Biological Assessment of Silver Lake: 2009

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Cover Photo: Cornell researcher Justin Chiotti sampling zooplankton on Silver Lake, August 20, 2009.

Acknowledgements

We thank the E.L. Rose Conservancy for sponsorship of this study and continued support of Cornell research on Silver Lake. The efforts of the Conservancy in cooperation with Cornell University continue to increase our understanding of the biological dynamics of Silver Lake. Furthering this understanding contributes to the stewardship of the unique resources of Silver Lake and provides information applicable 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 Rus Cole for his efforts in collecting Secchi disk measurements on several occasions during 2009. This enabled us to expand our understanding of recent water clarity dynamics in Silver Lake. We thank Tom Brooking of the Cornell Biological Field Station for his analysis of alewife age and condition. 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 actions provide a welcoming environment that greatly facilitates the work Cornell researchers are performing.

Executive Summary

The primary focus of Cornell researchers in 2009 was continuing to assess the status of the alewife population in Silver Lake. 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. The abundance of alewife was again estimated in 2009 to see how alewife abundance was changing in response to on-going trout stocking.

Dissolved oxygen and water temperature were measured on August 20 and October 19, 2009 to assess conditions for supporting trout during the summer and gain a better understanding of the physical condition of the lake. Water clarity and zooplankton community composition were evaluated on these same dates to continue monitoring changes in these measures since inception of the trout stocking program. The littoral (shallow-water) fish community was sampled using a seine at two locations on August 20, 2009 to further document fish community species composition. Alewife density in the lake was estimated based on the results of a hydroacoustic (sonar) survey conducted on October 19, 2009. The open-water fish community was sampled by gill nets concurrent with the hydroacoustic survey.

Results of investigations conducted in 2009 indicate that Silver Lake continues to be capable of supporting long-term survival of trout. Water temperature and dissolved oxygen levels during summer 2009 showed a large zone of cool, well-oxygenated water capable of supporting trout during the warmest time of the year. Prior to our 2009 surveys, 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. Secchi depths declined to levels similar to or less than those of years prior to trout stocking. Large zooplankton abundance was

the lowest found since trout stocking began (though still higher than prior to stocking). Estimates of alewife abundance derived from the hydroacoustic survey conducted in October 2009 confirmed the suspicion that these changes were the result of increased alewife abundance in 2009. The hydroacoustic survey resulted in an estimate of alewife density in Silver Lake of 3,831 fish/hectare (1,551 fish/acre). The estimated density and biomass of alewife in October 2009 increased by about 34% over October 2008 estimates. Our observations of decreased growth rate and relatively poor condition of alewife in Silver Lake in 2009 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. Based on findings from the 2009 biological monitoring program, the current level of trout stocking (300 fish/year) is 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 should 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 2009 field season marked the sixth 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. Five annual (2004-2008) 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 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 in 2008 was developing an estimate of alewife abundance in Silver Lake. This was accomplished through a hydroacoustic survey in which alewife abundance in the open lake was estimated by the use of sonar to detect and count fish. Research efforts in 2009 built upon information gathered in 2008 and included the following activities.

- A dissolved oxygen and water temperature profile of the lake was measured on August 20, 2009 to assess conditions for supporting trout during the summer when dissolved oxygen and water temperature conditions are most stressful to trout. A second profile was measured on October 19, 2009 in conjunction with a hydroacoustic survey.

- Water clarity was measured using a Secchi disk by Cornell researchers on August 20 and October 19, 2009 and by Silver Lake resident Rus Cole on August 28, September 2, and September 8, 2009.
- The zooplankton community was sampled near mid-lake on August 20 and October 19, 2009 to evaluate community structure and make inferences regarding impacts to zooplankton due to predation by alewife.
- The fish community inhabiting vegetated shallow-water habitat was sampled using a seine on August 20, 2009 to further document fish species composition and determine if young-of-year alewife were using this habitat.
- Hydroacoustic sampling of the open-water portion of the lake was conducted on October 19, 2009 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 and provide supporting data for the hydroacoustics analysis.

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 20, 2009 to further assess the suitability of Silver Lake for long-term survival of trout. Similar profiles were measured by Cornell researchers in 2005-2008, and some historic data from 1946, 1992, and 2002 are also available from Silver Lake.

Data collected on August 20, 2009 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 2009 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 20, 2009, the zone of the lake ranging in depth from about 15 to 36 ft contained water cooler than 72 ºF with dissolved oxygen levels greater than 5 mg/L.

The dissolved oxygen/water temperature profile measured on October 19 indicated that the lake was still stratified at this time, but the pattern of change in dissolved oxygen and temperature with increasing depth differed from that in August (Figures 5 and 6). In October, dissolved oxygen and temperature were relatively stable within the upper 33 ft of the water column and showed a marked decrease below this depth (marking the thermocline). The zone of the lake ranging from the surface to the thermocline contained water less than 72 ºF with dissolved oxygen greater than 5 mg/L. Dissolved oxygen was too low to support trout at depths below about 33 ft.

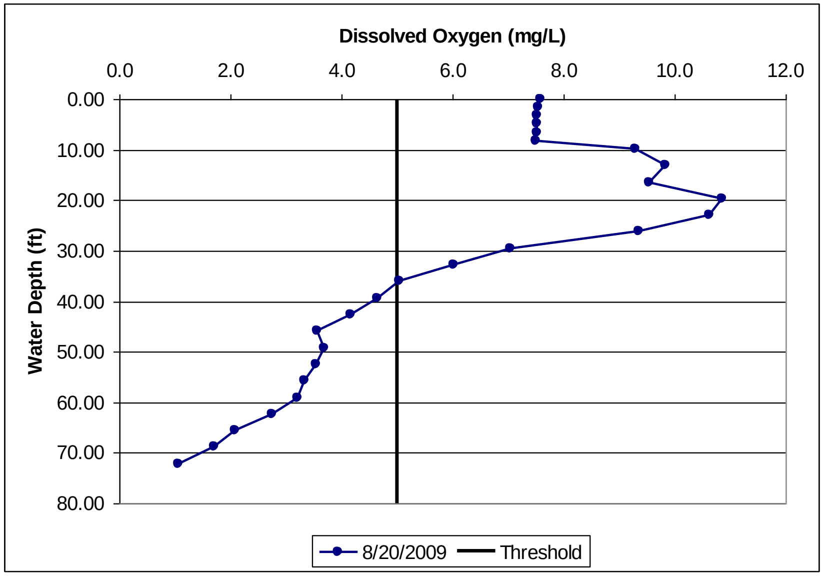

Figure 1. Dissolved oxygen profile for Silver Lake on August 20, 2009.

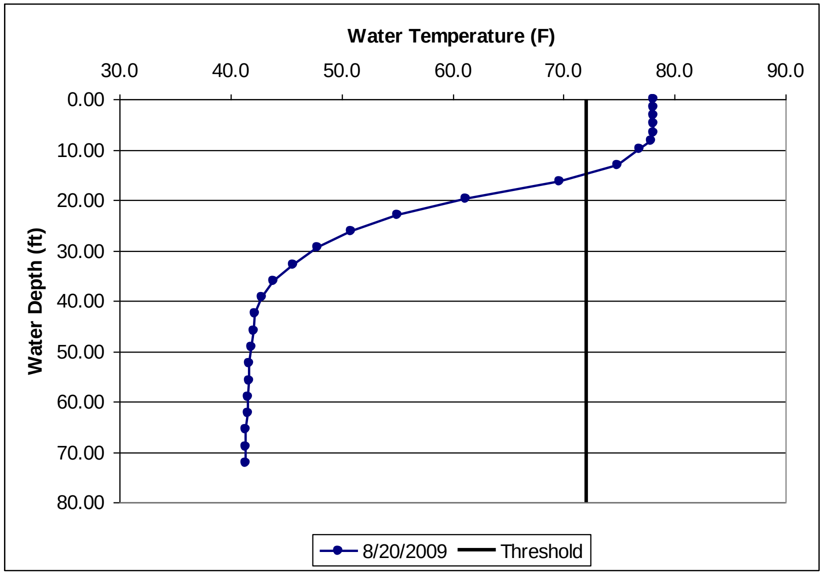

Figure 2. Water temperature profile for Silver Lake on August 20, 2009.

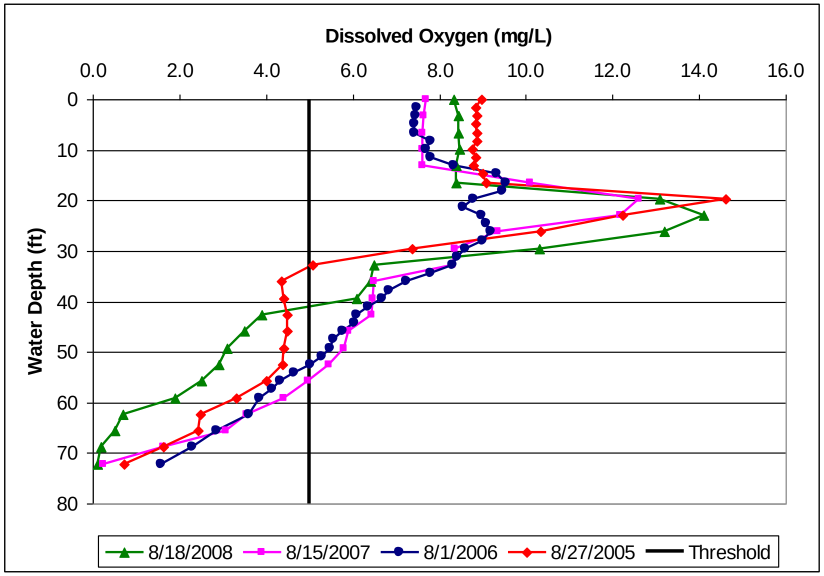

Figure 3. Dissolved oxygen profiles for Silver Lake on August 18, 2008, August 15, 2007, August 1, 2006, and August 27, 2005.

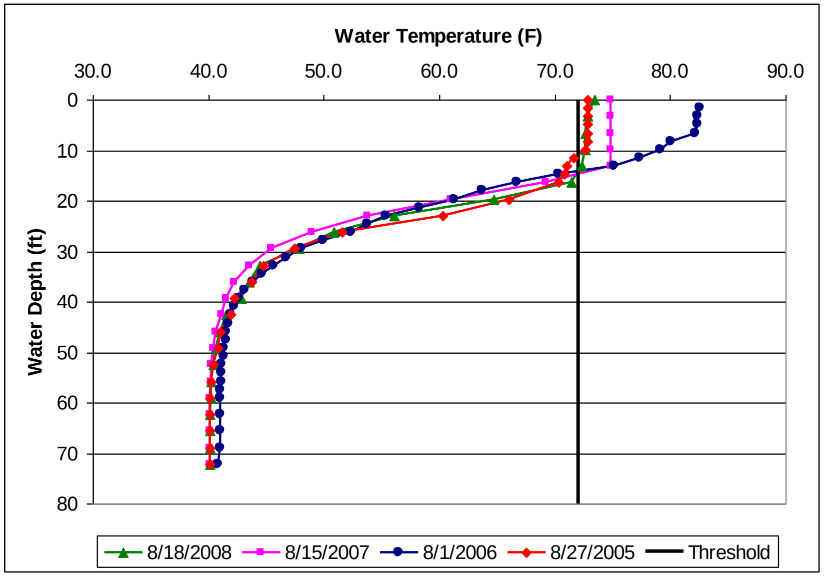

Figure 4. Water temperature profile for Silver Lake on August 18, 2008, August 15, 2007, August 1, 2006, and August 27, 2005.

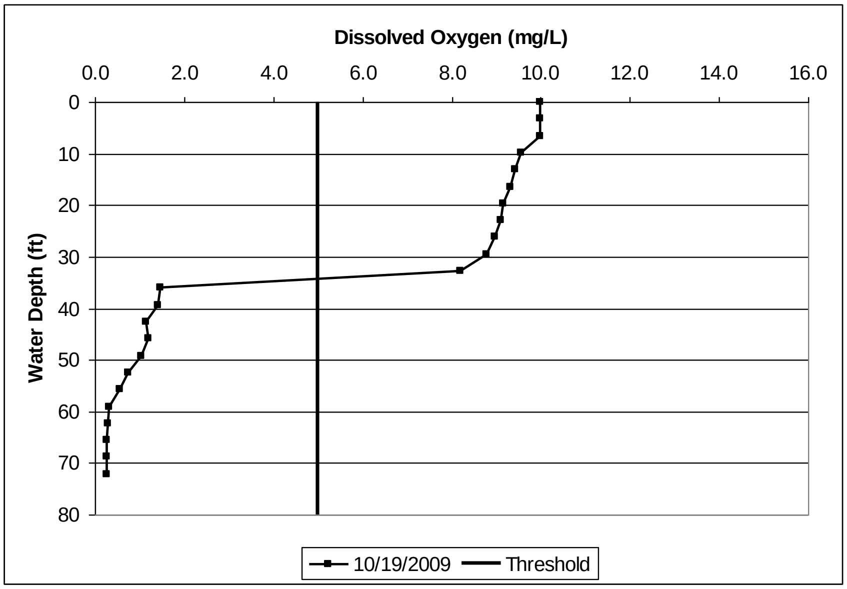

Figure 5. Dissolved oxygen profiles for Silver Lake on October 19, 2009.

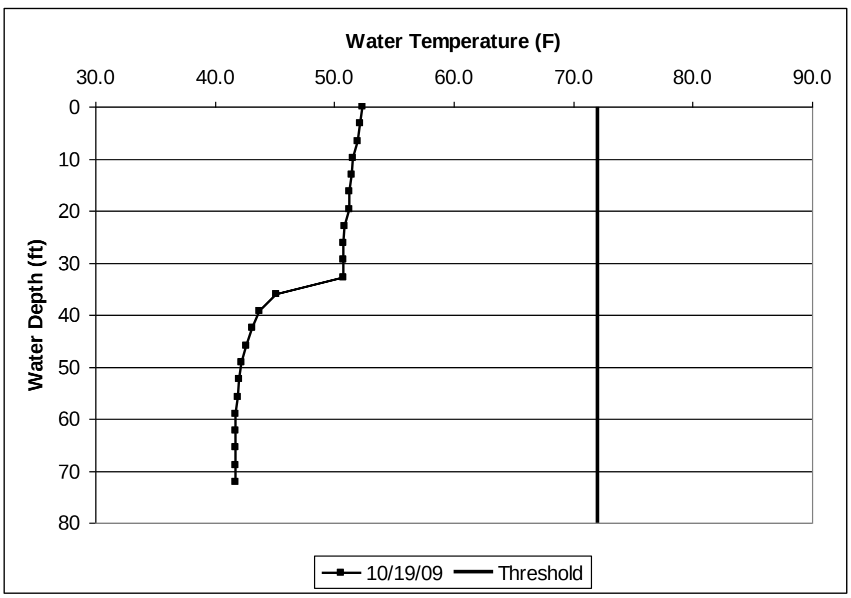

Figure 6. Water temperature profiles for Silver Lake on October 19, 2009.

Water Clarity

Water clarity can be 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 7). 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 was measured on August 20 and 28, and September 2 and 8, 2009. All values measured 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 7). 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 suggest 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 (Figure 8). Reduced consumption of phytoplankton by zooplankton could have resulted in greater phytoplankton abundance and subsequently lower water clarity.

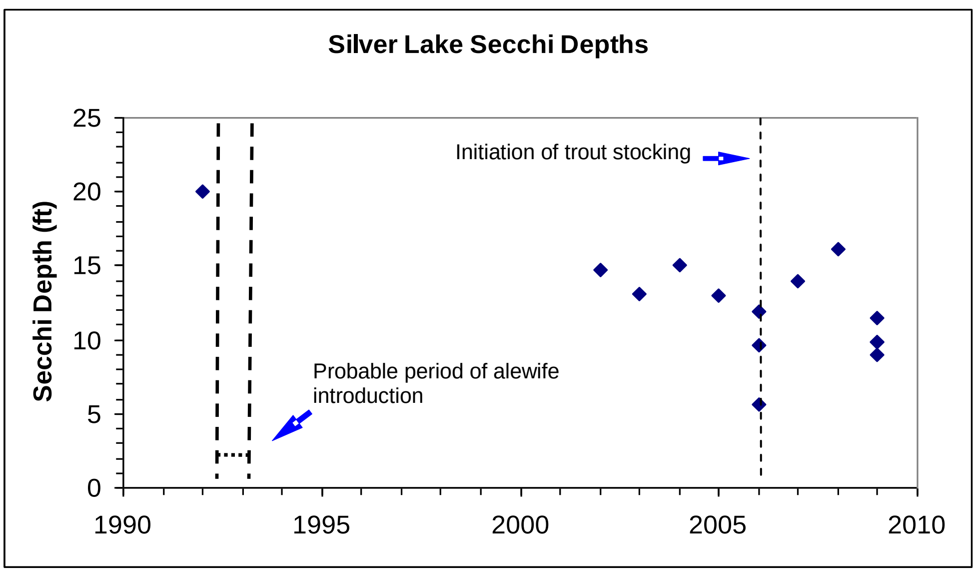

Figure 7. Secchi depths for Silver Lake, 1992, and 2002 through 2009. Measurements were made on three dates in 2006 and four dates in 2009.

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) and 2009 (August 20 and October 19). 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. 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.

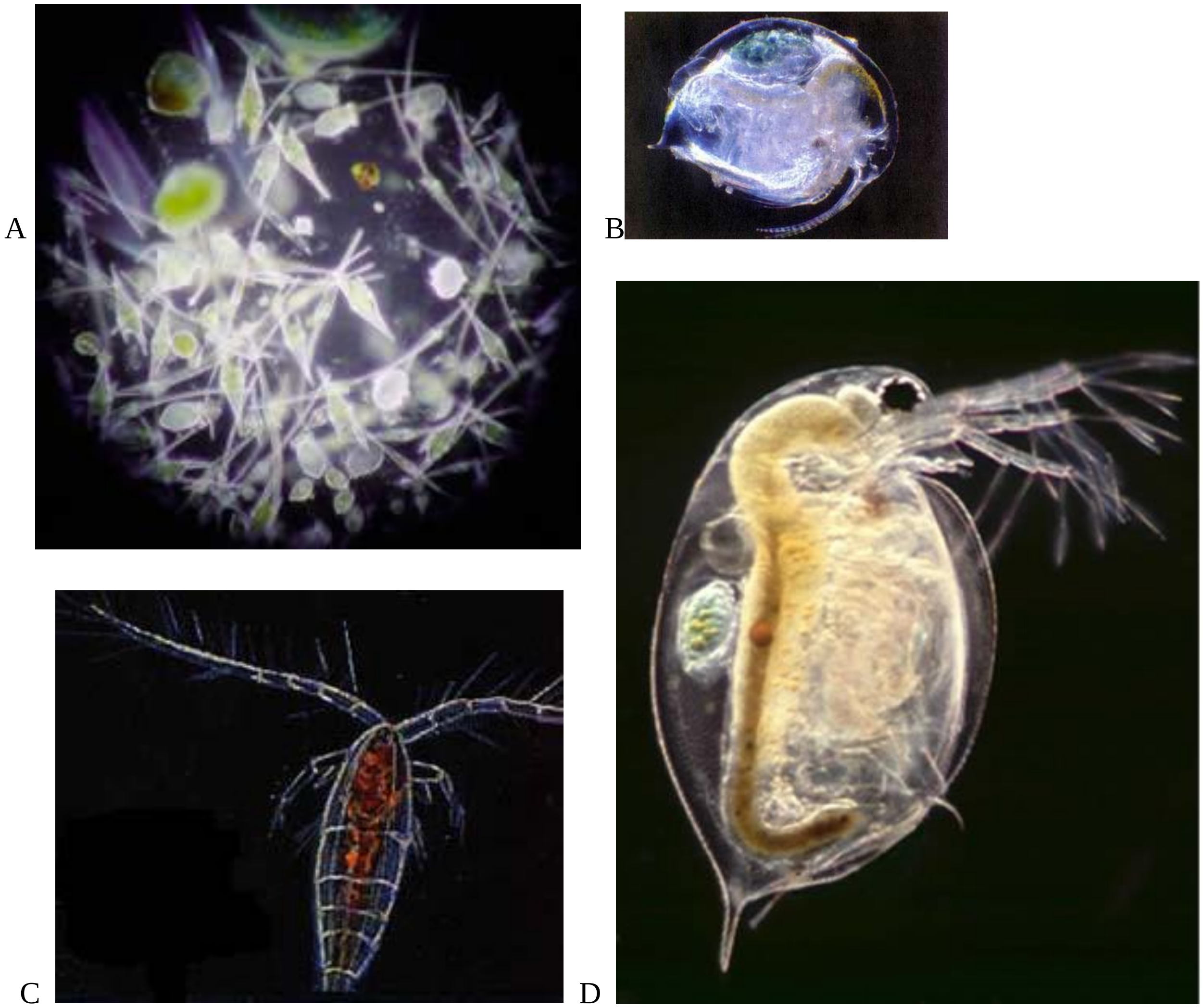

Figure 8. Phytoplankton (A) and zooplankton (B - small-bodied Cladocera; C – Copepoda; D - large-bodied Cladocera).

Alewife preferentially consume large zooplankton that graze upon the phytoplankton responsible for algal blooms in lakes. When large-bodied zooplankton (particularly Cladocera, which 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.

The 2006 zooplankton samples contained relatively low numbers of zooplankton overall and were dominated by small-bodied zooplankton, primarily *Bosmina* and small rotifers, that are ineffective in controlling phytoplankton abundance (Table 1). 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 large Cladocera) than in 2006.

Table 1. Estimated densities of various zooplankton groups in Silver Lake based on preliminary analysis of samples collected in 2006 through 2009.

Zooplankton Group	Size (mm)	Estimated Density (No./Liter)							
		Jun 06	Aug 06	Oct 06	Aug 07	Aug 08	Oct 08	Aug 09	Oct 09
Small Cladocera	<0.5	9.6	93.1	10.2	324.0	12.5	13.1	55.8	5.6
Large Cladocera	>0.5	0.0	0.0	0.0	0.9	2.8	3.0	0.4	0.6
Small Copepoda	<0.7	3.8	0.2	5.5	11.5	2.7	12.9	4.1	4.1
Large Copepoda	>0.7	0.4	0.0	0.9	13.0	8.4	0.4	6.9	11.8

Analysis of the zooplankton samples collected on August 18, 2008 showed reduced numbers of small zooplankton and a greater than three-fold increase in large Cladocera, which are highly effective consumers of phytoplankton, in comparison to August 2007. Large zooplankton were not numerous, but their abundance was increasing after being essentially absent in past samples. Zooplankton samples collected on October 14, 2008 showed a similar trend, with large Cladocera present in even slightly greater numbers in October 2008 than in August 2008. No large Cladocera were found in samples collected in October 2006. 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.

Zooplankton samples collected in 2009 did not show a continuation of the trend of increasing abundance of large-bodied Cladocera (Figure 9). In both August and October 2009, large-bodied Cladocera density declined from 2008 values by at least 80%. The August 2009 value was also less than half of the August 2007 value. The decline in large-bodied Cladocera in 2009 coincided with the decline in water clarity during this same period, again suggesting that alewife abundance may have increased since 2008 and the greater abundance of alewife was negatively affecting the abundance of large-bodied Cladocera.

Littoral Fish Community

Past work conducted on Silver Lake by Cornell University has documented a healthy, robust littoral fish community comprised of largemouth bass, pumpkinseed, yellow perch, rock bass, chain pickerel, and brown bullhead. The presence of these species was documented through various sampling efforts that included the use of angling, gill nets, baited minnow traps, and snorkeling. One notable feature of the Silver Lake littoral fish community has been the lack of forage fish species (minnows and other small, non-game species) found during Cornell sampling efforts. A cursory seine sampling effort was conducted in 2009 to once again sample the littoral zone of the lake with the objectives of 1) identifying any forage species that may exist in the lake in habitats that may not have been effectively sampled previously; 2) identify any additional species that may exist in the lake at low density or that have recently invaded the lake; and 3) determine if young-of-year alewife are inhabiting shallow-water habitats of Silver Lake and providing potential prey and/or competition for other littoral fish species.

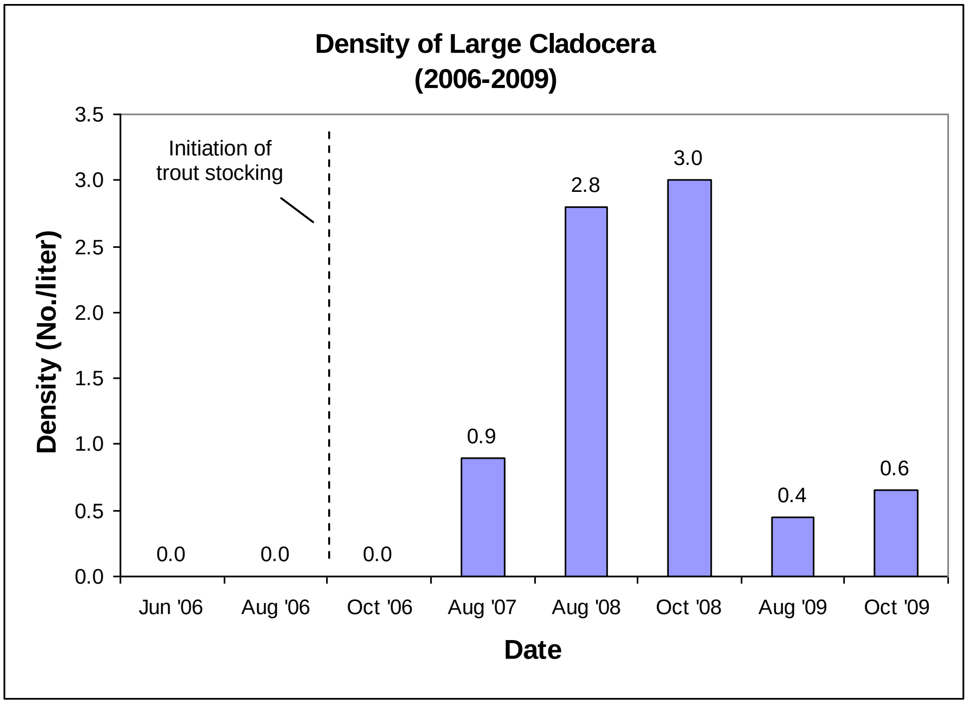

Figure 9. Density of large-bodied (>0.5 mm) Cladocera before and since initiation of the Silver Lake trout stocking program in September 2006.

A seine measuring 50 ft long by 6 ft deep with a ¼-inch mesh was used to sample two near-shore locations in Silver Lake (Figure 10). One end of the seine was positioned at the water's edge, and the other end was extended perpendicular to the shore and dragged in an arc back to the shoreline, capturing fish that were encircled by the path of the net (Figure 11). Collected fish were identified to species, measured for length and weight, and released alive back into the lake. Forty-five fish representing four species were collected during the seining effort (Table 2). All of the species collected were previously known from Silver Lake. No forage fish species, including young-of-year alewife, were collected. The only fish collected of a small enough size to serve as forage for adult game fish were five young-of-year largemouth bass, two young-of-year yellow perch, and one juvenile pumpkinseed.

Seining is typically an effective means of sampling small fish in near-shore areas. Since there appears to be ample spawning habitat for the littoral fish species in Silver Lake, the relatively low catch of small, forage-size fish from the lake suggests that predation by larger fish (primarily largemouth bass) is suppressing the number of young game fish. The observed condition of the near-shore fish community is not necessarily undesirable, and such conditions can produce fish populations comprised primarily of larger adult fish that can provide high-quality angling opportunities. As long as there is sufficient cover in the form of aquatic vegetation, fallen trees, etc. to allow some young game fish to avoid predation and grow to maturity, the fishery can sustain itself in its current state. The relatively low abundance of forage-size fish in the littoral zone might also result in predators such as largemouth bass switching from feeding predominantly on prey in the shallow, littoral zone to feeding on alewife occupying the deeper, open-water area of the lake. Cornell researchers observed largemouth bass feeding on schools of

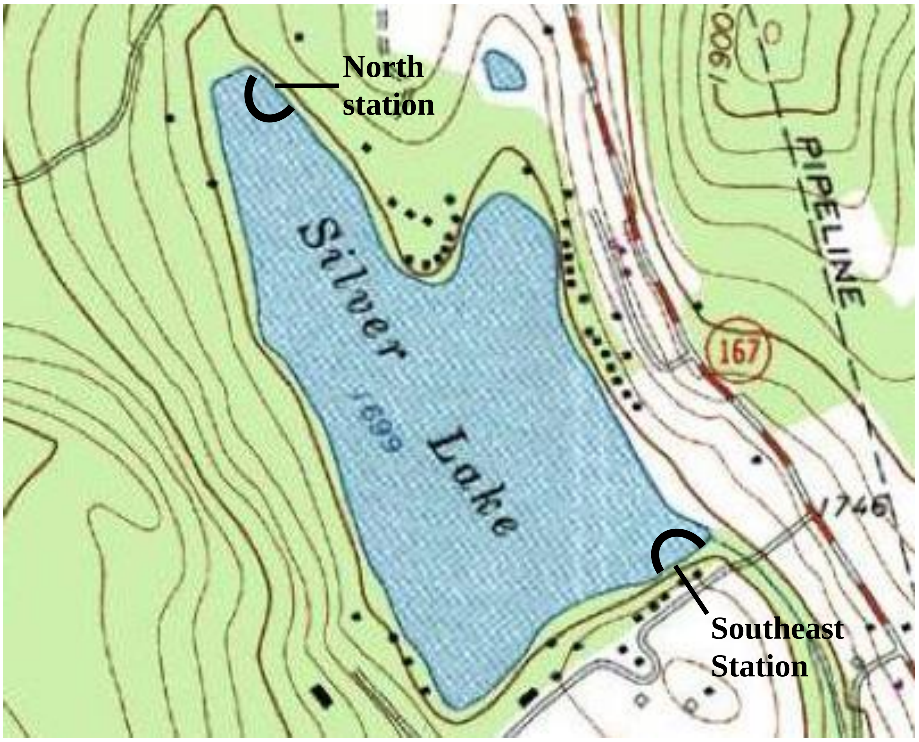

Figure 10. Location of stations sampled by seining in Silver Lake on August 20, 2009.


Figure 11. Seine sampling in the southeast corner of Silver Lake on August 20, 2009.

Table 2. Number and length and weight ranges for fish species collected by seine from two stations in Silver Lake on August 20, 2009.

Species	North End Station			Southeast Station		
	No.	Length (mm)	Weight (g)	No.	Length (mm)	Weight (g)
Chain pickerel	1	152	17			
Largemouth bass	7	49-55	1-2			
Pumpkinseed	4	130-160	41-79	20	63-190	4-136
Yellow perch	2	75	4	11	171-222	50-104

young-of-year alewife in open water in 2008 and saw further evidence of this during the August visit in 2009.

It is also possible that alewife predation on larval game fish is suppressing the abundance of forage-size fish in Silver Lake. Alewife can negatively impact populations of many fish species through predation upon larvae (Madenjian et al. 2008). Fish species, such as yellow perch, that produce larvae that drift in the water column for some period of time before moving to shallow, vegetated habitats are particularly susceptible to impacts from alewife (Brandt et al. 1987). Alewife can also negatively affect the young of other fishes through competition for forage. Changes in the zooplankton community brought about by alewife can reduce the growth and survival of young-of-year of other fish species that feed primarily on zooplankton during this life stage (Kohler and Ney 1981).

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. submitted). 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 19, 2009 to estimate the density and biomass of the lake’s alewife population. Data collected during the 2009 survey were then compared with data from a similar survey conducted on October 14, 2008 to determine if and how the abundance of the lake’s alewife population had changed during the past year.

Silver Lake was surveyed at night (8:42 p.m. - 9:34 p.m.) using a 123 kHz split beam echo sounder mounted off the side of a flat-bottom motor boat. A total of 2,434 m of acoustic transects (lines along which data were collected) were surveyed in 10 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 two ranges of depth: 2-6 m and 6 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 6 m deep.

Fish were also captured using vertical gill nets set at six locations concurrent with hydroacoustic sampling (Figure 12, Table 3). The nets were set at three lake locations from the surface to 6 m depth, at two locations from 6 m to 12 m depth, and at one location from 8 m to 14 m depth. Nets were retrieved after being set for 3.5 to 4.0 hours, and all captured fish were identified to species and the depth at which they were caught was recorded in 2-m intervals. A random subsample of 30 alewife per net and all individuals of other species captured were measured for total length in millimeters (mm) and total weight in grams (g).

Figure 12. Location of gill net sets in Silver Lake on October 19, 2009.

Gill net data. A total of 317 fish were caught in the gill nets (Table 3, 2.6 to 37.2 fish captured/hr). All but three of these fish were alewife. The other three fish were two rock bass (204 and 289 mm) and one brown trout (343 mm). These fish were released alive back into the lake. Alewife were found from the surface to 12 m (39 ft) deep, with a peak between 4 and 10 m. No fish were caught at depths ranging from 12-14 m. Fish were caught higher in the water column in the gill nets than observed with the acoustic gear, possibly the result of fish following the nets upwards after first encountering them. The thermocline was located at a depth or 10-11 m (32 ft) with low oxygen levels observed below this depth (Figure 5).

The alewife size distribution had three distinct modes: 50-70 mm, 85 to 110 mm and fish larger than 115 mm (Figure 13). A random subsample of fish was aged using otoliths (the inner ear bones of fish), and these modes corresponded to age-0, age-1 and 2, and older fish (Table 4). Age-0 fish represented animals shorter than 80 mm and were 38% of the total number caught (compared to 53% in 2008). In 2009, age-0 fished averaged 61.2 mm in length and 1.9 g in weight, and older fish averaged 105.9 mm and 10.3 g. These sizes are smaller than those observed in 2008 (67.6 mm, 2.5 g for age-0 fish; 109.2 mm, 10.7 g for older fish), suggesting a decrease in growth due to an increase in abundance. Alewife 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 grow larger (up to 140 mm) in productive lakes with large zooplankton (e.g., Oneida Lake and Canadarago Lake). Growth rates of older alewife in Silver Lake were also slow, and an index of condition (percent dry weight) was low compared to regional populations (Rudstam and Brooking 2005). Thus, both growth and condition of alewife in Silver Lake were low in 2009, consistent with a low productivity lake with a relatively large alewife population and small zooplankton sizes. Most importantly, the growth rate of alewife in Silver Lake appears to have declined since 2008.

Table 3. Summary of fish catches in gill nets set in Silver Lake on October 19, 2009.

Measure	**Site 1**	**Site 1**	**Site 2**	**Site 2**	**Site 3**	**Site 3**
Set time (h)	18:20	18:14	19:10	19:05	19:25	19:20
Retrieve time (h)	22:25	22:10	22:46	22:30	22:58	22:50
Time fished (h)	4.08	3.93	3.43	3.41	3.47	3.50
Depth fished (m)	0-6	6-12	0-6	6-12	0-6	8-14
Alewife						
No. of fish	75	45	36	127	22	9
Catch/hour	18.4	11.4	10.5	37.2	6.4	2.6
% in upper1/3	4.16	7.12	1.17	25.46	1.44	2.57
% in middle 1/3	6.37	3.81	2.91	8.49	1.15	0.00
% in lower 1/3	7.84	0.51	6.41	3.22	3.75	0.00
Mean length (mm)	71.8	93.2	75.2	104.0	99.3	87
Length range (mm)	51-110	55-132	52-115	51-144	90-118	55-124
Mean weight (g)	3.5	7.7	3.8	11.1	7.4	6.4
Weight range (g)	1.1-10.5	1.3-20.0	1.0-11.9	1.2-27.4	5.4-12.8	1.4-15.2
% <80 mm (age 0)	67	27	67	18	0[1]	44
Other fish			Brown trout (1)	Rock bass (1)		Rock bass (1)

1 - Net panel with the smallest mesh size did not set correctly. The low catches in this net and the low number of age-0 fish may be due to this problem.

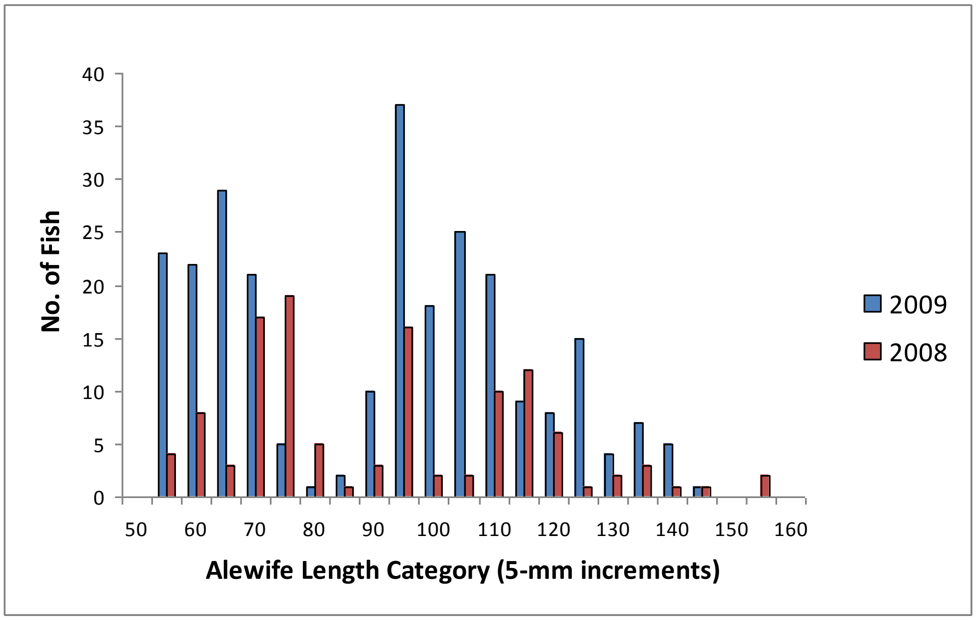

Figure 13. Size distribution of measured alewife captured in gill nets set in Silver Lake, October 14, 2008 and October 19, 2009.

Table 4. Length and percent dry weight (DW) at age for alewife from Silver Lake caught in October 2008 and 2009. 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			

Acoustic data. Fish density calculated from data obtained from each transect in October 2009 was 3,831 fish/ha (1,551 fish/acre) (Table 5). Fish densities for individual transects ranged from 81 to 8,263 fish/ha (33 to 3,345 fish/acre). The fewest fish were found along transect 6 in the northwest bay of the lake. All fish densities were calculated as the sum of densities for two depth ranges: 0-6 m and 6 m to the bottom. The densities obtained for the 0-6 m water depth assumed that the density of alewife at depths from 2-6 m was the same as at depths from 0-2 m that were not surveyed by the sonar gear. The surface density may have been lower, as fish density decreased towards the surface. However, this would not affect density estimates to a substantial degree because most fish were observed below the 6 m depth in Silver Lake. Under the assumption that all of the fish observed in the acoustic surveys were alewife and using an average alewife weight of 7.1 g (mean for all alewife captured by gill net), the alewife biomass in Silver Lake in October 2009 was estimated as 27.2 kg/ha (24.0 lb/acre; Table 5). This is considerably larger than the October 2008 biomass estimate (20.2 kg/ha; 18.0 lb/acre).

The alewife density obtained from the 2009 survey was greater than in 2008 (3,831 compared to 2,850 fish/ha) and catches in gill nets were also larger in our 2009 survey than in 2008. These densities are similar to or greater than those observed in larger New York lakes (Fitzsimons et al. 2005) and Onondaga and Cayuta lakes (Brooking and Rudstam 2009, Wang et al. in press). They were still lower than results from some other New York lakes, such as Otsego Lake, Otisco Lake and Conesus Lake, where alewife densities average 4,000 to 8,000 fish/ha (Brooking and Rudstam 2009). Low growth rate and condition of alewife in Silver Lake are also consistent with our acoustic estimate of large (and increased, by comparison with 2008) alewife abundance in this lake.

Table 5. Estimates of alewife density in Silver Lake based on hydroacoustic data collected October 19, 2009. 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 (fish/ha)**
1	258	1,944
2	482	2,279
3	358	5,159
4	196	3,337
5	141	2,835
6	442	81
7	307	8,623
8	251	4,956
9	321	3,239
10	287	7,628
Mean	**304**	**3,831**
Biomass (kg/ha)		27.2

Trout Stocking in 2009

Following a recommendation by Cornell researchers, the Silver Lake Lake Association stocked an additional 150 rainbow trout and 150 brown trout into Silver Lake in November 2009. These fish were stocked at the same density (~3 fish/acre, both species combined) as was stocked in September 2006 and November 2007 and 2008. The purpose of the stocking was to supplement the existing trout populations in the lake, further increasing predation of alewife in order to reduce the impact of alewife on water clarity and the aquatic food web in Silver Lake. Periodic stocking of trout will be 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.

The stocking of trout into Silver Lake to control alewife numbers has resulted in the additional benefit of creating a recreational trout fishery. Although no specific data on angler catch of stocked trout has been gathered, Cornell researchers have received anecdotal information suggesting that some Silver Lake anglers are targeting trout, and some of these fish are being harvested for food. Cornell researchers encourage anglers to enjoy the recreational fishing opportunity provided by the presence of trout in Silver Lake, while practicing catch-and-release so that the trout stocking program can accomplish its primary goal of limiting alewife abundance. To this end, the Silver Lake Lake Association distributed to its members in November 2009 a catch-and-release advisory prepared by Cornell researchers. Included in this advisory were suggested practices to follow when catching and releasing rainbow trout and brown trout in order to minimize angling mortality.

Conclusions and Recommended Plans for 2010

Results of investigations conducted in 2009 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. Secchi depths 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 the summer of 2009 suggested that alewife abundance increased since 2008, and estimates of alewife abundance derived from the hydroacoustic survey conducted in October 2009 confirmed this. The estimated density and biomass of alewife in Silver Lake in October 2009 had increased by about 34% over 2008 estimates. The observed decrease in growth rate and relatively poor condition of alewife also suggest that this population was more abundant in 2009 in relation to the productivity of the lake than in 2008. In 2009, a larger population of alewife were competing for relatively limited food resources, resulting in slower growth and poorer condition for alewife of all sizes. This intense competition for food has resulted in a reduced number of large Cladocera, increases in phytoplankton abundance, and resultant decreases in water clarity.

The current level of trout stocking (300 fish/year) initially seemed to have beneficial impact upon water clarity, but these benefits were not sustained during 2009. Although the reasons for the substantial increase in alewife numbers from 2008 to 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. Although we do not know with confidence that trout survival has declined, we need to be alert to the possibility that angler-induced mortality could be a major contributor to poor trout survival in any lake.

Regardless of the cause(s) of the increase in alewife abundance in 2009, the results of the 2009 monitoring program 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 will be considered during our 2010 efforts. The information gathered in the past two 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. In retrospect, it is serendipitous that water quality surveys have been conducted in Silver Lake in recent years, thereby providing an unusually comprehensive record of water quality prior to any gas drilling in the nearby area. In 2010, Cornell staff will expand the suite of chemical constituents measured a mid-summer water sample from Silver Lake in an attempt to expand our knowledge of current water quality conditions. We also 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. These efforts 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.

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