Biological Assessment of Silver Lake: 2008

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TABLE OF CONTENTS

Cover Photo: Adult alewife captured from Silver Lake, October 14, 2008.

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 have enhanced our collective 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. We would also like to personally thank Patty and Billy Bloomer for the use of their boat, trolling motor, and property and their extra efforts to make Cornell researchers feel comfortable while conducting sampling efforts. Their hospitality and concern for Silver Lake are greatly appreciated.

Executive Summary

The primary focus of Cornell researchers in 2008 was developing an estimate of alewife abundance 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 this population.

Dissolved oxygen and water temperature were measured on August 18 and October 14, 2008 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 to measure 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 14, 2008. The open-water fish community was sampled by gill nets concurrent with the hydroacoustic survey.

Results of investigations conducted in 2008 indicate that Silver Lake continues to be capable of supporting long-term survival of trout, and the trout stocking program appears to be having the desired effect of reducing alewife abundance and the impact of alewife on water clarity. 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. Summer water clarity as measured by secchi depth readings has continued to improve since the stocking of trout, with the August 18, 2008 value of 16.0 ft being the highest recorded since the introduction of alewife in the early 1990s. Desirable changes in the zooplankton community, most notably increasing abundance and variety of large zooplankton, indicate that alewife abundance has been reduced enough to allow populations of large zooplankton to begin recovery in Silver Lake.

The hydroacoustic survey resulted in an estimate of alewife density in Silver Lake of 2,850-2,909 fish/ha (7,042-7188 fish/acre). These alewife densities are in the lower range of those observed in other lakes in New York State, which range from 4,000 to almost 20,000 fish/acre. Only alewife were captured in the gill nets, and young (age-0) fish represented 53%

the alewife caught. The growth rate of alewife in Silver Lake appears to be relatively low, consistent with the relatively limited abundance of large zooplankton in the lake. Findings from the 2008 investigation support a recommendation to continue trout stocking as a means of controlling undesirable impacts of alewife within Silver Lake.

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 and improve the water quality, fisheries and aquatic ecosystem associated with Silver Lake. The 2008 field season marked the fifth year of the cooperative relationship between the E.L. Rose Conservancy and Cornell University in an effort to monitor and manage 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. Four annual (2004-2007) reports summarizing the findings of these investigations have been prepared.

Items of concern raised by initial work conducted in 2004 included low oxygen levels in the hypolimnion (water below the thermocline) of Silver Lake and the possibility that nutrient loading may be a problem within the Silver Lake watershed. Based on these findings Cornell researchers focused their 2005 effort on assessing the offshore fish community and further characterizing the water quality of Silver Lake, with an emphasis on evaluating phosphorus levels, the limiting nutrient in most freshwater systems. During 2006 the Cornell research team focused on: (1) assessing the impacts of the introduced rock bass and alewife in the system, and (2) measuring mercury levels in tissue from several fish species within Silver Lake. Secondary goals included conducting a littoral zone survey for available prey items and additional evaluations of thermal and oxygen conditions within Silver Lake. The 2007 research effort primarily focused on evaluating the effectiveness of stocking trout to control alewife and their associated impact on water clarity.

Alewife are a non-native fish species believed to have been introduced to Silver Lake sometime after 1992, and subsequently caused a decrease in water clarity as a result of overgrazing of 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 is 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. The following activities were conducted by Cornell researchers in 2008.

- A dissolved oxygen and water temperature profile of the lake was measured on August 18, 2008 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 14, 2008 in conjunction with a hydroacoustic survey.
- Water clarity was measured using a secchi disk on August 18, 2008.

- The zooplankton community was sampled near mid-lake on August 18 and October 14, 2008 to evaluate community structure and make inferences regarding impacts to zooplankton due to predation by alewife.
- Hydroacoustic sampling (using sonar) of the open-water portion of the lake was conducted on October 14, 2008 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 18, 2008 to further assess the suitability of Silver Lake for long-term survival of trout. Similar profiles were measured by Cornell researchers in 2005-2007, and some historic data from 1946, 1992, and 2002 are also available from Silver Lake.

Data collected on August 18, 2008 were consistent with similar data collected in recent years (Figures 1 and 2) 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, since 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, there must be a great enough volume of cool, well-oxygenated water within the hypolimnion to allow trout to survive throughout the summer. Past data and the data collected in 2008 indicate that a sufficiently large volume of the hypolimnion in Silver Lake remains well oxygenated during the warmest time of the year to support cold-water species such as trout (Figures 1 and 2). On August 18, 2008, the zone of the lake ranging in depth from about 14 to 41 ft contained water cooler than 72 ºF with dissolved oxygen greater than 5 mg/L.

The dissolved oxygen/water temperature profile measured on October 14 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 3 and 4). In October, dissolved oxygen and temperature were relatively stable within the upper 30 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 about 41 ft deep contained water less than 72 ºF with dissolved oxygen greater than 5 mg/L.

Water Clarity

Water clarity was measured on August 18, 2008 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 depths for Silver Lake prior to the establishment of alewife were high, ranging from 15 to 20 ft (Figure 5). Following the introduction of alewife sometime after 1992, secchi depths remained relatively high

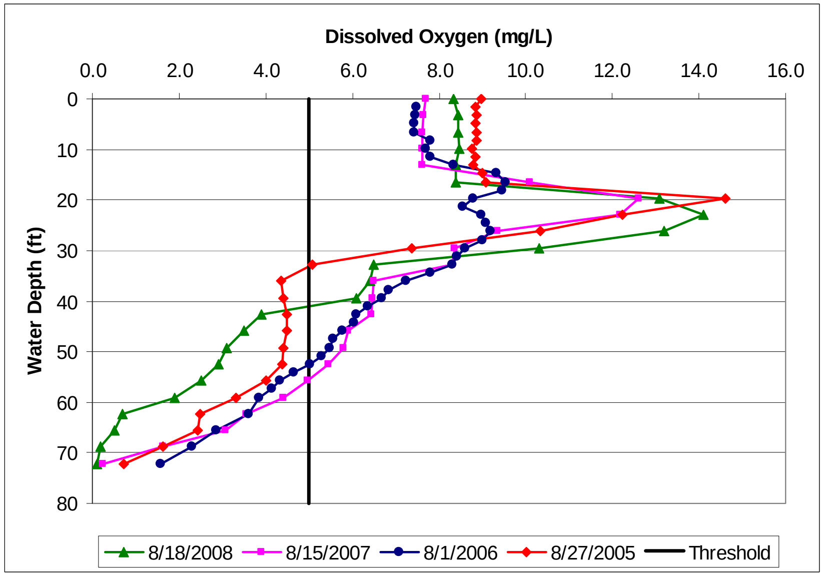

Figure 1. Dissolved oxygen profiles for Silver Lake on August 18, 2008, August 15, 2007, August 1, 2006, and August 27, 2005.

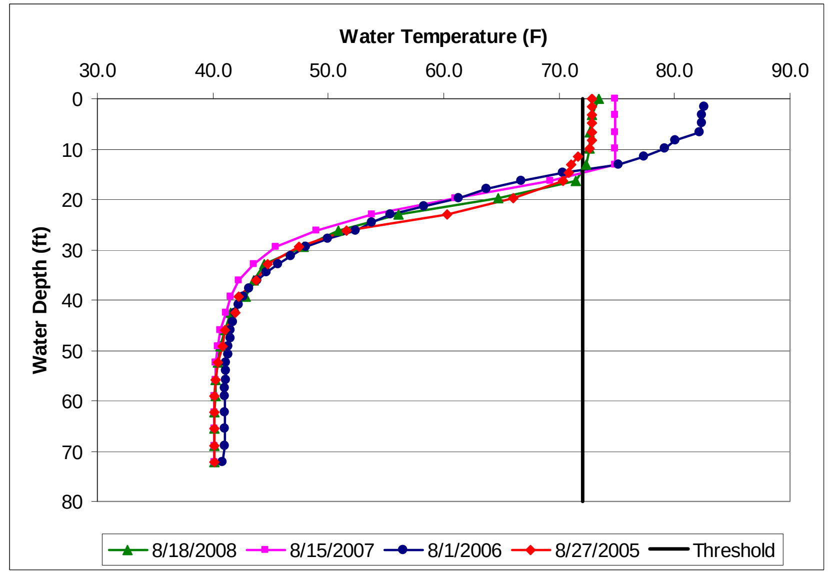

Figure 2. Water temperature profiles for Silver Lake on August 18, 2008, August 15, 2007, August 1, 2006, and August 27, 2005.

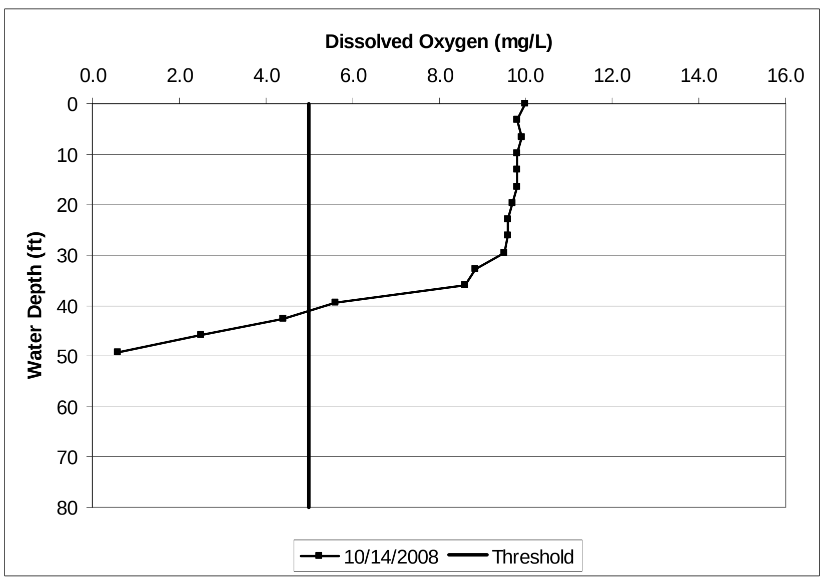

Figure 3. Dissolved oxygen profile for Silver Lake, October 14, 2008.

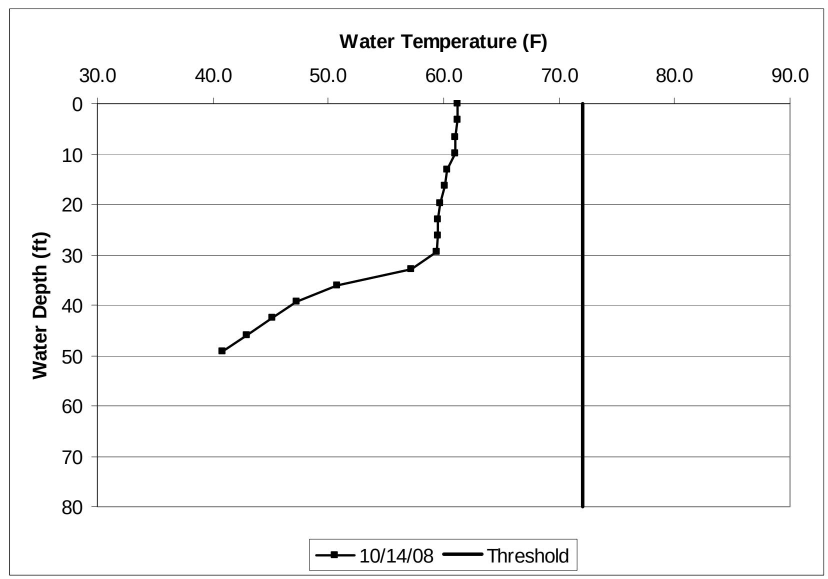

Figure 4. Water temperature profile for Silver Lake, October 14, 2008.

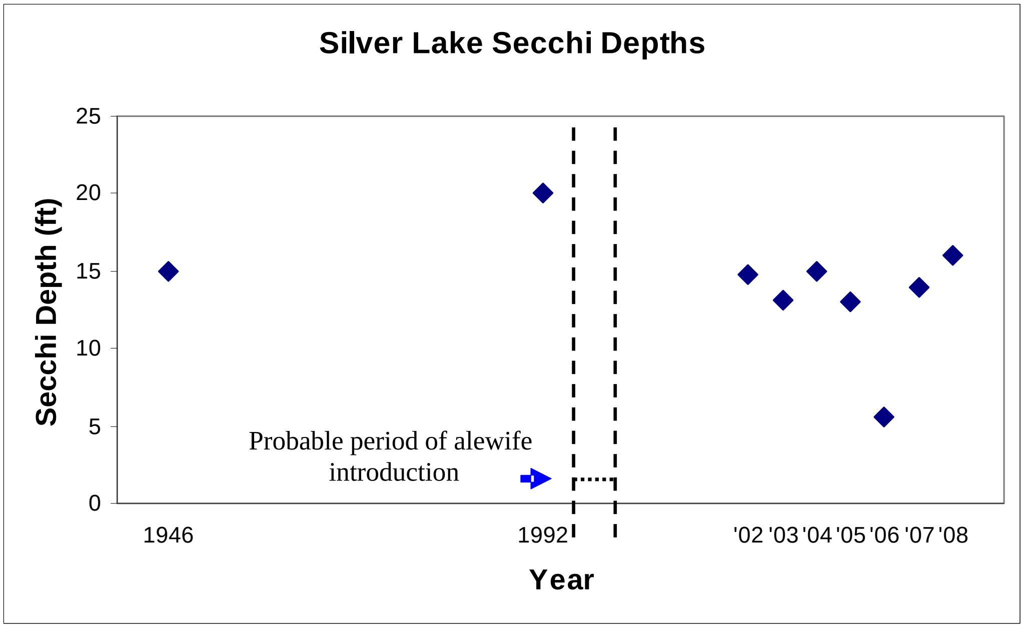

Figure 5. Secchi depths for Silver Lake, 1946, 1992, and 2002 through 2008. Points represent data collected on the nearest date to June 30th to minimize seasonal differences. Data collected in 2006 were associated with a flood event.

(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. Furthermore, while conducting fish sampling on October 16, 2007, Cornell researchers anecdotally noted that the water clarity appeared even better than during their August 15, 2007 visit to the lake. Unfortunately, no secchi depth was measured on October 16 to confirm this observation. 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 represents the second consecutive year in which secchi depth has increased since trout stocking began in 2006.

Zooplankton Community

The zooplankton (micro-crustaceans and other animals living within the water column) community 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). 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. Alewife preferentially consume large zooplankton that graze upon the phytoplankton (microscopic algae) responsible for algal blooms in lakes. When large-bodied zooplankton 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 high numbers of zooplankton overall, a greater variety of zooplankton, and, most importantly, greater numbers and variety of large-bodied zooplankton than in 2006.

Table 1. Estimated densities of various zooplankton groups in Silver Lake based on preliminary analysis of samples collected in 2006 through 2008.

Zooplankton Group	**Size (mm)**	**Estimated Density (No./Liter)**					
		6/30/06	**8/1/06**	**10/12/06**	**8/15/07**	**8/18/08**	**10/14/08**
Small Cladocera	<0.5	9.6	93.1	10.2	324.0	12.5	13.1
Large Cladocera	>0.5	0.0	0.0	0.0	0.9	2.8	3.0
Small Copepoda	<0.7	3.8	0.2	5.5	11.5	2.7	12.9
Large Copepoda	>0.7	0.4	0.0	0.9	13.0	8.4	0.4

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 is increasing after being 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 suggest that the stocking of trout since October 2006 is having a positive impact on the zooplankton community by reducing the abundance of alewife and consequently the level of predation on large-bodied zooplankton.

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 14, 2008 to estimate the density and biomass of the lake's alewife population.

Silver Lake was surveyed at night using a 123 kHz split beam echo sounder mounted off the side of a flat-bottom motor boat. Within a two-hour period between about 9 and 11 p.m., a total of 1,348 m of acoustic transects (lines along which data were collected) were surveyed in eight sections corresponding to roughly parallel SE to NW transects (Figure 6). Acoustic data were recorded directly to 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. Lake-wide averages were calculated using the average fish density from each transect.

Fish were also captured using vertical gill nets set at six locations concurrent with hydroacoustic sampling (Figure 7, Table 2). 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 14 m to 20 m depth. Nets were retrieved after being set for approximately four hours, after which 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 captured per net was measured for total length in millimeters (mm) and total weight in grams (g).

Gill net data. A total of 150 fish were caught in the gill nets (Table 2, 0.3 to 12.8 fish/hr), and alewife was the only species caught. Fish were found from the surface to 12 m deep. Only one fish was caught in the deep net, corresponding to low acoustic density observed at that depth. In general, alewife were distributed at depths above the thermocline, which had higher dissolved oxygen levels than water depths below the thermocline.

Three distinct modes were observed in the alewife size distribution: fish smaller than 85 mm, fish 85 to 100 mm, and fish larger than 100 mm (Figure 8). The smaller length mode most likely consisted of age-0 fish hatched in 2008. These young fish represented slightly over half of the fish caught (80 out of 150), and a subsample of these fish will be aged to confirm this assumption. For now, it is assumed that the larger fish were all age 1 and older fish. Average length and weight was 67.6 mm and 2.5 g for the age-0 fish and 109.2 mm and 10.7 g for the older fish. Alewives typically reach lengths of 60-90 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, Rudstam unpubl. data). Therefore, the observed growth rate of alewives in Silver Lake appears to be relatively low, consistent with relatively small zooplankton sizes.

Acoustic data. Fish density calculated from both transect-specific hydroacoustic signal data and data from all transects combined was 2,850 fish/ha (7,042 fish/acre) and 2,909 fish/ha (7,188 fish/acre), respectively (Table 3, Figure 9). Fish densities for individual transects ranged from 76 to 4,758 fish/ha (188 to 11,757 fish/acre). The fewest fish were found along transect 1 at the northern end 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. This seems reasonable because almost exactly 1/3 (33.1%) of the fish caught in our 0-6 m nets were indeed caught at depths of 0-2 m. By further assuming all of these fish were alewife and using an average alewife weight of 7.2 g (Table 1), the average Silver Lake alewife biomass was calculated as 20 kg/ha (17.8 lb/acre; Table 3).

Figure 6. Approximate track taken during hydroacoustic survey and locations of transects 1 through 8 surveyed in Silver Lake on October 14, 2008.

Figure 7. Location of gill net sets in Silver Lake on October 14, 2008.

Table 2. Summary of fish catches in gill nets set in Silver Lake on October 14, 2008. Note: All fish captured were alewife.

Measure	**Net 1**	**Net 2**	**Net 3**	**Net 4**	**Net 5**	**Net 6**
Set time (h)	1836	1845	1856	1902	1909	1918
Retrieve time (h)	2245	2235	2301	2308	2316	2316
Time fished (h)	4.15	3.83	4.08	4.07	4.12	3.97
Depth fished (m)	0-6	6-12	0-6	14-20	0-6	6-12
No. of fish	25	49	29	1	25	21
Catch/hour	6.02	12.79	7.11	0.25	6.07	5.29
% in upper1/3	20	51	66	0	8	38
% in middle 1/3	52	39	21	100	48	43
% in lower 1/3	28	10	14	0	44	19
Mean length (mm)	70.6	107.4	72.8	96	72.8	116.6
Length range (mm)	65-76	82-152	53-135		52-108	92-145
Mean weight (g)	2.8	10.3	4.5	6.1	3.5	12.4
Weight range (g)	2.2-3.4	4-27.9	1.3-19		1.0-10.4	5.2-23.9
% <85mm (age 0)	100	0	86	0	92	41

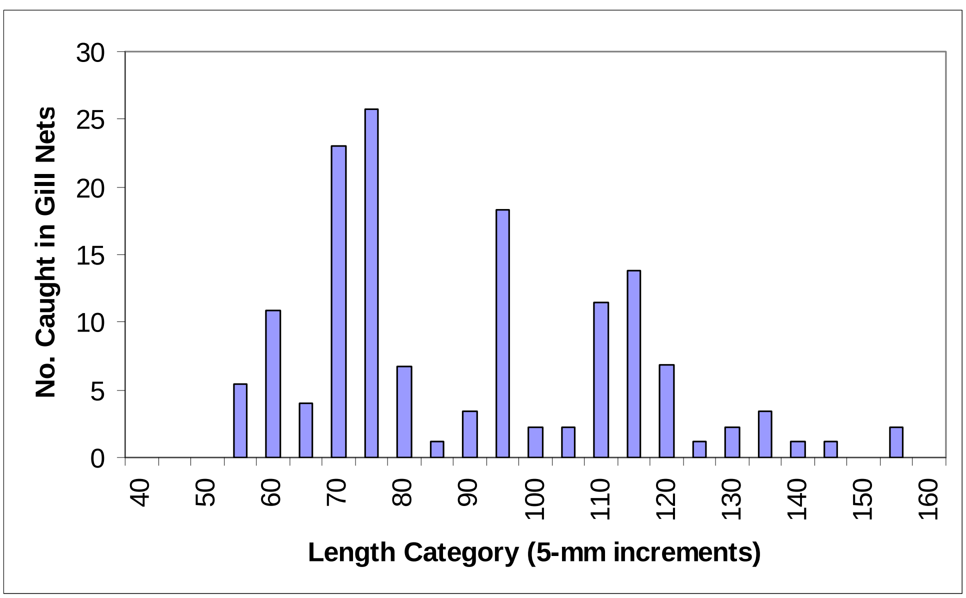

Figure 8. Size distribution of alewife captured in gill nets set in Silver Lake, October 14, 2008.

Table 3. Estimates of alewife density in Silver Lake based on hydroacoustic data collected October 14, 2008. Density[1] is calculated using transect-specific data. Density[2] is calculated using lake-wide average 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[1] (fish/ha)**	**Density[2] (fish/ha)**
1	131	76	78
2	94	4557	2417
3	110	518	555
4	117	4345	2845
5	270	2261	2244
6	224	3574	3901
7	189	4758	6927
8	213	2483	2355
Mean	**168**	**2850**	**2909**
Biomass (kg/ha)		20.2	20.6

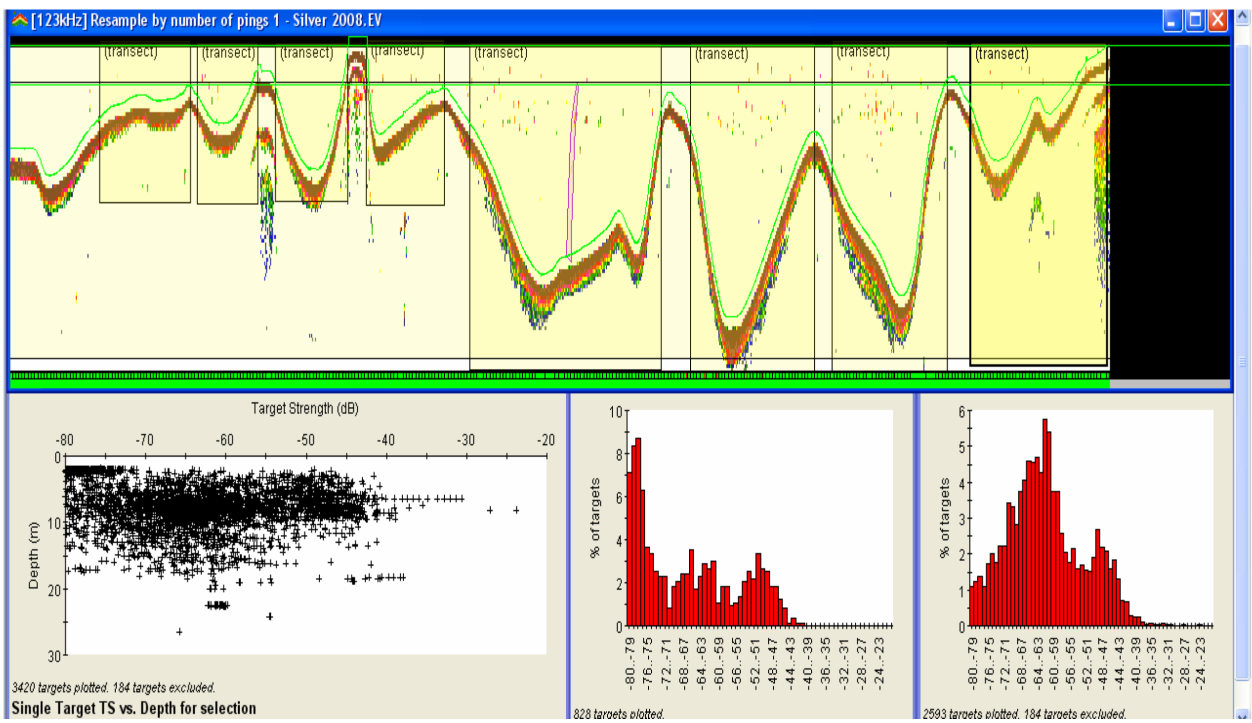

Figure 9. Hydroacoustic software output for data collected during survey of Silver Lake on October 14, 2008. Top panel shows distribution of transects along sampling

track; undulating band represents lake bottom; colored marks above lake bottom indicate targets (primarily fish) detected by sonar.

Alewife densities obtained from the 2008 Silver Lake survey were comparable to alewife densities in larger New York lakes (Fitzsimons et al. 2005) and Onondaga and Cayuta lakes (Brooking and Rudstam 2009, Wang et al. submitted). They were lower than observed densities from some other New York lakes such as Otsego Lake, Otisco Lake, and Conesus Lake, which had average densities of 4,000 to 8,000 fish/ha (9,884 to 19,768 fish/acre). We will continue to evaluate alewife density data from Silver Lake in more detail once fish age determinations are completed. This will allow us to estimate alewife mortality rates and the density of trout needed to reduce the 2008 alewife population to a specific level, if that is of interest to the Silver Lake community.

Trout Stocking in 2008

Following a recommendation by Cornell researchers, the Silver Lake Lake Association stocked an additional 150 rainbow trout and 150 brown trout into Silver Lake on November 20, 2008. These fish were stocked at the same density (~3 fish/acre, both species combined) as were stocked in September 2006 and November 2007. 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, since neither brown nor rainbow trout are likely to be able to reproduce within Silver Lake due to the lack of appropriate spawning habitat.

Conclusions and Recommendations

Results of investigations conducted in 2008 indicate that Silver Lake is capable of supporting long-term survival of trout, and the stocking of trout since September 2006 is having the desired effect of reducing alewife abundance and the impact of alewife on water clarity and other aquatic resources of Silver Lake. 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. Water clarity as measured by secchi depth readings has continued to improve since the stocking of trout. Desirable changes in the zooplankton community, most notably increasing abundance and variety of large zooplankton (especially large Cladocera) indicate that alewife abundance has been reduced enough to allow some recovery of large zooplankton. Estimates of alewife density based on hydroacoustic sampling indicate that alewife density in Silver Lake is similar to densities in several lakes in New York State but not nearly as high as measured in some New York lakes. This further suggests that trout stocking is serving to control alewife numbers.

Past reports prepared by Cornell University regarding Silver Lake have included several recommendations that are still relevant. These include continuing efforts to minimize inputs of nutrients and pollutants to preserve lake water quality and conducting periodic monitoring of total phosphorus, chloride, alkalinity, pH, water temperature, and dissolved oxygen in order to characterize any changes that may occur through time. Preserving the integrity of undeveloped shoreline and the large amount of wood present along that shoreline should be continued to support native fish populations by providing habitat for forage and refuge. A small evaluation was conducted on Silver Lake fish in 2006 to explore potential concerns regarding mercury contamination in fish. As previously recommended, anglers harvesting fish for consumption should be aware of fish consumption advisory limits published by the Pennsylvania Division of Water Quality Assessment and Standards.

Finally, results of the 2008 investigation of Silver Lake support a recommendation to continue trout stocking as a means of controlling undesirable impacts of alewife within Silver Lake, and this recommendation has already been heeded with the stocking of an additional 300 trout in November 2008. 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 implement this effort.

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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