# Biological Assessment of Silver Lake: 2005

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## Executive Summary

The 2005 Silver Lake field evaluations focused on open water habitat conditions and water quality. They also included a cursory investigation into the composition of the fish community with emphasis on the potential presence of rare native and non-native species.

The 2005 study consisted of monthly (May through September) visits to collect information on water temperature and dissolved oxygen profiles, nutrient concentrations and other basic water quality parameters to compare current conditions with previously observed conditions. To collect and identify current fish species, two fish sampling efforts were undertaken, one by angling in June followed by a netting survey in October.

Results of those activities showed a lake that is generally oligotrophic (low productivity) with very good water quality and a highly desirable sport fishery capable of supporting both warm and cold-water species. Water quality results did indicate that the lake is limited in cold-water fisheries habitat due to undesirably warm surface water temperatures and dissolved oxygen concentrations that were below minimally accepted levels.

The unseasonably warm summer of 2005 exacerbated oxygen depletion caused by the buildup of nutrients in the hypolimnion region of the lake and contributed to the habitat limitation. Nutrient enrichment in the hypolimnion is suspected to have resulted from anthropogenic sources associated with development in the Silver Lake watershed.

Therefore, we recommend nutrient input minimization efforts in the riparian areas of the lake, even though phosphorus levels in the epilimnion remain relatively low. Improvements in property management practices and septic system maintenance will be necessary to minimize the loading of excessive nutrients to the lake and maintain current conditions.

Other water chemistry evaluations were unremarkable and pointed to a lake that is in very good condition. Future monitoring, especially for temperature, dissolved oxygen and phosphorus, is recommended to evaluate ongoing trends in these parameters.

Our lake fishery investigation revealed a system with numerous large warm-water game fish but few forage species in the littoral zone. Of particular importance was the observation of rock bass and alewife that had not been recorded as being present in the lake prior to 1992, indicating that they are new arrivals. Only one cold-water species besides alewife was collected, that being a large brown trout believed to have been stocked into the lake more than 9 years ago. This result was surprising given the numerous trout that have been stocked in Silver Lake. Efforts to identify other rare native or non-native species in the lake were unsuccessful.

The Pennsylvania Department of Environmental Protection reported this year that a single Silver Lake largemouth bass was tested for mercury in 2004 and found to have elevated levels in its tissue. No further actions were taken in light of this observation, pending the results of future sampling for mercury levels in fish.

Finally, we conducted several outreach efforts concurrent with our field investigations to promote the development of constituent-based goal setting with the ultimate goal of developing a management plan to maintain the high quality of the resources of Silver Lake.

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## Introduction

In the recent and the historic past there have been numerous efforts to study the natural landscape and waterways in northern Pennsylvania. This is especially true in Susquehanna County where a variety of investigations have been conducted to inventory environmental conditions and provide information necessary to develop plans for the preservation and improvement of various natural and cultural resources.

The E. L. Rose Conservancy of Susquehanna County and its members have supported environmental conservation with a philosophy of stewardship and a desire for contemporary knowledge of the area's natural resources, leading to this investigation of water quality and fisheries within Silver Lake.

The 2005 field season reported here represents the second consecutive year Cornell has participated in water related investigations in Susquehanna County. Associates from the Adirondack Fishery Research Program (AFRP) of the Department of Natural Resources, focused their efforts on Silver Lake and its watershed during the open water season.

In 2004, activities focused on an evaluation of the fish community and water quality through qualitative biological assessments of the lake's littoral zone and the collection and review of historic Silver Lake reports. The 2004 study showed a lake that maintains very good to excellent water quality with a robust fishery that is potentially vulnerable to: (1) over-fishing, (2) changes in water chemistry, and (3) introductions of new fish species. Recommendations from last year emphasized the need to establish goals for maintaining and regularly assessing lake water quality and managing the fish community to ensure that the quality and unique nature of Silver Lake is preserved.

Since the maintenance of water quality is a recommended goal, it is important to define this term. One definition of water quality is: "the physical, chemical and biological characteristics of water necessary to sustain desired water uses" (World Resources Institute, 2005). This definition emphasizes the necessity to determine desired water uses. This is of paramount importance, as the stewards of land and water resources must ultimately identify water quality goals based on desired uses, and then, in turn, decide what costs and actions should be undertaken to achieve them.

Establishing water quality goals should be at the forefront of all efforts regarding the stewardship of Silver Lake. Therefore, one of this season's objectives was to collect information and provide recommendations for the stakeholders to develop a lake management plan allowing them to articulate and attain their water quality goals for Silver Lake -- and ultimately, other lakes in this region.

Fulfilling this objective involved monthly visits to Silver Lake during the field season. Water chemistry was measured to evaluate potential chemical pollutants and nutrient levels. These measurements will qualitatively assess the current conditions and also provide information necessary to detect future changes in nutrient enrichment within the lake (eutrophication), as explained by Gannon (1981). Our analysis also incorporated

Silver Lake water quality data that was collected through the Pennsylvania Department of Environmental Conservation's (PADEP) Citizens Volunteer Monitoring Program during the 2002 and 2003 field seasons (K. Frey, 2005, unpublished data).

Fisheries work involved both a qualitative assessment of known resident fish species as well as a search for rare native and non-native species. This effort was of particular interest given the historic intentional manipulations of the fishery and the suggestions from fishermen that new species have recently been observed in Silver Lake. An additional, more thorough investigation of open water (pelagic) cold-water fish species was also performed.

A final fisheries issue that has recently become evident is the potential for mercury contamination of fish, likely due to atmospheric deposition. This issue extends throughout the eastern U.S., but this issue became a more immediate concern for Silver Lake residents after the PADEP evaluated Silver Lake fish in 2004 and found higher than desirable levels in a single largemouth bass (A. Frey, 2005, personal correspondence). No actions have yet been taken, pending the results of additional sampling by the PADEP.

Outreach efforts made up the final component of this year's work, with opportunities taken to better understand the desires and goals of residents involved in the protection of the area's water resources. This component of our work is very important in helping maintain an effective trajectory for stewardship activities in the region, and needs to be an ongoing component of any management policy to maintain the good water quality of Silver Lake and other lakes in the region.

## **Study Site**

The study area for the 2005 field season consisted of Silver Lake and its near shore (riparian) areas. Silver Lake is 90 acres in size with a 1.7 square mile watershed (K. Frey, 2004). The lake is deep for its size, exceeding 100 ft. in depth at one location. Silver Lake has been historically described as a relatively oligotrophic (low productivity), clear-water lake in a glaciated area of the Silver Lake Township in northern Susquehanna County, Pennsylvania.

The lake can be further classified as a groundwater drainage lake, owing to groundwater and runoff being the primary hydraulic inputs to the lake, with groundwater outflow, evaporation and a small outlet stream (Silver Creek) being the main mechanisms for water discharges from the system (see Figure 1). There is no stream input to this lake.

Figure 1. Topographical map of Silver Lake. (Maptech, 2005.)

A relatively important feature of groundwater drainage lakes is that they tend to have relatively low flushing rates. There are two previous estimates regarding the amount of time it takes for water, on average, to leave Silver Lake. The first estimate by Gallagher and Herbstritt (1992) reported a “flush rate” of 96 years. The second estimate, reported by K. Frey (2004), identified a “detention time” of 609 days (1.7 years). The importance of these admittedly diverse estimates is that they indicate that introduced excess nutrients or pollutants are not quickly removed from the lake. For additional and more detailed basin and lake descriptions the reader is directed to previous reports by Trembly and Trembly (1946), Gannon (1981) and Gallagher and Herbstritt (1992).

## Methods

An emphasis on lake aesthetics and fisheries management for this season’s sampling was deemed appropriate based on evaluations of historic information, watershed observations and concerns expressed by members of the conservancy. Our primary approach was to gather baseline water chemistry and fish-presence information. A strong effort was also made to collect data that could be used to evaluate trends in water quality when compared to data previously acquired on Silver Lake, as well as for setting benchmarks for future trend analyses.

Data collection involved six visits to Silver Lake in 2005. Water quality testing occurred on June $26^{th}$, July $30^{th}$, August $27^{th}$, and September $17^{th}$. An observational visit was conducted on June $16^{th}$, while fish sampling occurred on June $26^{th}$ (concurrently with the water quality sampling) and on October $31^{st}$. Each visit was initiated in the late morning or early afternoon hours to maintain some consistency for sampling and observational conditions. Weather conditions were primarily warm with sunny or mostly sunny skies with low to moderate winds.

Dissolved oxygen (D.O.) and temperature profiles, and Secchi disc and pH measurements were taken during each water quality sampling events. D.O. and temperature profiles were measured using a Yellow Springs Instrument probe at the deepest part of the lake (referred to here on as the "central lake " location). This location provides the best opportunity to observe fully developed oxygen and temperature profiles.

Figure 2. Sample site locations for water quality parameters during the 2005 field season.

Water clarity was measured at the same location with a standard black and white Secchi disc, and a pH meter was used to take pH measurements. AFRP water quality sampling protocols were followed when collecting all samples.

Water chemistry samples for total phosphorus, total Kjeldahl nitrogen (ammonium plus organic nitrogen), alkalinity, sulfate ($SO_4^{-2}$) and chlorides were collected using a Kemmerer sampler or a standard grab sample technique, again following AFRP protocols. Samples were then preserved on ice and/or with fixatives as prescribed by the Community Science Institute, Inc., Ithaca, NY, where the samples were analyzed.

Samples were primarily collected at the central lake sampling location in order to best represent the general water quality conditions within the lake. Phosphorus was more aggressively sampled at other lake locations as it is most commonly the limiting nutrient in freshwater systems (Wetzel, 1983).

Phosphorus measurements were taken at a variety of locations to attempt to determine the potential range of variability of this element. Experience with lake monitoring in the mid-western U.S. has indicated that phosphorus levels in near-shore (littoral) areas can often be greater than those in the deeper pelagic portions of the lake due to nutrient recycling in shallow sediments and proximity to phosphorus inputs such as over-land runoff (F. Koshere, Wisconsin Department of Natural Resources, 2005, personal correspondence, and J. Panuska, University of Wisconsin – Extension, 2005, personal correspondence). Phosphorus levels in near-shore areas can often be used to more quickly identify accelerated eutrophication than samples collected from the well-mixed open waters of a lake.

Two cursory sampling efforts to evaluate the fish community in Silver Lake were conducted. One evaluation of the fish community was an angling survey of the warm-water species in the littoral zone. Observations of angling-collected and free-swimming fish were noted, primarily to confirm the presence of various warm-water species.

A second survey utilizing 300 ft. long by 8 ft. tall entanglement nets was employed in mid-fall to attempt to assess the status of the cold-water fishery, specifically attempting to verify the presence of rare native and non-native species (e.g. lake trout, brook trout). A total of fifteen nets were set during this one-day effort for the shortest necessary time period to minimize the amount of stress on the netted fish (following AFRP protocols for netting cold water species).

Plans were also made to sacrifice a small number of fish (trout) to evaluate their tissue for mercury in conjunction with the netting survey. Unfortunately, no trout were harvested in the size ranges representative of those commonly consumed by anglers; consequently no testing for mercury was conducted.

## Results

Sampling of the D.O. and temperature profiles showed that Silver Lake was thermally stratified during all four visits, with surface water (epilimnion) temperatures exceeding a generally accepted upper temperature threshold of $72^{o}$ F for cold-water fish (down to a depth of at least 10 ft. on each occasion). Temperatures then decreased steadily through the middle layer (metalimnion) before becoming constant near 40 degrees in the lower layer (hypolimnion).

Figure 3. Temperature profiles for Silver Lake collected at the central lake sampling location during the 2005 field season.

Comparisons of the temperature profiles available from previous investigations for similar time periods (mid to late summer) indicate that the 2005 sampling season recorded the "warmest" temperature profile observed to date.

The warmer condition of the water is attributable in part to the fact that the daily average temperature for the period of June through August, as recorded by the National Weather Service station in Johnson City, NY, showed that the average air temperatures for 2005 were $0.5^{o}$ F warmer than in 2002 and nearly $7^{o}$ F warmer than those experienced in 1992. (R. Brady, 2005, personal communication). (Air temperature data was not available for the summer of 1946, as temperature records at Johnson City only go back to 1951.)

Figure 4. Temperature profiles from historic records on Silver Lake.

Note: data sources are as follows: 1946 – Trembly, 1992 – Tethys (Gallagher and Herbstritt), 2002 -PADEP, 2005 – Cornell University.

D.O. profiles from the 2005 field season showed adequate levels of oxygen in the epilimnion while the hypolimnion oxygen levels were well below the 5.0 mg/L general minimum standard used for the protection of fisheries habitat.  Just below the surface there is a general trend for oxygen concentrations to increase due to the presence of cooler water temperatures and increased algal abundance.  This trend is quickly reversed in the metalimnion and down into the hypolimnion where the D.O. levels fall below the minimum threshold for fish survival in the deepest portion of the water column.

Figure 5.  Dissolved oxygen profiles for Silver Lake collected at the central lake sampling location during the 2005 field season.

Of note is the water depth at which the D.O. concentration falls below threshold of 5.0 mg/L.   Over the course of the sampling period, the depth at which fish would generally have access to adequate oxygen retreated from a depth of more than 70 feet in late June to only slightly more than 30 ft. by mid-September.  It is notable that in contrast to previous profiles on record for Silver Lake, only the 2005 (mid-summer) readings fall below this oxygen threshold.

Figure 6. Dissolved oxygen profiles from historic records on Silver Lake.

Note: data sources are as follows: 1946 – Trembly, 1992 – Tethys, 2002 -PADEP, 2005 – Cornell University.

Measurements of pH remained within the desired ranges of 6.0-9.0 standard units (s.u.), with the exception of one value that registered 9.27. Secchi disk readings varied through the summer, ranging from a reading approaching very good to that of merely fair based on guidelines established by Shaw (2002). The lower readings were taken in the latter parts of the summer, with the lowest reading coming on August 27 during a very windy day. The lower readings also corresponded with a noticed increase in algal abundance that occurred between the August and September site visits.

Table 1. Secchi disc and pH values collected from the central lake sampling location during the summer of 2005 on Silver Lake.

Notes:
1-Measurement taken 0.5 meters below the surface.
2-Measurement based on grab sample analyzed at the AFRP Field Station.
3-Measurement taken at surface.
4-Windy and overcast, gusts to 20 mph.

Total phosphorus results showed some variability, with concentrations being greatest in the deep water and outlet samples, while chloride values were nearly homogeneous through the lake's surface waters. Alkalinity was relatively stable based on the two samples collected. The single sulfate result showed levels to be relatively low based on the data summarized by Shaw (2002) in Wisconsin and are on par with the values reported by the PADEP (S. Wills, personal correspondence) for Crystal Lake in southeastern Pennsylvania (around 8 mg/L).

Total Kjeldahl nitrogen was measured to provide a cursory assessment of the total nitrogen concentrations in the lake. Additional samples were not collected given the data made available from the PADEP sponsored sampling of Silver Lake in 2002 and 2003. Results from those efforts showed the total nitrogen average concentration to be 0.25 mg/L with an average nitrogen to phosphorus ratio of 20:1, indicating that, from a productivity standpoint, the lake is somewhat phosphorus limited (K. Frey, 2004). Water chemistry results are summarized in Tables 2 and 3 below.

Table 2. Chemical specific results collected on June 26, in Silver Lake.

Note: See sample location map for 8/27/05

Table 3. Chemical specific results collected on August 27, 2005 at various locations in Silver Lake.

Notes**:**

1-See sample location map for 8/27/05.
2-Complication in laboratory test, value may be 10% lower than reported (see lab sheet).
Site A – surface: central lake, over deepest portion of lake, 1.5 ft. below surface
Site A – deep: central lake, over deepest portion of lake, approximately 30 ft. below surface.
Site B: East shore, directly off the lakeside edge of the Bloomer dock.
Site C: West shore, Conservancy property, 20 yards, off leaning tree, 6 yards out from shore.
Site D: Outlet of lake, shallow area, 30 ft from east shore at poplar trees.

Fishery assessment efforts included habitat evaluations associated with water chemistry and an investigation of the presence of fish species in the lake, particularly cold-water species.  The results of the fishery work is as follows:

Observations from the original scouting trip on June 16, 2005, produced numerous sightings of large pumpkinseed sunfish in the littoral zone in the eastern and northern shallow waters of the lake.   The specimens appear to have been in territories near current/former nesting areas and were very brilliantly colored.

Figure 7.  Adult pumpkinseed sunfish from Silver Lake.

Numerous sightings of largemouth bass, mostly large adults, were also made. Additionally, there were sightings of at least 10 schools of small fish in the central part of the lake beyond of the littoral zone.  The fish were not confirmed as alewife, but were clearly in the 1 to 3 inch size range and silver in color. Each school was estimated to have at least 100-200 specimens based on observations that occurred during mid-day.

Similar sightings for pumpkinseed sunfish and largemouth bass were made during the June 26, 2005, angling and observation effort.  Species caught during that effort included pumpkinseed sunfish, rock bass, brown bullhead, chain pickerel and largemouth bass, with a total of 11 individuals collected. Large bass were often observed near submerged large trees (woody debris), as was the case during Weidel's (2004) snorkel survey.   Of particular note was the seeming absence of any small minnows, forage fish, juvenile panfish or juvenile game fish species.  Crayfish were found to make up a large part of the diet for the rock bass and largemouth bass when evaluating the stomach contents of the live fish, providing direct evidence of the presence of these crustaceans in the lake.

The October netting survey concluded with 10 netting hours being logged and a total of 38 fish being captured.  Collected species included alewife, yellow perch, pumpkinseed sunfish, rock bass and brown trout.

Figure 8.  Large adult brown trout captured in Silver Lake.

All specimens were relatively small fish, except for the brown trout that measured 26.5 inches in length and 9.9 pounds in weight.  If current stocking records are correct, it is likely that this specimen was stocked into the lake prior to 1996.  No rainbow trout were captured during this sampling effort, which was somewhat surprising given the numbers of fish that have reportedly been stocked in recent years.

## **Discussion and Conclusions**

Overall, Silver Lake continues to sustain highly desirable water quality, sufficient to support recreational uses such as swimming and fishing, provide cottages with drinking water, and contribute to the natural scenic beauty of the area.  Although there are many other lakes that can support similar uses, Silver Lake stands out as being an outstanding lake in terms of its collective attributes - given our experiences on other lakes.

Based on the comments of local residents during this summer's efforts, maintaining the above attributes of Silver Lake is of significant importance to those who use this lake. Discussions also indicated a strong desire to maintain the overall water quality of this lake as well as others in the region, owing to the fact that good water quality contributes significantly to their enjoyment of the area.

One of the most basic assessments of a lake's condition is reflected in the measurement of temperature and dissolved oxygen profiles.  Consequently, the primary effort this year was to document the profiles' changes over the course of the season and compare current measurements to historic measurements in Silver Lake.

This summer's observations showed a well stratified lake with greater temperature extremes than those observed in previous profiles conducted during the mid to late summer period. This is likely a consequence, in part, of the very warm summer – a fortuitous circumstance that allowed us to observe the lake under conditions that are most likely limiting for cold-water fishes.

During 2005 the region experienced warmer than normal air temperatures that increased surface water temperatures above those previously reported. This warm upper layer of water likely supported increased algal biomass and production (as indicated by the large spikes in the D.O. curve about 20 ft. below the surface). Decaying algal biomass sinks into the hypolimnion where decomposition occurs, lowering dissolved oxygen and producing the oxygen deficits observed this summer. Increases in lake phosphorus levels could also be contributing to increased algal biomass, thereby also contributing to observed low oxygen levels.

Historic profiles do not show oxygen deficits similar to those observed in summer 2005, suggesting that there is potential for a eutrophication problem to begin developing within Silver Lake. Although accelerated eutrophication is a concern, we stress that the conditions in 2005 may be simply be a result of an unusually warm summer and unique water chemistry that favored the development of large algal populations. Future observations of temperature and dissolved oxygen profiles are essential to determine if these are recurring trends in the lake, or if the 2005 conditions were simply representative of an atypical year.

Secchi disc readings showed a trend of decreasing values from June to September. Early season water clarity (about 15 ft.), as indexed by the Secchi measurements, was similar to conditions reported by Gallagher and Herbstritt (20 ft., 1992), and Trembly and Trembly (15 ft (average), 1946). Subsequent measurements in the later part of the summer showed a marked decrease in water clarity, likely caused by the increase in observed algal activity.

This decrease in clarity is often disturbing to lake residents. Residents' comments indicated that there is a perception of a decreasing water clarity trend in recent years, presumed to be a result of increasing lake phosphorus levels.

While this may be true, it is important to realize that water clarity will vary throughout the summer due to temperature, seasonal natural peaks in algae populations, and other environmental conditions. We are cautious in drawing conclusions until sufficient data is collected that will allow trends to be consistently observed. Lake water clarity trends can be easily monitored with routine Secchi disc measurements, and if changes are observed, future work could focus on identifying the responsible factors.

Total phosphorus (phosphorus) concentrations measured during the 2005 field season in Silver Lake averaged 11.7 ug/L, a value that is within the expected range for this type of lake. This phosphorus level classifies Silver Lake as oligotrophic or oligotrophic/mesotrophic (Shaw, 2002 and Wetzel, 1983), meaning that the lake is relatively low in nutrients levels and will likely continue to have low biological productivity if nutrient inputs remain constant. The lake is also generally considered to be phosphorus limited (Shaw, 2002) given the 20:1 nitrogen to phosphorus ratio reported by K. Frey (2005, personal correspondence) for Silver Lake. This means that excessive phosphorus inputs could lead to increased algae production, which in turn can decrease water clarity.

The data collected this summer and from the PADEP sponsored effort are, however, insufficient to make a firm assessment regarding seasonal dynamics or to make an assessment regarding long-term phosphorus trends in Silver Lake. Instead, these data provide initial values to reference in longer term trend monitoring efforts. Setting goals for future management of this lake and establishing consistent monitoring efforts are necessary to sustain present conditions. This is particularly important with regard to the management of phosphorus because: (1) phosphorus has a great influence on water clarity and dissolved oxygen, and (2) phosphorus is one of the few constituents of lake water chemistry that can be successfully managed by watershed residents. We have thus identified the control of phosphorus as one of the highest priorities for protecting Silver Lake.

During the summer there were also multiple discussions regarding large-scale efforts to evaluate phosphorus loadings into the lake as a result, in part, of past efforts to install a central sewer system around the lake. At the present time a more sophisticated evaluation beyond simple monitoring (conducting a mass balance study for example) is not recommended because the primary corrective measures can be prescribed without additional information. At the present time, available water quality data are too sparse and do not suggest a serious phosphorus problem requiring significant action.

The proper management of yard run-off (fertilizers, grass clippings, vegetative buffers), septic systems (which can contribute significant amounts of phosphorus to the lake), construction site activities, etc., should be common goals of lake shoreline residents regardless of phosphorus data collection efforts or any long-term plan to pursue a central lake sewer system. (Note: septic systems were also brought up in both discussions and in the historic files as potentially contributing to bacterial contamination of lake water. Bacterial testing was outside the scope of our sampling efforts for 2005; however, a bacterial sampling protocol should included in a lake management plan to maintain the safety of lake water for swimming and drinking.)

Another frequent topic associated with the issue of phosphorus was the perception of many residents that there is a trend toward increased macrophyte populations (commonly described as weeds) in the lake – presumably a direct result of increased phosphorus levels in Silver Lake. Biological assessments of macrophytes were not conducted; however, monitoring of aquatic plants does warrant some future consideration. While nuisance plant growth is often a result of elevated nutrient levels, there are occasions where aquatic plants will show significant increases that appear to be independent of eutrophication processes (F. Koshere, 2005, personal communication). Consequently, macrophyte surveys are warranted in the future to address resident's concerns and to provide information that can be used for regional trend analyses.

Investigation into the pH of the lake showed that levels were acceptable from a biological perspective (6-9 s.u.). One value taken on August was slightly outside the normal range but could have been a result of an isolated pocket of increase biological activity and not representative of the overall chemistry of the lake on that day. Alkalinity was measured to provide an initial assessment into the lake's susceptibility to acid rain, which is considered moderate based on data provided by Shaw (2002).

Concerns about undesirable lowering of the pH values in Silver Lake due to acid rain are not warranted at his time because data from the 2002-2003 sampling and the 2005 samples shows pH levels to be within acceptable ranges during each survey. Continued monitoring is suggested, however, since this region of Pennsylvania tends to lie downwind of major sources of industrial emissions that can lead to acid rain.

Sulfate was measured as it acts as an indicator of the presence of acid rain entering a water body. The observed sulfate concentration (7.8 mg/L) represents a baseline value for future reference to determine if acid rain inputs are increasing in Silver Lake. Additional monitoring for this compound is not deemed necessary at the present time as the observed value is well within the range common in lakes that do not receive large inputs of acid rain (Shaw, 2002).

Nitrogen testing results were limited to a single value for total Kjeldahl nitrogen, which is a measurement of ammonium and organic nitrogen; it was used a functional substitute for a measurement of the amount of total nitrogen in the water and was intended to provide a baseline value for future analyses. Nitrogen in general was not aggressively evaluated given the recent PADEP efforts on Silver Lake and the aforementioned conclusion that the lake is phosphorus and not nitrogen limited.

Sampling was also conducted to evaluate potential accumulations of chloride in the lake from septic systems and road de-icing activities. Results showed chlorides to be at levels that are commonly found in unpolluted waters and well below levels that are suspected of being toxic to fish and aquatic life based on Environmental Protection Agency criteria. No additional testing is recommended for this element, as there are no apparent concerns regarding chloride levels.

From an aesthetic point of view there were no quantitative measurements that were taken and there are no standards to provide a baseline for an assessment. However, it is strongly suggested that the property owned by the conservancy be maintained in its current state. (The purchase of this property for preservation will likely pay great dividends over time from a water quality perspective.) Additionally, the lake residents should maintain their near shore areas (riparian zones) in a manner compatible with modern shoreline management guidelines (for the maintenance of water quality, wildlife habitat and natural scenic beauty). By keeping the shoreline in an as-close-to-natural setting, and by also continuing the ban on outboard motors, the aesthetic integrity of the lake will be far more likely to be maintained over the years ahead.

From a cold-water fishery perspective, this year's profiles show that the water column was unsuitable at depths greater than 32 ft. during late summer due to D.O. concentrations below the minimum standard. The water column was likewise in poor condition from the surface down to a depth of 13 ft. due to excessive temperatures. These conditions effectively eliminate much of the lake habitat from use by fish needing cool and well-oxygenated water during summer. Fish can only tolerate these temperature and D.O. conditions for short periods of time without lasting consequences. However, prolonged stress exposure produces both lethal and non-lethal effects, often limiting the ability of a species to live within a lake.

This summer's conditions may have been relatively rare and not part of a normal cycle of conditions experienced in Silver Lake. If, however, a trend towards warmer summer water conditions and lower D.O. concentrations continues, the ability to sustain cold-water species in Silver Lake may be compromised. As with phosphorus, all results should be viewed as preliminary until more data is acquired to establish current trends for Silver Lake. Future monitoring will help determine the long-term characteristics of the summer fish habitat conditions.

Regarding the warm-water fishery, there are some simple actions that can be taken to help maintain the current populations. The first is to support the existence and recruitment of large woody cover by allowing trees that fall into the water to remain in place. The practice of removing such trees is commonplace amongst cottage owners nation-wide; this practice, however, would be especially detrimental on Silver Lake as submerged and partially submerged trees provide some of the best available habitat in the lake. Likewise, the removal of macrophytes in areas around docks and shorelines should be kept to a minimum as these plants also provided critically needed shelter for aquatic life. Any removal of macrophytes around docks should be limited to that necessary for watercraft to reach open waters.

Our second recommendation in this area is to encourage a catch and release program that returns captured fish to the lake. Many of the fish observed were susceptible to over harvest, especially pumpkinseed sunfish and adult largemouth bass. This is not to say that angling for an occasional fish dinner should be forbidden, but rather that limits on the fish harvest will help maintain the current fishery.

The fishery community within Silver Lake has been dynamic based on historical records, with some species becoming rare or absent, and others being introduced. Recent captures of both rock bass and alewife, along with angler accounts, suggest that rock bass have been introduced to the lake in the last five to seven years and that alewife were probably introduced within the last four to five years. Rock bass compete with other native fishes in the littoral zone, while alewife represent a potentially new forage species in all portions of the lake, therefore the long-term consequences of their introduction are unclear. Past introductions of other fishes have previously shifted the structure of the fish community, and ongoing introductions of new species will continue this trend. No actions are recommended at this time, other than to be aware of the potential problems associated with the introduction of any species (fish, plant, etc.) into the lake, whether intentional or not.

One of the more surprising results of this summer was the absence of any rare native and non-native cold-water species captured in the entanglement nets set in late October. With the exception of one very large brown trout, no other fish were caught other than warm-water species. The absence of any rainbow trout in the nets was most surprising given the numbers that have been historically stocked (Weidel, 2004). No conclusions can be drawn regarding the status of stocked trout in Silver Lake since our sampling effort employed may have been inadequate. Yet the fact that a large brown trout was captured is an indication that some individuals can survive and even thrive in Silver Lake for long periods of time.

To better understand the survivability of the stocked trout in the lake, we recommended conducting a specific survival study, potentially by marking stocked fish and employing angler diaries to evaluate the condition of captured fish. We do not currently promote the stocking of any particular fish species until the lake fish community has been more fully evaluated.

The final subject to address regarding the Silver Lake fishery pertains to the release of a letter, dated October 6, 2005 from Aaron Frey of the PADEP, indicating that a single largemouth bass collected from Silver Lake in 2004 was tested for mercury and found to have elevated levels in its tissue (reported as “0.280 ug/L”). No fish consumption advisories have been issued for Silver Lake, pending further investigation by the PADEP. The possible presence of elevated mercury levels in Silver Lake fish is will remain of concern until further testing is completed.

Evaluating fish mercury levels is beyond the scope of this project and is better addressed by state environmental health agencies. The residents of Silver Lake are strongly encouraged to follow up on the issue of mercury contamination of fish with the PADEP in order to make informed decisions regarding the consumption of fish.

**Recommendations**

The following recommendations are provided for consideration by the conservancy, lake association and members of the community regarding strategies to collect data and develop management plans for maintaining the water quality and angling opportunities within Silver Lake (and, where applicable, other lakes in the region).

* - Develop and set specific goals and management plans for the maintenance of water quality in Silver Lake. Include an educational component in the plan to inform landowners of these issues and the potential actions required. Likewise, develop and set specific goals for the lake fishery.

* - Monitor the oxygen and temperature profiles over the deepest portion of the lake on a monthly basis from May through September. This should be repeated in 2006 and at subsequent 3-year intervals to evaluate possible changes or trends in the lake's temperature and D.O. profiles.

* - Establish a phosphorus monitoring plan to assess the current trends of this element. Simultaneously develop and implement a phosphorus input minimization strategy for landowners in the watershed to follow.

* - Establish a periodic monitoring plan for bacteria to assess the presence of unhealthy conditions in the lake as a result of improperly functioning septic systems.

* - Educate homeowners regarding the proper maintenance of septic systems and conduct surveys to ensure they are functioning properly. The use of holding tanks/hauling for peak use periods should also be considered.

* - Measure surface pH and alkalinity as part of a long-term monitoring program to assess potential impacts from acid rain. Measurements should be taken at the central lake sampling location once a month from May through September every third year.

* - Maintain the riparian zones to resemble a natural shoreline condition, protect water quality, provide habitat for wildlife and sustain the natural scenic beauty of the lake. Also continue to maintain the ban on outboard motors to preserve the tranquility of the area and minimize the amount of petroleum-based contaminants entering the lake.

* - Develop a digital photo record of the riparian zone. Every fifth year record the condition of the near shore areas of the entire lake during each season of the year (winter, spring, summer, fall).

* - Encourage the recruitment and preservation of large trees within the waters of the littoral zone (i.e. do not remove trees that fall in the water).

* - Minimize the amount of macrophyte removal from around docks and shorelines to only that which is needed to gain access to the open water areas of the lake.

* - Encourage catch and release practices for anglers pursuing naturally self-sustaining fish populations.

* - Educate lake users regarding the practices necessary to prevent the introduction of exotic or unwanted new species of fish, plants or other aquatic organisms into Silver Lake.

* - Conduct follow-up investigations into the potential presence of elevated mercury concentrations in fish tissues with the relevant state environmental health agencies.

* - Consider developing angler based surveys to quantify the success of any future fish stocking efforts.

* - Develop a digital record of all documents, data and reports generated on Silver Lake for quick and complete access to all historic information that may be of use to future investigators and residents.

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**Appendix**

Temperature and dissolved oxygen profile data from the central lake sampling location. All data collected during the 2005 field season.

Silver Lake temperature and dissolved oxygen profile data
Susquehanna County, Pennsylvania
Central lake sampling location: E.UTM 0421011, N.UTM 4642818

| June 26, 2005 | | | | |
|---|---|---|---|---|
| Depth (meters) | Depth (feet) | Temperature (Celsius) | Temperature (Fahrenheit) | D.O. (mg/L) |
| 0.0 | 0.0 | 25.6 | 78.1 | 7.5 |
| 0.5 | 1.6 | 25.7 | 78.3 | 7.8 |
| 1.0 | 3.3 | 24.6 | 76.3 | 8.0 |
| 1.5 | 4.9 | 23.4 | 74.1 | 8.2 |
| 2.0 | 6.6 | 23.0 | 73.4 | 7.5 |
| 2.5 | 8.2 | 22.6 | 72.7 | 7.6 |
| 3.0 | 9.8 | 22.3 | 72.1 | 8.3 |
| 3.5 | 11.5 | 21.2 | 70.2 | 8.3 |
| 4.0 | 13.1 | 18.9 | 66.0 | 10.7 |
| 4.5 | 14.8 | 17.7 | 63.9 | 11.3 |
| 5.0 | 16.4 | 16.2 | 61.2 | 11.9 |
| 6.0 | 19.7 | 12.7 | 54.9 | 13.8 |
| 7.0 | 23.0 | 10.1 | 50.2 | 13.9 |
| 8.0 | 26.2 | 8.2 | 46.8 | 14.0 |
| 9.0 | 29.5 | 7.0 | 44.6 | 11.1 |
| 10.0 | 32.8 | 6.2 | 43.2 | 9.1 |
| 11.0 | 36.1 | 5.6 | 42.1 | 7.3 |
| 12.0 | 39.4 | 5.2 | 41.4 | 7.2 |
| 13.0 | 42.7 | 5.0 | 41.0 | 6.9 |
| 14.0 | 45.9 | 4.8 | 40.6 | 6.6 |
| 15.0 | 49.2 | 4.7 | 40.5 | 6.5 |
| 16.0 | 52.5 | 4.6 | 40.3 | 6.1 |
| 17.0 | 55.8 | 4.5 | 40.1 | 6.1 |
| 18.0 | 59.1 | 4.5 | 40.1 | 5.8 |
| 19.0 | 62.3 | 4.5 | 40.1 | 5.6 |
| 20.0 | 65.6 | 4.4 | 39.9 | 5.5 |
| 21.0 | 68.9 | 4.4 | 39.9 | 5.3 |
| 22.0 | 72.2 | 4.4 | 39.9 | 4.8 |
| 23.0 | 75.5 | 4.4 | 39.9 | 3.9 |
| 24.0 | 78.7 | 4.4 | 39.9 | 3.5 |
| 25.0 | 82.0 | 4.4 | 39.9 | 1.8 |

| July 30, 2005 | | | | |
|---|---|---|---|---|
| Depth (meters) | Depth (feet) | Temperature (Celsius) | Temperature (Fahrenheit) | D.O. (mg/L) |
| 0.0 | 0.0 | 25.1 | 77.2 | 7.5 |
| 0.5 | 1.6 | 24.7 | 76.5 | 7.3 |
| 1.0 | 3.3 | 24.6 | 76.3 | 7.2 |
| 1.5 | 4.9 | 24.5 | 76.1 | 7.3 |
| 2.0 | 6.6 | 24.5 | 76.1 | 7.1 |
| 2.5 | 8.2 | 24.5 | 76.1 | 7.1 |
| 3.0 | 9.8 | 24.5 | 76.1 | 7.3 |
| 3.5 | 11.5 | 24.2 | 75.6 | 7.3 |
| 4.0 | 13.1 | 23.9 | 75.0 | 7.5 |
| 4.5 | 14.8 | 23.6 | 74.5 | 7.9 |
| 5.0 | 16.4 | 20.8 | 69.4 | 13.3 |
| 6.0 | 19.7 | 15.4 | 59.7 | 14.2 |
| 7.0 | 23.0 | 12.2 | 54.0 | 14.3 |
| 8.0 | 26.2 | 9.5 | 49.1 | 12.6 |
| 9.0 | 29.5 | 7.5 | 45.5 | 8.4 |
| 10.0 | 32.8 | 6.3 | 43.3 | 6.1 |
| 11.0 | 36.1 | 5.7 | 42.3 | 5.1 |
| 12.0 | 39.4 | 5.3 | 41.5 | 5.2 |
| 13.0 | 42.7 | 5.0 | 41.0 | 5.2 |
| 14.0 | 45.9 | 4.8 | 40.6 | 5.3 |
| 15.0 | 49.2 | 4.7 | 40.5 | 5.2 |
| 16.0 | 52.5 | 4.6 | 40.3 | 5.2 |
| 17.0 | 55.8 | 4.5 | 40.1 | 4.7 |
| 18.0 | 59.1 | 4.5 | 40.1 | 4.4 |
| 19.0 | 62.3 | 4.5 | 40.1 | 4.1 |
| 20.0 | 65.6 | 4.5 | 40.1 | 3.5 |
| 21.0 | 68.9 | 4.4 | 39.9 | 3.3 |
| 22.0 | 72.2 | 4.4 | 39.9 | 2.6 |
| 23.0 | 75.5 | 4.2 | 39.6 | 2.2 |
| 24.0 | 78.7 | ---- | ---- | ---- |
| 25.0 | 82.0 | ---- | ---- | ---- |

| August 27, 2005 | | | | |
|---|---|---|---|---|
| Depth (meters) | Depth (feet) | Temperature (Celsius) | Temperature (Fahrenheit) | D.O. (mg/L) |
| 0.0 | 0.0 | 22.7 | 72.9 | 9.0 |
| 0.5 | 1.6 | 22.7 | 72.9 | 8.8 |
| 1.0 | 3.3 | 22.7 | 72.9 | 8.9 |
| 1.5 | 4.9 | 22.7 | 72.9 | 8.9 |
| 2.0 | 6.6 | 22.7 | 72.9 | 8.9 |
| 2.5 | 8.2 | 22.7 | 72.9 | 8.9 |
| 3.0 | 9.8 | 22.6 | 72.7 | 8.8 |
| 3.5 | 11.5 | 22 | 71.6 | 8.8 |
| 4.0 | 13.1 | 21.7 | 71.1 | 8.8 |
| 4.5 | 14.8 | 21.6 | 70.9 | 9.0 |
| 5.0 | 16.4 | 21.3 | 70.3 | 9.1 |
| 6.0 | 19.7 | 18.9 | 66.0 | 14.6 |
| 7.0 | 23.0 | 15.7 | 60.3 | 12.2 |
| 8.0 | 26.2 | 10.9 | 51.6 | 10.3 |
| 9.0 | 29.5 | 8.6 | 47.5 | 7.4 |
| 10.0 | 32.8 | 7.1 | 44.8 | 5.1 |
| 11.0 | 36.1 | 6.5 | 43.7 | 4.4 |
| 12.0 | 39.4 | 5.7 | 42.3 | 4.4 |
| 13.0 | 42.7 | 5.5 | 41.9 | 4.5 |
| 14.0 | 45.9 | 5 | 41.0 | 4.5 |
| 15.0 | 49.2 | 4.9 | 40.8 | 4.4 |
| 16.0 | 52.5 | 4.7 | 40.5 | 4.4 |
| 17.0 | 55.8 | 4.6 | 40.3 | 4.0 |
| 18.0 | 59.1 | 4.5 | 40.1 | 3.3 |
| 19.0 | 62.3 | 4.5 | 40.1 | 2.5 |
| 20.0 | 65.6 | 4.5 | 40.1 | 2.4 |
| 21.0 | 68.9 | 4.5 | 40.1 | 1.6 |
| 22.0 | 72.2 | 4.5 | 40.1 | 0.7 |
| 23.0 | 75.5 | 4.5 | 40.1 | 0.3 |
| 24.0 | 78.7 | ---- | ---- | ---- |
| 25.0 | 82.0 | ---- | ---- | ---- |

| September 17, 2005 | | | | |
|---|---|---|---|---|
| Depth (meters) | Depth (feet) | Temperature (Celsius) | Temperature (Fahrenheit) | D.O. (mg/L) |
| 0.0 | 0.0 | 22.7 | 72.9 | 7.6 |
| 0.5 | 1.6 | 22.7 | 72.9 | 7.3 |
| 1.0 | 3.3 | 22.7 | 72.9 | 7.3 |
| 1.5 | 4.9 | 22.7 | 72.9 | 7.3 |
| 2.0 | 6.6 | 22.7 | 72.9 | 7.2 |
| 2.5 | 8.2 | 22.7 | 72.9 | 7.2 |
| 3.0 | 9.8 | 22.6 | 72.7 | 7.2 |
| 3.5 | 11.5 | 22.6 | 72.7 | 7.0 |
| 4.0 | 13.1 | 22.5 | 72.5 | 6.9 |
| 4.5 | 14.8 | 21.8 | 71.2 | 6.5 |
| 5.0 | 16.4 | 21.7 | 71.1 | 5.8 |
| 6.0 | 19.7 | 18.9 | 66.0 | 7.1 |
| 7.0 | 23.0 | 13.7 | 56.7 | 9.4 |
| 8.0 | 26.2 | 10.1 | 50.2 | 7.4 |
| 9.0 | 29.5 | 8.9 | 48.0 | 6.5 |
| 10.0 | 32.8 | 7.5 | 45.5 | 3.9 |
| 11.0 | 36.1 | 6.3 | 43.3 | 3.7 |
| 12.0 | 39.4 | 5.6 | 42.1 | 3.5 |
| 13.0 | 42.7 | 5.1 | 41.2 | 3.5 |
| 14.0 | 45.9 | 5 | 41.0 | 3.7 |
| 15.0 | 49.2 | 4.8 | 40.6 | 3.7 |
| 16.0 | 52.5 | 4.6 | 40.3 | 3.6 |
| 17.0 | 55.8 | 4.6 | 40.3 | 3.4 |
| 18.0 | 59.1 | 4.5 | 40.1 | 3.3 |
| 19.0 | 62.3 | 4.5 | 40.1 | 1.8 |
| 20.0 | 65.6 | 4.5 | 40.1 | 1.1 |
| 21.0 | 68.9 | 4.5 | 40.1 | 0.8 |
| 22.0 | 72.2 | 4.4 | 39.9 | 0.3 |
| 23.0 | 75.5 | 4.4 | 39.9 | 0.2 |
| 24.0 | 78.7 | ---- | ---- | ---- |
| 25.0 | 82.0 | ---- | ---- | ---- |