types of best management practices could be successfully used in the Conesus Lake watershed should be undertaken.

3. A nutrient control program or best management practice (BMP) should be initiated on South McMillan and North McMillan Creeks. These two watersheds contribute almost 50% of the phosphorus to the lake.

4. Losses of deicing salt from the Wilkins and Hanna's Creek need to be managed better. There has been a significant increase in sodium levels within the lake that is approaching levels considered to be of concern to those on restricted sodium diets.

5. Three watersheds (Inlet, South and North McMillan) represent over 50% of the watershed of Conesus Lake. Much of this area is unsewered and relatively undeveloped, particularly the Inlet watershed. In the future, unmanaged development in these watersheds could have significant effects on water quality and perhaps macrophyte production. Development and/or enforcement of zoning codes within these watersheds is an important consideration for the future.

6. If macrophyte control is truly desireable and the need immediate, consideration should be given to use of the sterile grass carp.

LITERATURE CITED

Abraham, W.J. 1975. Proposed Regulation Changes for the Conesus Lake Walleye Fishery. Senior Fishery Biologist. New York State Department of Environmental Conservation. Avon, N.Y.

Abraham, W.J. 1986. Conesus Lake walleye population estimate for 1986. Senior Fishery Biologist. New York State Department of Environmental Conservation. Avon, N.Y.

Abraham, W.J. 1988. Colonization of Conesus Lake by the alewife. Bureau of Fisheries Report. New York State Department of Environmental Conservation (NYSDEC), Avon, N.Y.

Abraham, W.J. 1989. Conesus Lake fish stock assessment comparisons between 1985 and 1988 netting data. Bureau of Fisheries Report. New York State Department of Environmental Conservation (NYSDEC), Avon, N.Y.

Anderson, H.T. 1976. The Diamonds are Dancing: A History of Conesus Lake. Conesus Lake Association.

Andersson, G., H. Berggren, C. Cronberg and C. Gelin. 1978. Effects of planktivorous and benthivorous fish on organisms and water chemistry in eutrophic lakes. Hydrobiologia 59:9-15.

APHA. 1989. Standard Methods for the Examination of Waste and Wastewater. American Public Health Association, 17th ed. New York, N.Y. 1134p.

Bannister, T. and R. Burton 1979. Nitrogen and phosphorus discharge by Irondequoit Creek and total inputs to Irondequoit Bay, 1969-79. Irondequoit Bay Report Number 5. Available from the Monroe County Health Department.

Bauer, D.L. and, D.W. Willis. 1990. Effects of triploid grass carp on aquatic vegetation in two South Dakota lakes. Lake Reserv. Manage. 6(2):175-180.

Berg, C.O. 1966. The middle Atlantic states. *In* Limnology in North America. D.G. Frey (ed.) U. Of Wisconsin Press.

Birge, E.A. and C. Juday. 1914. A limnological survey of the Finger Lakes of New York. Bull. U.S. Bur. Fish. 37:524-609.

Bloomfield, J.A. 1978. Lakes of New York State. Vol 1. Ecology of the Finger Lakes. Academic Press., New York. 499p.

Brooks, J.C. and S. Dodson. 1965. Predation, body size and the composition of the plankton. Science 150:28-35/

Brooks, J.C. 1968. The effects of prey size selection by lake planktivores. Syst. Zool. 17:272-291.

Burton, R. 1988. Personal Communication. Monroe County Health Department, Rochester, N.Y.

Carpenter, S.R., J.F. Kitchell and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. Bioscience 35:634-639.

Chamberlain, H.D. 1975. A comparative study of the zooplankton communities of Skaneateles, Owasco, Hemlock and Conesus Lake. Ph.D. Thesis, Cornell University, Ithaca, N.Y.

Chidester, F.E. 1912. The biology of the crayfish. The American Naturalist. 46:279-293.

Chow, Ven Te. 1964. Handbook of Applied Hydrology. McGraw-Hill Book Company. N.Y.

Crocker, D.W. and D.W. Barr. 1968. Handbook of the crayfishes of Ontario. University of Toronto Press., Buffalo New York. 158p.

Dean, J.L. 1969. Biology of the crayfish *Orconectes causeyi* and its use for control of aquatic weeds in trout lakes. U.S. Dept. Inter. Bur. Sport Fish. Wildl. Tech. Pap. 24:1-15.

Elser, J.J., M.M. Elser, M.A. Mackay and S.R. Carpenter. 1988. Zooplankton mediated transitions between N and P limited algal growth. Limnol. Oceanogr. 33:1-14.

Elliot, E.T., L.G. Castanares, D. Perlmutter and K.G. Porter. 1983. Trophic level control of production and nutrient dynamics in an experimental planktonic community. Oikos 41:7-16.

EPA. 1978. Microbiological Methods for Monitoring the Environment. Water and Wastes. Environmental Protection Agency. EPA-600/8-78-017.

EPA. 1979. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory. Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-020.

Evans, M.S. and D.J. Jude. 1986. Recent shifts in *Daphnia* community structure in southeastern Lake Michigan: A comparison of the inshore and offshore regions. Limnol. Oceanogr. 31:56-67.

Everhart, W.H. and W.D. Youngs. 1981. Principles of fishery science. 2nd edition. Cornell University Press.

Flint, W.R. and C.R. Goldman. 1975. The effects of a benthic grazer on the primary productivity of the littoral zone of Lake Tahoe. Limnol and Oceanogr. 20(6):935-944.

Forest, H.S. 1977. Study of submerged aquatic vascular plants in northern glacial lakes (New York State, U.S.A.). Folia. Geobot. Phytotax.,Praha, 12:329-341.

Forest, H.S. 1986. Submersed Aquatic Macrophytes. IN: Water Quality of Conesus Lake. J.C. Makarewicz. Report to Villages of Avon and Geneseo Town of Livonia. 1986. Department of Biological Sciences. Drake Memorial Library, SUNY at Brockport, Brockport, New York. 14420.

Gilbert, J.J. 1988. Suppression of rotifer populations by *Daphnia*: A review of the evidence, the mechanisms, and the effects on zooplankton community structure. Limnol. Oceanogr. 33: 1286-1303.

Groves. R.E. 1985. The Crayfish: its Nature and Nurture. Fishing News Books Ltd., Farnham Survey. England.

Haith, D.A. 1975. Land use and nutrient export in rural watersheds tributary to Cayuga Lake. In: Influence of land development and land use patterns on water quality. (G.D. Gates and D.A. Haith, ed.). PB 248 071. NTIS.

Henry, R.L. 1985. The impact of zooplankton size structure on phosphorus cycling in field enclosures. Hydrobiologia 120: 3-9.

Interactive Microware. 1984. Curve Fitter. Interactive Microware Inc. P.O. Box 139, State College, PA.

Kerfoot, W.C. 1974. Net accumulation rates and the history of cladoceran communities. Ecology 55:51-61.

Lembi, C.A., B.G. Ritenour, E.M. Iverson, and E.C. Forss. 1978. The effects of vegetation removal by grass carp on water chemistry and phytoplankton. Trans. Am. Fish. Soc. 107:161-71.

Leslie, A.J., Jr., L.E. Nall and, J.M. Van Dyke. 1983. Effects of vegetation control by grass carp on selected water-quality variables in four Florida lakes. Trans. Am. Fish. Soc. . 112:777-87.

Leslie, A.J.Jr., J.M. VanDyke, R.S. Hestand and, B.Z. Thompson. 1987 Management of Aquatic plants in Multi-us Lakes with Grass Carp (*Ctenopharyngodon idella*). Lake Resv. Managr. 3:266-276.

Lynch, M. and J. Shapiro. 1981. Predation, enrichment and phytoplankton community structure. Limnol. Oceanogr. 26:86-102.

MacNeill, D. 1989. Ontogenetic shifts in gillraker morphology and prey capture efficiency of the alewife, *Alosa pseudoharengus*, with field applications of a retention model. M.S. Thesis. SUNY Environmental Science and Forestry, Syracuse, N.Y.

Makarewicz, J.C. 1986. Water Quality of Conesus Lake, 1985-1986. Available from Drake Memorial Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C. 1988. Chemical analysis of water from Buttonwood, Larkin and Northrup Creeks, Lake Ontario basin west, May, 1987 - May, 1988. Report to the Monroe County, NY. Department of Health.

Makarewicz, J.C. and T. Lewis. 1989. Limnological Studies of Sodus Bay and its Tributaries. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

McNaught, D.C., M. Buzzard, D. Griesmer and M. Kennedy. 1980. Zooplankton grazing and population dynamics relative to water quality in southern Lake Huron. EPA-600/3-80-069. U.S. Environmental Protection Agency. NTIS, Springfield VA.

McQueen, D.J. 1969. Reduction of zooplankton standing stocks by predaceous *Cyclops bicuspidatus thomasi* in Marion Lake, British Columbia. J.Fish. Res. Board Can. 17:13-20.

McQueen, D.J., M.R.S. Johannes, J.R. Post, T.J. Stewart and D.R.S. Lean. 1989. Bottom-up and top-down impacts on freshwater pelagic community structure. Ecol. Monogr. 59: 289-309.

Mills, E.L. 1975. Phytoplankton composition and comparative limnology of four Finger Lakes, with emphasis on lake typology. Ph.D. Thesis, Cornell University, Ithaca, N.Y.

Moore, L.M. 1987. NALMS Management Guide for Lakes and Reservoirs. North American Lake Management Society. Washington D.C. 42p.

Morsell, J.W. and C.R. Norden. 1968. Food habits of the alewife, *Alosa pseudoharengus*, in Lake Michigan. Proc. 11th Conf. Great Lakes Res. 96-102.

New York State Department of Environmental Conservation. 1986. Nonpoint Source Management Strategy. Division of Water. Albany, N.Y. 61pp.

NYSDEC. 1987. Characteristics of New York State Lakes Gazetteer of Lakes, Ponds and Reservoirs. 3rd edition. Albany, N.Y.

New York State Sanitary Code. 1981. Albany, N.Y.

Nichols, S.A. 1986. Community Manipulation for Macrophyte Management. Lake and Reservoir Management Volume II. Proc. 5th Conf. Int. Symp. North.Am. Lake Manage. Soc. Nov. 13-16, 1985, Geneva, Wisc, North Am. Lake Manage. Soc., Washington, D.C.

Nielsen, L.A. and D.L. Johnson. 1983. Fisheries techniques. Southern Printing Com., Blacksburg, VA.

O'Brien & Gere. 1983. Nationwide Urban Runoff Program: Irondequoit Basin Study. Final report. Monroe County Department of Engineering. Rochester, N.Y. 164pp.

Oglesby, R.T. and W.R. Schaffner. 1978. Phosphorus loadings to lakes and some of their responses. Part 2. Regression models of summer phytoplankton standing crops, winter total phosphorus and transparency of New York Lakes with known phosphorus loadings. Limnol. and Oceanogr. 23: 135-145.

Page, L. 1978. Salt and drinking water. In: Drinking Water: Its Effect on Health. Massachusetts Audubon Society. Lincoln, Mass.

Peet. M., R.S. Burton, J. Baker et al. Irondequoit Basin Water Quality Management. Annual Progress Report for 1985. Available from the Monroe County Health Department.

Pennak, R.W. 1953. Fresh-water Invertebrates of the United States. Ronald Press Company, New York. 769p.

Peverly, J.H. and R.L. Johnson. 1987. Aquatic plant management and control. A Cornell Cooperative Extension Publication. Information Bulletin 107. Ithaca, New York. 24p.

Peters, R.H. 1975. Phosphorus regeneration by natural populations of limnetic zooplankton. Verh. Internat. Verein. Limnol. 19: 273-279.

Puckett, N. 1989. Master's thesis. Trophic Level Changes and Alewife Predation in Conesus Lake. Biology Dept. SUNY at Brockport.

Ricker, W.E. 1971. Methods for the assessment of fish production in fresh waters. Blackwell Scientific Publ., Oxford, England.

Seagrave, C. 1988. Aquatic Weed Control. Fishery News Books Ltd. Furnham Surrey England.

Stemberger, R.S. 1979. A guide to rotifers of the Laurentian Great Lakes. EPA-600/4-79-021. U.S. Environmental Protection Agency. NTIS, Springfield VA.

Stuart, K.M. and S.J. Markello. 1974. Seasonal variations in concentrations of nitrate and total phosphorus and calculated nutrient loading for six lakes in western New York. Hydrobiologia 44:61-89.

Tack, P.I. 1941. The life history and ecology of the crayfish, *Cambarus immunis*, Hagen. Am. Midl. Nat. 25:420-466.

Tuthill, R.W. and E.J. Calabrese. 1981. Drinking water, sodium and blood pressure in children: A second look. Amer. J. Public Health. 7:1-22.

USEPA. United States Environmental Protection Agency. 1974. National eutrophication survey report on Conesus Lake, Livingston County. New York. EPA Region II. Working Paper No. 156. Pacific Northwest Environmental Research Laboratory.

Vollenweider, R.A. 1974. A Manual on Methods for Measuring Primary Production in Aquatic Environments. 2nd. Edition. IBP Handbook No.12. Blackwell Scientific Publishers., Oxford, London, Edinburgh, Melbourne. 225p.

Vollenweider, R.A. 1974. A Manual on Methods for Measuring Primary Production in Aquatic Environments. 2nd. Edition. IBP Handbook No.12. Blackwell Scientific Publishers., Oxford, London, Edinburgh, Melbourne. 225p.

Vollenweider, R.A. 1976. Advances in defining critical loading levels for phosphorus in lake eutrophication. Mem. Ist. Ital. Idrobiol. 33: 53-83.

Ward, H.B. and G.D. Whipple. 1965. Fresh Water Biology. W.T. Edmondson. (ed.) Wiley and Sons.

Wells, L. 1970. Effects of alewife predation on zooplankton populations in Lake Michigan. Limnol. Oceanogr. 15:556-565.

Westlake, D.F. 1963. Comparisons of plant productivity. Biol. Rev. 38:385-425.

Wetzel, R. and G.E. Likens. 1979. Limnological Analysis. W.B. Saunders Company. 357pp.

Woltmann, E., D. Goetke. 1985. An evaluation of aquatic vegetation control with sterile grass carp. Final Project Report. New York State Department of Environmental Conservation. 55p.

Appendix A

Descriptions of Each Macrophyte Sampling Location

McPherson Point. Sampling was started off the mouth of South Gully at Hartson Point and continued north along the 1-meter deep contour for 1400 meters (8 stations, 24 replicates). There was no macrophyte growth off South Gully (Station 1).

North End. Sampling was started off 150 Pebble Beach Road on the 1-meter deep contour and continued northerly and easterly along that contour for 2000 meters to the vicinity of Tuxedo Park (11 stations, 33 replicates).

Long Point. Sampling was started half way along the north side of Long Point on the 1-meter deep contour and continued southerly along that contour for 1000 meters (6 stations, 18 replicates).

Cottonwood Cove. Sampling was started off Cottonwood Gully on the 1-meter deep contour and continued north for 600 meters (4 stations, 12 replicates).

South End. Sampling was started at 1609 West Lake Road on the 1-meter deep contour and continued easterly for 1600 meters along that contour to the vicinity of Walkley's Landing (9 stations, 27 replicates).

McPherson Cove. Sampling was started off 2700 East Lake Road on the 1-meter deep contour and continued north for 1400 meters to Old Orchard Point (8 stations, 24 replicates).

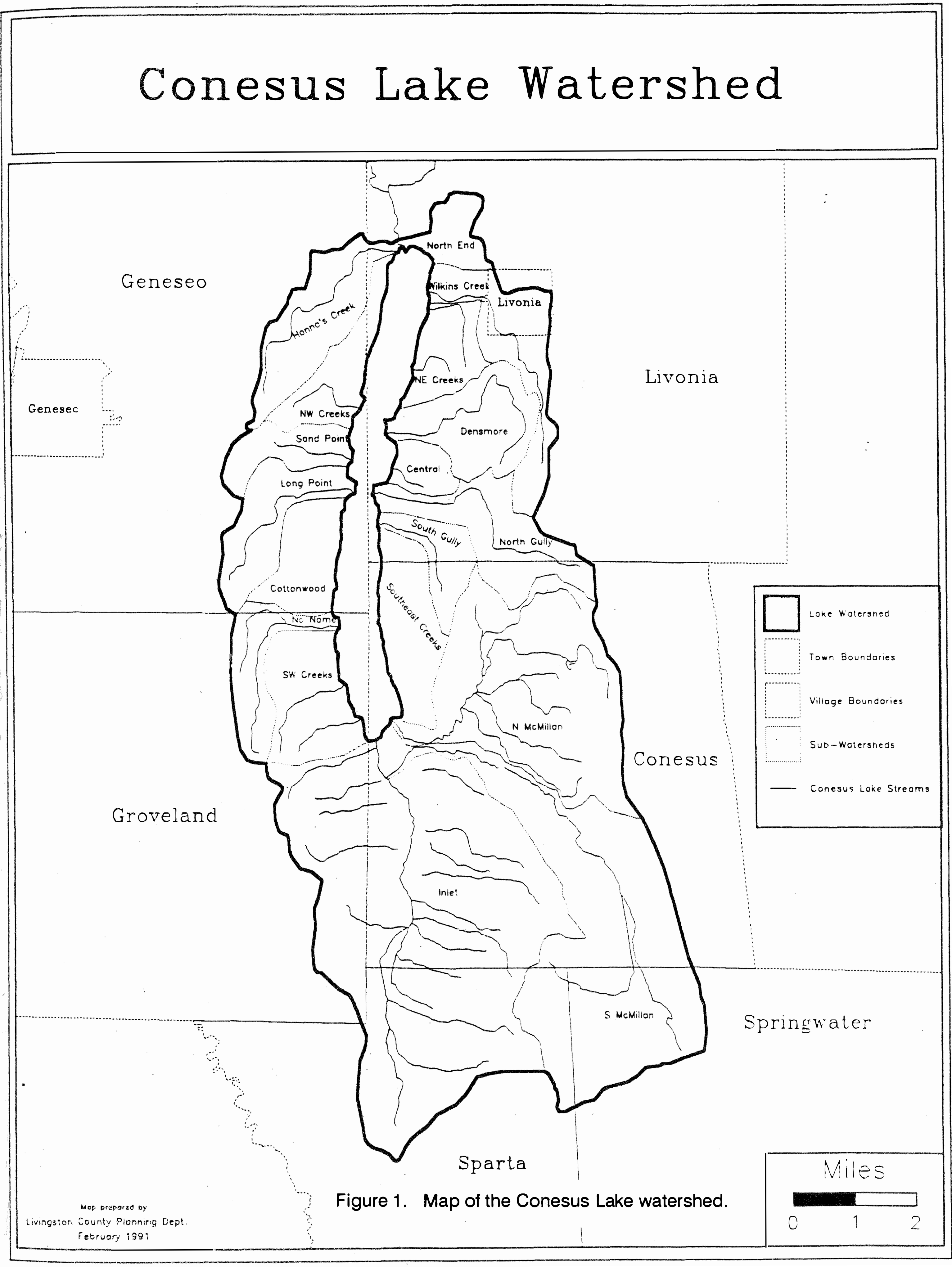


Figure 1. Map of the Conesus Lake watershed.

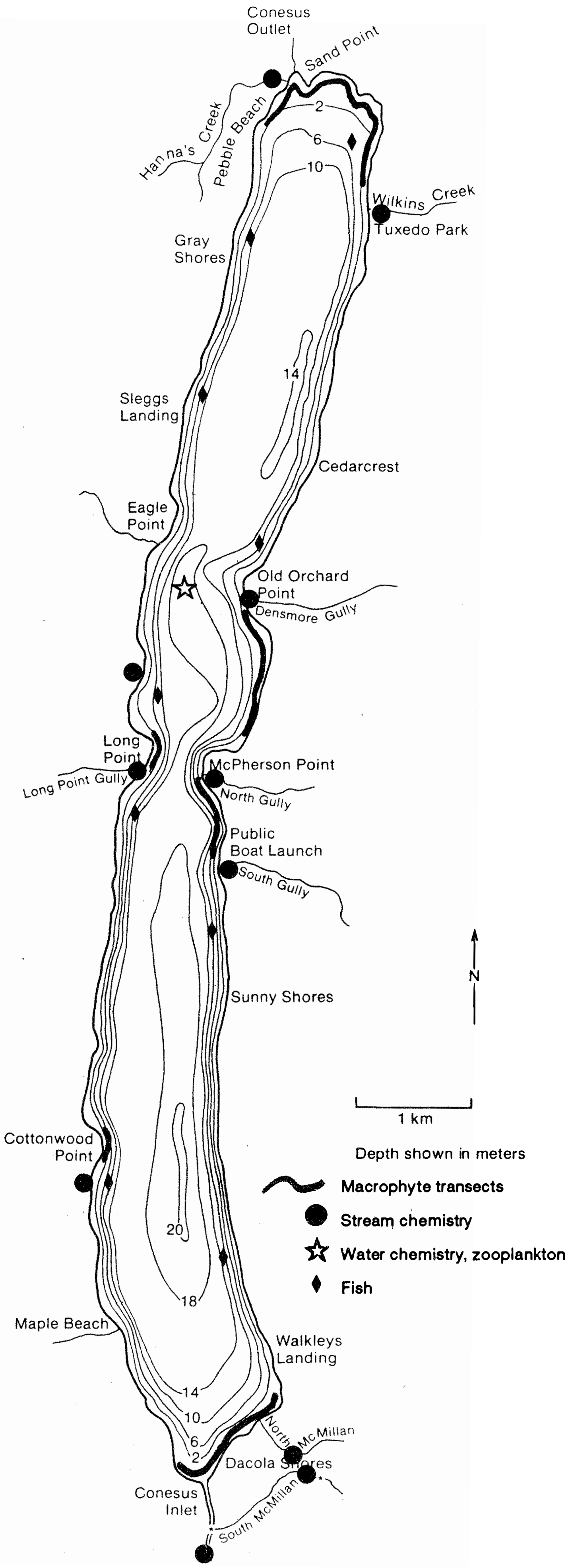


Figure 2. Conesus Lake and its tributaries showing lake sampling stations and tributary sampling sites, Livingston County, N.Y.

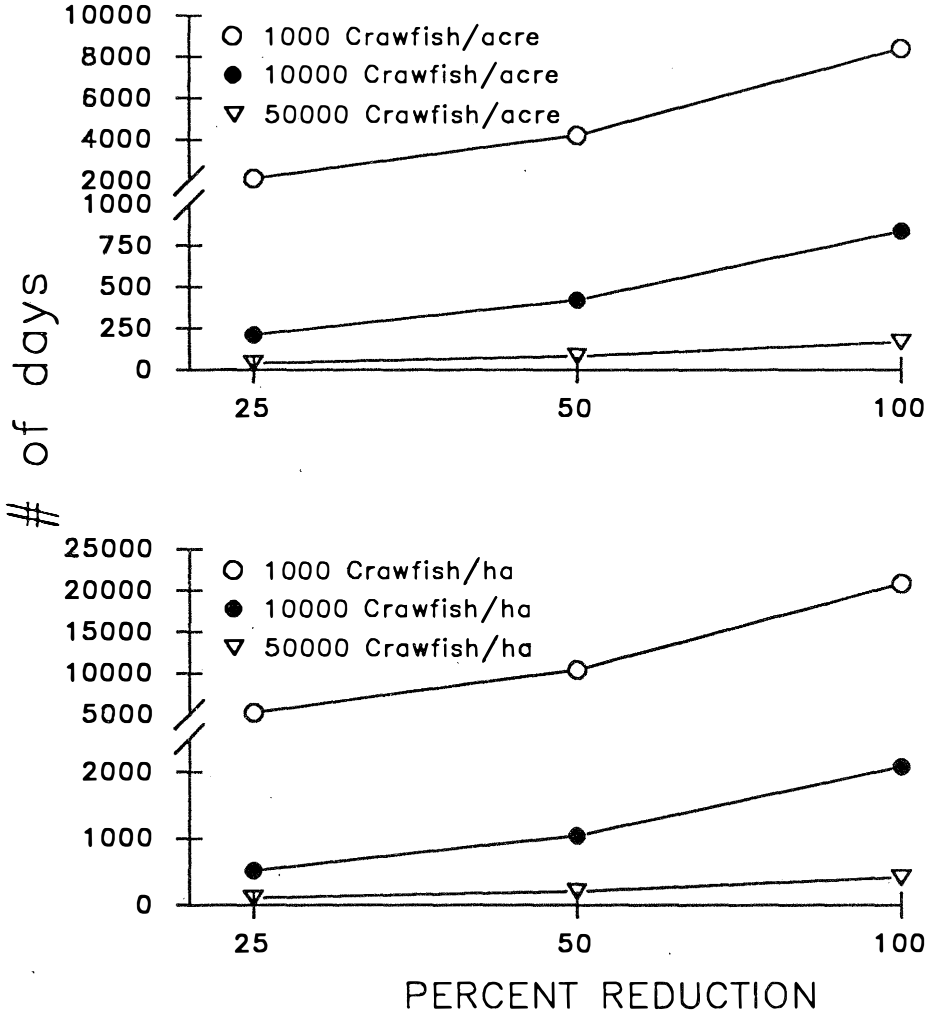


Figure 3. The relationship between Crayfish abundance and percent reduction of macrophytes.

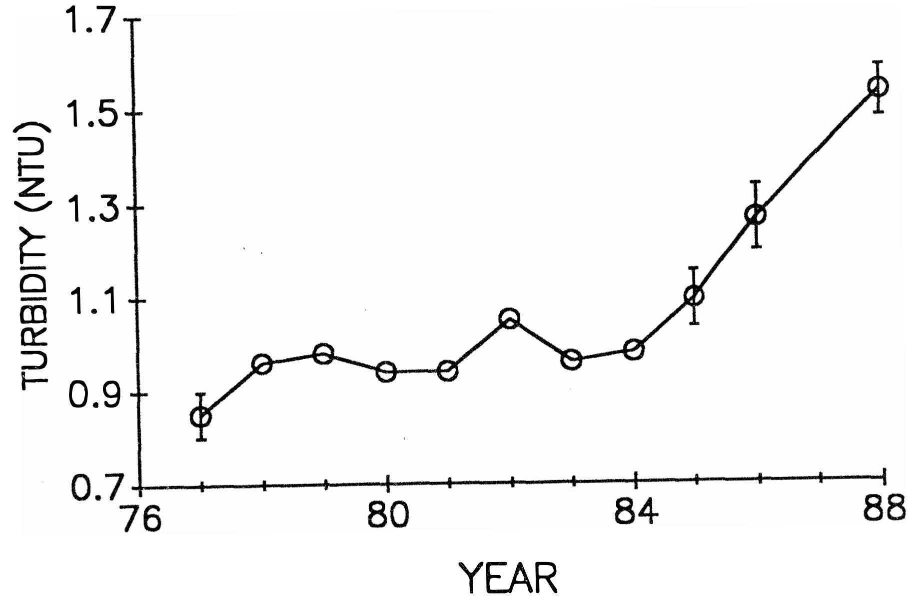


Figure 4. Mean annual daily turbidity levels, Conesus Lake. Data are from the Avon Water Treatment Plant. Brackets indicate the standard error. The 1987 data point is missing due to instrument failure during a portion of the year.

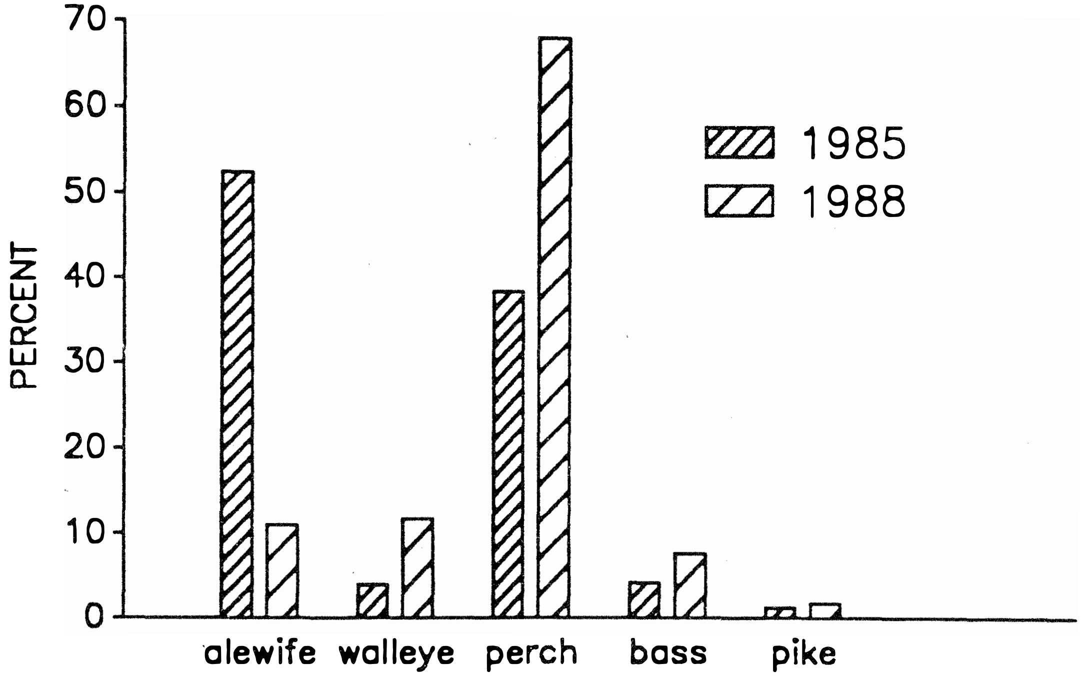


Figure 5. Relative abundance of selected fish in 1985 and 1988. Gill net census data were taken in 1985 and 1988 by N.Y.S. Department of Environmental Conservation, Region 7, Avon, N.Y.

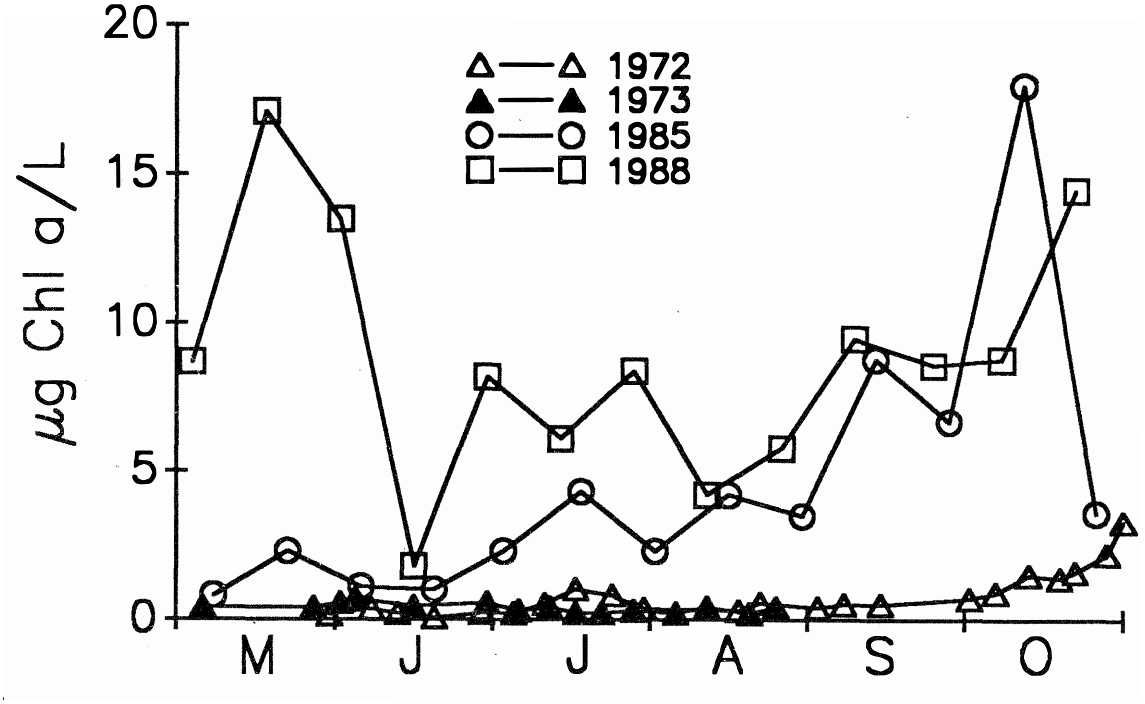


Figure 6. Seasonal chlorophyll *a* concentrations, 1972, 1985 and 1988, Conesus Lake.

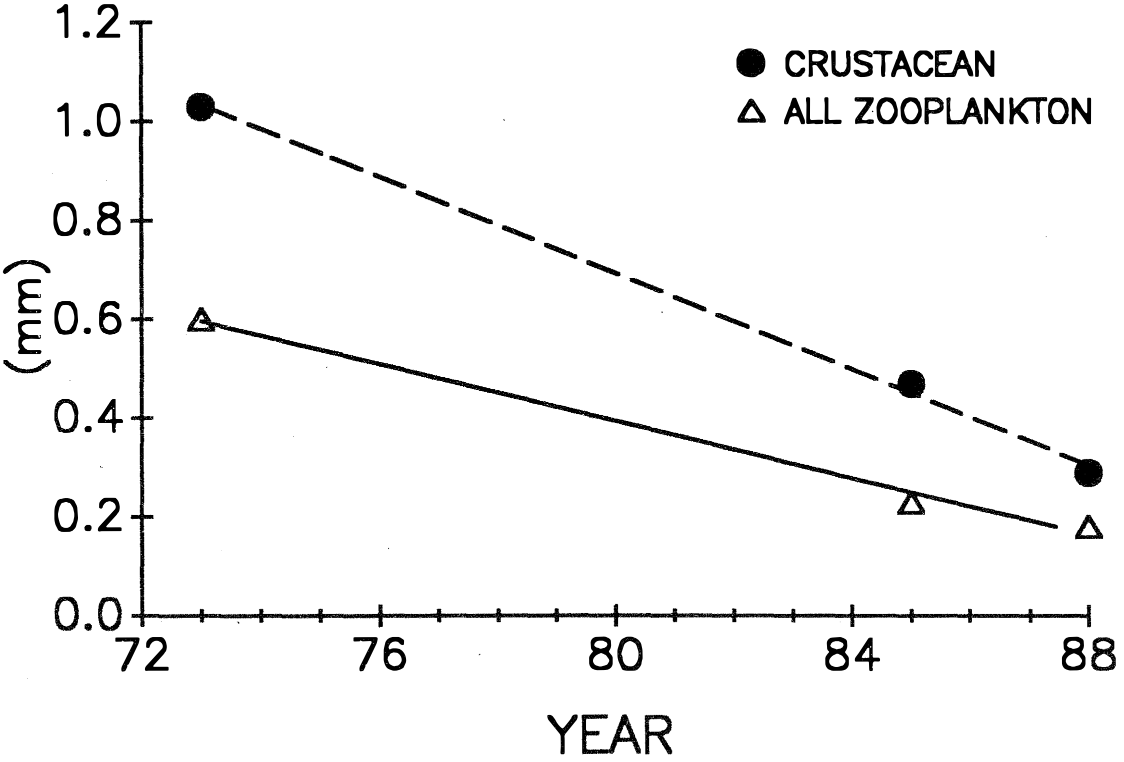


Figure 7. Length-frequency distribution of Crustacea in Conesus Lake in 1972-74, 1985 and 1988. The 1972-73 data (Chamberlain 1975) are combined to form a May through October period for comparison to the 1985 and 1988 data.

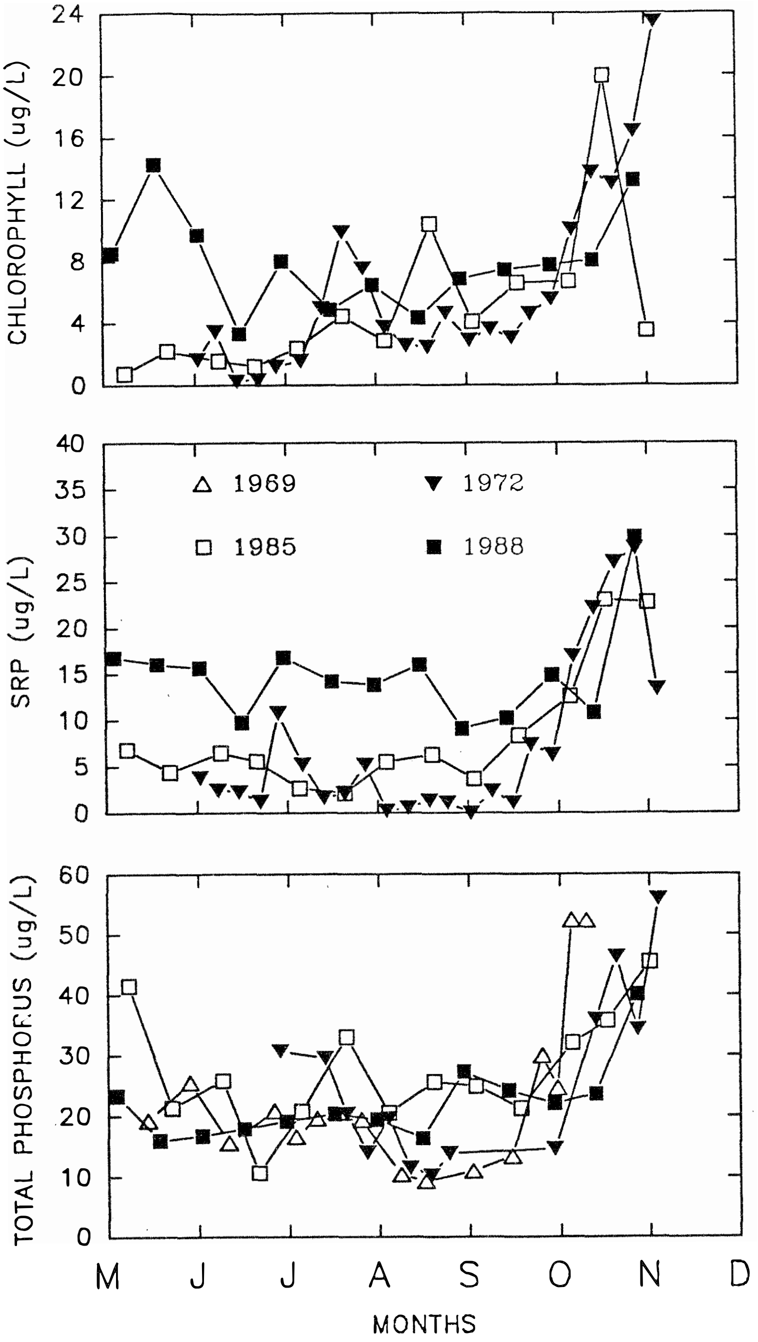


Figure 8. Historical seasonal epilimnetic chlorophyll a, soluble reactive phosphorus and total phosphorus data. Raw data were kindly provided by K. Stewart (total phosphorus, 1969) and E. Mills (chlorophyll and soluble reactive phosphorus, 1972). The 1985 and 1988 data are the average of the 1m and 8m samples. The 1972 data represent the average of the 0m and 5m samples. The 1969 data are the mean of the 0, 3 and 6m samples.

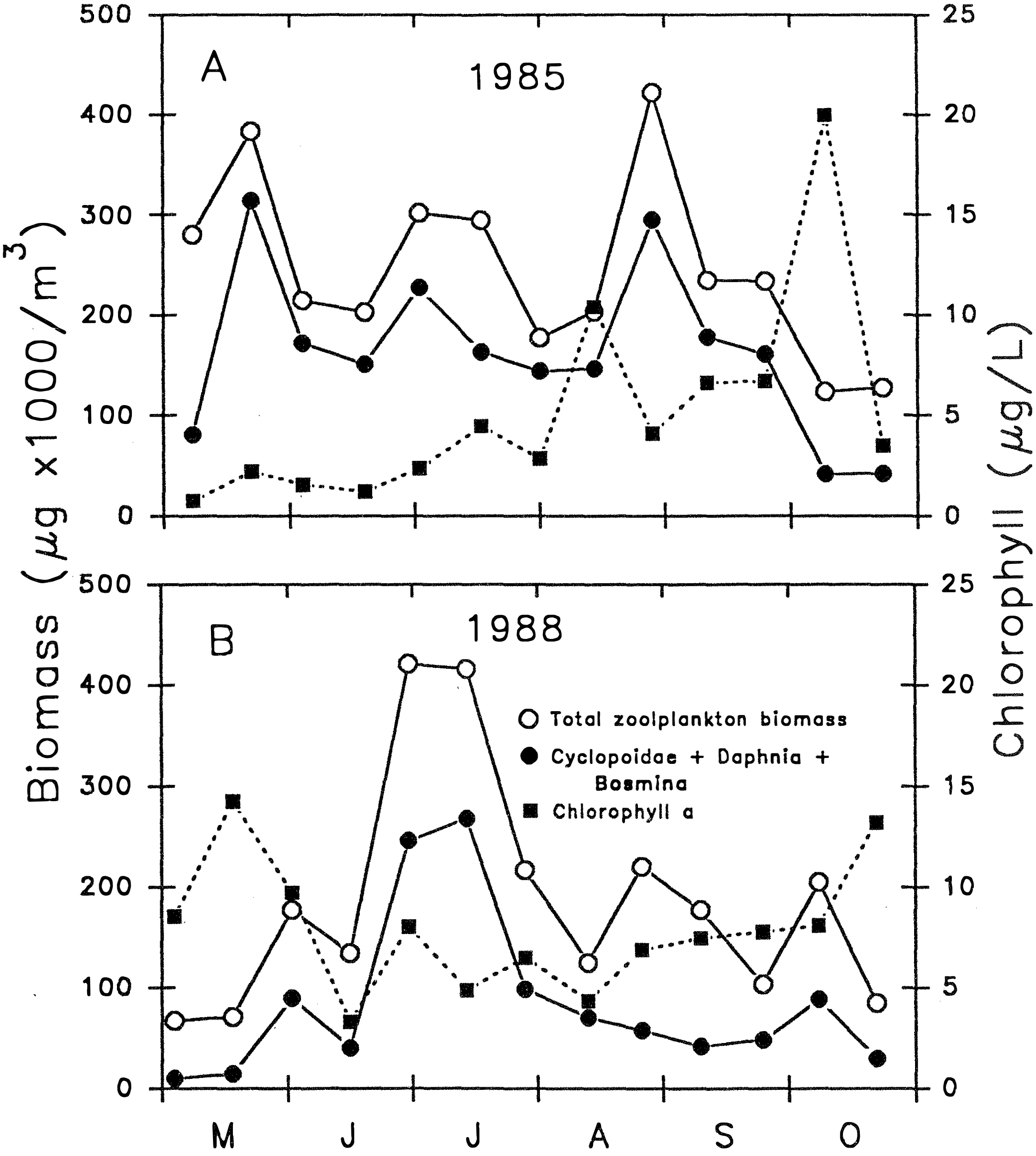


Figure 9. Seasonal chlorophyll a concentrations and zooplankton biomass in 1985 and 1988, Conesus Lake.

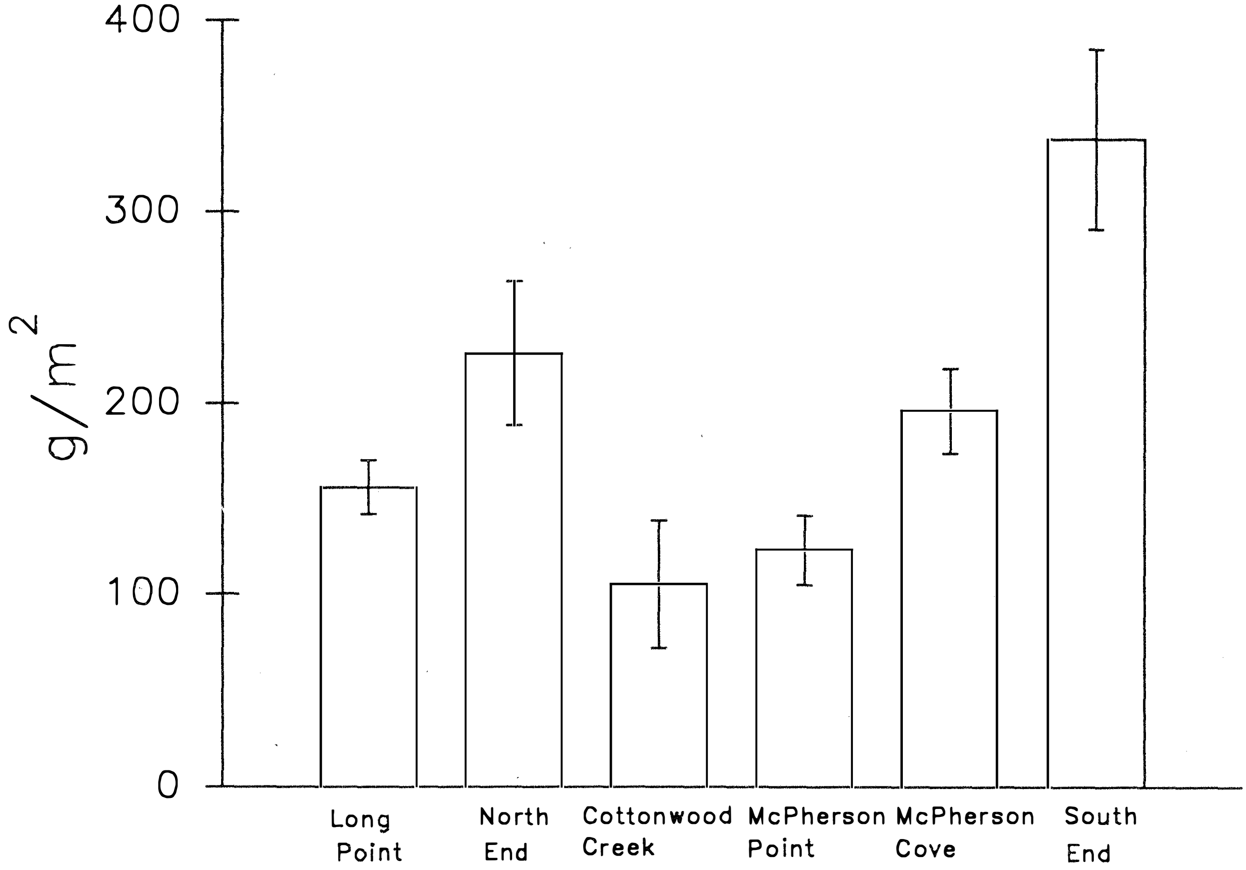


Figure 10. Mean macrophyte biomass (dry weight) for selected sites on Conesus Lake during August of 1990. Values are the mean ± standard error.

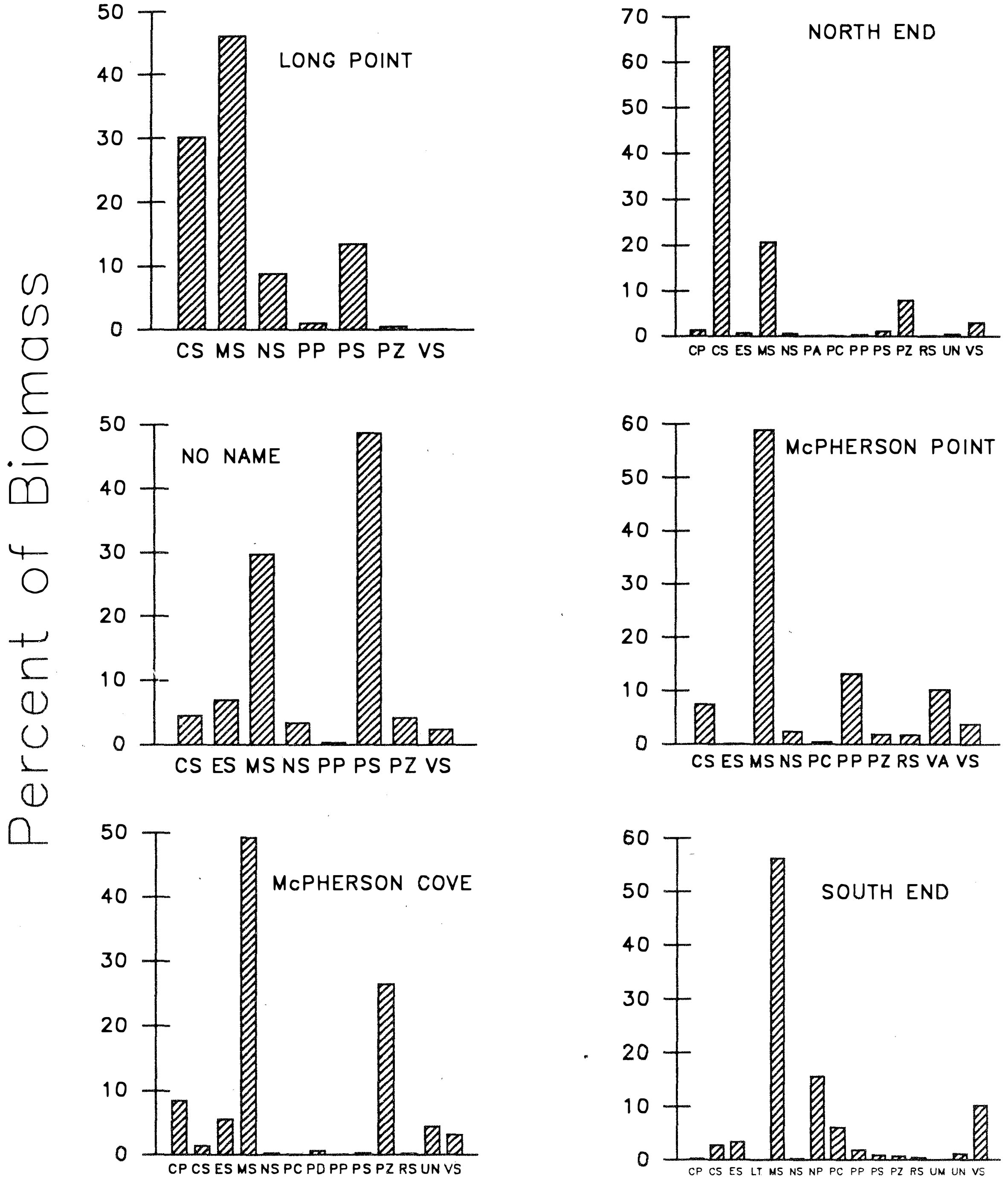


Figure 11. Individual relative biomass of macrophytes, August, 1990. CP=*Ceratophyllum* sp., CS=*Chara* sp., ES=*Elodea* sp., LT=*Lemna trisulca*, MS=*Myriophyllum* sp., NS=*Najas* sp., NP=*Naphar* sp., PA= *Potamogeton americanus*, PC= *P. crispus*, PD= *P. diversifolius*, PP= *P. pectinatus*, PS = *Potamogeton* sp., PZ = *P. zosteriformis*, UM = Unidentified Plant, VA = *Vallesnaria americana*, VS = *Vallesnaria* sp.

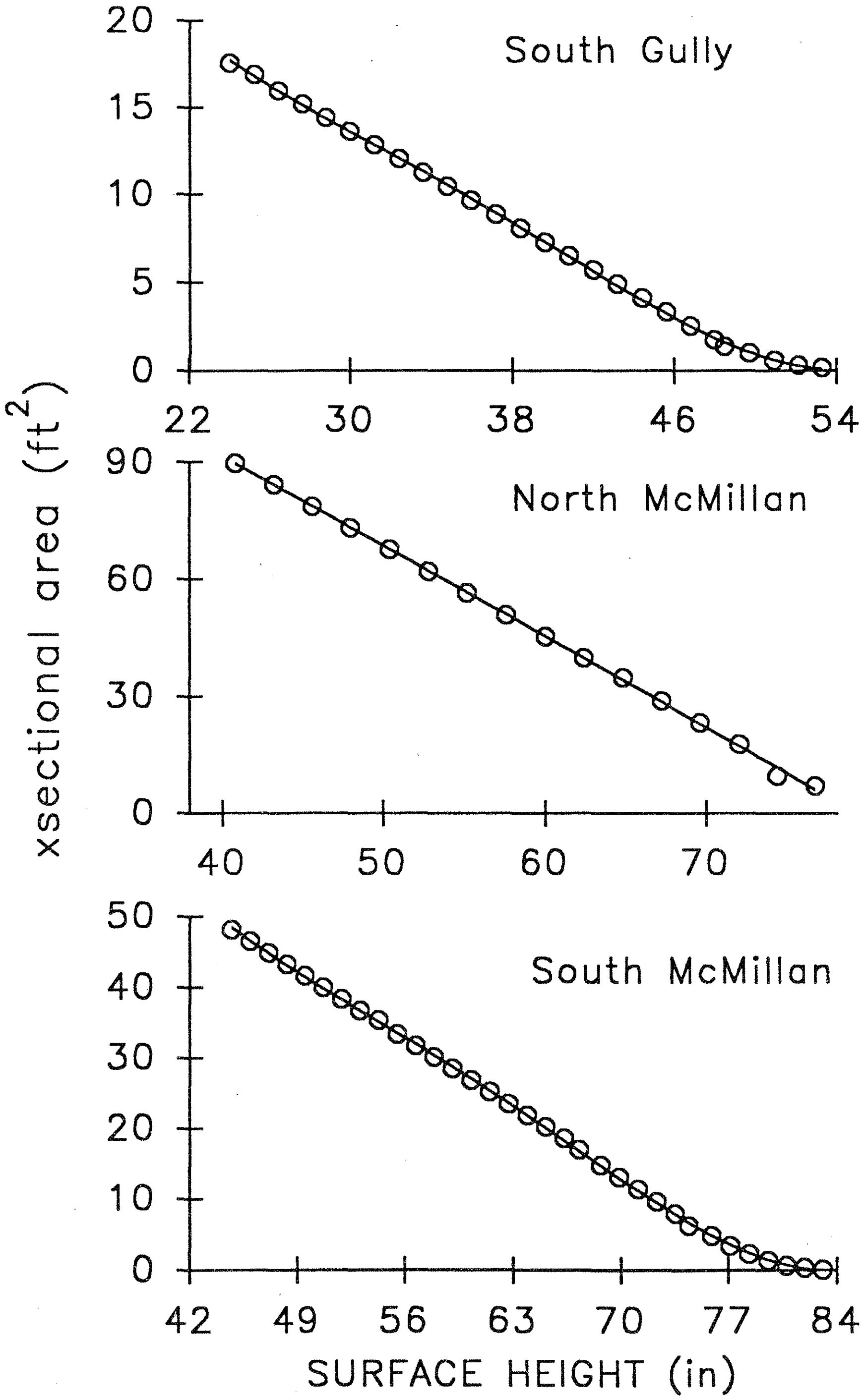


Figure 12. Cross-sectional area of the South Gully, North McMillan and South McMillan sampling site versus stream height. Stream height is the distance from the top of the culvert or bridge to the surface of the stream. Thus the higher the stream gets the lower the stream height is on the graph.

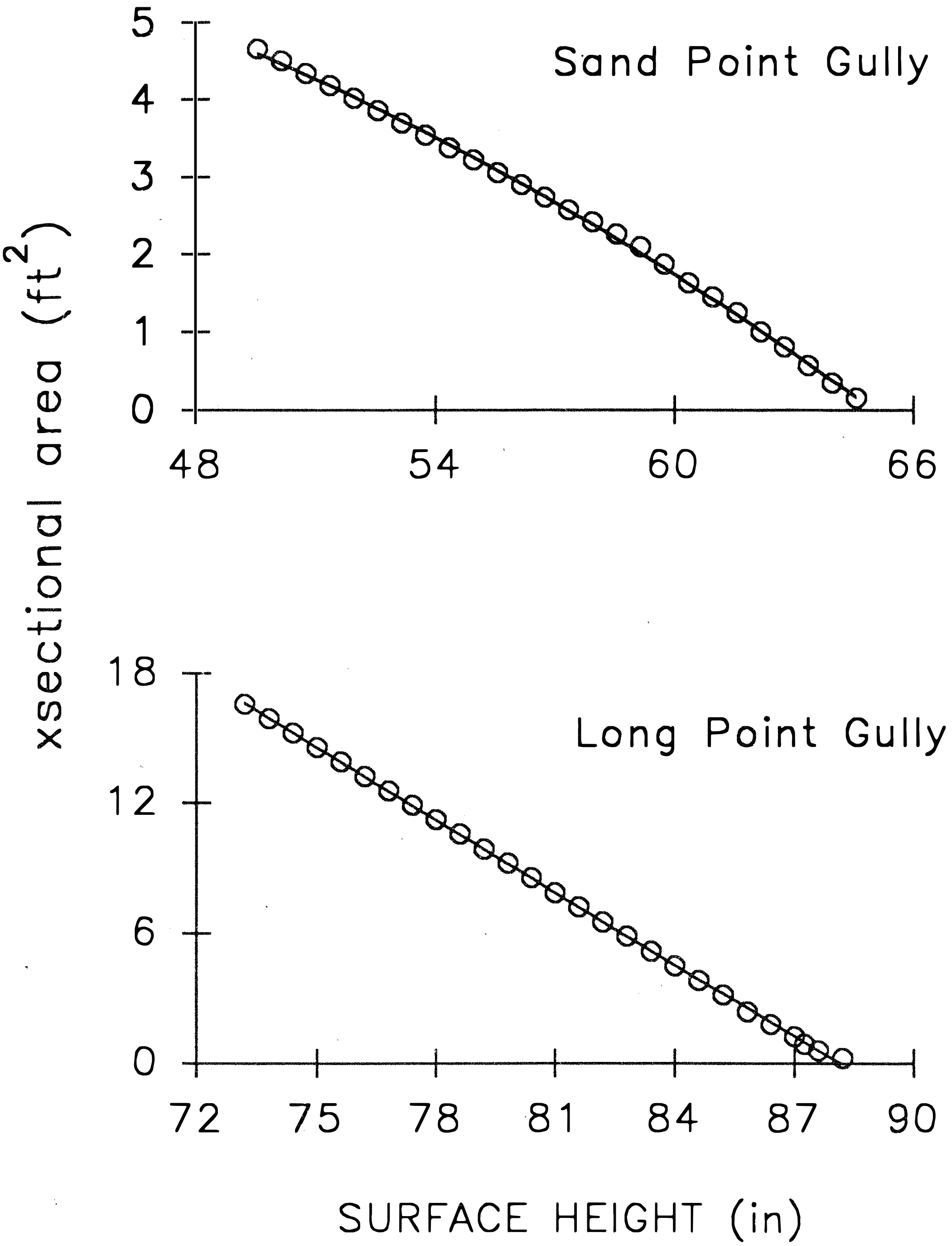


Figure 13. Cross-sectional area of the Sand Point and Long Point Gully sampling site versus stream height. Stream height is the distance from the top of the culvert or bridge to the surface of the stream. Thus the higher the stream gets the lower the stream height is on the graph.

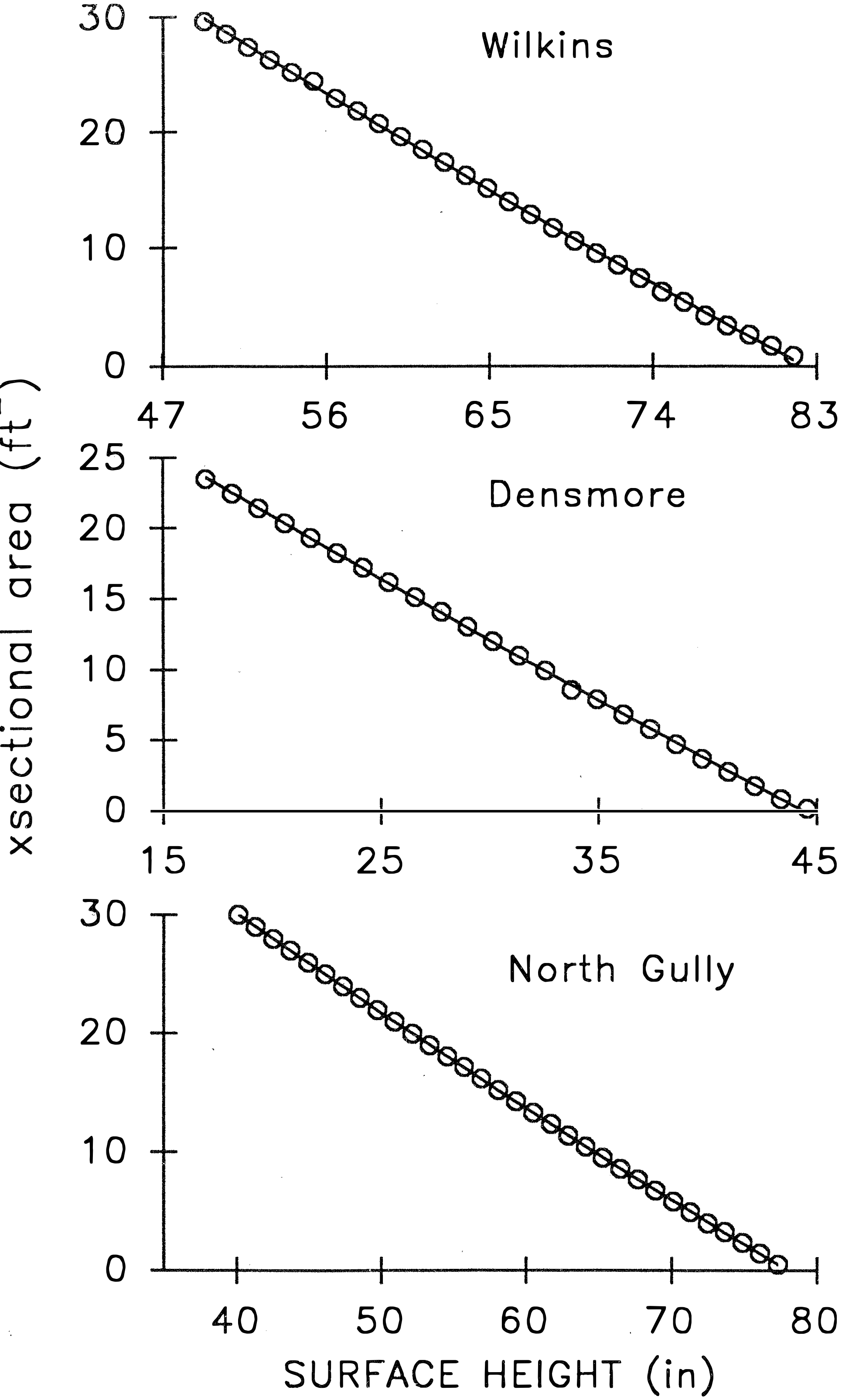


Figure 14. Cross-sectional area of the Wilkins, Densmore and North Gully sampling site versus stream height. Stream height is the distance from the top of the culvert or bridge to the surface of the stream. Thus the higher the stream gets the lower the stream height is on the graph.

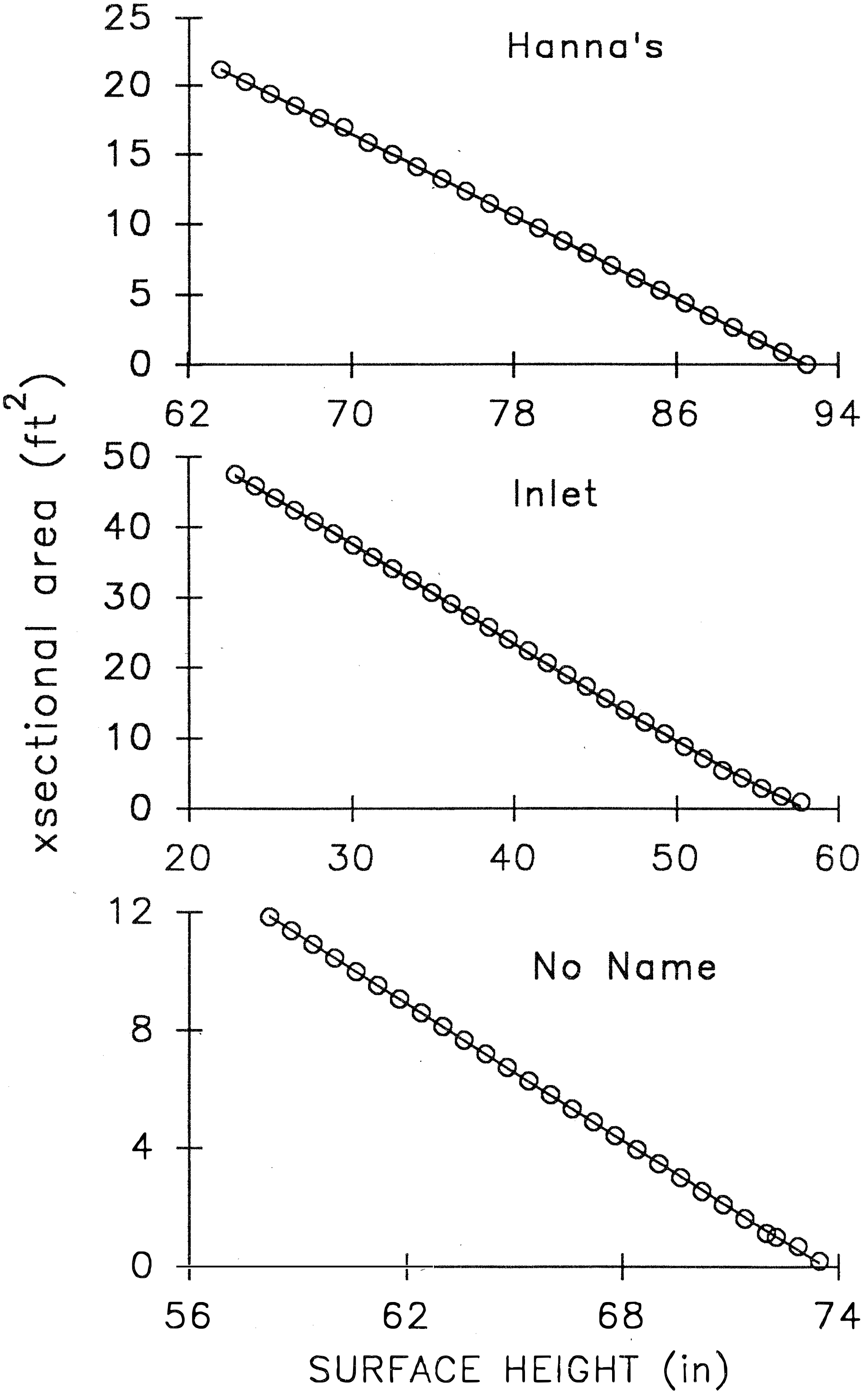


Figure 15. Cross-sectional area of the Hanna's, Inlet and "No Name" sampling site versus stream height. Stream height is the distance from the top of the culvert or bridge to the surface of the stream. Thus the higher the stream gets the lower the stream height is on the graph.

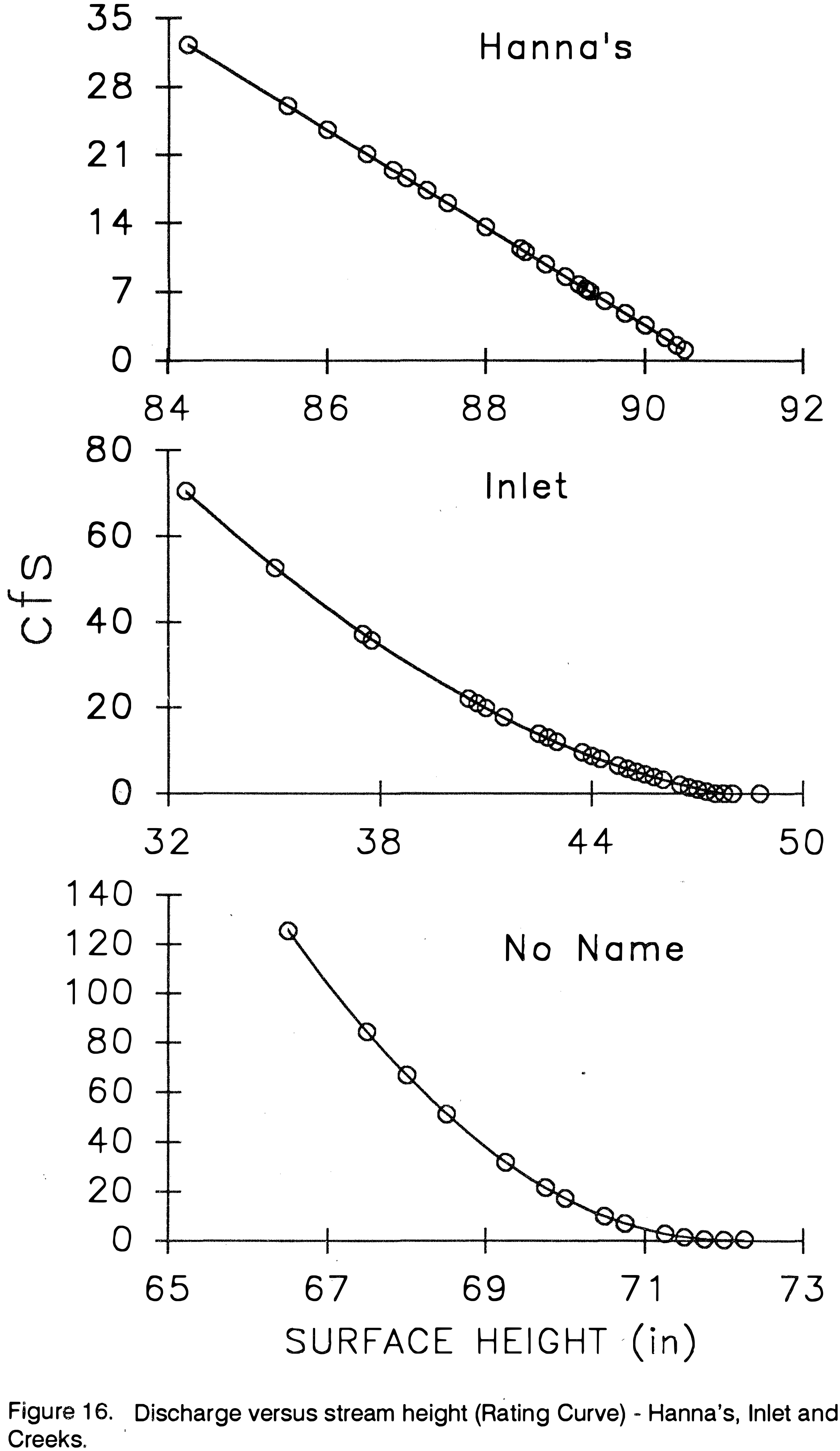


Figure 16. Discharge versus stream height (Rating Curve) - Hanna's, Inlet and "No Name" Creeks.

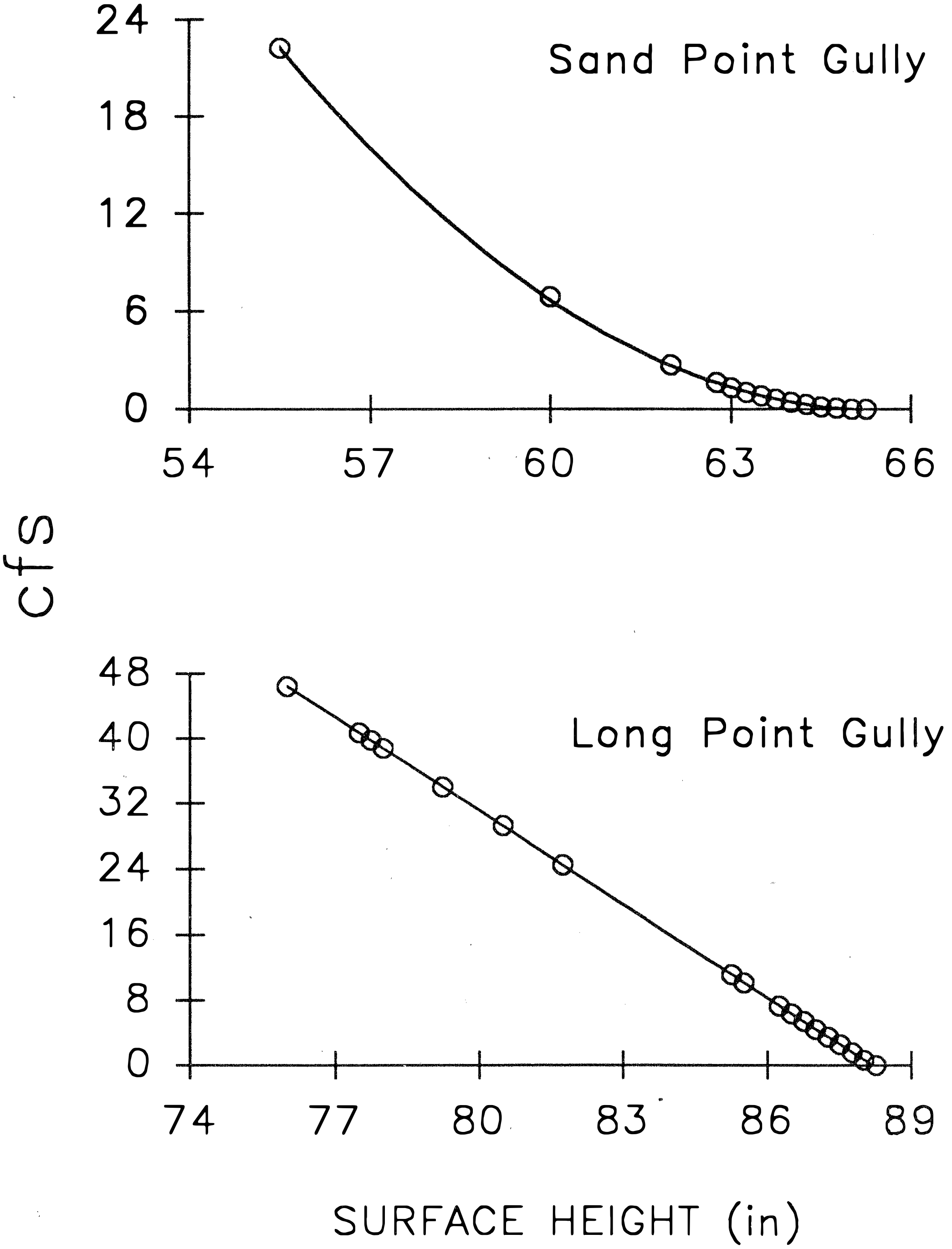


Figure 17. Discharge versus stream height (Rating Curve) - Sand Point Gully and Long Point Gully Creek.

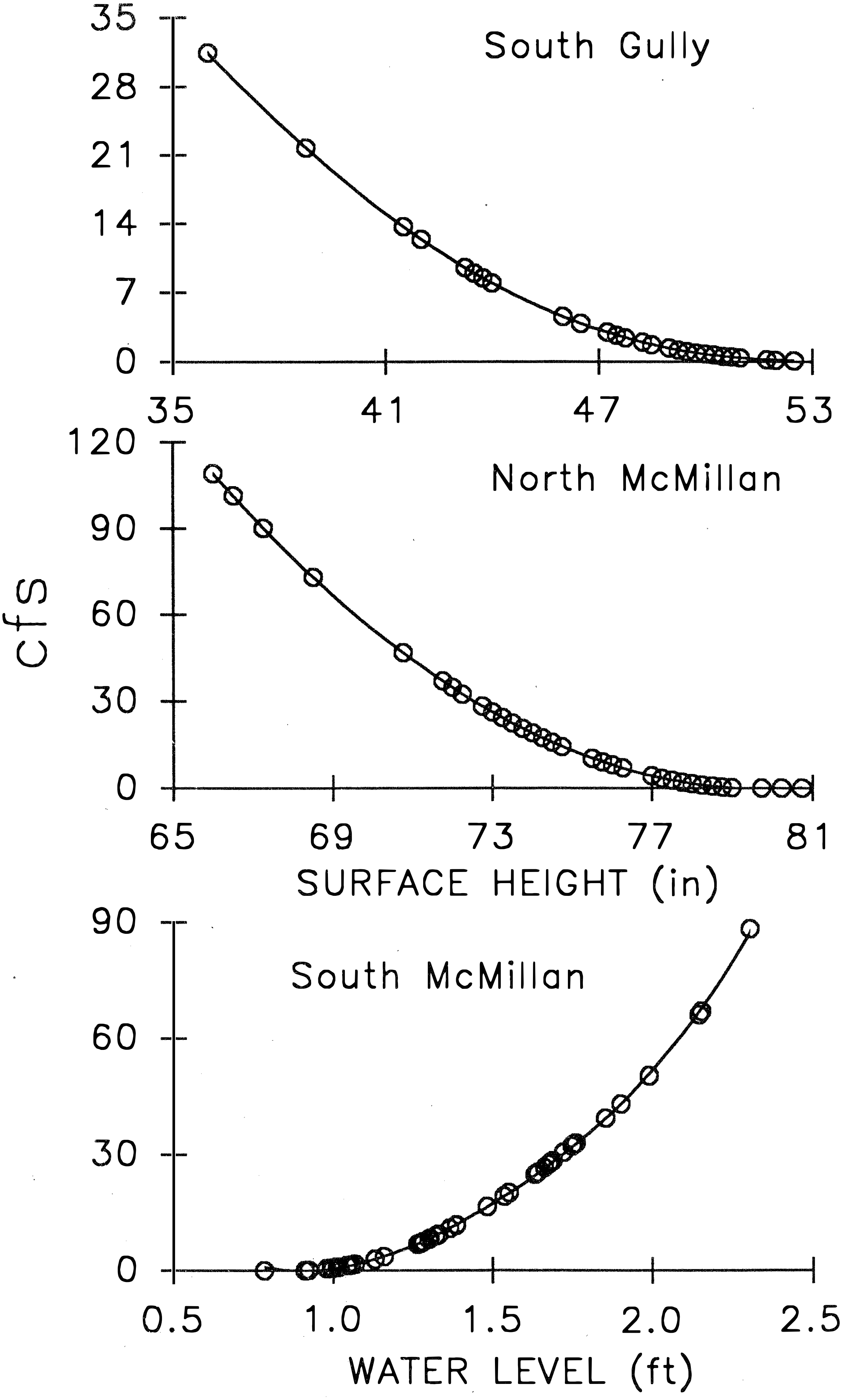


Figure 18. Discharge versus stream height (Rating Curve) - South Gully, North McMillan and South McMillan Creek. With South McMillan, water depth is plotted versus discharge.

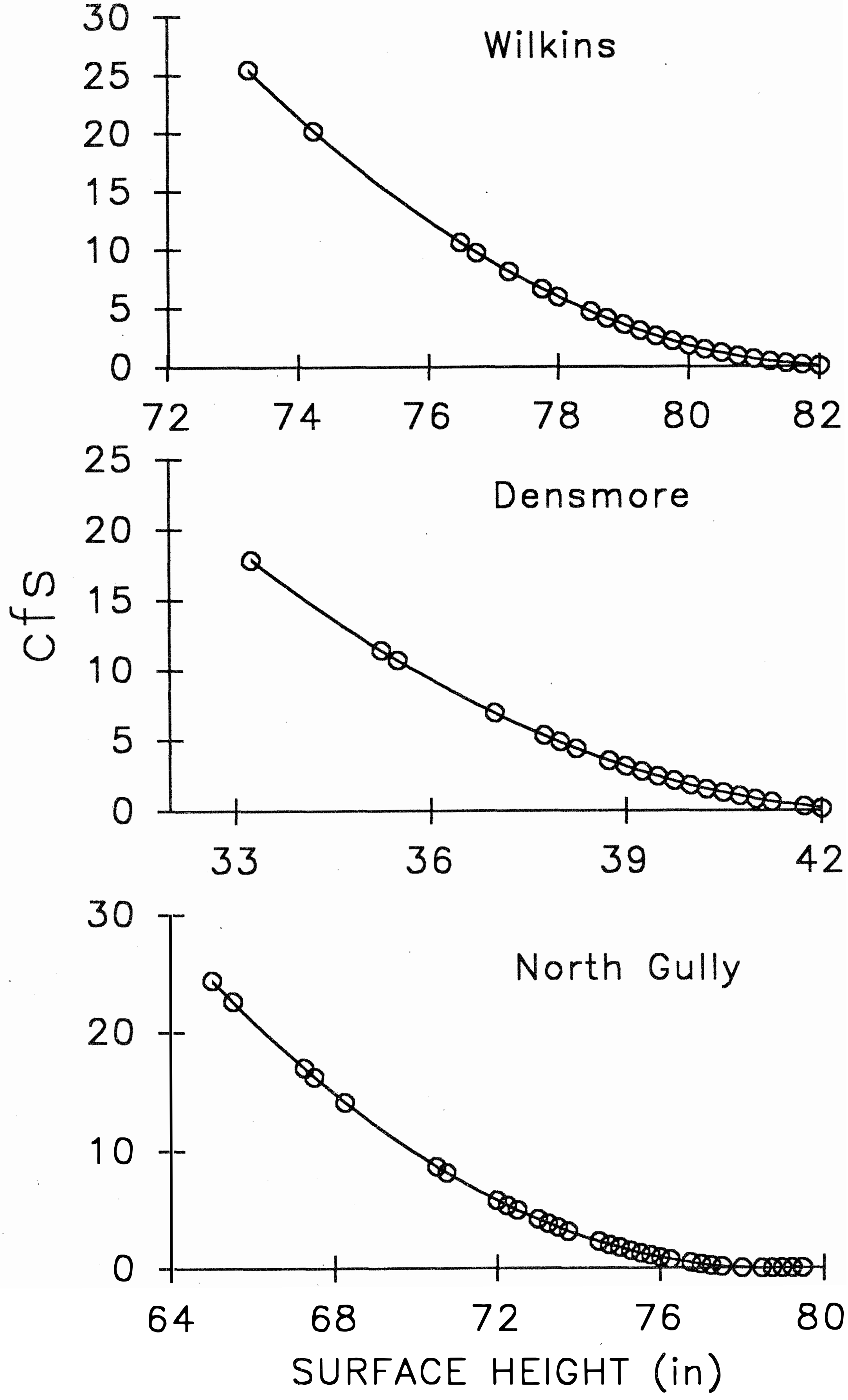


Figure 19. Discharge versus stream height (Rating Curve) - Wilkins, Densmore and North Gully Creeks.

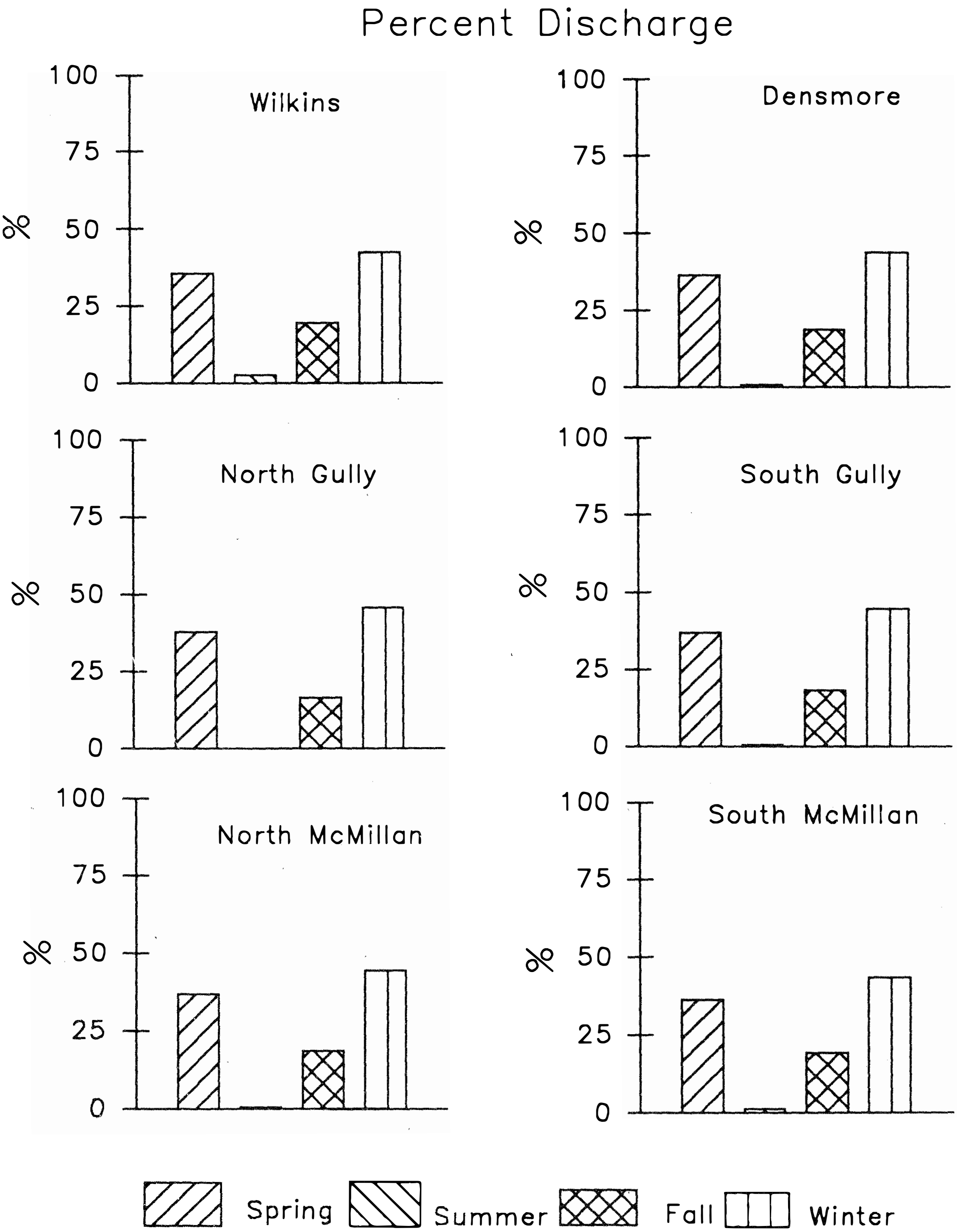


Figure 20. Relative seasonal discharge of selected Conesus Lake tributaries.

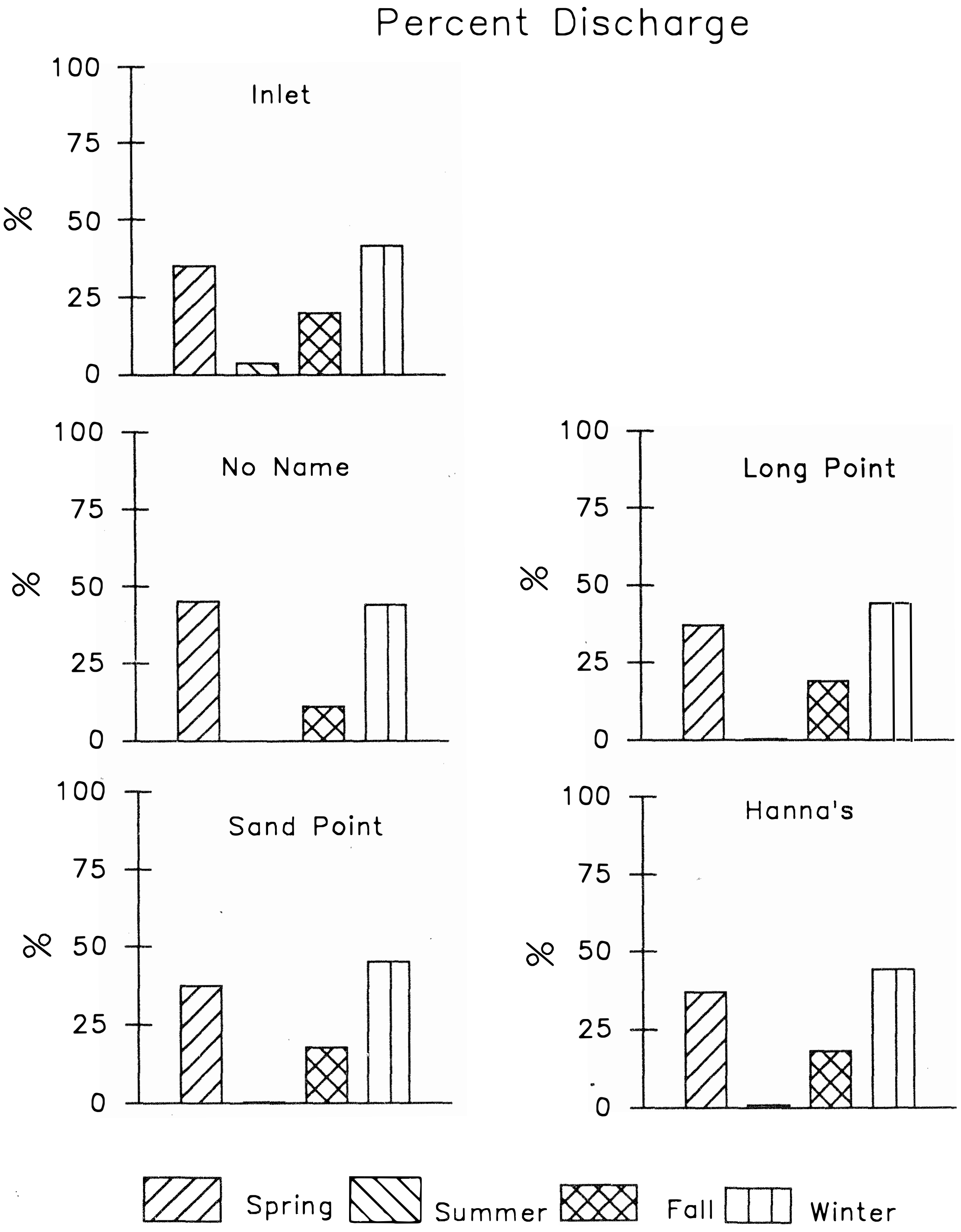


Figure 21. Relative seasonal discharge of selected Conesus Lake tributaries.

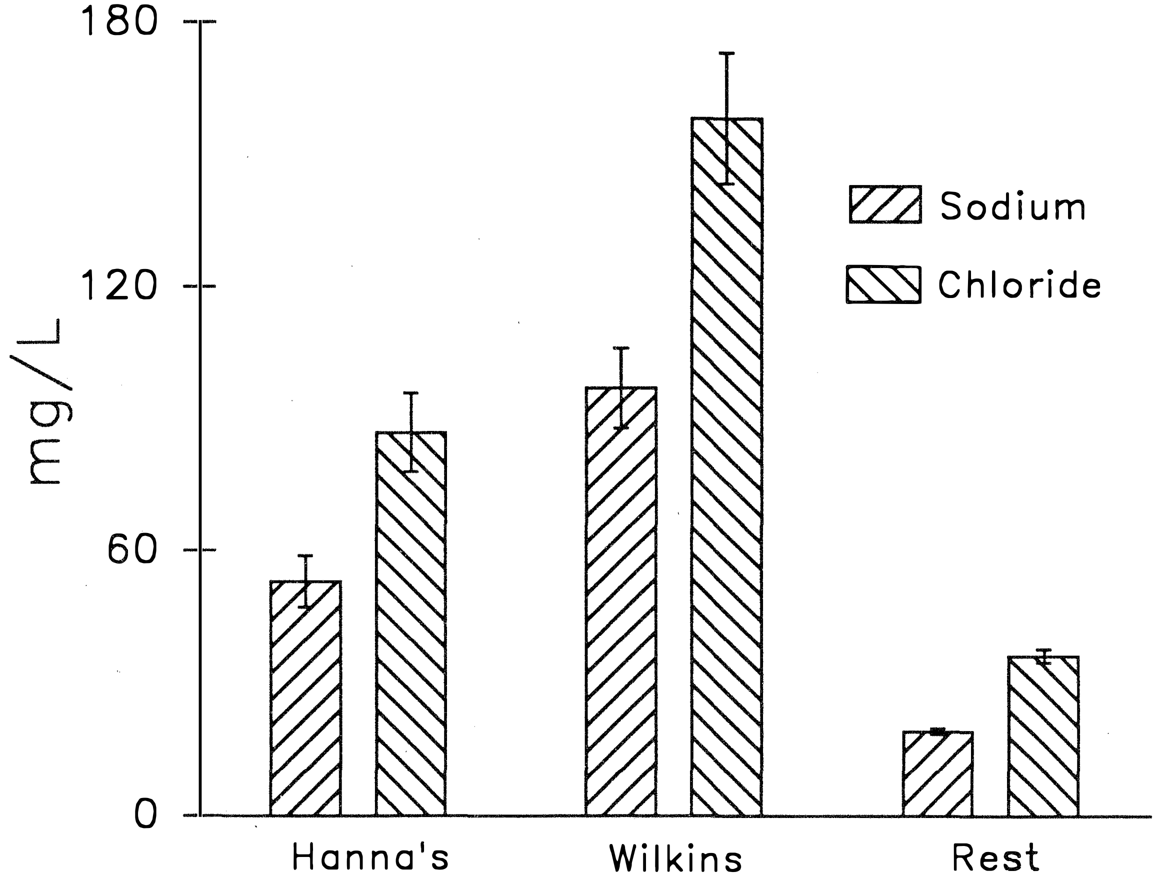


Figure 22. Comparison of sodium and chloride concentrations (annual mean) of Hanna's and Wilkins Creeks to other tributaries of Conesus Lake.

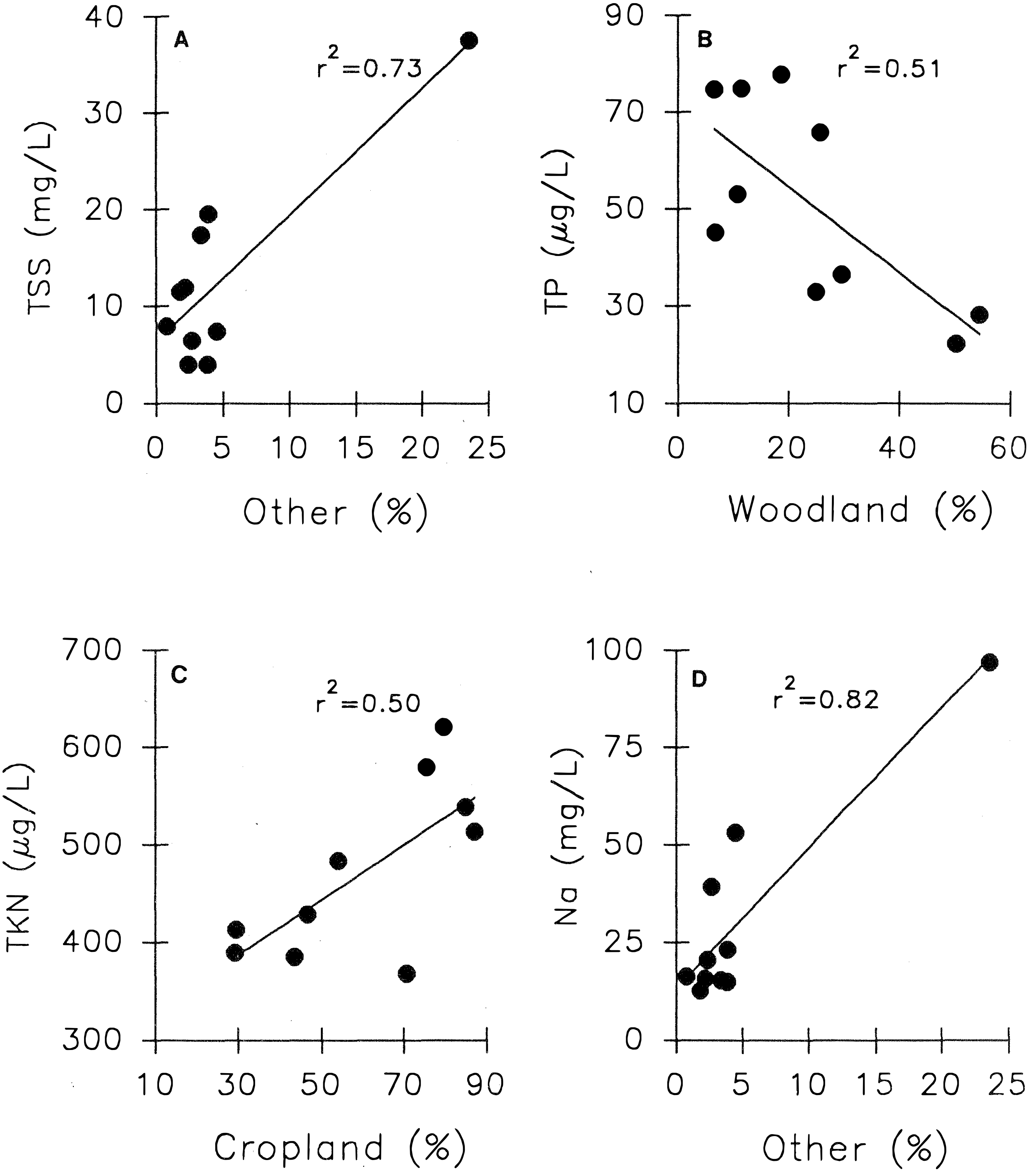


Figure 23. Relationship between land usage and mean annual concentrations of total suspended solids (TSS), total phosphorus (TP), total kjeldahl nitrogen (TKN) and sodium in streams of Conesus Lake. The land use Other refers to urban, wetlands and sand pits.

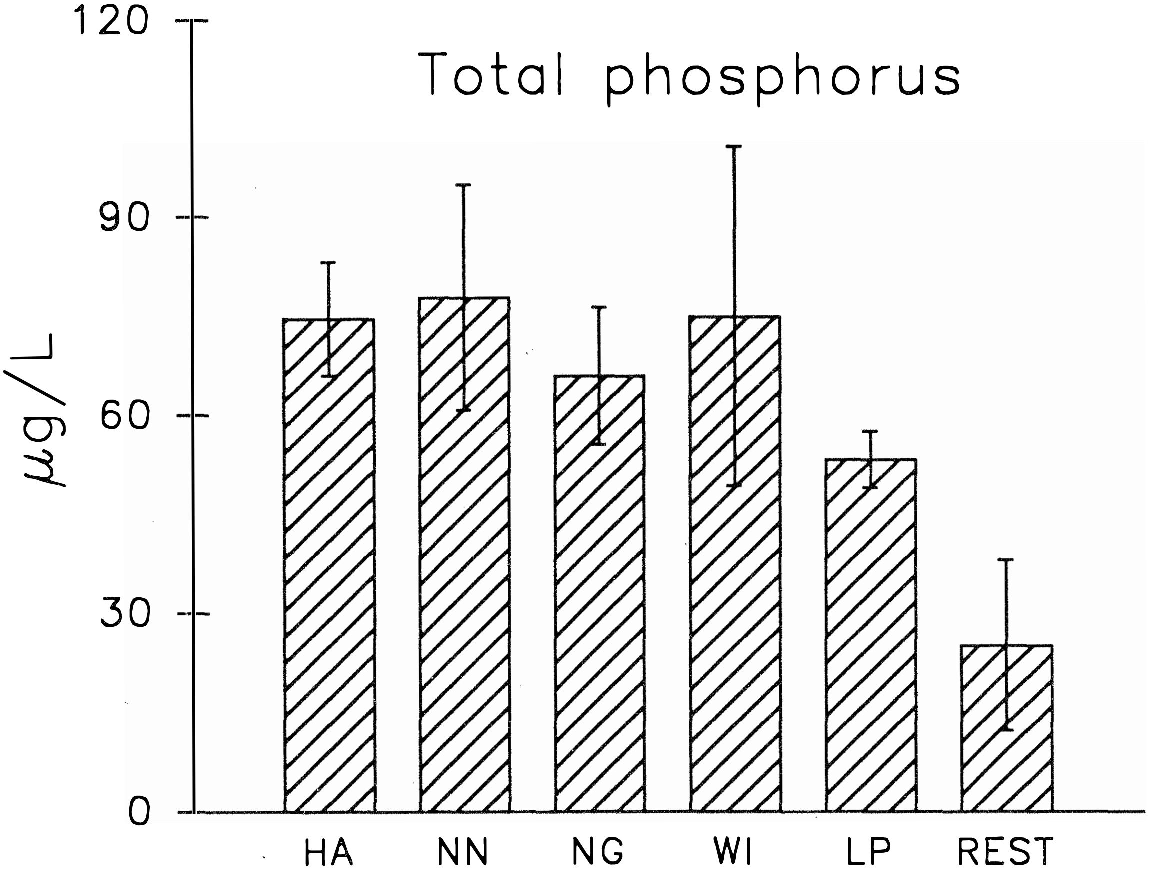


Figure 24. Comparison of total phosphorus concentrations (annual mean) of selected tributaries of Conesus Lake.

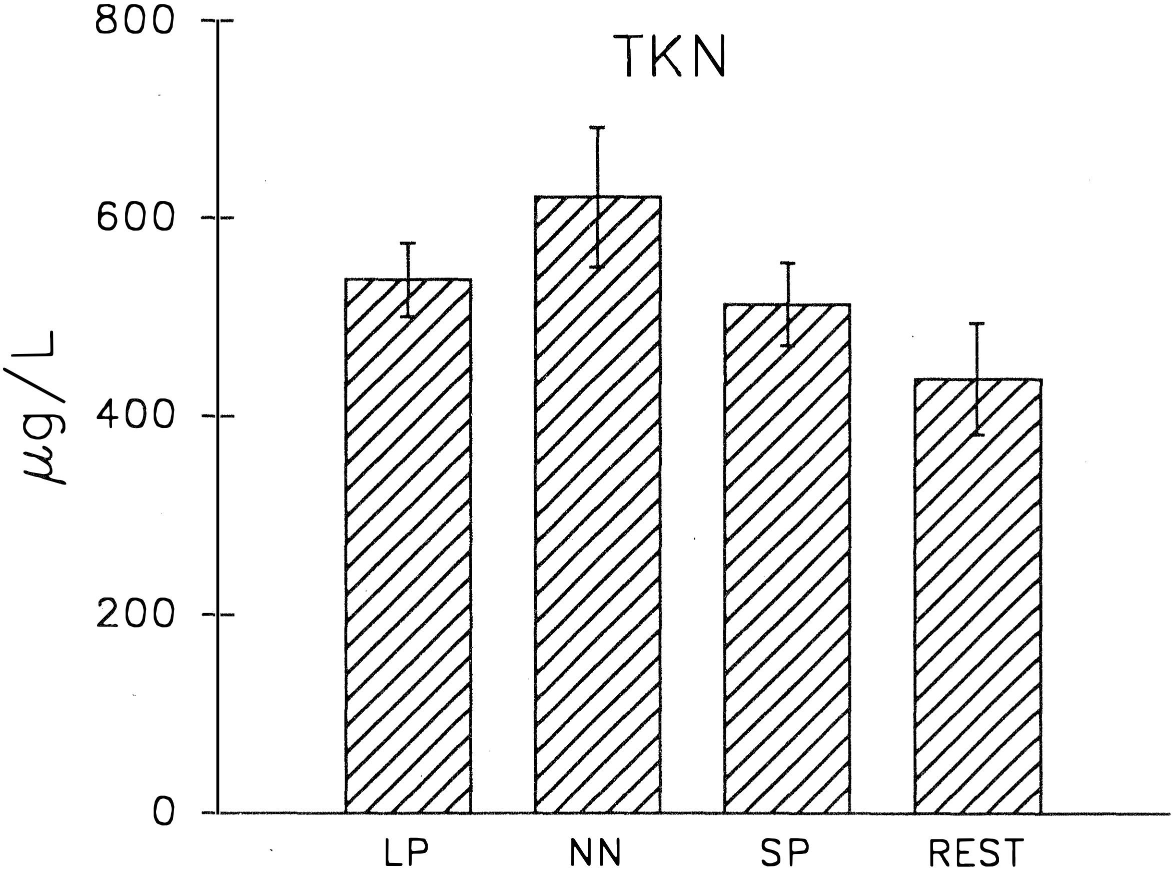


Figure 25. Comparison of total kjeldahl nitrogen concentrations (annual mean) of selected tributaries of Conesus Lake.

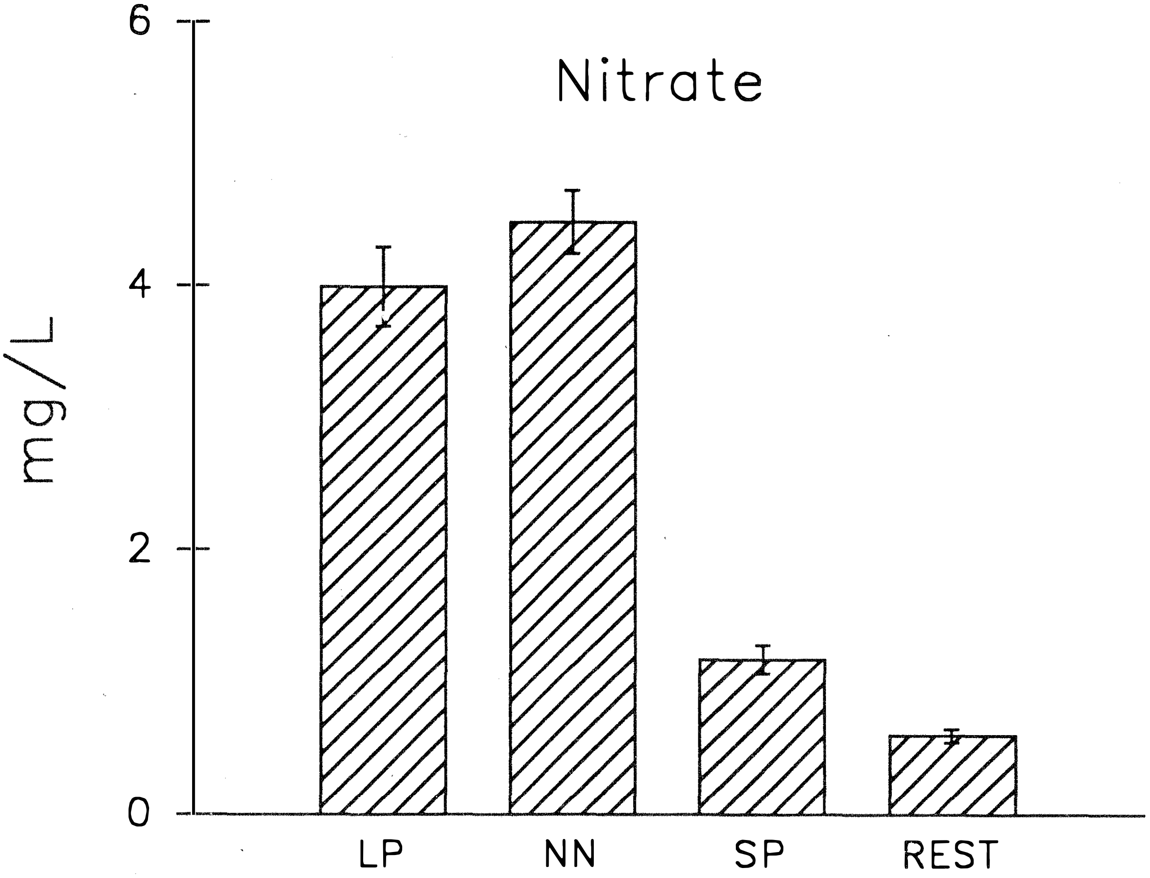


Figure 26. Comparison of nitrate concentrations (annual mean) of selected tributaries of Conesus Lake.

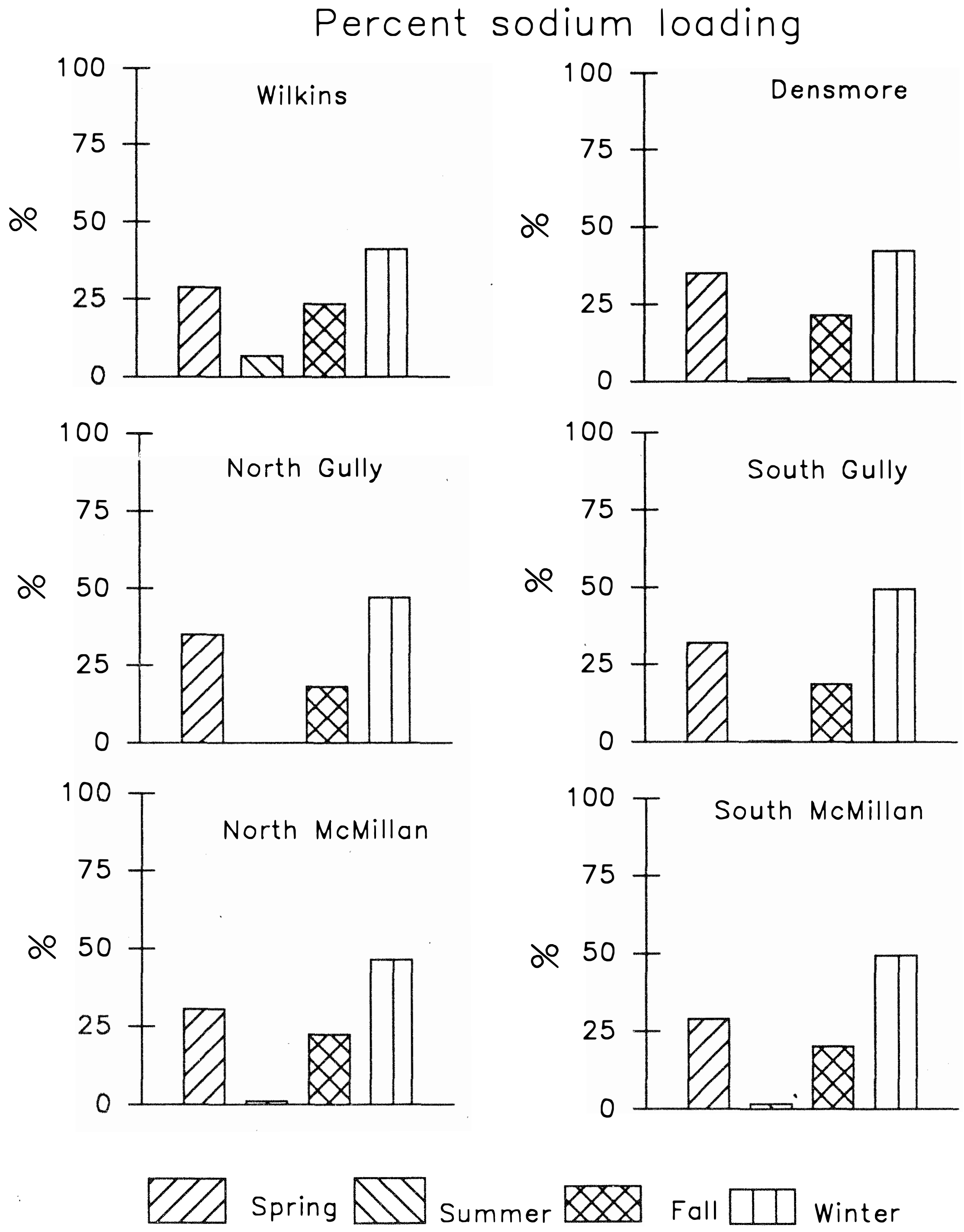


Figure 27. Relative seasonal sodium loading of selected Conesus Lake tributaries.

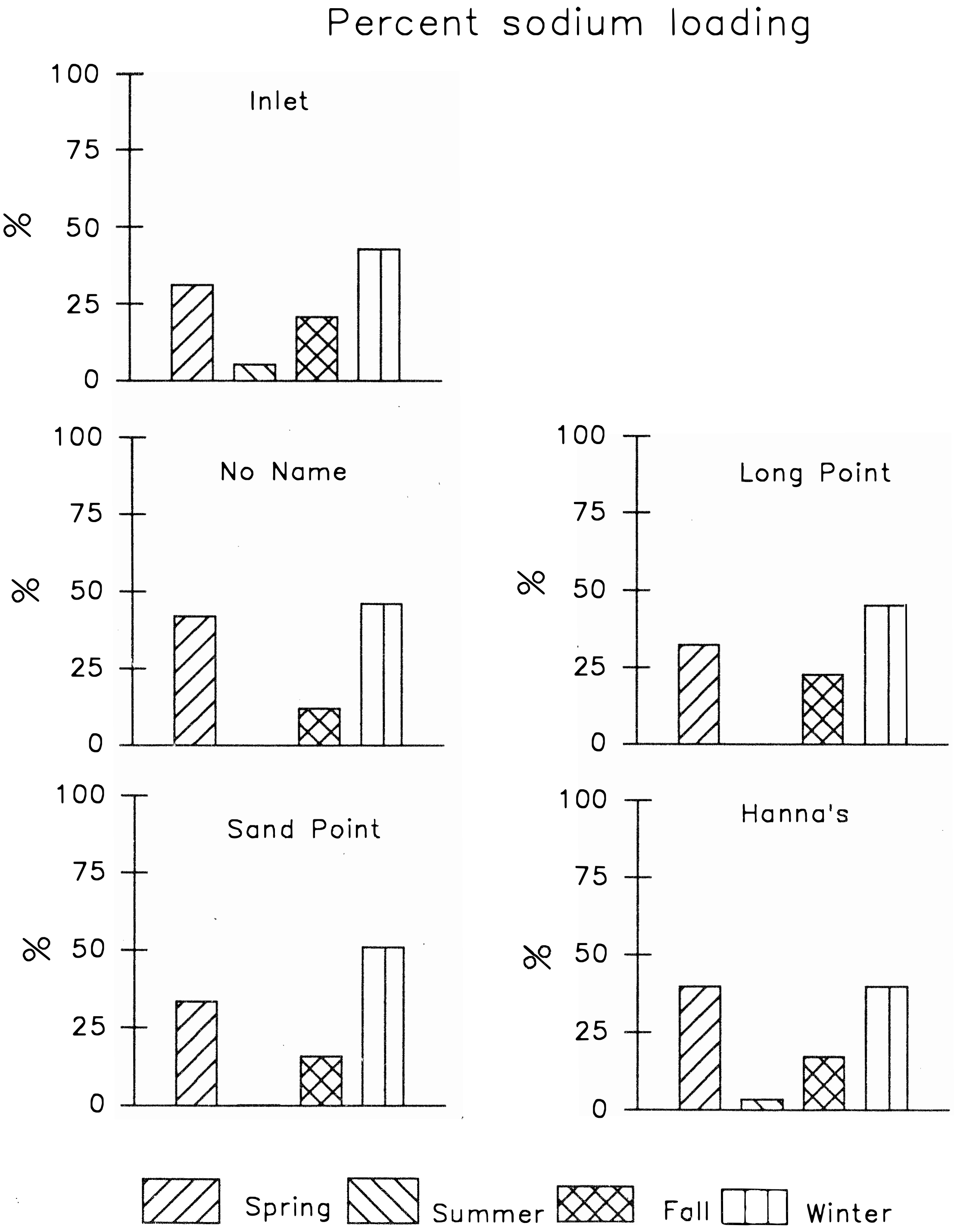


Figure 28. Relative seasonal sodium loading of selected Conesus Lake tributaries.

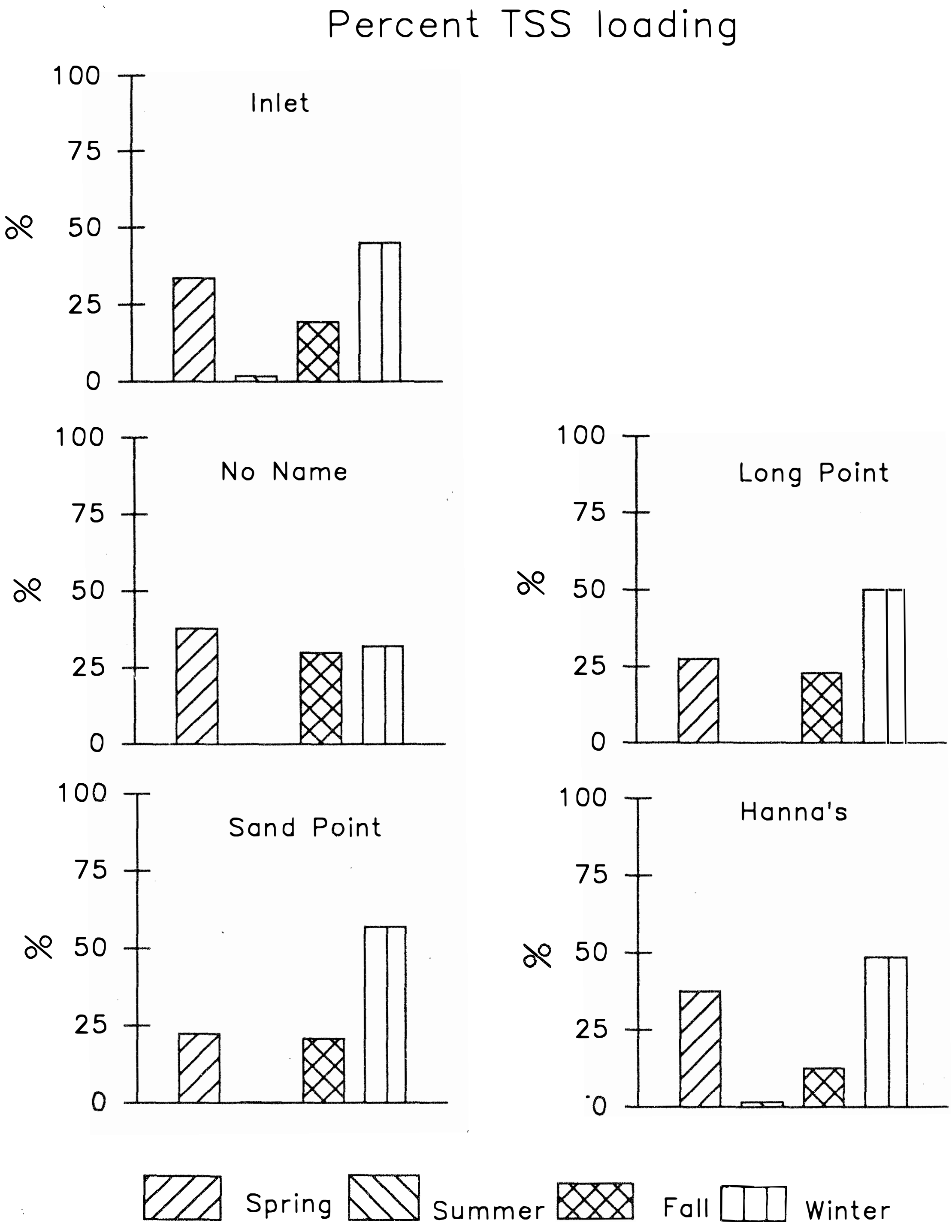


Figure 29. Relative seasonal total suspended solids loading of selected Conesus Lake tributaries.

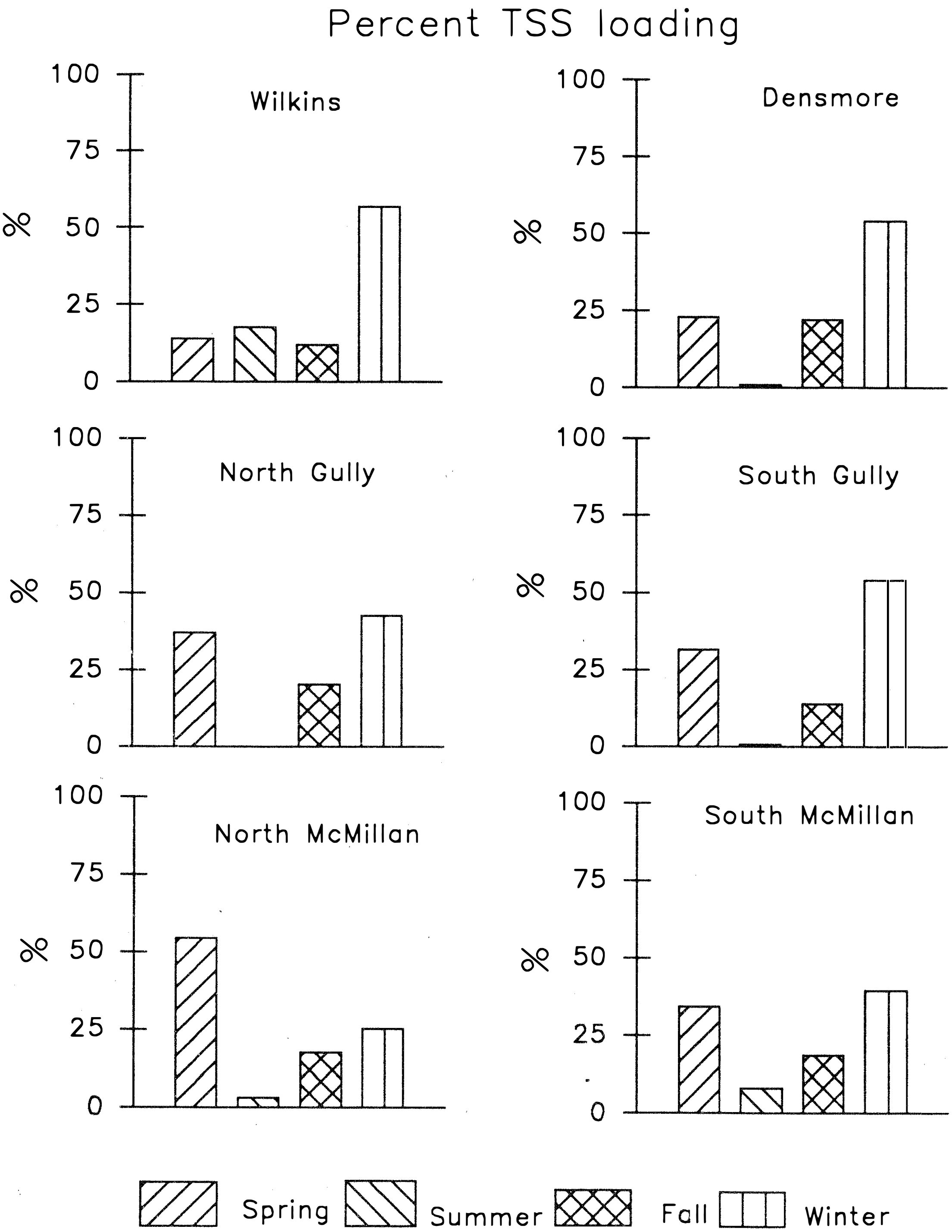


Figure 30. Relative seasonal total suspended solids loading of selected Conesus Lake tributaries.

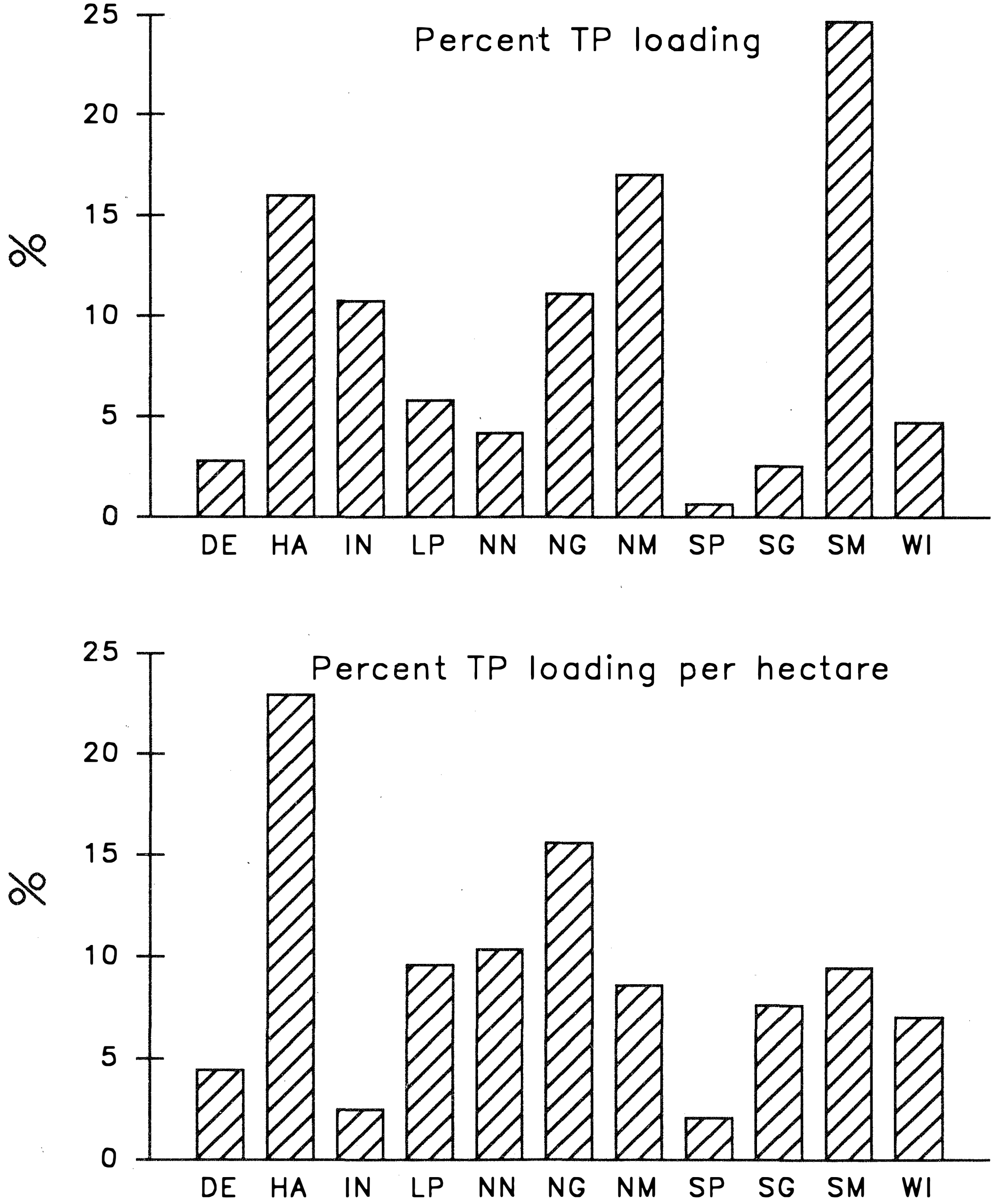


Figure 31. Comparison of relative annual total phosphorus loading for Conesus Lake streams.

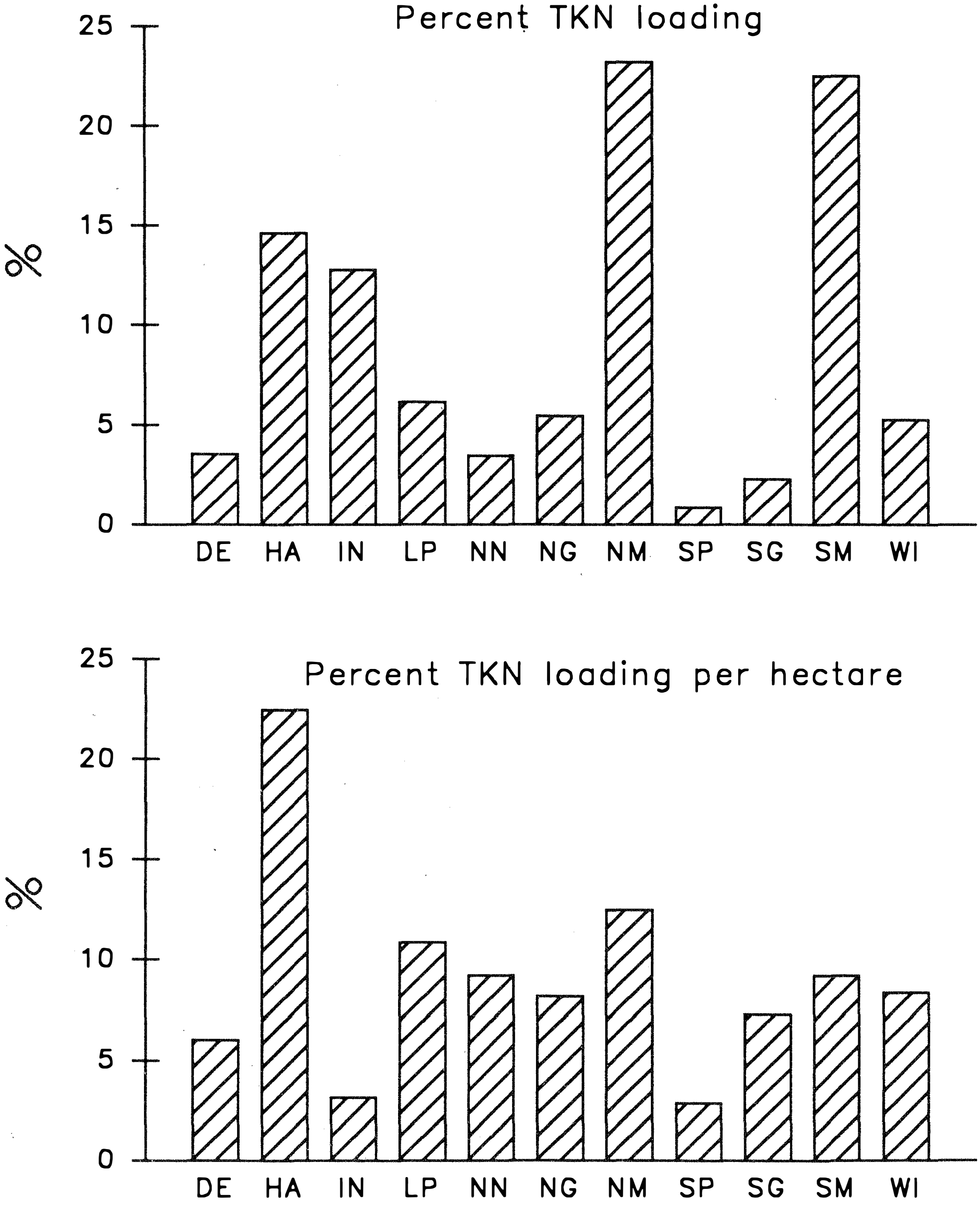


Figure 32. Comparison of relative annual total kjeldahl nitrogen loading for Conesus Lake streams.

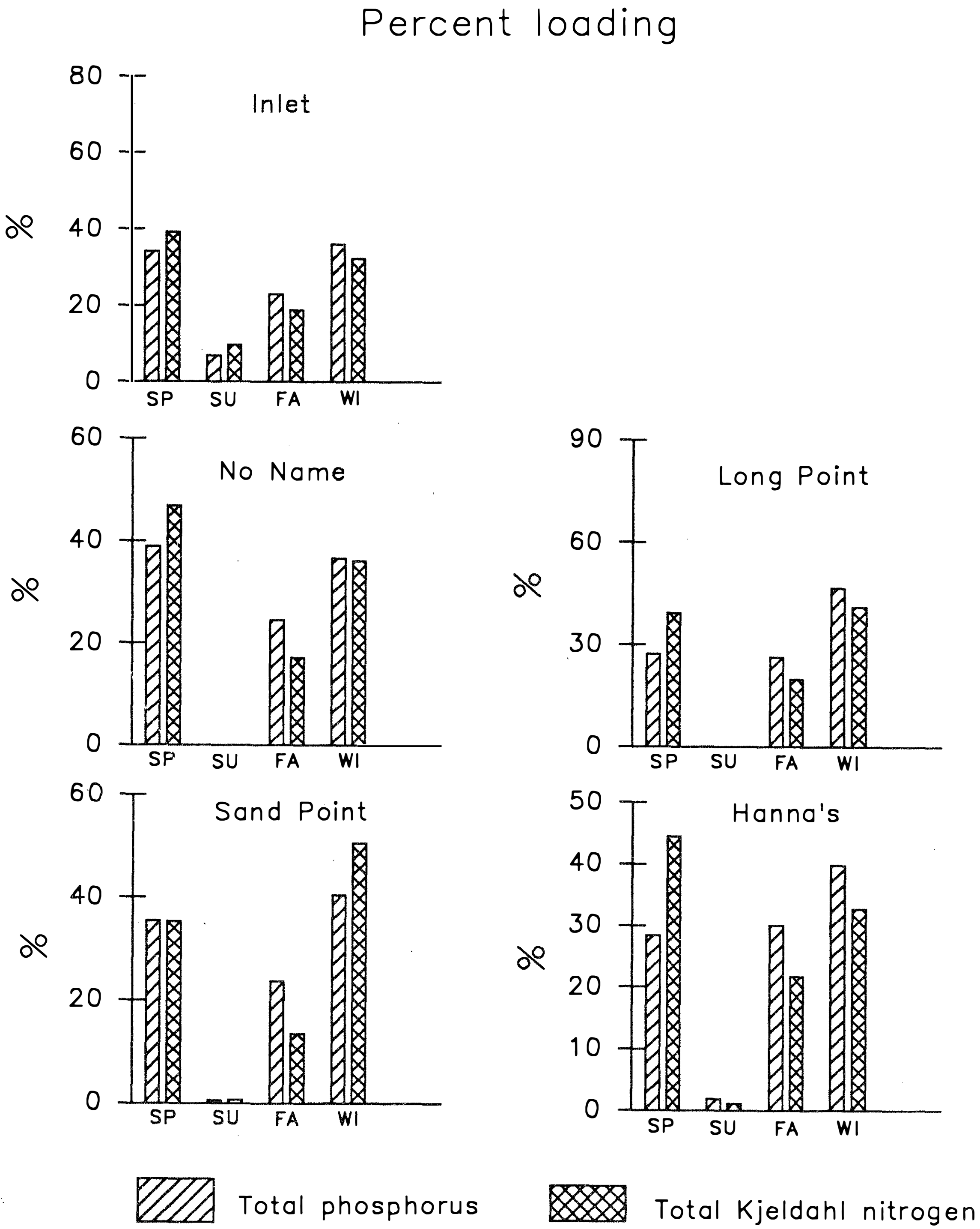


Figure 33. Relative seasonal total phosphorus and total kjeldahl nitrogen loading of selected Conesus Lake tributaries.

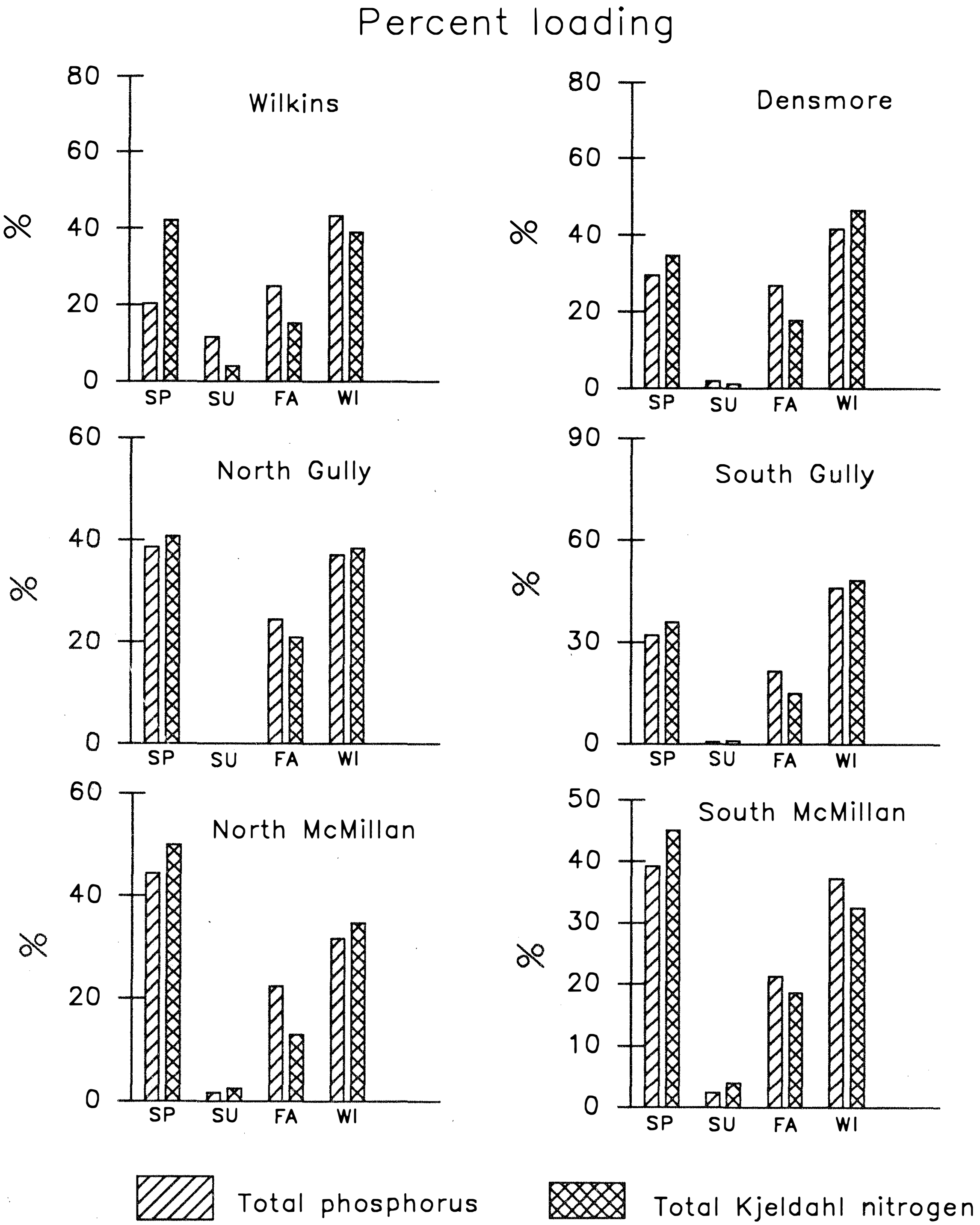
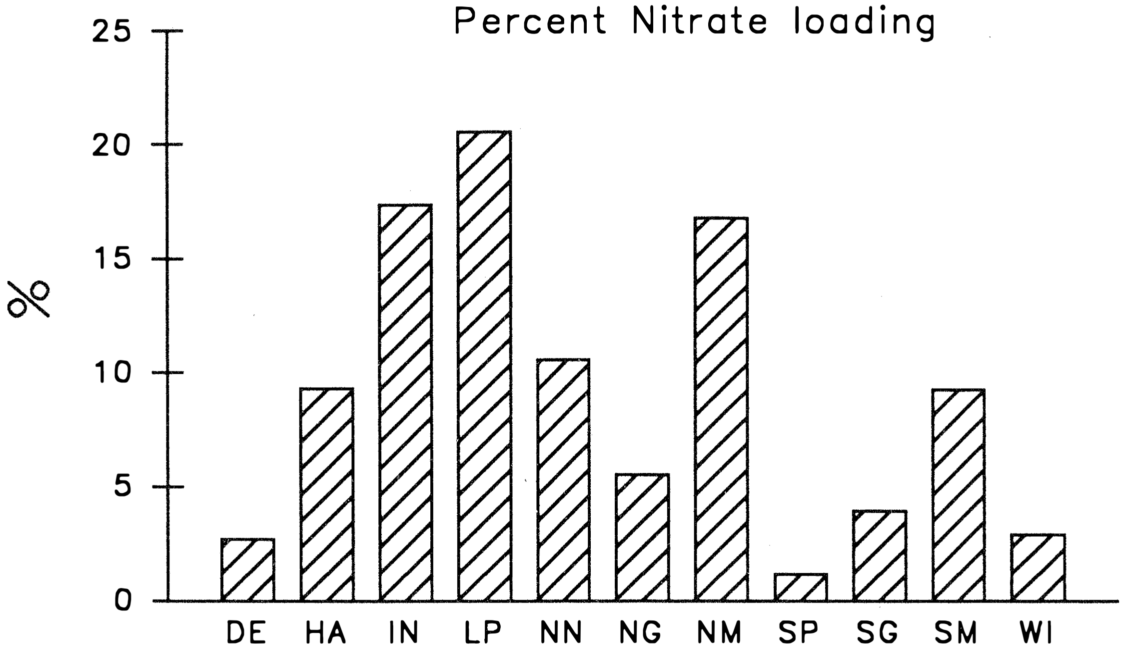


Figure 34. Relative seasonal total phosphorus and total kjeldahl nitrogen loading of selected Conesus Lake tributaries.



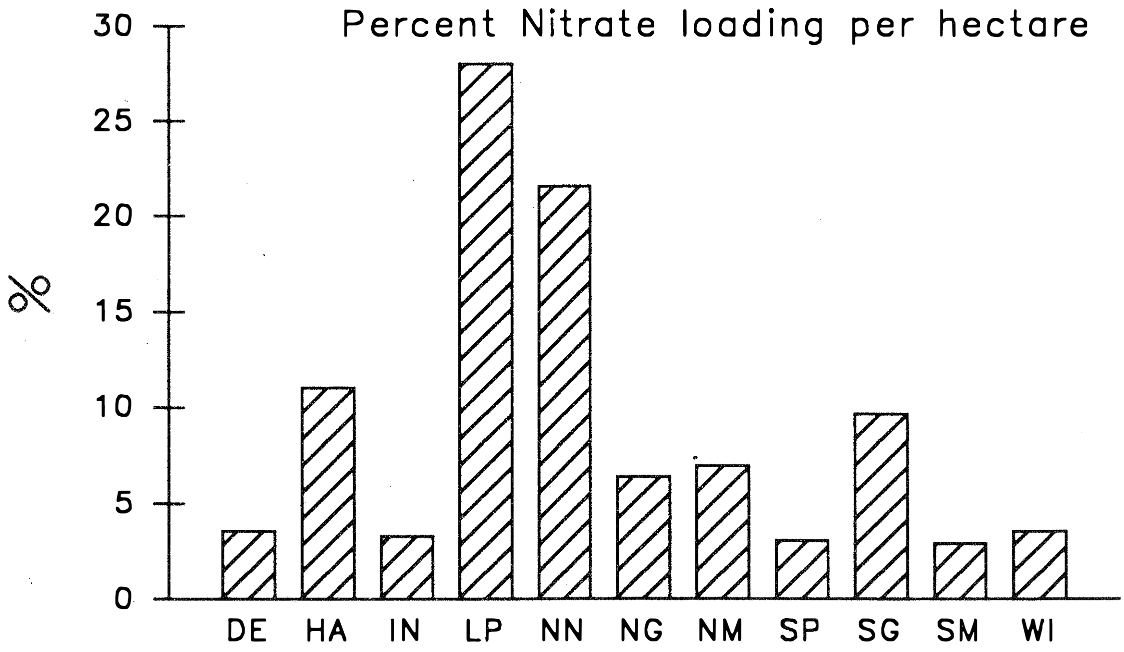


Figure 35. Comparison of relative annual nitrate loading for Conesus Lake streams.

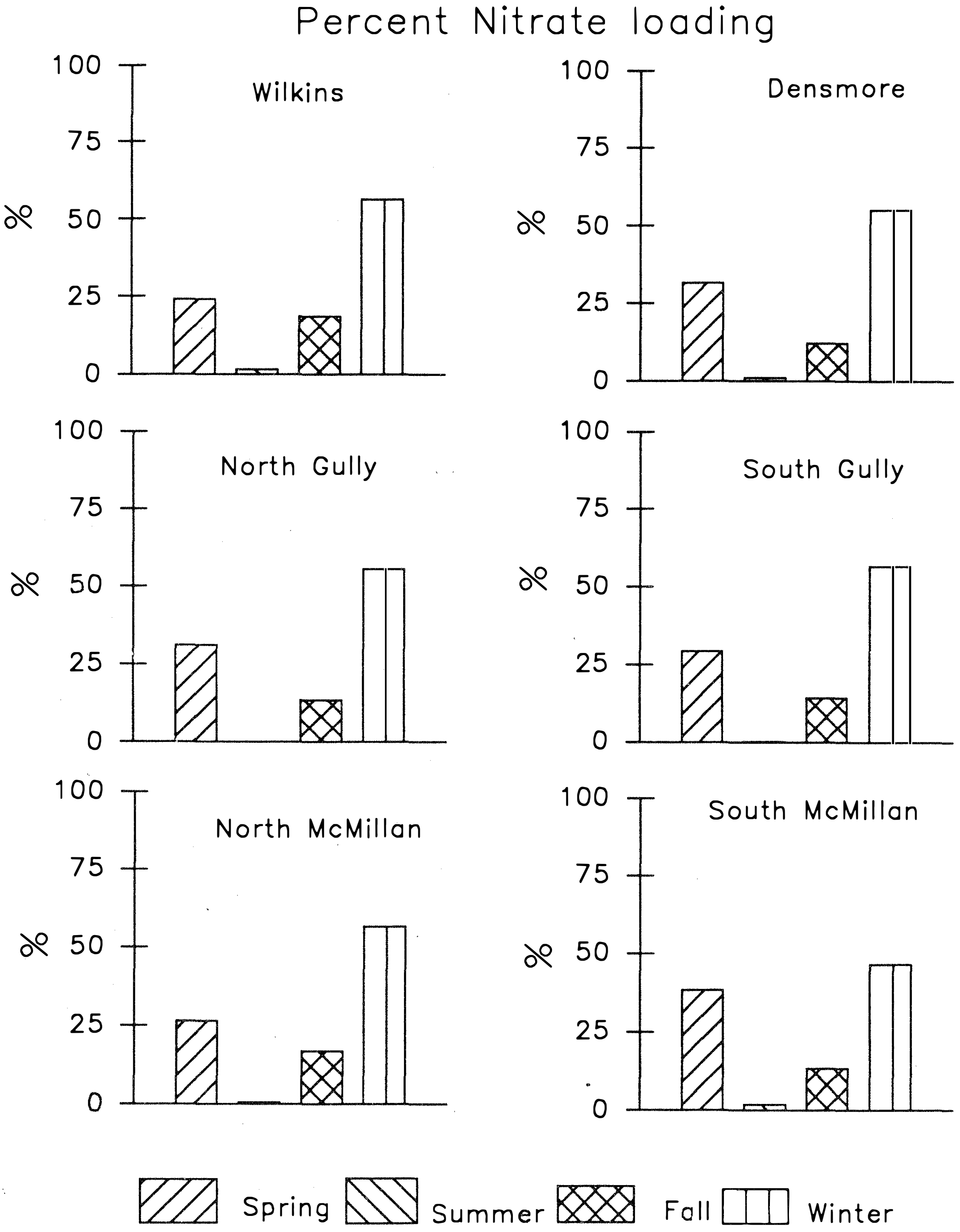


Figure 36. Relative seasonal nitrate loading of selected Conesus Lake tributaries.

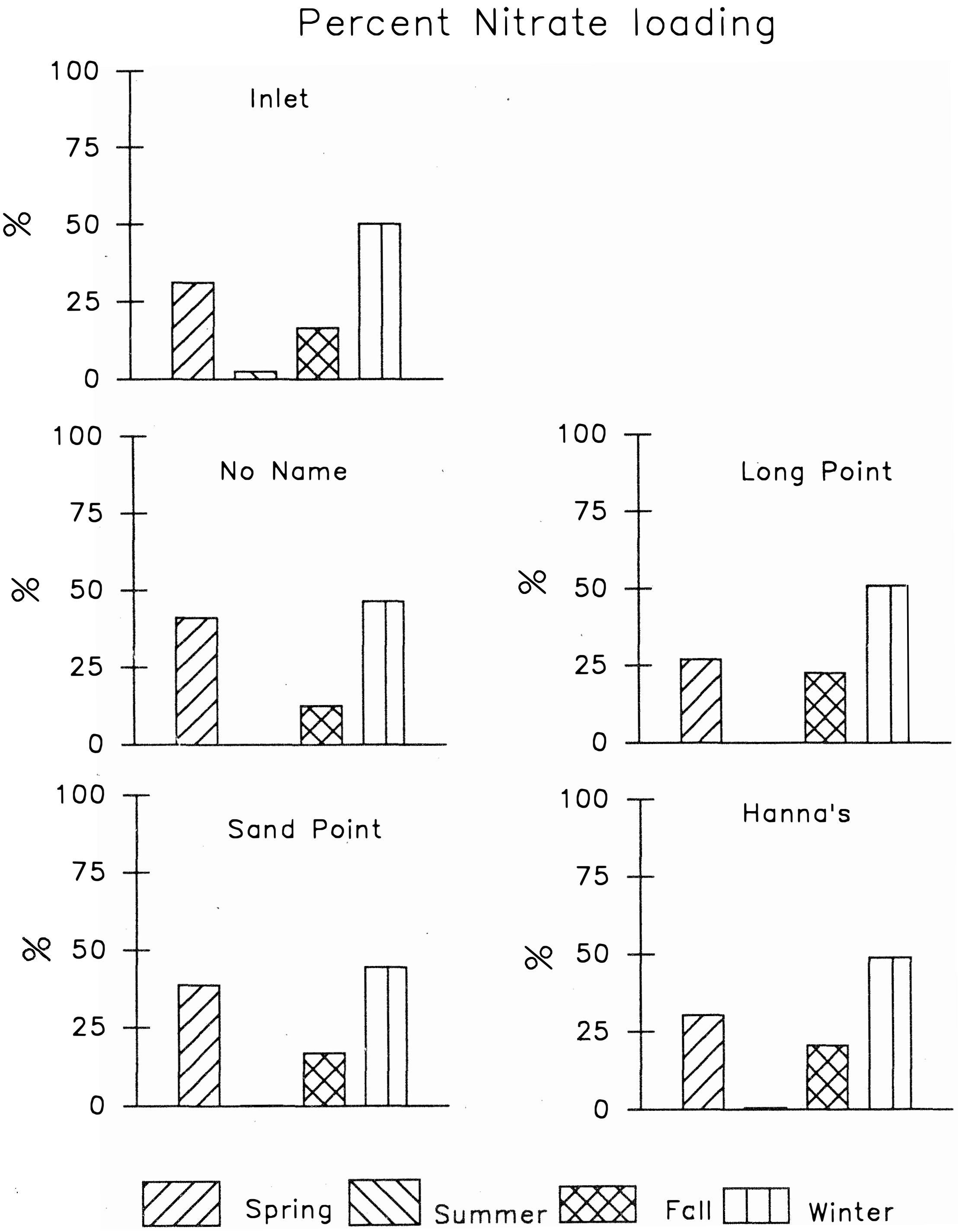


Figure 37. Relative seasonal nitrate loading of selected Conesus Lake tributaries.

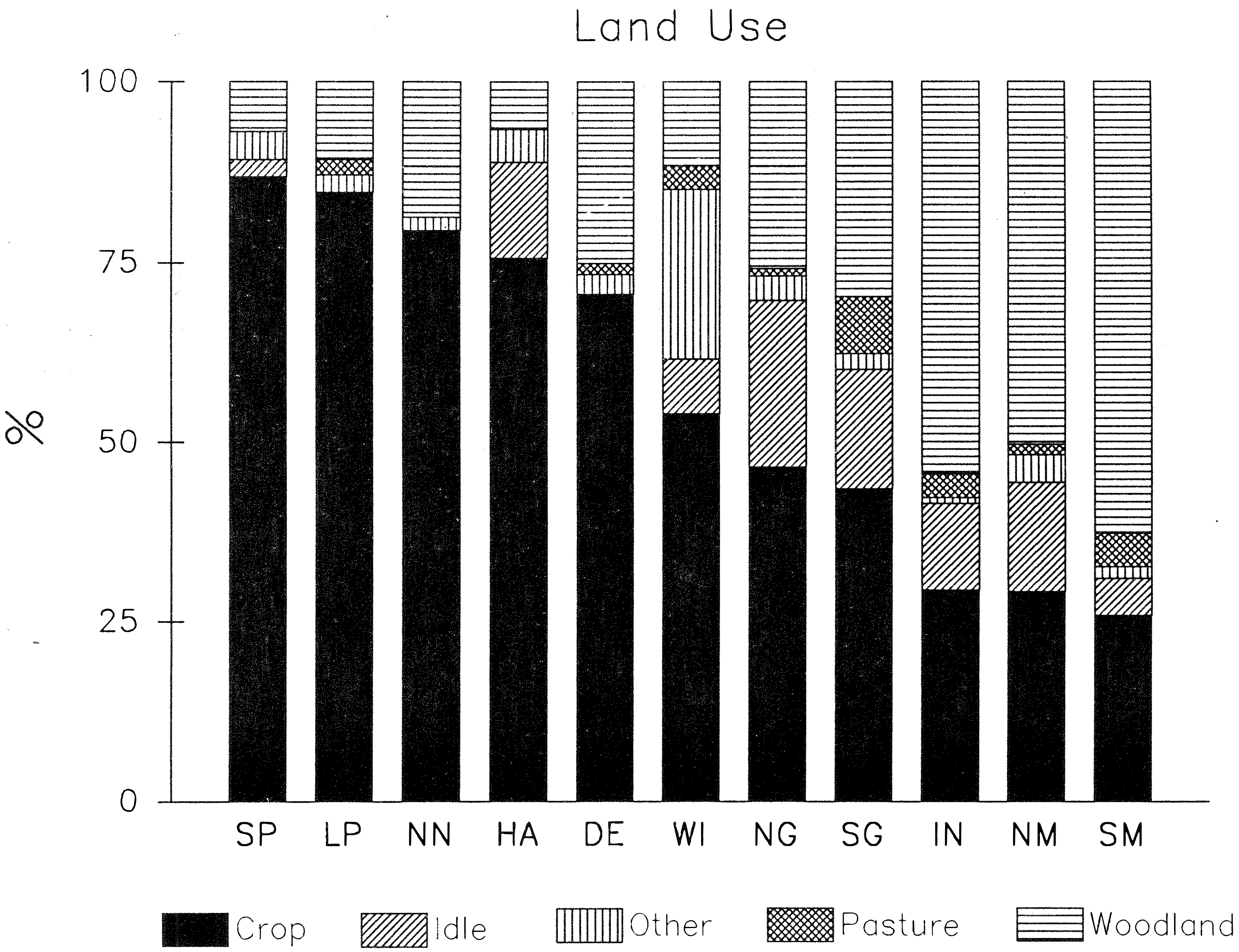


Figure 38. Land use patterns of Conesus Lake watersheds. Data are from 1984 and wre gathered by the Livingston County Soil and Conservation District.

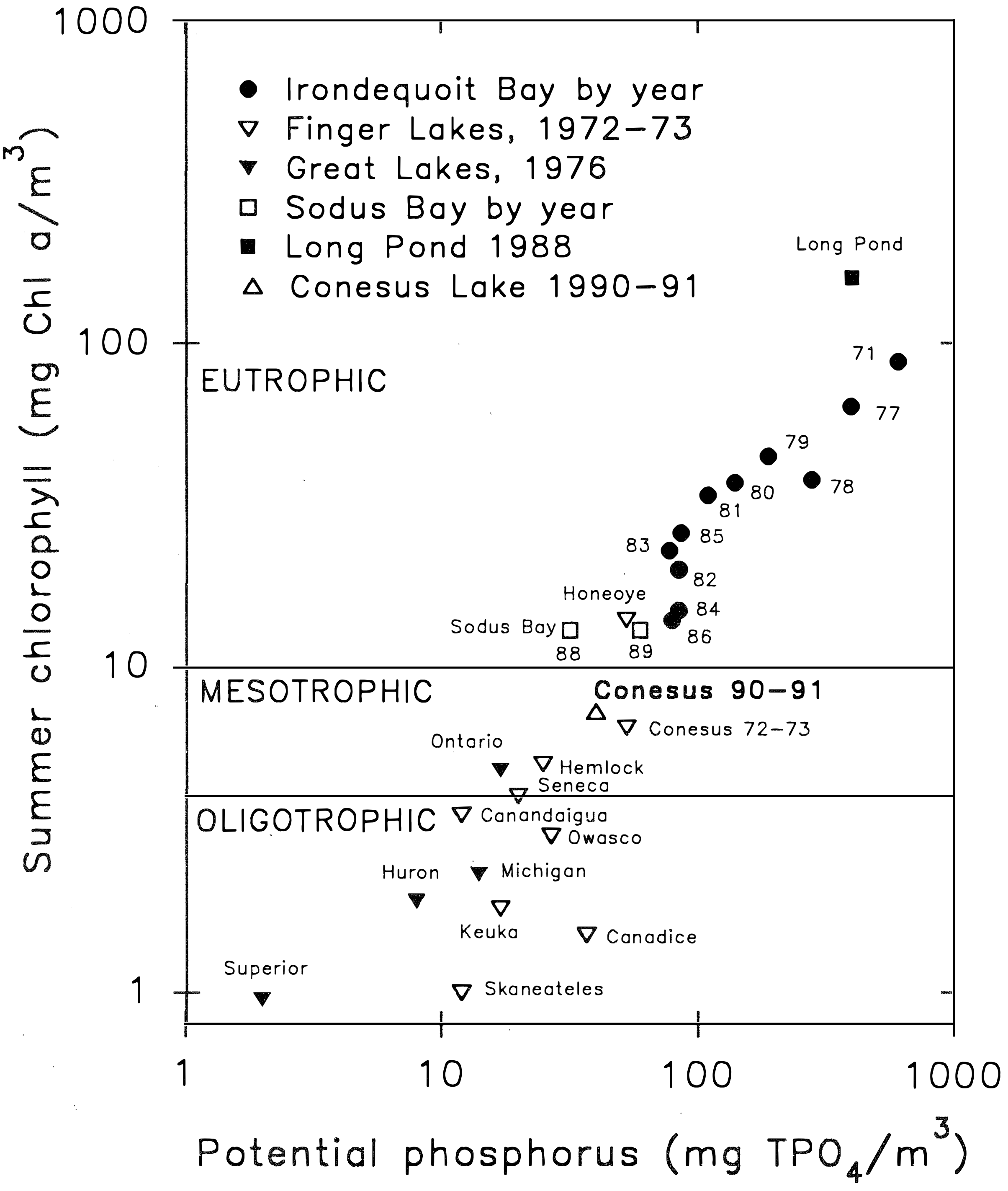


Figure 39. Relationship between mean summer chlorophyll concentration (mg Chl a/m^3) and potential phosphorus (mg TPO$_4$/m^3), a function of retention time and total phosphorus loading.