# LONG-TERM, COMMUNITY-BASED CONSERVATION PLANNING AND MANAG EMENT

## E. L. ROSE CONSERVANCY OF SUSQUEHANNA COUNTY, PA

## 2010 ANNUAL REPORT

**James P. Lassoie**
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**Cornell University**

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THE EL. ROSE CONSERVANCY of SUSQUEHANNA COUNTY

Cornell University
Department of Natural Resources

## Forward – James P. Lassoie

For the past 12 years it has been my pleasure to help coordinate the conservation partnership between the Department of Natural Resources at Cornell University and the E.L. Rose Conservancy of Susquehanna County, Pennsylvania. Beginning in 1998, we have worked together to better understand the dynamic nature of the county's rural landscapes and to promote sound approaches to protecting its unique natural resources in the face of increasing development pressures. We have learned much over the years, and strongly believe that our efforts have contributed greatly to the conservation of Susquehanna County's lakes and lands and to the many people who use and enjoy them. As always, we remain deeply indebted to the Actus Foundation for their continuing support of this unique, long-term collaboration.

Early on, the partnership identified program priorities and approaches that would specifically address the intensified development and use of Susquehanna County's lakes and forests. Like many regions across the Northeast, this county was experiencing rapid land-use changes associated with the proliferation of individual home sites as large, defunct dairy farms were subdivided and sold. Within this context, we focused on gaining a better understanding of lake dynamics, inventorying and enhancing biodiversity, photo-documenting landscapes, and illustrating local human interests and values in protecting the integrity of rural landscapes. Our many activities over the years have illustrated the efficiency and effectiveness of building a long-term project that involved a land trust, an academic institution, and a foundation. The iterative nature of our work ensured that members of the Conservancy and the Cornell Team worked and learned together. This has included the involvement of graduate and undergraduate students who were able to participate in 'conservation in practice' – something impossible to provide in an on-campus setting. Our experiences working together also have positioned us well to address emerging threats to the natural environment of Susquehanna County, such as those now associated with the exploitation and development of the region's Marcellus Shale gas reserves.

The 2010 Annual Report continues this legacy. First, Kristi L. Sullivan and Stephen J. Morreale summarize their Conservation Enhancement for a Living Landscape Project, which this year focused on wildlife conservation and monitoring efforts involving the Cornell Conservation Education Program and E.L. Rose Conservancy members and volunteers. Then, the Biological Assessment of Silver Lake report by Kurt J. Jirka, Lars G. Rudstam, Clifford E. Kraft, Thomas E. Brooking, and Per G. Rudstam presents the results of their continuing efforts to monitor the status of the lake's alewife population and the effectiveness of a trout-stocking program as a means of controlling impacts from alewife. Each report concludes by proposing plans and recommendations for 2011, which are being discussed with E.L. Rose Conservancy Board Members for possible implementation over the next year.

This year marked a 'watershed' for the partnership in that the E. L. Rose Conservancy will begin sharing financial responsibilities with the Actus Foundation for future work beginning in 2011. This change is significant for the Conservancy, as it is one indicator of its maturation and success as a county-based land trust. It also means that Conservancy Board Members will be more actively involved in setting priorities for the partnership. The mutual trust, openness, and confidence that have been developed over the past dozen years bode well for the continuing success of this new arrangement for many years to come.

This year also marked the end of my formal involvement as the Cornell-based director of this partnership. It was certainly with mixed feelings that I decided new leadership was warranted beginning in 2011, as I greatly value my 12-year involvement with the Conservancy and the Actus Foundation – personally, it has been fun and enjoyable, and professionally it has been inspiring and educational. However, I can confidently pass leadership responsibilities on to long-time Cornell Team Member Dr. Stephen J. Morreale knowing that “the best is yet to come.”

# Program: Conservation Enhancements for a Living Landscape

*Kristi L. Sullivan and Stephen J. Morreale*
Cornell University

## 2010 Conservation Activities
**E.L. Rose Conservancy**




## *2010 Overview*

In 2010, cooperative conservation and monitoring efforts involving the Cornell Conservation Education Program and E.L. Rose Conservancy members and volunteers focused on a critical wildlife conservation issue. Beginning in winter 2006/2007, scientists in New York, Vermont, Connecticut and Massachusetts began observing bats flying outside during the day in the winter, clustered near cave entrances, or dead or dying inside their winter hibernacula. Because many of these animals had a mysterious white fungus on their nose, or on the tail, wings, or ears, the affliction was termed “white nose syndrome”. The fungus, thought to have originated in Europe and spread to the United States on the clothing of spelunkers, has been identified as the direct cause of bat mortality. From four known sites in one state (NY) in 2007, the fungus rapidly spread to 15 states and Canada by 2010. Over a million bats from at least 10 different species have died as a result of the fungus. In many caves, the mortality rate has been greater than 90% since the disease was first detected. The declining number of bats could mean the loss of entire local populations, and have far-reaching effects on our forest ecosystems.

In 2010, E.L. Rose Conservancy members joined with citizens from the local community, Rockwell Collins employees, and the Cornell Conservation Education Program to address bat conservation in the area. The focus was increasing awareness of the issue, locating and monitoring summer maternity roosts, and installing bat boxes in an effort to enhance habitat for these important predators of night-flying insects.

## *Bat Monitoring and Community Involvement*

### Project Objectives

The objectives of the bat monitoring project were to 1) inform the public about declining bat numbers and white nose syndrome; 2) engage the local community in bat monitoring efforts; 3) collect baseline maternity colony information for the area, and contribute that data to the “Appalachian Bat Count” project led by the Pennsylvania Game Commission; and 4) provide guidelines for bat box placement in the region.

### Public Outreach and Training

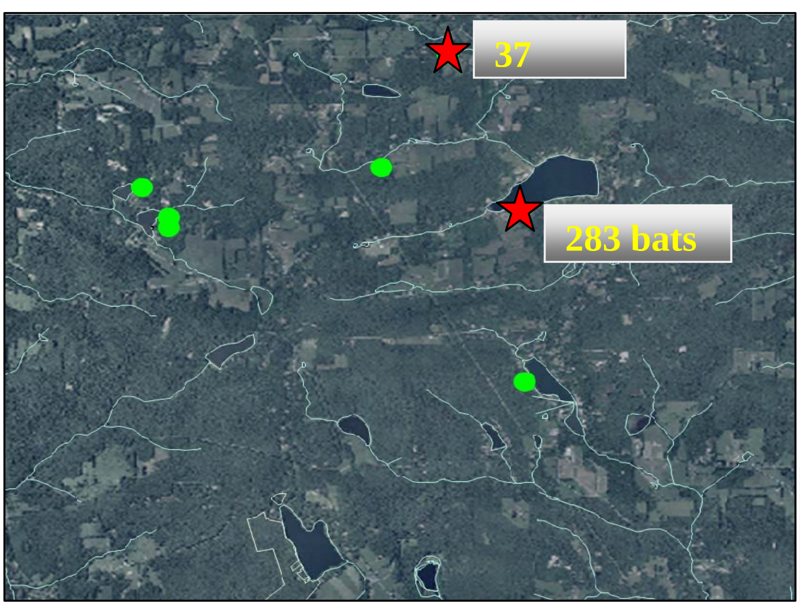
Several outreach events were held to inform the public about bats and white nose syndrome, teach people how to conduct bat emergence counts (counting bats as they emerge from their roost sites at dusk), and solicit input on potential bat roost locations. Outreach efforts began with a presentation to Conservancy members and the public at the Wilkerson’s barn. At that time, potential bat survey participants were recruited and we scheduled our first training and monitoring opportunity, which took place the following week at the Greenwood Barn. There, we introduced acoustic monitoring opportunities, reviewed species identification, and conducted our first emergence count. Subsequently, we conducted brief educational overviews with homeowners and other participants at each of the sites where we conducted emergence counts.

## Bat Monitoring

The attic of this house contains a maternity colony, as evidenced by the brown staining next to the chimney at the peak of roof.

Bat emergence counts can help establish baseline numbers of bats in a local area. By conducting annual counts at identified summer maternity roost sites, changes in bat colony size can be tracked over time. Although maternity colony size can vary for a number of reasons, a significant or prolonged decrease in one colony, or across several colonies in an area, can indicate a problem. If some colonies are declining while others remain stable, emergence counts also may provide clues about factors influencing susceptibility to white nose syndrome. In addition, the locations of maternity colonies can be correlated with habitat features in the area and as such can inform habitat enhancement efforts and bat box placement over time.

In 2010 we surveyed eight sites from Quaker Lake south to the Greenwood property near Dimock (Figure 1). Twenty-two people participated in monitoring efforts, while five others helped us find sites and connect with landowner. Volunteers logged an impressive 50 hours of time on this effort. At most of the sites we visited, there were a small number of bats, but not enough to be considered maternity colonies. Most people indicated that the number of bats they were seeing in 2010 had substantially declined from the previous year. Although no counts were conducted in the past to support these observations with quantitative data, the reports of perceived declines were consistent across the area and therefore have merit. Two of the counts were very successful. One count on Arrowhead Lake Rd. yielded about 37 bats of two different species. At another site on Quaker Lake we counted 283 bats emerging from next to the chimney. Even at this location, though, the owner felt the number of bats was lower than in the past.



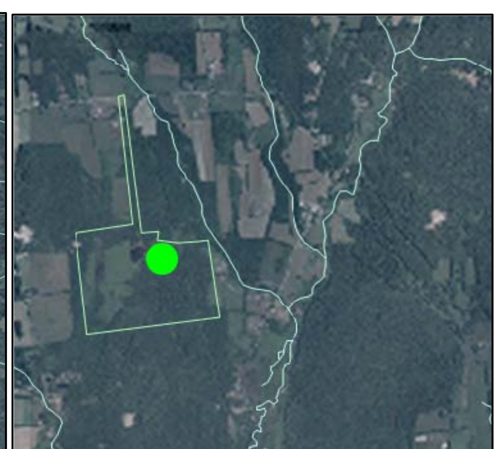



**Figure 1.** Emergence counts were conducted at eight sites in 2010. Two of these sites, indicated on the map with stars, housed maternity colonies.

## Using GIS to Identify Ideal Bat Habitat

We used Geographic Information Systems to help identify suitable habitat for bats in the area. Based on a literature review and the results of our surveys, we considered the presence of mixed open and wooded habitat, in combination with proximity to streams, rivers and lakes > 3 acres in size. Areas of mixed habitat (Figure 2) within 300 ft of water (Figure 3) were considered as primary habitat, while areas of mixed habitat from 300-400 ft of streams was considered secondary habitat.

This house contains a maternity colony. The surrounding habitat is ideal for bats with a mix of open habitat, woodlands, and a small orchard

This information can be used in two ways. First, it can be used to identify more potential maternity roost locations to survey. Second, it can be used to inform bat box placement as a method of enhancing roosting opportunities in areas of suitable habitat.

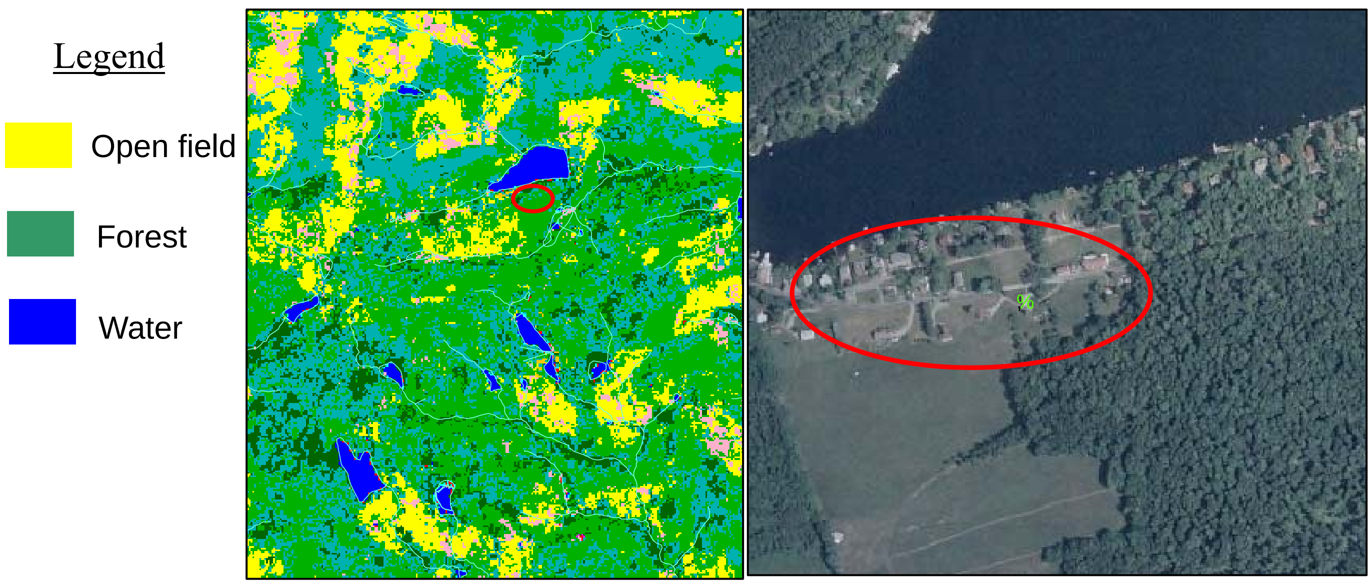



**Figure 2.** The area within the red circle in the picture on the left is also depicted in the aerial photo on the right. Both show the mixture of habitat types surrounding a bat maternity colony location.

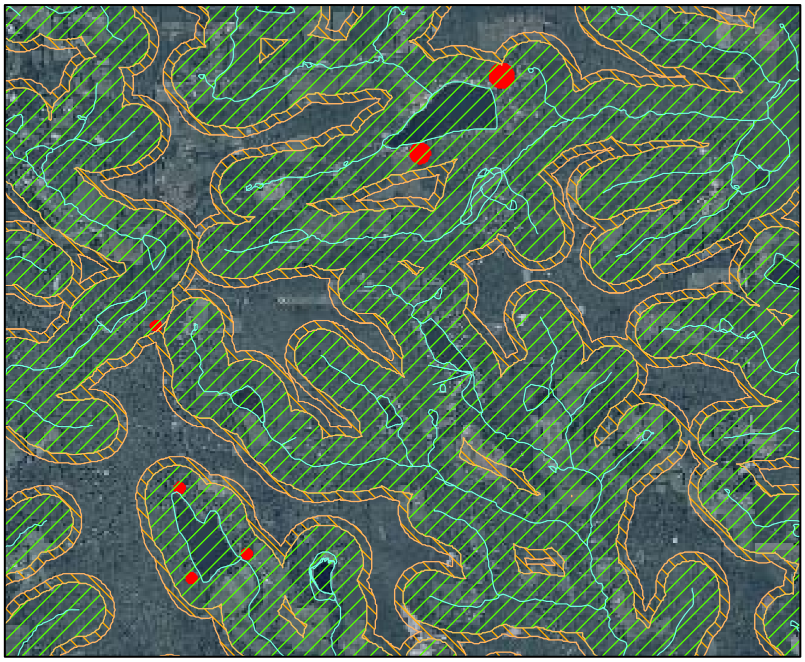


**Figure 3.** Areas indicated by green hatch marks are located within 300 m of water and are considered potential primary habitat where they overlap with a mix of habitat types (examples indicated with red dots). Those areas indicated by orange hatch marks are located from 300-400 m from water and are considered secondary habitat sites.

## Bat Box Placement

We developed the GIS project in part to help inform bat box placement in the area. Tim Matthews, Conservancy President, secured a "Green Communities Grant" from Rockwell Collins to build and erect bat boxes in the local area. Our results can be used to guide that effort. In addition, homeowners can also use the information to choose sites for bat boxes on their own properties. Bat boxes should be erected facing southwest or southeast at a location where they will receive seven or more hours of daylight (Figure 4). Sunlight is needed to warm the box and allow young bat pups to devote more energy to growth, rather than using the energy to maintain body temperature. Once suitable habitat has been located, boxes should be erected at heights of 10 feet or higher, with 12-20 feet preferred. They should be located at sites protected from wind, and within an existing bat travel corridor. Travel corridors can be determined by visiting the site at dusk and watching the movement of bats as they feed. The travel corridor indicates regular use of the site, and placing the box nearby can help bats find, and begin using, the box sooner.

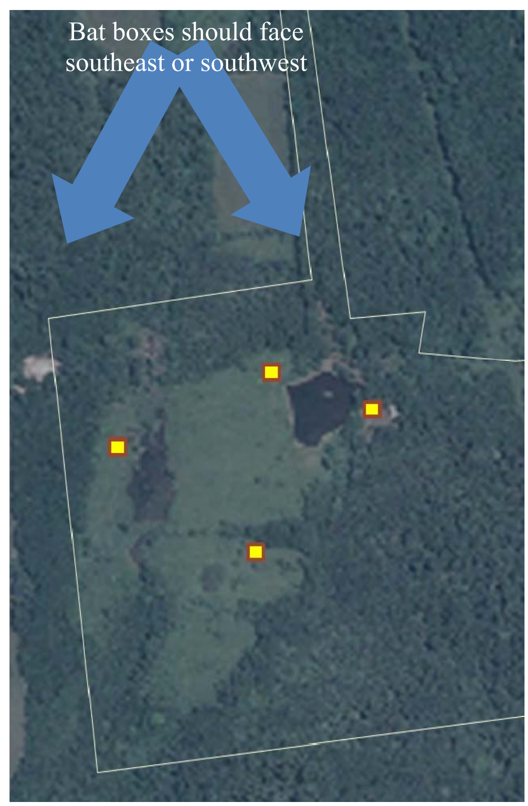



**Figure 4.** Image depicts potential suitable sites (yellow) for bat box placement at Greenwood based on habitat and distance from water. Bat boxes should face southeast or southwest, and should be sheltered from wind.

## *Summary and Future Plans*

Through our collaborative efforts in 2010, we initiated a long-term monitoring program, began collecting baseline data, and raised awareness of the issue within the local community. Enthusiasm for participation is high and we plan at minimum, to monitor the two maternity sites again in 2011.

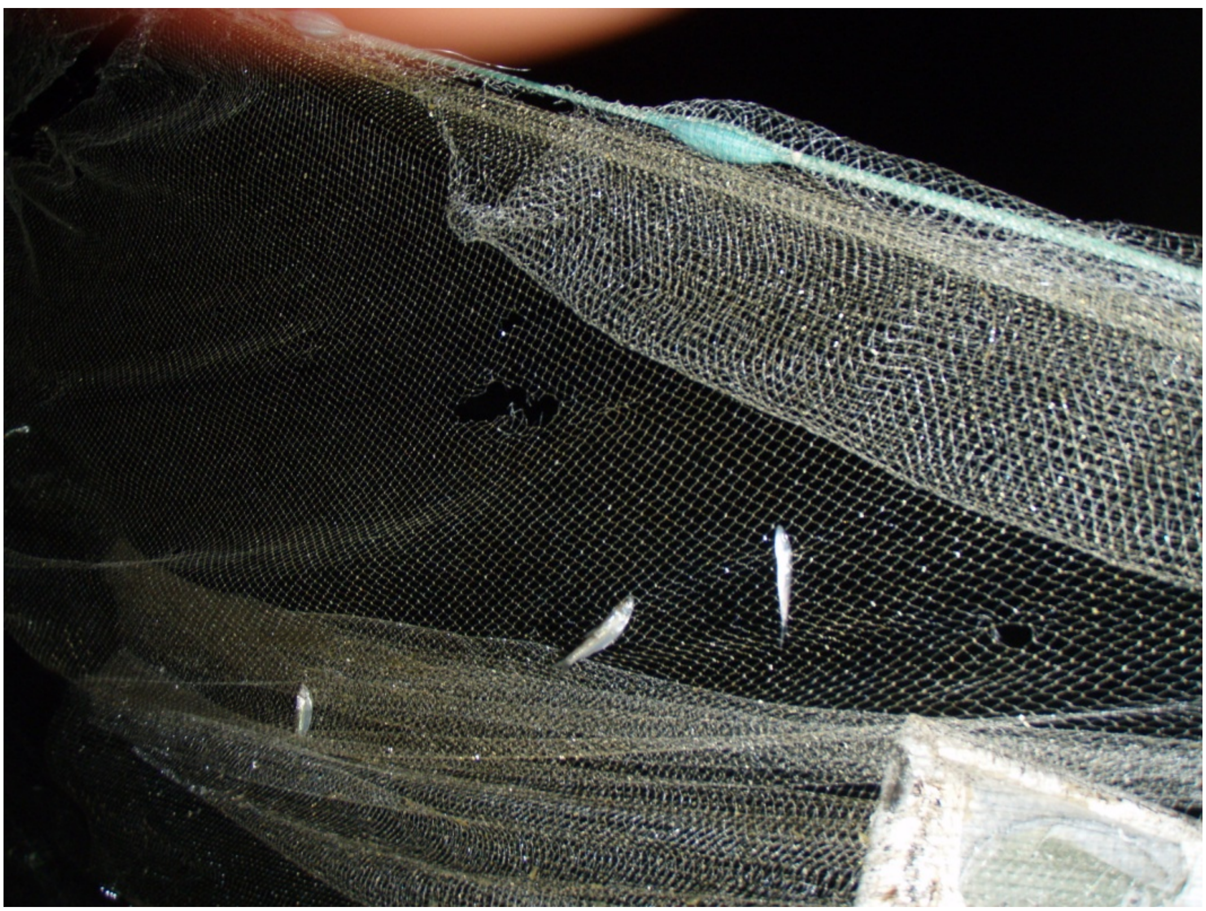
Our guidelines for bat box placement can aid landowners and homeowners in providing the best habitat possible for bats, and we will provide maps of specific areas for landowners at their request. Because bats are known to forage regularly along riparian corridors, maintaining or restoring forest cover adjacent to streams and other waterways will benefit bats in the area. Maintaining or creating snags (standing dead trees), particularly those over 14 inches in diameter, is also beneficial. The holes, or cavities, that develop in snags provide roost sites for bats. Snags are particularly beneficial when left along riparian areas, forest edges, and in regenerating stands. However, snags left in mature woodlands also provide benefits, as do living trees with cavities.

**E.L. Rose Conservancy of Susquehanna County**
**2010 Annual Report**

# Biological Assessment of Silver Lake: 2010

Kurt J. Jirka, Lars G. Rudstam, and Clifford E. Kraft,
Thomas E. Brooking and Per G. Rudstam

Cornell University



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Page 11 Photo: Young alewife captured in a gill net during a hydroacoustic survey of Silver Lake.

## Acknowledgements

We thank the E.L. Rose Conservancy for sponsorship of this study and continued support of Cornell research on Silver Lake. Our partnership with the Conservancy has lead to a deeper understanding of factors influencing the biological and physical features of Silver Lake. Insights gained through our work on Silver Lake also have potential applications to protection and management of other lakes in the region. This work is becoming increasingly important as development pressures continue to increase and stress the natural resources of northern Pennsylvania. We also want to thank Russ Cole for his efforts in collecting Secchi disk measurements on several occasions during 2010. This enabled us to expand our understanding of recent water clarity dynamics in Silver Lake. We thank Jonathan Swan and Chris Hotaling of the Cornell Biological Field Station for processing of zooplankton samples. Finally, we thank Patty and Billy Bloomer for the use of their boat, trolling motor, and property and the hospitality they continue to extend to us. Their assistance is greatly appreciated.

## Executive Summary

The primary focus of Cornell researchers in 2010 was continuing to assess the status of the alewife population in Silver Lake and the effectiveness of a trout stocking program as a means of controlling impacts from alewife. Alewife is a non-native fish species believed to have been introduced to Silver Lake sometime after 1992, and this has subsequently caused a decrease in water clarity as a result of overgrazing of large zooplankton. A trout stocking program was initiated in September 2006 with the goal of reducing alewife abundance through predation by trout and subsequently increasing water clarity. The 2008 research effort focused on estimating the abundance of alewife in the lake in order to better understand the dynamics of the alewife population and gauge the effectiveness of the trout stocking program to control alewife. Findings from the 2009 investigation suggested that the apparent initial success of the trout stocking program in 2008 was not sustained. The abundance, condition, and growth of alewife was again estimated in 2010 to further evaluate the on-going trout stocking program and better characterize the overall status of the alewife population in Silver Lake

Dissolved oxygen and water temperature were measured on August 30, 2010 to assess conditions for supporting trout during the summer and characterize the physical condition of the lake. Water clarity and zooplankton community composition also were evaluated on this date to continue monitoring changes in these measures since inception of the trout stocking program. Alewife density in the lake was estimated based on the results of a hydroacoustic (sonar) survey conducted on October 18, 2010. The open-water fish community was sampled by gill nets concurrent with the hydroacoustic survey, and the zooplankton community was also sampled again at this time.

Results of investigations conducted in 2010 indicate that Silver Lake continues to be capable of supporting long-term survival of trout. Water temperature and dissolved oxygen levels during summer 2010 showed a large zone of cool, well-oxygenated water capable of supporting trout during the warmest time of the year. Prior to 2009, it seemed as if the stocking of trout since September 2006 was having the desired effect of reducing alewife abundance and the impact of alewife on water clarity and other aquatic resources of Silver Lake. Unfortunately, these preliminary improvements did not continue through 2009 and 2010. Secchi depths declined to levels similar to or less than those of years prior to trout stocking. Abundance of large zooplankton, such as *Daphnia* spp., remained at the depressed levels found in 2009. The estimate of alewife abundance derived from the hydroacoustic survey conducted in October 2010 was

61% greater than that from 2009, which was 34% more than the October 2008 estimate. The alewife population in Silver Lake appears to have produced consecutive strong year classes of offspring. The high reproductive effort in 2009 may have been a compensatory response to reduced adult abundance brought on by high predation by trout. The cause of the large age class produced in 2010 is unclear, but it seems likely that there was high mortality of alewife over the 2009/2010 winter or in spring 2010 (due possibly to the poor condition of fish late in 2009, spawning stress, or trout predation). This could have stimulated another compensatory response that led to an increase in overall alewife population abundance.

Observations of decreased growth rate and relatively poor condition of alewife in Silver Lake in 2009 and again in 2010 suggest that this population is dense in relation to the productivity of the lake. Alewife are competing with one another for relatively limited food resources, resulting in slower growth and poorer condition for alewife of all sizes. This intense competition for food has led to a renewed reduction in numbers of large zooplankton (particularly Cladocera), increases in phytoplankton abundance, and resultant decreases in water clarity seen in 2009 and 2010. Based on findings from the 2009 and 2010 biological monitoring programs, the level of trout stocking (300 fish/year) was not sufficient to control the alewife population to the degree desired. If the goal is to reduce the alewife population in Silver Lake to potentially induce increased phytoplankton grazing by zooplankton and thereby clearer water, a more aggressive stocking policy using brown and rainbow trout will need to be implemented.

## Introduction

The E. L. Rose Conservancy of Susquehanna County has supported environmental conservation with a philosophy of stewardship and a desire for contemporary knowledge of the area's natural resources. This desire has led to the cooperative relationship between the Conservancy and Cornell University in an effort to understand, improve, and protect the water quality, fisheries and aquatic ecosystem associated with Silver Lake. The 2010 field season marked the seventh year of the cooperative relationship between the E.L. Rose Conservancy and Cornell University in an effort to monitor and manage the aquatic resources of Silver Lake. The initial focus of Cornell researchers was to review available historical information on the aquatic resources of Silver Lake and assess the biological integrity and fish community of Silver Lake through a variety of field sampling efforts. Work in recent years has concentrated on investigating impacts from introduced alewife and evaluating the stocking of trout as a means to control impacts of alewife. Six annual (2004-2009) reports summarizing the findings of these investigations have been prepared.

Alewife are a non-native fish species believed to have been introduced to Silver Lake sometime after 1992, which subsequently caused a decrease in water clarity as a result of alewife overgrazing large zooplankton. With support from the E.L. Rose Conservancy and the Silver Lake Lake Association, a trout-stocking program (using both rainbow trout and brown trout) was implemented in 2006 with the goal of reducing alewife abundance through predation by trout and subsequently increasing water clarity. Results of investigations conducted in 2007 indicated that stocking of trout was having the desired effect of reducing alewife abundance and the impact of alewife on water clarity and other aquatic resources of Silver Lake. The primary focus of Cornell researchers from 2008 through 2010 has been developing annual estimates of alewife abundance in Silver Lake using hydroacoustic surveys in which alewife abundance in the open lake was estimated by the use of sonar to detect and count fish. Information gathered through these surveys has been used to assess the effectiveness of trout stocking as a means of controlling alewife numbers and to understand how alewife abundance is influencing physical and biological components of the Silver Lake ecosystem. Research activities performed in 2010 included the following.

- A dissolved oxygen and water temperature profile of the lake was measured on August 30, 2010 to assess conditions for supporting trout during the summer when dissolved oxygen and water temperature conditions are most stressful to trout.
- Water clarity was measured using a Secchi disk by Cornell researchers on August 30 and by Silver Lake resident Russ Cole on June 21 and 25, August 28, and September 2 and 8, 2010.
- The zooplankton community was sampled near mid-lake on August 30 and October 18, 2010 to evaluate community structure and make inferences regarding impacts to zooplankton due to predation by alewife.
- Hydroacoustic sampling of the open-water portion of the lake was conducted on October 18, 2010 to develop estimates of the density and biomass of alewife in Silver Lake.
- Gill-net surveys were conducted concurrently with hydroacoustic sampling to sample the fish community in open-water portions of the lake, provide supporting data for the hydroacoustics analysis, and to obtain specimens of alewife for evaluating the overall condition and age structure of the population.

## *Dissolved Oxygen/Water Temperature*

Rainbow and brown trout require cool, well-oxygenated water year-round. These species prefer water temperatures below 72 ºF and dissolved oxygen levels above 5 mg/L. Dissolved oxygen and water temperature profiles were measured near mid-lake on August 30, 2010 to further assess the suitability of Silver Lake for long-term survival of trout. Similar profiles were measured by Cornell researchers in 2005-2009, and some historic data from 1946, 1992, and 2002 are also available from Silver Lake.

Data collected on August 30, 2010 were consistent with similar data collected in recent years (Figures 1 through 4) and indicate thermal stratification in this lake is fairly consistent during late summer (i.e., a layer of warm, less dense water overlays a dense, colder water layer). The transition area between these water layers is known as the thermocline. Typically, trout are limited to waters below the thermocline (known as the hypolimnion) during summer because waters shallower than the thermocline are unsuitably warm. However, dissolved oxygen levels can sometimes be depressed within the hypolimnion due to minimal mixing with more oxygenated surface waters and biological oxygen demand associated with bottom sediments. If a lake is to sustain trout year-round, a large enough volume of cool, well-oxygenated water must be available within the hypolimnion to allow trout to survive throughout the summer. Past data and the data collected in 2010 indicate that a sufficiently large volume of the hypolimnion in Silver Lake remains well oxygenated and cool enough during the warmest time of the year to support cold-water fishes such as trout (Figures 1 and 2). On August 30, 2010, the zone of the lake ranging in depth from about 8 to 32 ft contained water cooler than 72 ºF with dissolved oxygen levels greater than 5 mg/L.

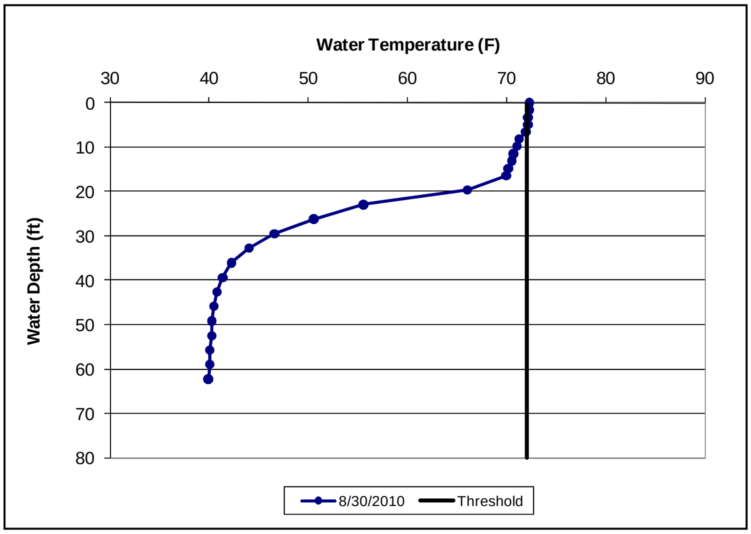


**Figure 1.** Water temperature profile for Silver Lake on August 30, 2010.

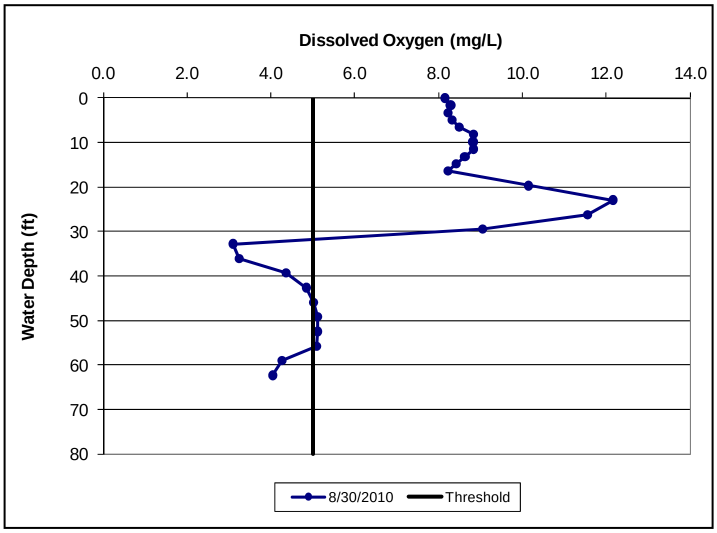


**Figure 2.** Dissolved oxygen profile for Silver Lake on August 30, 2010.

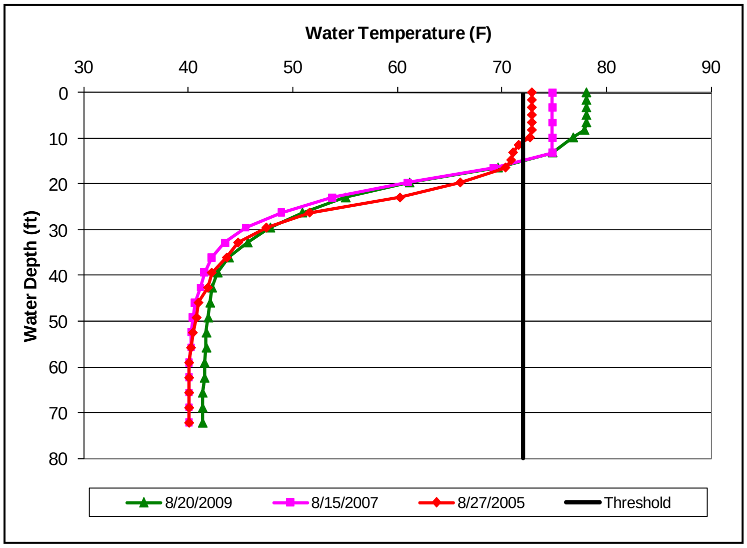


**Figure 3.** Examples of past August water temperature profiles for Silver Lake.

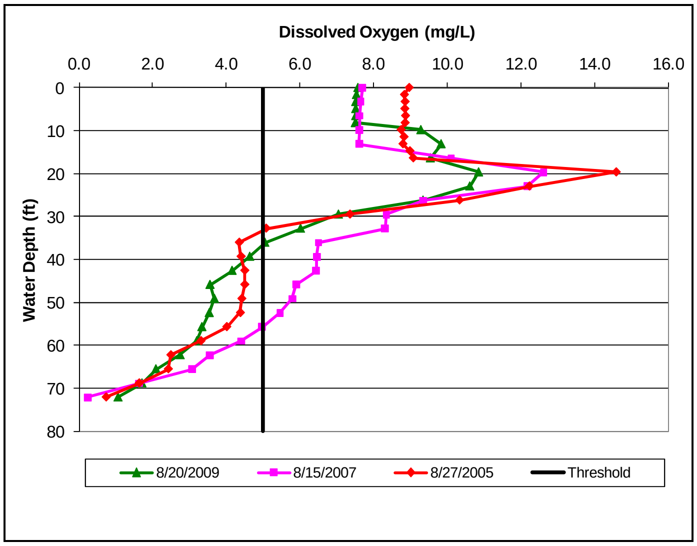


**Figure 4.** Examples of past August dissolved oxygen profiles for Silver Lake.

## Water Clarity

Water clarity in Silver Lake has been measured with a Secchi disk, a weighted, 8-inch diameter disk with four alternately colored black-and-white sections. The depth to which the disk can be viewed provides a standardized measure of water clarity. Secchi depth data for Silver Lake prior to the establishment of alewife is available for only two dates, but these values were high, ranging from 15 in 1946 to 20 ft in 1992. Following the introduction of alewife sometime after 1992, Secchi depths remained relatively high (13-15 ft) until 2006, when they declined to as low as 5.6 ft (Figure 5). Values measured in 2006 ranged from 5.6 ft on June 30 to 11.9 ft on October 12. The 5.6-ft value was measured during a flood event and therefore likely reflects a worst-case scenario, but the values for August 1 (9.6 ft) and October 12, 2006 (11.9 ft) were still lower than any previous measurements. The Secchi depth measured on August 15, 2007 was 13.9 ft, well within the range of values recorded prior to 2006 and very near values recorded before the establishment of alewife in the lake. The secchi depth measured on August 18, 2008 was 16.0 ft. This is the second highest Secchi depth recorded for Silver Lake and the highest recorded since the introduction of alewife in the early 1990s. This also represented the second consecutive year in which Secchi depth had increased since trout stocking began in September 2006.

Secchi depth measurements in 2009 were lower than values measured during the previous two years and were similar to values measured in 2006 prior to initiation of the trout stocking program (Figure 5). Secchi depths measured in 2009 also showed a declining trend over time, going from a high of 11.5 ft on August 20 to a low of 9.0 ft on September 8. These data suggested that alewife abundance may have increased since 2008, and the greater abundance of alewife was negatively affecting the abundance of zooplankton that graze upon the phytoplankton (microscopic algae) responsible for algal blooms in lakes. Reduced consumption of phytoplankton by zooplankton could have resulted in greater phytoplankton abundance and subsequently lower water clarity.

Secchi depth readings were obtained on several dates in 2010, providing insight into how water clarity changed over the course of the summer (Figures 5 and 6). Secchi readings in the latter half of June ranged from 13.1 ft to 14.8 ft, ranking among some of the best values recorded since 2002 and close to the value of 15 ft measured in 1946. However, Secchi readings in late August and early September 2010 declined to 8.7-9.8 ft, values similar to those seen in August and September 2009. The temporary increase in water clarity early in 2010 suggests that there may have been substantial mortality of alewife between the end of 2009 and summer 2010. Alewife are known to be susceptible to over-winter die-offs, particularly in populations exhibiting slow growth and poor condition, as the Silver Lake alewife population did in 2009 (O'Gorman et al. 2004). Other potential causes of a decline could be spawning stress or high predation by trout. Regardless of the cause, a reduction in the abundance of alewife would allow larger zooplankton that graze on phytoplankton to increase in abundance, reduce the abundance of phytoplankton in the water column, and result in increased water clarity. The subsequent decline in water clarity by late August 2010 is likely the result of increasing zooplankton predation by the growing year-class of alewife produced in 2010.

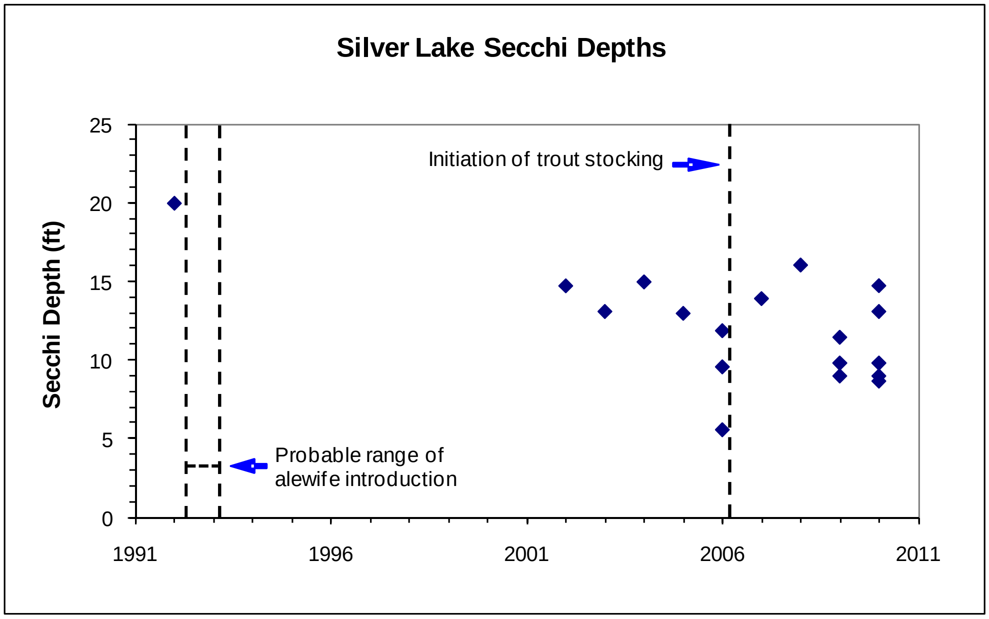


**Figure 5.** Secchi depth readings for Silver Lake, 1992, and 2002 through 2010.

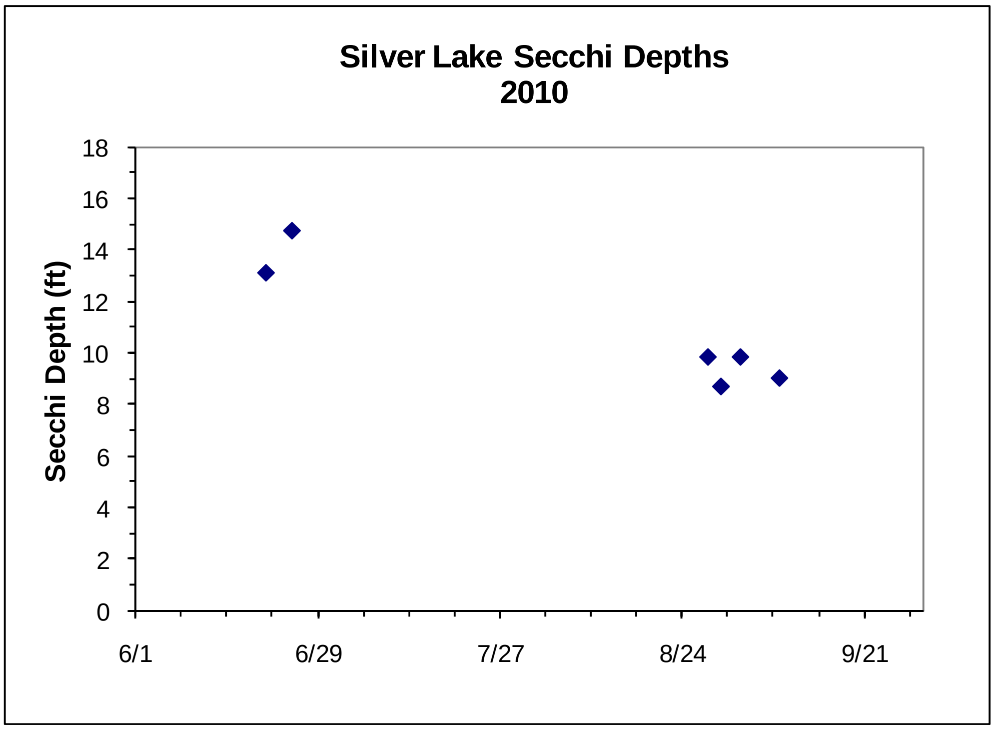


**Figure 6.** Secchi depth readings for Silver Lake on June 21 and 25, August 28 and 30, and September 2 and 8, 2010.

## Zooplankton Community

The zooplankton community (micro-crustaceans and other animals living within the water column) of Silver Lake was first investigated by Cornell researchers in 2006 (sampled on June 30, August 1, and October 12) and was sampled once again in 2007 (August 15), and twice in 2008 (August 18 and October 14), 2009 (August 20 and October 19), and 2010 (August 30 and October 18). Samples were collected near mid-lake using a Wisconsin-style plankton net that was lowered to a depth of 20 meters (~66 ft) and slowly lifted vertically to the surface. Alewife preferentially consume large zooplankton that graze upon the phytoplankton responsible for algal blooms in lakes. When large-bodied zooplankton (particularly *Daphnia* species, a type of Cladocera that are highly effective consumers of phytoplankton) are reduced or eliminated by heavy predation, the density of phytoplankton in the water column increases and water clarity decreases due to reduced light penetration.

Preliminary analysis of the 2006 samples found that large-bodied zooplankton were scarce or absent. This finding strongly supported the hypothesis that alewife were the cause of decreasing water clarity in Silver Lake. In contrast, the 2007 zooplankton samples contained relatively large numbers of zooplankton overall, a greater variety of zooplankton, and, most importantly, greater numbers and variety of large-bodied zooplankton (including *Daphnia*) than in 2006. The 2008 zooplankton data showed a continued gradual increase in *Daphnia*. These findings strongly suggested that the stocking of trout since October 2006 was having a positive impact on the zooplankton community by reducing the abundance of alewife and consequently the level of predation on large-bodied zooplankton such as *Daphnia*.

Zooplankton samples collected in 2009 and in 2010 did not show a continuation of the trend of increasing abundance of *Daphnia*. In 2009 and 2010, average density (number/liter of water) of *Daphnia* declined from 2008 values by 52-88% (Figure 7). The decline in *Daphnia* in 2009 coincided with the decline in water clarity during this same period, again suggesting that alewife abundance had increased since 2008 and the greater abundance of alewife was negatively affecting the abundance of efficient phytoplankton grazers like *Daphnia*. Similar water clarity conditions occurred in August and September 2010 when Daphnia density was similarly depressed.

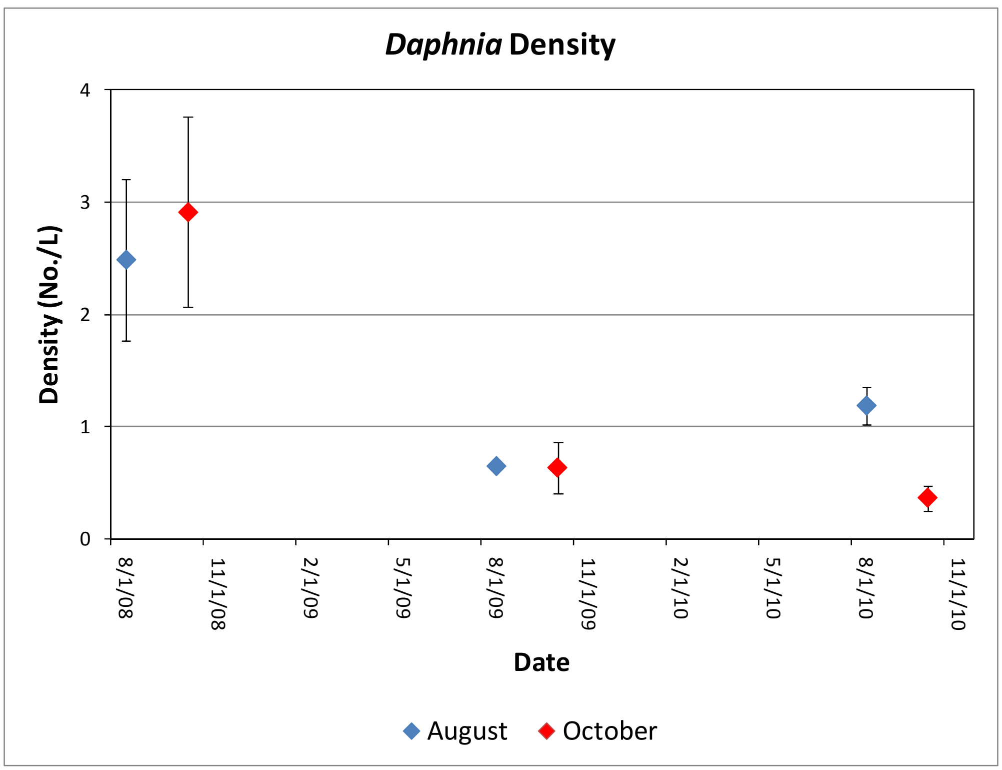


**Figure 7.** Mean density of *Daphnia* spp. from August and October samples from Silver Lake, 2008-2010. Error bars are one standard error (a measure of variability).

## Hydroacoustic Survey

Alewife are an effective planktivore, and abundant alewife populations cause declines in large, efficient zooplankton grazers (Brooks and Dodson 1965). Therefore, abundant alewife populations are usually associated with high chlorophyll levels (due to abundant phytoplankton) that result in decreased water clarity (Harman et al. 2002, Wang et al. 2010). Understanding water clarity changes in Silver Lake therefore requires an understanding of the dynamics of the alewife population. A hydroacoustic survey of Silver Lake was conducted on October 18, 2010 to estimate the density and biomass of the lake's alewife population. Data collected during the 2010 survey were then compared with data from similar surveys conducted on October 14, 2008, and October 19, 2009 to determine if and how the abundance of the lake's alewife population had changed during the past two years.

Silver Lake was surveyed at night (8:56 p.m. - 9:51 p.m.) using a 123 kHz split beam echo sounder mounted off the side of a flat-bottom motor boat. A total of 3,279 m of acoustic transects (lines along which data were collected) were analyzed in 7 sections that encompassed the main body of the lake. Acoustic data were recorded directly by a laptop computer in the boat from which the sonar gear was deployed. Data from each transect were analyzed to determine the number of alewife present at three ranges of depth: 2-8 m, 8-12 m, and 12 m to the lake bottom. The acoustic equipment and methods used in this survey were not able to detect fish in the top 2 m of water, so fish densities in the top 2 m were assumed be the same as in water from 2 to 8 m deep. Lake-wide averages of alewife density and biomass were calculated using the average density from each transect.

Fish were also captured using vertical gill nets set at two locations (two nets at each location) concurrent with hydroacoustic sampling (Figure 8, Table 1). The nets were set in pairs at two locations, with one net fishing from the surface to 6 m depth and the other from about 8 to 14 m at location 1 and from about 6 to 11 m at location 2. Nets were retrieved after being set for about 2.5 hours, and all captured fish were identified to species and the depth at which they were caught was recorded in 2-m intervals. Total length (in mm) and weight (nearest 0.1 g) were determined for each fish. Age and dry weight (a measure of condition or energy status) were determined for a subset of fish using otoliths (inner ear bones of fish) and by drying whole fish in an oven at 60 °C for five days.

***Gill net data.*** A total of 73 fish were caught in the gill nets (Table 1, 1.2 to 15.3 fish/hr). All of the fish caught were alewife. Alewives were found from the surface to 13-m depth, with a peak between 8 and 12 m. Acoustic and net data show the same depth distribution with peaks in the 2-6 m and 8-12 m depths. However, catches in shallow water was substantially lower compared to acoustic data than in the deeper layer. We believe this indicate that some of the targets in the shallow region were either alewife too small (<50 mm) to be caught in the nets, or some other target.

As in 2009, the alewife size distribution had three modes: 50-80 mm, 85 to 110 mm, and fish larger than 115 mm (Figure 9). However, there were also a number of fish larger than 150 mm that were not observed in 2008 and 2009. These length groups corresponded to age-0, age-2, and age 3 and older fish (Table 2). Two larger fish aged were age 6 (175 mm) and age 7 (187 mm) and one fish was 210 mm long.

**Figure 8.** Approximate location of gill net sets in Silver Lake on October 18, 2010.

**Table 1.** Summary of fish catches in gill nets set in Silver Lake on October 18, 2010. Total catch/hour includes alewife for which the depth of capture could not be determined.

| **Measure** | **Site 1** | **Site 1** | **Site 2** | **Site 2** |
|---|---|---|---|---|
| Set time (h) | 19:51 | 19:43 | 20:09 | 20:04 |
| Retrieve time (h) | 22:15 | 22:09 | 22:35 | 22:45 |
| Time fished (h) | 2.40 | 2.43 | 2.43 | 2.68 |
| Depth fished (m) | 0.0-6.0 | 8.0-13.5 | 0.0-6.0 | 6.0-10.8 |
| **Alewife** | | | | |
| No. of fish | 18 | 11 | 3 | 41 |
| Catch/hour | 7.5 | 4.5 | 1.2 | 15.3 |
| No. in upper 1/3 | 2.08 | 1.64 | 0.41 | 0.37 |
| No. in middle 1/3 | 2.50 | 1.23 | 0.41 | 10.43 |
| No. in lower 1/3 | 1.67 | 0.41 | 0.00 | 3.73 |
| Mean length (mm) | 75.1 | 98.4 | 68.7 | 105.6 |
| Length range (mm) | 59-112 | 70-169 | 55-98 | 68-210 |
| Mean weight (g) | 3.0 | 8.2 | 1.9 | 11.7 |
| Weight range (g) | 1.3-9.7 | 2.3-35.3 | 1.1-5.4 | 2.0-70.0 |
| % <80 mm (age 0) | 83 | 27 | 67 | 12 |
| **Other fish** | None | None | None | None |

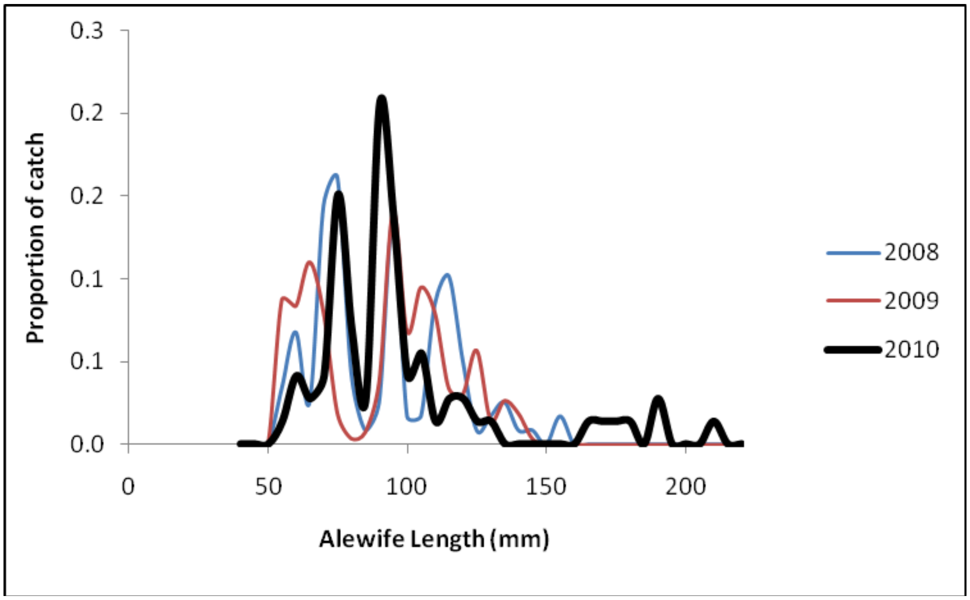


**Figure 9.** Size distribution of measured alewife captured in gill nets set in Silver Lake, October 2008, 2009, and 2010.

**Table 2.** Length and percent dry weight (DW) at age for alewife from Silver Lake caught in October 2008-2010. All fish age 2 and older were grouped together for dry weight analysis.

| Age | Length (mm) | Length Range | No. Aged | % DW | DW Range | No. Analyzed for DW |
|---|---|---|---|---|---|---|
| **2008** | | | | | | |
| 0 | 69.2 | 58-80 | 6 | 22.3 | 17.7-25.3 | 12 |
| 1 | 92.0 | 85-97 | 10 | 22.9 | 20.2-24.3 | 10 |
| 2 | 111.8 | 105-120 | 10 | 25.0 | 22.7-28.2 | 18 |
| 3 | 130.7 | 119-144 | 3 | | | |
| 4 | 140.7 | 133-152 | 3 | | | |
| | | | | | | |
| **2009** | | | | | | |
| 0 | 63.8 | 55-69 | 10 | 23.4 | 21.0-25.9 | 15 |
| 1 | 86.7 | 80-92 | 4 | 23.8 | 22.3-26.4 | 8 |
| 2 | 105.5 | 99-110 | 6 | 25.2 | 22.9-27.2 | 17 |
| 3 | 126.0 | 118-136 | 7 | | | |
| 4 | 137.0 | 133-143 | 3 | | | |
| | | | | | | |
| **2010** | | | | | | |
| 0 | 65.0 | 55-75 | 10 | 22.4 | 19.3- 24.7 | 17 |
| 1 | 76.0 | 70-82 | 2 | 21.7 | - | 1 |
| 2 | 90.2 | 83-108 | 9 | 22.2 | 29.3-22.5 | 22 |
| 3 | 113.5 | 106-121 | 4 | | | |
| 6 | 175 | | 1 | | | |
| 7 | 187 | | 1 | | | |

With the exception of one age-1 fish that was 70 mm long, all aged fish shorter than 75 mm were age-0. Therefore, we defined age-0 fish as all alewife shorter than 75 mm. These age-0 fish represented 27% of the catch, had an average length of 68.9 mm, an average weight of 2.1 g. Older fish defined as alewife 76 mm and larger represented 73% of the catch, and had an average length of 105.5 mm and average weight of 11.1 g. Age-0 fish represented a smaller proportion of the catch in 2010 compared to 2009 (38%). The proportion of age-0 fish was higher in the surface nets (0-6 m) than in the deeper nets (Table 1) indicating a segregation in depth by size in Silver Lake (also observed in 2009). Alewives typically reach lengths of 60 to 90 mm by September of their first year of life in New York inland lakes (Rudstam and Brooking 2005) but can get larger (up to 140 mm) in productive lakes with large zooplankton (e.g., Oneida Lake and Canadarago Lake). Age-0 alewife in Silver Lake in 2010 were below average size. Size of older fish and an index of condition (22 % dry weight) were also low compared to regional populations (Rudstam and Brooking 2005). Thus, both growth and condition of alewife in Silver Lake is low, consistent with a low productivity lake with a relatively large alewife population and small zooplankton sizes.

***Acoustic data***. Fish density calculated from data obtained from each transect in October 2010 was 5,555 fish/ha (2,249 fish/acre) at depths from 0–8 m and 610 fish/ha (247 fish/acre) at depths from 8 m to the bottom (Table 3). Densities in 0-2 m were calculated from acoustic densities in 2-6 m assuming the catchability in the gill nets was the same from 2-6 m as in 0-2m of water (see Rudstam et al. 2010). Alewife distribution was uneven across the lake and densities among transects ranged from 1,844 to 19,783 fish/ha (747-8,009 fish/acre). Assuming all of these fish were alewife and an average weight of alewife of 2.93 g in 0-8 m and 10.94 g in 8-14 m of water (Table 1), the alewife biomass was calculated to 23.0 kg/ha (20.5 lb/acre). This is less than the 27.2 kg/ha (24.0 lb/acre) estimated during the 2009 survey, but larger than the October 2008 biomass estimate (20.2 kg/ha; 18.0 lb/acre).

Acoustic densities obtained from the 2010 survey were higher than in 2008 and 2009 (6,165 fish/ha compared to 3,831 and 2,850 fish/ha) while catches in gill nets were similar to 2008 but lower than 2009 (7.3 fish/net hr in 2010 compared to 6.2 and 14.4 fish/net hr in 2008 and 2009). Densities of over 6,000 fish/ha are similar or higher than observed in larger New York lakes (Fitzsimons et al. 2005, Brooking and Rudstam 2009, Wang et al. 2010). Low growth rate and conditions are also indications of high alewife abundance. However, density in areas of the lake greater than 8 m deep that likely represents adult alewife is only 610 fish/ha, which is not high compared to other lakes in the region.

The high density in the surface layer compared to the 8-14 m depth complicates the interpretation of the survey results. One interpretation is that alewife smaller than the sizes catchable by the gill nets (≥50 mm) were present in the surface water. This interpretation is consistent with the smaller target strengths observed in the upper water column with acoustics. Therefore, it is likely that the biomass presented here is biased high. This interpretation also affects the proportion of age-0 compared to adult alewife in the lake. The proportion of age-0 in the population based on net catches was 33%, whereas the proportion assuming that all fish targets in the top 0-8 m are age-0 alewife and all fish below 8 m are age-1 and older is 90%, a more likely number. The 2010 year class is therefore likely to have been relatively large in 2010. Whether these smaller alewives will survive the winter of 2010-2011 is uncertain as over-winter mortality increase with decreasing alewife size (O'Gorman et al. 2004).

**Table 3.** Estimates of alewife density in Silver Lake based on hydroacoustic data collected October 18, 2010. Density is calculated using transect-specific data. Biomass is the density multiplied by the average weight of all alewife caught in gill nets. Mean density and biomass is weighted by length of the transect.

| Transect | Transect Length (m) | Density (0-8 m) (fish/ha) | Density (8 m-bottom) (fish/ha) |
|---|---|---|---|
| 1 | 464 | 1,287 | 557 |
| 2 | 578 | 943 | 685 |
| 3 | 338 | 18,683 | 1,100 |
| 4 | 372 | 3,542 | 217 |
| 5 | 401 | 8,342 | 86 |
| 6 | 307 | 7,471 | 17 |
| 7 | 815 | 4,632 | 1,046 |
| **Mean** | **304** | **5,555** | **610** |
| Biomass (kg/ha) | | 16.3 | 6.7 |

## Trout Stocking

Annual stocking of trout into Silver Lake has occurred since 2006 as recommended by Cornell researchers. Each year 150 rainbow trout and 150 brown trout approximately 300 mm (11-12 inches) have been stocked in the fall. The purpose of the stocking was to establish and supplement the trout populations in the lake, increasing predation of alewife in order to reduce the impact of alewife on water clarity and the lake's food web. Periodic stocking of trout was deemed necessary in order to maintain trout populations at a level capable of controlling alewife abundance because neither brown nor rainbow trout are likely to be able to reproduce within Silver Lake due to the lack of appropriate spawning habitat.

Initially (through 2008), the stocking of trout appeared to be having the desired effect of reducing alewife abundance and improving zooplankton community structure and water clarity in Silver Lake. However, beginning in 2009 and continuing through 2010, alewife abundance has increased, and zooplankton community structure and water clarity has showed a corresponding decline. Alewife have a great capacity to produce strong year classes of offspring to compensate for low adult abundance (Rudstam et al., in press). This trait complicates controlling alewife populations through the stocking of predators because it can be difficult to anticipate the reproductive response of a population to predation pressure. Because recent data showed that trout stocking was not fully achieving the desired effect on the alewife population, and considering the cost to Silver Lake residents of continuing to stock trout, Cornell researchers recommended foregoing trout stocking in fall 2010 until the results of the 2010 acoustic survey could be fully analyzed and a more informed decision could be made regarding a stocking program in the future. It was believed that not stocking for a year would not result in any negative long-term consequences and could provide useful information regarding how the alewife population responds without supplemental trout stocking one year.

## *Conclusions and Recommendations*

Results of investigations conducted in 2010 indicate that Silver Lake is capable of supporting long-term survival of trout. Water temperature and dissolved oxygen levels during summer indicate a large zone of cool, well-oxygenated water capable of supporting trout during the warmest time of the year. Prior to 2009, the trout stocking program initiated in September 2006 seemed to be having the desired effect of reducing alewife abundance and improving water clarity and other aquatic resources of Silver Lake. Desirable changes in the zooplankton community, most notably an increased abundance and variety of large zooplankton (especially large Cladocera), indicated that alewife abundance had been reduced enough to allow some recovery of large zooplankton. Unfortunately, these improvements did not continue through 2009, and results of the 2010 investigation were similar to those of 2009. Secchi depths have declined to levels similar to or less than those observed in years prior to the recent trout stocking effort. The abundance of large Cladocera was the lowest observed since trout stocking began (though were still greater than prior to stocking).

The observed changes in Secchi depth and the zooplankton community during 2009 and 2010 suggest that alewife abundance increased since 2008, and estimates of alewife abundance derived from the hydroacoustic survey conducted in October 2009 and 2010 confirmed this. The estimated density and biomass of alewife in Silver Lake in October 2009 had increased by about 34% over 2008 estimates. Alewife density increased an additional 61% from 2009 to 2010, but estimated biomass actually decreased by 15% from the 2009 estimate. This indicates that alewife numbers were much larger in 2010 than in 2009, but the population consisted primarily of smaller fish. It appears that there was a strong year class of alewife produced in 2010, and these age-0 fish constitute a large portion of the current population. The Silver Lake alewife population showed poor growth and condition in 2010, as it did in 2009, reflecting a relatively dense population of alewife competing for relatively limited food resources. This intense competition for food has resulted in a reduced number of large Cladocera, increases in phytoplankton abundance, and resultant decreases in water clarity in Silver Lake in the past two years.

Trout stocking to control the alewife population initially seemed to have a beneficial impact upon water clarity, but this benefit was not sustained during 2009 or 2010. Although the reasons for the substantial increase in alewife numbers beginning in 2009 are uncertain, several factors could be responsible. A particularly strong year-class (i.e., high spawning success and survival of young) of alewife could have been produced in 2009 as a compensatory response to the reduction in adult alewife abundance in previous years due to trout predation. It is also possible that over-winter conditions for survival of age-0 and age-1 alewife during winter 2008-2009 might have been particularly favorable. Finally, trout survival may have also declined from 2008 to 2009. There is anecdotal evidence (improved water clarity in June 2010) that suggests that there may have been considerable mortality of alewife during the 2009/2010 winter. However, the 2010 hydroacoustic survey indicates that there was a strong year-class of alewife produced in 2010, possibly another compensatory response to the reduction in alewife abundance during the previous winter. Although we do not know with confidence the exact causes of recent shifts in the abundance and composition of the alewife population, we do know such changes are occurring.

Regardless of the cause(s) of the increase in alewife abundance in 2009 and 2010, the results of the 2009 and 2010 monitoring programs indicate that the level of trout stocking has not been sufficient to control the alewife population to the degree desired. In order to achieve the goal of reducing the alewife population in Silver Lake to induce increased phytoplankton grazing by zooplankton and thereby produce clearer water, a more aggressive stocking policy using brown and rainbow trout should be considered. The information gathered in the past three years regarding the growth and abundance of alewife in Silver Lake can be used to better estimate the number of trout needed to reduce the alewife population to the desired level, and ongoing evaluations of alewife population abundance and growth rates should continue through this management experiment. Future monitoring of water clarity, the zooplankton community, and aspects of the fish community (species composition, trout abundance and growth, piscivore diet composition, alewife density) can be used to measure the long-term effectiveness of the stocking program and potentially identify ways to more effectively reduce alewife abundance. Results from this type of experimental evaluation in Silver Lake would be of interest not only to Cornell researchers and residents of Silver Lake, but to a broad community of lake and fisheries managers.

Past reports prepared by Cornell University regarding Silver Lake have included several other recommendations that are still relevant, particularly in light of concerns regarding water quality impacts related to exploitation of Marcellus Shale gas reserves. We continue to advocate maintaining efforts that minimize inputs of nutrients and pollutants to preserve lake water quality. Efforts to preserve the integrity of the undeveloped shoreline along Silver Lake and the large amount of wood present along that shoreline should be continued in order to support native fish populations by providing habitat for forage and refuge.

Silver Lake is highly valued for a variety of reasons by watershed residents as evidenced through the efforts sponsored by the E.L. Rose Conservancy to understand, protect, and enhance the Silver Lake ecosystem. The lake also provides a natural laboratory for studying the processes and factors that control and influence the composition and function of the lake's ecosystem. Studies of this nature continue to improve our knowledge of the lake and identify means by which the valued resources of the lake can be sustained or improved. In addition, lessons learned from studying and managing Silver Lake are applicable to the management and protection of aquatic resources associated with other lakes in the region.

## *Literature Cited*

Brooking, T. E. and L. G. Rudstam. 2009. Hydroacoustic target strength distributions of alewife in a net cage compared to field surveys: deciphering target strength distributions and effect on density estimates. Transactions of the American Fisheries Society 138: 471–486.

Brooks, J. L. and S. I. Dodson. 1965. Predation, body size, and composition of zooplankton. Science 150:28-35.

Fitzsimons, J. D., B. Williston, J. Zajicek, D. Tillitt, S. Brown, L. Brown, D. C. Honeyfield, D. Warner, L. G. Rudstam, and W. Pearsall. 2005. Thiamine content and thiaminase activity of ten freshwater stocks and one marine stock of alewives. Journal of Aquatic Animal Health 17: 26-35.

Harman, W. N., M. F. Albright, and D. M. Warner. 2002. Trophic changes in Otsego Lake, NY following the introduction of the alewife (*Alosa pseudoharengus*). Lake and Reservoir Management 18:215-226.

O'Gorman, R., B. F. Lantry, and C. P. Schneider. 2004. Effect of stock size, climate, predation, and trophic status on recruitment of alewives in Lake Ontario, 1978-2000. Transactions of the American Fisheries Society 133:853-865.

Rudstam, L. G. and T. E. Brooking. 2005. Alewife (*Alosa pseudoharengus*) abundance in Onondaga Lake, 2004-2005. A report to Onondaga County. Cornell Biological Field Station, Bridgeport, NY. 24 pp.

Rudstam, L. G., T. E. Brooking, S. D. Krueger, J. R. Jackson, and L. Wetherbee. In press. Analysis of compensatory responses in land-locked alewife to walleye predation: a tale of two lakes. Transactions of the American Fisheries Society.

Wang, R. W., L. G. Rudstam, T. E. Brooking, R. Snyder, M. Arrigo, E. Mills, and J. Mastriano. 2010. Food web effects and the disappearance of the spring clear water phase following enhancements at the Metro in Onondaga Lake, New York. Lake and Reservoir Management 26:169-177.