Appendix F-5

Alewife (*Alosa pseudoharengus*) abundance in Onondaga Lake, 2013.

A report to Onondaga County.

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Abstract: The alewife (*Alosa pseudoharengus*) population in Onondaga Lake was surveyed May 30 and October 22, 2013 using small mesh pelagic gill nets and hydroacoustics (123 kHz split beam). Catches of all species in the vertical gill nets averaged 137 fish/hr (range: 105 to 188 fish/hr) in May and 90 fish/hr (range: 38-140 fish/hr) in October. The majority of fish caught were alewife (May 92%; October 90%). May mean catch rates were higher than in 2011 or 2012. Other species caught included brown bullhead (*Ameiurus nebulosus*), emerald shiner (*Notropis atherinoides*), gizzard shad (*Dorosoma cepedianum*), golden shiner (*Notemigonus crysoleucas*), yellow perch (*Perca flavescens*), round goby (*Neogobius melanostomus*) and longnose gar (*Lepisosteus osseus*). Average length and weight of alewife was 128 mm (range 99-153 mm; May) and 127 mm (88-153 mm; October). Mean wet weights were 17.8 g (May) and 17.2 g (October). The length distribution was bimodal in both May and October. In May, age 1 fish lengths ranged from 95-117 mm whereas older alewives were larger than 110 mm indicating minimal overlap between age 1 and age 2 fish. In October, age 0 fish were smaller than 105 mm and age 1 fish ranged from 118-134 mm. Gas bubbles were not present in the lake during the two 2013 surveys. This is in contrast to previous years' surveys where bubbles were a significant source of error. Alewife density was estimated with hydroacoustics to be 1045 fish/ha in May (age 1 and older), corresponding to 18.5 kg/ha. Fish density in spring 2013 was similar to densities from 2010-2012, and higher than densities in 2008-2009. Biomass in May 2013 was similar to the biomass in spring 2012. The October alewife density estimate was 6324 fish/ha with an estimated biomass of 108.8 kg/ha. Because this is our first fall estimate, we cannot compare the fall densities with previous years.

Introduction

Alewife, *Alosa pseudoharengus*, increased dramatically in Onondaga County's electrofishing samples in 2003 and remained high in 2004 to 2007 (Wang et al. 2010). This increase was due to a strong 2002 year class. Alewife biomass increased as these young fish grew throughout the summer of 2002 and alewife predation is the most likely cause for the concomitant decline in large *Daphnia* and large calanoid copepods (Wang et al. 2010). Additional year classes of alewife were produced in 2004 – 2007 and the abundance of alewife remained high from spring of 2005 through the spring of 2007 (over 1600 fish/hectare (ha)) (Wang et al. 2010). Large *Daphnia* were mostly absent from the lake between 2003 and 2007, although the smaller *Daphnia retrocurva* was present in 2007. Alewife declined to low abundance (<100 fish/ha) in the spring of 2008, remained low in the spring of 2009 and increased again due to a strong year class in 2009 to around 1000 fish/ha in 2010. This was directly correlated with changes in zooplankton. Large *Daphnia* returned in 2008 and 2009 and disappeared in the fall of 2009 concomitant to the increase in biomass of the 2009 alewife year class and have continued to be absent through 2012. Water clarity was high in 2008 and early 2009 and relatively low in 2010-2013. Such cascading trophic interactions have been observed with increases in alewife elsewhere (Brooks and Dodson 1965, Harman et al. 2002). This report presents the results of the 2013 spring and fall surveys of alewife and discusses the effects of alewife on zooplankton and phytoplankton through 2012.

Materials and Methods

Fish were sampled using vertical gill nets set at four locations in the SE, NE, SW and NW quadrants of the lake (Tables 1 and 2). The 6 meter (m) deep and 21 m long nets consisted of 7 panels, each with a different mesh size (6.25, 8, 10, 12.5, 15, 18.75, 25 millimeter (mm) bar mesh). This set of mesh sizes will catch alewife between 50 and 240 mm (Warner et al. 2002). The nets were set from the surface to 6 m depth for approximately 2 hours (hrs) in water with bottom depth of about 8 m. Fish were identified to species and depth of catch recorded in 2 m intervals. A random subsample of 30 (May) or 50 (October) alewives or all individuals of other species were measured for total length in mm, and weight in grams (g) from each net site. Alewives were aged using whole otoliths extracted from a subsample of 100 alewives in May and 50 alewives October (Table 3) Dry weight was obtained after drying for 5-7 days in 60 C for alewives caught in May and for 7 days at 70 C for alewives caught in October.

Concurrent to net sampling, Onondaga Lake was surveyed using a 123 kHz split beam echo sounder (settings in Table 4) along seven roughly parallel transects running SW to NE or NE to SW (total transect length 8.8 km (May) and 9.5 km (October)). The surveys were conducted on the nights of May 30, 2013 between 21:12 and 23:33 and October 22, 2013 between 20:43 and 22:57. Spatial location of the data was measured with a GPS unit that recorded latitude and longitude directly to the acoustic data stream (Figures 1 and 2). The transducer was towed at 0.5 m depth looking downwards.

Acoustic data were recorded directly to a laptop computer in the field and analyzed with the EchoView software (version 5.3.36 Myriax Inc. Hobart, Tasmania, Australia). The units were calibrated on May 18 (Cornell unit, used in May), Sep 9 and

Oct 24, 2013 (Oneonta unit, used in October) with a standard -40.4 dB 33.2 mm tungsten sphere (Table 4). Calibration offset was 0.7 dB for 0.2 ms pulse length for the Cornell transducer. No gain corrections were needed for the Oneonta transducer (field calibrations within +/- 0.5 dB of factory calibrations). All data were visually inspected for consistent bottom detection, interference from surface bubbles and aquatic vegetation and corrected when needed. The ambient noise levels measured in the Sv domain were -121.24 dB (May) and -126.19 dB (October). This is low enough to register fish with a TS of -60 dB without bias at all depths present in Onondaga Lake (maximum depth 19.5 m). Analysis was done for each transect from 2 m to 6 m and from 6 m depth to the bottom in May and from 2 to 9 m and 9 m to the bottom in October based on fish distributions. The near-field of these transducers is approximately 1.5 m and they were mounted on a rigid pole 0.5m below the surface. Therefore, the acoustic analysis is restricted to depth below 2 m from the surface.

Target density in May 2013 was calculated from the average measured in situ TS and ABC following the standard operating procedure for Great Lakes acoustics (Parker-Stetter et al. 2009). The minimum threshold for fish TS was chosen to be -55 dB in both May and October based on the in situ TS distributions. Appropriate depth varying thresholds were applied to the Sv data (-61 dB minimum "TS" threshold in EchoView). All calculations are made in the linear domain and back transformed to dB unit when appropriate.

Bubbles were not observed in May or October of 2013 in contrast to previous years' surveys where bubbles were a significant source of error. To account for the proportion of targets < -55dB that were alewife, we converted the alewife catch in the gill nets to an expected TS distribution based on the net cage observations by Brooking and Rudstam (2009). The expected TS distribution from each 5 mm size group was calculated, weighted by the number of fish in each 5 mm group caught in the gill nets, summed, and normalized to obtain an expected TS distribution of alewife from the alewife population present in the May and October 2013 surveys (Figure 3). The proportion of expected targets <-55dB was then calculated and the alewife density based on fish >-55dB increased to account for these smaller targets (Table 5) This approach was used in several other lakes by Brooking and Rudstam (2009) and Rudstam et al. (2011).

Alewives were caught between the surface and 2 m depth in the vertical gill nets; depths that were not surveyed with acoustics due to the near-field effect. To account for these fish, we assumed that catchability per unit area of netting was the same in water 0-2 m as in 2-6 m and calculated the density in 0-2 m based on the ratio of the catch and acoustic density from 2 to 6 m depth (see Rudstam et al. 2011). Finally, the proportion of targets assumed to be alewife were obtained from the average proportions of alewife in the four net sets.

Results

May 30, 2013 survey:

Net sampling. A total of 1245 fish were caught in the gill nets (Tables 1 and 6; 105 to 188 fish/hr, average 137 fish/hr). Other fish species caught in May 2013 included one brown bullhead (*Ameiurus nebulosus*), 79 emerald shiner (*Notropis atherinoides*), 12 gizzard shad (*Dorosoma cepedianum*), 10 golden shiner (*Notemigonus crysoleucas*), and 2 longnose gar (*Lepisosteus osseus*). Alewife represented 92% of the catch (89 – 97%). Of the total alewife catch, 53% were caught in 0-2m, 34% in 2-4m and 13% in 4-6m depth.

The alewife size distribution had two distinct modes: fish larger than 125 mm and fish smaller than 125 mm (Figure 4). Of the aged fish, all fish smaller than 110 mm were age 1, however, both age 1 and age 2 fish were between 110 mm and 120 mm. This suggests that the smaller length mode consisted mainly of age-1 alewives with a few age-2 fish. Fish smaller than 125mm represented 38% of the measured alewife catch. The larger length mode consisted of age-2 and older alewife. Average length of all measured alewife was 128 mm (N=121, range 99-153 mm). Average length of age 1 fish was 109 mm and average length of age-2 fish was 129 mm (Table 3).

Acoustic data. Target density for targets larger than -55 dB ranged from 24 to 1043 targets/ha (Table 5). About 10% of the expected targets from the alewife caught in the gill nets would be smaller than -55 dB. The total alewife density was therefore increased by 10% (Brooking and Rudstam 2009). Surface correction represented 1.53 times the density in 2-6 m depth; this was applied to each transect. Resulting alewife density ranged from 101 to 2018 fish/ha in the 7 transects and an average alewife density of 1045 fish per hectare weighted by transect length (Standard error 248 calculated from the transect densities, Table 5). Given the average weight of alewife in the net sample (17.7 g, Table 1), the alewife biomass was 18.5 kg/ha (Table 5). The fish distribution was patchy with most fish found in the north basin (Figure 1).

October 22, 2013 survey:

Net sampling. A total of 719 fish were caught in the gill nets (Table 2 and 6; 38 to 140 fish/hr, average 90 fish/hr). Other fish species caught in October 2013 included 17 gizzard shad, 32 golden shiner, 24 emerald shiner, one round goby (*Neogobius melanostomus*) and one yellow perch (*Perca flavescens*). Alewife represented 90% of the catch (54 - 99%). Alewife catches in the three depth layers averaged 38% (0-2m), 44% (2-4m) and 18% (4-6m).

The alewife size distribution in October was also bimodal (Figure 4) with 16% of measured fish below 110 mm. The first mode (<110mm) consisted of age-0 alewives. The fish larger than 115 mm were age 1 and older fish. Average length of all measured alewife was 127 mm (N=200, range 88-153 mm). Average length of age-0 fish was 99 mm and age-1 fish was 125 mm (Table 3).

Acoustic data. Target density for targets larger than -55 dB ranged from 1634 to 11072 targets/ha (Table 5). About 9% of the expected targets from the alewife caught in the gill nets would be smaller than -55 dB. The total alewife density was therefore increased by 9%. Surface correction represented 1.38 times the density in 2-6 m depth; this was applied to each transect. Of the total fish targets in 2-6 m, 90% were assumed to be alewife. Resulting alewife density ranged from 1981 to 14433 fish/ha in the 7 transects and an average alewife density of 6324 fish per hectare weighted by transect length (Standard error 1650 calculated from the transect densities, Table 5). Given the average weight of alewife in the net sample (17.2 g, Table 2), the alewife biomass was 108.8 kg/ha (Table 5). Fish were more evenly distributed in October than in May and more fish were found in the south basin than in the north basin (Figure 2).

Discussion

In 2013, alewife dominated the open water region of Onondaga Lake even though a larger number of gizzard shad, golden shiner and emerald shiner were caught in 2013 than in previous years' surveys. Densities in the spring of 2013 were similar to observations made since 2010 and higher than densities during the low alewife years of 2008 and 2009, but lower than estimates from 2005-2007 (Table 7, Figure 5). This general pattern is consistent with the zooplankton composition in 2012. The zooplankton community in 2012 was dominated by small *Bosmina longirostris* (Rudstam and Hotaling 2013). Large *Daphnia*, which are correlated with higher water transparency, were only present in high abundance in years prior to 2002 and in 2008-2009; years with low alewife abundance (Wang et al. 2010, Rudstam and Hotaling 2013). The relatively low growth rate of alewife in the lake also indicates high abundance (Rudstam et al. 2011). Dry weight to wet weight ratio (an indicator of condition) was 0.24 (range 0.20 – 0.28) in spring 2013 which was similar or greater than the ratio in 2011 (0.23) and 2012 (0.25), but lower than 2010 (0.29) and 2009 (0.31). Length at age-1 was higher than in 2011 and 2012 but similar to 2010 (Table 3, Figure 4).

A high proportion of the alewives caught in May were in the top 2 m of the nets. This suggests that our density estimates from the spring may be biased low. Even though our methods attempt to account for fish in the surface water, the estimates are more uncertain when more fish are found above 2 m. Alewife in Onondaga Lake may be avoiding the boat causing our acoustic estimates in 2-4m of water to be biased low. Interestingly, net catches were very high in the spring of 2013 – the highest average catch on record since 2005 (Table 6, Figure 5). In general, spring net catch per effort do not correlate well with acoustics densities estimates (Figure 5). Alewives generally spawn in shallow water in June (Klumb et al. 2003) and the four net sites were close to shore (8 m depth). This may result in higher alewife catches at those sites compared to the lake-wide average densities. The cumulative effects of boat avoidance behavior in the top of the water column and high concentrations of alewife staging for spawning in the nearshore may have resulted in a high biased spring net survey and a low biased spring acoustic survey.

Alewives were more evenly distributed in the fall. Fish were recorded down to a depth of roughly 16 m in the acoustic data. Water below that depth had low oxygen concentrations. Catches in 0-2m were not higher than in 2-6 m of water (Tables 2 and 6), which also indicates a more even depth distribution of alewife in the fall. However, the deeper targets appeared to be smaller than the more surface oriented fish (Figure 3), suggesting that smaller alewives may be more abundant in deeper water that was not sampled by the net. The October gillnet sample may therefore be biased towards larger fish and the biomass estimate from the fall may be biased high.

The alewife density estimate from October was greater than 6000 fish/ha. These values for alewife density are intermediate to those seen elsewhere in New York State. In Cayuta Lake, alewife densities range from 5000 to 20000 alewife/ha, while in Canadarago Lake, alewife densities range from 300 to 1200 alewife /ha (Rudstam et al. 2011). Length-at-age and condition (% dry weight) of Onondaga Lake alewife in the fall was similar to the values in the high density lake (Cayuta Lake) and lower than Canadarago Lake, where age-1 fish can reach lengths of 200 mm and larger by the fall. Zooplankton species composition and size distribution were also similar between Onondaga and Cayuta Lake. These indicators (acoustics, growth and zooplankton community variables) suggest that Onondaga Lake has a high-density alewife population.

Density in the fall was about six times the density measured in the spring. Alewife can have high overwinter mortality rates (O'Gorman and Stewart 1999), which will result in higher fall than spring estimates. We should also expect higher fall densities as a new year class of young fish hatched in 2013 are included in the fall but not in the spring estimates from that year. However, the age structure indicates that not all these additional fish observed in fall 2013 were from the new 2013 year class. There are a number of possible reasons for this. First, the proportion of age-0 fish in fall of 2013 may be higher than indicated in the net catches. Smaller acoustic targets were observed in deeper water not sampled by the nets. Second, we may be underestimating the spring density of age-1 and older fish due to spawning migrations and boat avoidance (discussed above). Third, alewife may move out into the canal system during the winter and spring and have not yet returned to the lake in May. The length and age distribution in May and October show a predictable increase in the length of the age 1 fish which suggest that we are aging the fish correctly.

As fall surveys are now possible due to the decline in bubble release from the sediment, we suggest changing the alewife survey to the fall. Fall surveys are also more comparable with alewife surveys elsewhere in inland New York lakes (e.g. Rudstam et al. 2011). The number of alewife present in the fall includes age-0 fish, which can have large effect on zooplankton and the ecology of the lake and is a useful measure of abundance before a possible over-winter mortality event. The fish are also more spread out in the water column in the fall compared to the spring. However, a few additional years of coupled spring and fall surveys would help determine the causes for the higher densities in the fall. Future fall surveys should also sample the fish deeper in the lake with additional nets to better identify the deeper targets.

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Table 1. Summary of fish catches in the four vertical gill nets with variable mesh size set in Onondaga Lake on May 30, 2013. Nets were set after dark and retrieved 2.2 to 2.4 hours later. Proportion by depth layer is based on alewife only. 92% of the fish caught were alewife.

	SE Quadrant	NE Quadrant	SW Quadrant	NW Quadrant	Averages
Latitude N	N 43° 05.387'	N 43° 06.533'	N 43° 04.921'	N 43° 05.980'	
Longitude W	W 76° 11.797'	W 76° 13.710'	W 76° 12.580'	W 76° 14.275'	
Soak time (h)	2.2	2.4	2.2	2.3	2.3
# fish caught	277	305	231	432	311
Water depth (m)	8	8	8	8	8
Catch / hour	125.9	129.8	105.0	187.8	137.1
Proportion 0-2 m	0.40	0.53	0.55	0.65	0.53
2-4 m	0.45	0.36	0.32	0.25	0.34
4-6 m	0.15	0.11	0.14	0.10	0.13
Alewife	270	281	205	385	285
Catch / hour	122.7	119.6	93.2	167.4	125.7
Mean Length (mm)	132	135	119	124	128
Range of lengths (mm)	106-146	108-153	99-148	108-144	99-153
Mean Weight (g)	24.3	18.6	13.2	14.9	17.8
Golden shiner	4	2	2	2	3
Catch / hour	1.8	0.9	0.9	0.9	1.1
Mean Length (mm)	171	174	162	201	177
Emerald Shiner	0	20	14	45	20
Catch / hour	0	8.5	6.4	19.6	8.6
Mean Length (mm)	--	84	84	86	85
Gizzard Shad	1	2	9	0	3
Catch / hour	0.5	0.9	4.1	0	1.4
Mean Length (mm)	118	163	166	--	149
Longnose Gar	2	0	0	0	0.5
Catch / hour	0.9	0	0	0	0.2
Mean Length (mm)	1110	--	--	--	1110
Brown Bullhead	0	0	1	0	0.25
Catch / hour	0	0	0.5	0	0.1
Mean Length (mm)	--	--	183	--	183

Table 2. Summary of fish catches in the four vertical gill nets with variable mesh size set in Onondaga Lake on October 22, 2013. Nets were set after dark and retrieved 2 hours later. Proportion by depth layer is based on alewife only. 90% of the fish caught were alewife.

	SE Quadrant	NE Quadrant	SW Quadrant	NW Quadrant	Averages
Latitude N	N 43° 05.397'	N 43° 06.559'	N 43° 04.927'	N 43° 05.983'	
Longitude W	W 76° 11.797'	W 76° 13.719'	W 76° 12.585'	W 76° 14.265'	
Soak time (h)	2.0	2.0	2.0	2.0	2.0
# fish caught	140	280	224	75	180
Water depth (m)	8	8	8	8	8
Catch / hour	70.0	140.0	112.0	37.5	89.9
Proportion 0-2 m	0.24	0.37	0.49	0.42	0.38
2-4 m	0.67	0.46	0.30	0.34	0.44
4-6 m	0.09	0.17	0.21	0.23	0.18
Alewife	75	275	221	73	161
Catch / hour	37.5	137.5	110.5	36.5	80.5
Mean Length (mm)	127	127	123	129	127
Range of lengths (mm)	89-150	91-152	88-144	97-153	88-153
Mean Weight (g)	17.1	17.5	16.4	17.9	17.2
Golden shiner	28	4	0	0	8
Catch / hour	14.0	2.0	0	0	4.0
Mean Length (mm)	75	80	--	--	78
Emerald Shiner	20	1	3	0	6
Catch / hour	10.0	0.5	1.5	0	3.0
Mean Length (mm)	95	77	89	--	87
Gizzard Shad	17	0	0	0	4
Catch / hour	8.5	0	0	0	2.1
Mean Length (mm)	205	--	--	--	205
Yellow Perch	0	0	0	1	0.3
Catch / hour	0	0	0	0.5	0.1
Mean Length (mm)	--	--	--	202	202
Round Goby	0	0	0	1	0.3
Catch / hour	0	0	0	0.5	0.1
Mean Length (mm)	--	--	--	84	84

Table 3. Age distribution and length-at-age of alewife in Onondaga Lake from 2005 to 2013. All ages were assigned using otoliths. Age 0 fish are only caught in the fall.

Age	0	1	2	3	4	5	Total # aged
	Proportions (%)						
2005[a]		0	10	84	6	0	50
2006		46	31	23	0	0	26
2007		25	20	33	18	5	40
2008		46	14	24	14	2	50
2009		40	26	10	19	5	25
2010		60	24	10	6	0	50
2011		26	74	0	0	0	50
2012		52	13	28	7	0	85
2013-May		41	35	17	6	1	100
2013-October	12	64	10	12	2	0	50
	Mean length-at-age (mm)						
2005[a]			133	138	152		
2006		122	151	161			
2007		123	155	157	159	162	
2008		127	148	156	162	162	
2009		145[b]	179	181	196	194	
2010		111	174	192	200		
2011		103	123				
2012		103	120	127	133		
2013-May		109	129	136	139	150	
2013-October	99	125	139	139	138		

a) Age structure and length at age from October 2004 translated to ages for spring of 2005. Lengths assumes no over winter growth or size selective over winter mortality.
b) Estimated from the size structure

Table 4. Settings used for acoustic estimates of alewife and total fish densities in Onondaga Lake on the nights of May 30 and October 22, 2013. Thresholds and detection limits according to Parker-Stetter et al. (2009).

Parameter	**Values**	**Values**
Date (m/d/y) and time	5/30/2013 21:14-23:33	10/22/2013 20:43-22:57
Unit	Biosonics 123 kHz, 7.2 ^{o} beam width, split beam	Biosonics 123 kHz, 7.5 ^{o} beam width, split beam
Analysis software	EchoView 5.3	EchoView 5.3
Analyzed by	Per Rudstam, 1/2/2014	Per Rudstam, 1/2/2014
Pulse rate/ pulse length	3 pps / 0.2 ms	3 pps / 0.2 ms
Lower threshold for fish	-55 dB, based on TS distribution.	-55 dB, based on TS Distribution.
Absorption coefficient and sound speed	Constant 0.0039 dB/m and 1465m/s	Constant 0.0047 dB/m and 1447 m/s
Equivalent beam angle	-20.35 dB	-20.12 dB
Noise at 1 m (Sv/TSu)	-121.2 dB / -149.9 dB	-126.2 dB / -154.7 dB
Detection limit TS -60dB without bias	**77m**	**103m**
Calibration offset Sv	Sv: 0.70 dB	Sv: 0.00 dB
<u>Single fish detection criteria</u>		
Max beam compensation	6 dB	6 dB
Pulse duration min, max	0.6, 1.5	0.6, 1.5
Standard Deviation of angles	0.6, 0.6	0.6, 0.6

Table 5. Acoustic data and density estimates of alewife in Onondaga Lake on May 30 and October 22, 2013 using a 123 kHz split beam unit. Average TS reflects all targets >-55dB. Alewife Density includes the whole water column accounting for alewife in the surface layer (see methods). ABC is the area back scattering coefficient associated with these targets (for targets >-55dB, from 2m depth). Target Density is calculated from ABC/σ_{bs}, where σ_{bs} is the backscattering cross section of all targets > -55dB. Target Density does not include the near-field of the transducer (0-2m). Finally, Total Alewife Density includes an estimate of near-field density, and the lower tail of the TS distribution from alewife (predicted number alewife targets with TS < -55dB). In May, the number of expected smaller targets were 10% and in October they were 9% of the density of targets > -55dB. The total fish density was also adjusted for the proportion of alewife in the catch (92% in May, 90% in October) to yield total alewife density. Mean values are weighted by transect length. Biomass is the mean fish density multiplied with the average weight of alewives caught in gill nets.

May 30, 2013

Transect #	Transect Length (m)	Average TS (dB)	ABC (m^2/ha)	Target Density (>-55dB) (#/ha)	Alewife Density (fish/ha)
1	1103	-40.8	0.002	24	101
2	1459	-46.6	0.010	466	1096
3	1337	-45.6	0.009	312	727
4	1445	-39.0	0.005	43	381
5	1294	-45.6	0.014	525	1095
6	1203	-45.5	0.019	682	1515
7	916	-46.3	0.024	1043	2018
Average	1251	-44.2	0.012	416	1045
Biomass (kg/ha)					18.5

October 22, 2013					
Transect #	Transect Length (m)	Average TS (dB)	ABC (m^2/ha)	Target Density (>-55dB) (#/ha)	Alewife Density (fish/ha)
1	1348	-45.0	0.347	11072	14433
2	1461	-45.2	0.195	6532	7567
3	1440	-45.2	0.080	2616	3172
4	1435	-37.1	0.859	4361	6270
5	1593	-38.0	0.282	1789	2153
6	1271	-43.1	0.188	3815	4468
7	954	-43.6	0.071	1634	1981
Average	1357	-42.5	0.289	4605	6324
Biomass (kg/ha)					108.8

Table 6. Average fish catches in the vertical gill nets with variable mesh size set in Onondaga Lake in 2005-2013. Four nets were set in each survey with the exception of the 2012 survey which only includes data from three nets (see footnote). Details on the sets for 2013 are in Tables 1 and 2.

Date	**5/17 2005**	**6/4 2006**	**6/6 2007**	**6/4 2008**	**6/4 2009**	**5/20 2010**	**6/9 2011**	**6/7 2012[b]**	**5/30 2013**	**10/22 2013**
Soak time (h)	2.4	5.6[a]	2.3	2.0	2.1	2.0	2.1	2.0	2.3	2.0
Proportion (0-2m)	0.38	0.43	0.42	0.37	0.23	0.20	0.24	0.36	0.53	0.38
(2-4m)	0.41	0.24	0.31	0.46	0.44	0.38	0.28	0.36	0.34	0.44
(4-6m)	0.21	0.32	0.27	0.17	0.33	0.42	0.48	0.28	0.13	0.18
<u>Alewife (#/h)</u>										
Catch/hour	75.4	56[a]	95	66	42	97	58	78.5	125.7	80.5
Mean length (mm)	149	132	153	145	170	135	119	117.8	127.5	126.5
Min length (mm)	108	110	104	115	123	95	89	91	99	88
Max length (mm)	164	169	195	176	204	219	137	153	153	153
Mean weight (g)	33.7	24.9	28.4	28.0	49.2	26.5	12.9	12.0	17.8	17.2
<u>Other sp. (#/h)</u>										
Gizzard shad	0	6.7	1.0	0	0	0	0	5.5	1.4	2.1
White perch	0.1	0.1	0.4	1.4	0.3	0	1.2	0.33	0	0
Yellow perch	0	0	0.5	0.1	0	0	0	0	0	0.13
Walleye	0	0	0	0.2	0	0	0	0	0	0
Emerald shiner	0	1.4	0	0.1	0	0	0	0.83	8.6	3.0
Golden shiner	0	0	0	0	0.4	1.5	0.9	0.33	1.1	4.0
Smallmouth bass	0	0	0.2	0.2	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Brown trout	0.1	0.02	0	0.1	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0	0	0
Longnose gar	0	0	0	0	0.5	0	0	0.17	0.23	0
Rock bass	0	0	0	0	0	0.12	0	0	0	0
Round Goby	0	0	0	0	0	0	0	0	0	0.13
Rainbow smelt	0	0	0	0	0.2	0	0	0	0	0
Brown Bullhead	0	0	0	0	0	0	0	0	0.11	0

a) One net left overnight for 12 hours. Excluding that net yields a catch per hour of 64 fish/hr
b) One net was excluded from depth proportion catch and catch per hour averages because it was three meters rather than six.

Table 7. Results from May-June acoustic-gillnet surveys of alewife in Onondaga Lake 2005 to 2013. Bubbles were not present in the surveys of 2013, 2011 and 2005-2007, but occurred in 2012 and 2008-2010. All fish were assumed to be alewife up to 2012. The 2013 values are adjusted for the proportion of alewife in the gillnet catch. Target strength thresholds used in the calculations are given (TS minimum).

Date of survey	# net sites	Soak time (h)	Average proportion alewife %	Alewife catch per net-hour (range)	Age-1 (%)	0-2 m % (range)	TS minimum (dB)	Alewife Abundance 2m-bottom (fish/ha)	Alewife Abundance surface-bottom (fish/ha)	Biomass (kg/ha)
5/17/2005	4	2.4	99	75 (35-174)	4	38 (29-49)	-60	1890	2242	75.5
6/4/2006	4	5.6	88	56 (11-92)	62	43 (35-54)	-60	1656	2328	50.4
6/6/2007	4	2.3	98	99 (44-148)	17	42 (26-57)	-60	1084	1632	46.2
6/4/2008	4	2.0	97	66 (22-87)	32	37 (29-42)	-47	60	94	2.7
6/4/2009	4	2.1	97	43 (24-66)	38	22 (4-43)	-45	95	122	6.0
5/20/2010	4	2.0	98	97 (73-147)	69	20 (13-26)	-47	708	912	24.2
6/9/2011	4	2.1	96	56 (36-111)	29	24 (9-49)	-56	498	525	6.8
6/7/2012	3	2.0	92	69 (64-77)	53	36 (31-41)	-49	909	1346	14.9
5/30/2013	4	2.3	92	126 (93-167)	41	54 (40-65)	-55	447	1045	18.5
10/22/2013	4	2.0	90	81 (37-138)	64	38 (24-49)	-55	4573	6324	108.8

Figure 1. May 30, 2013 spatial distribution of alewife from acoustic data and alewife catch per hour from gill net data. Transects and transit time between transects are included. Gray bubbles represent acoustically derived alewife densities. Alewife targets detected by acoustics are assumed to be in the same proportion as alewife caught in the gill net survey. The maximum bubble size for acoustic densities is 2853 alewife/ha. Red bubbles represent alewife caught per hour for gill net sites in the SE, SW, NE and NW sections of the lake. Maximum bubble size for gill net data represents 167 alewife caught per hour.

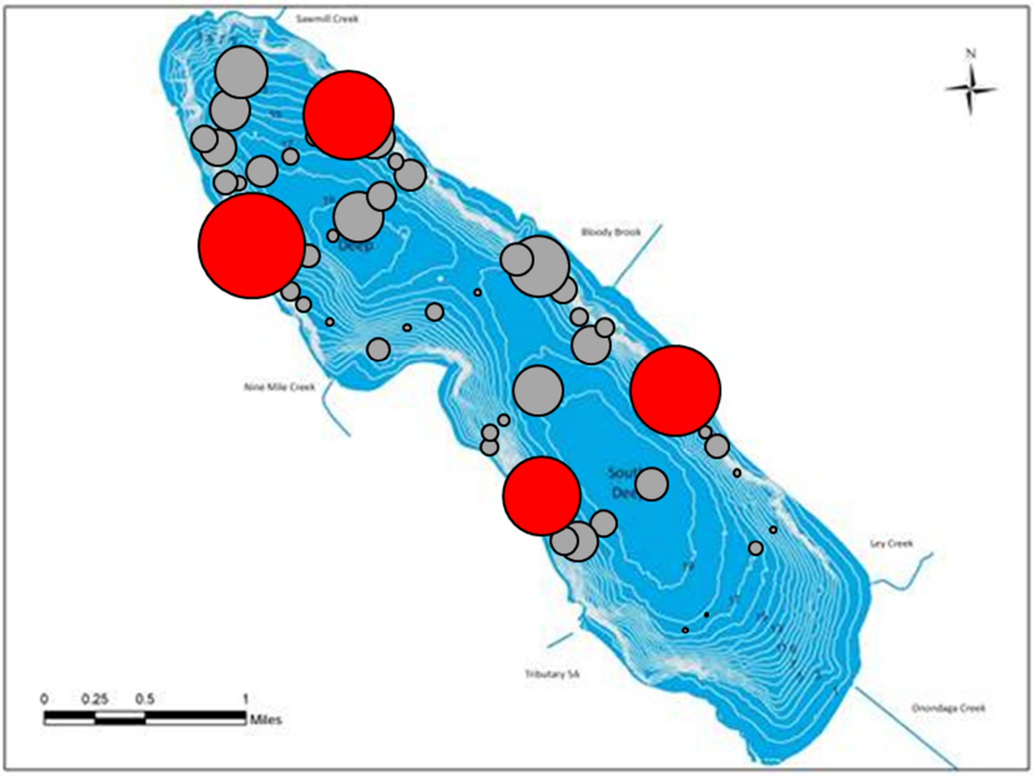


Figure 2. October 22, 2013 spatial distribution of alewife from acoustic data and alewife catch per hour from gill net data. Transects and transit time between transects are included. Gray bubbles represent acoustically derived alewife densities. Alewife targets detected by acoustics are assumed to be in the same proportion as alewife caught in the gill net survey. The maximum bubble size for acoustic densities is 24337 alewife/ha. Red bubbles represent alewife caught per hour for gill net sites in the SE, SW, NE and NW sections of the lake. Maximum bubble size for gill net data represents 138 alewife caught per hour.

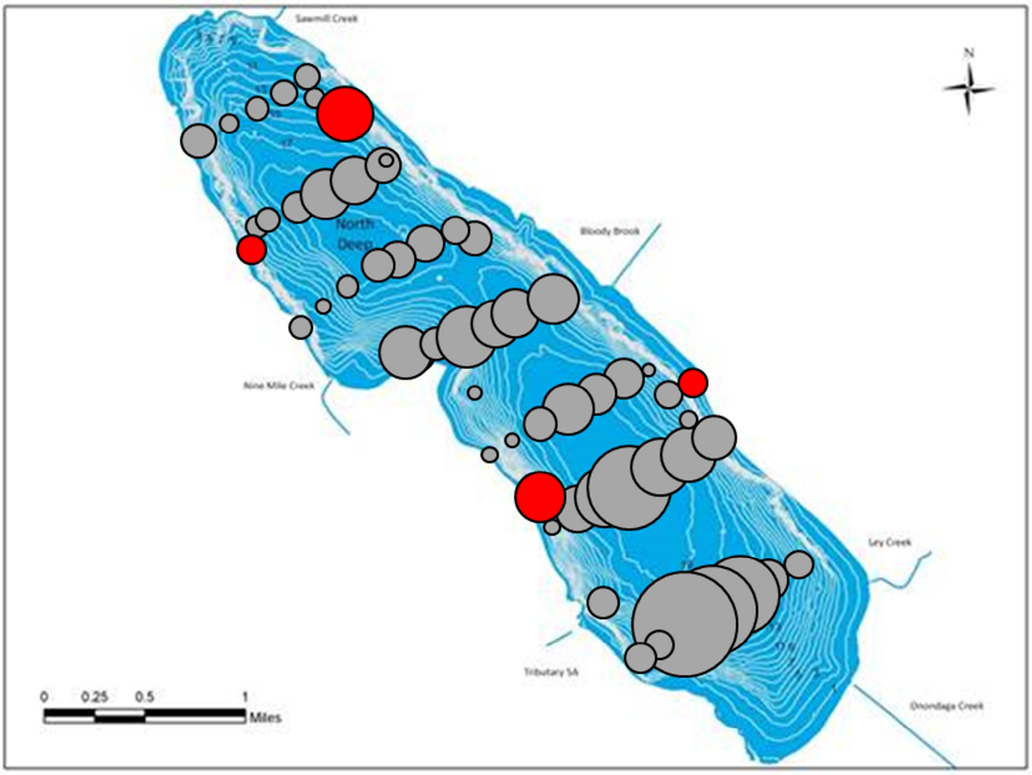
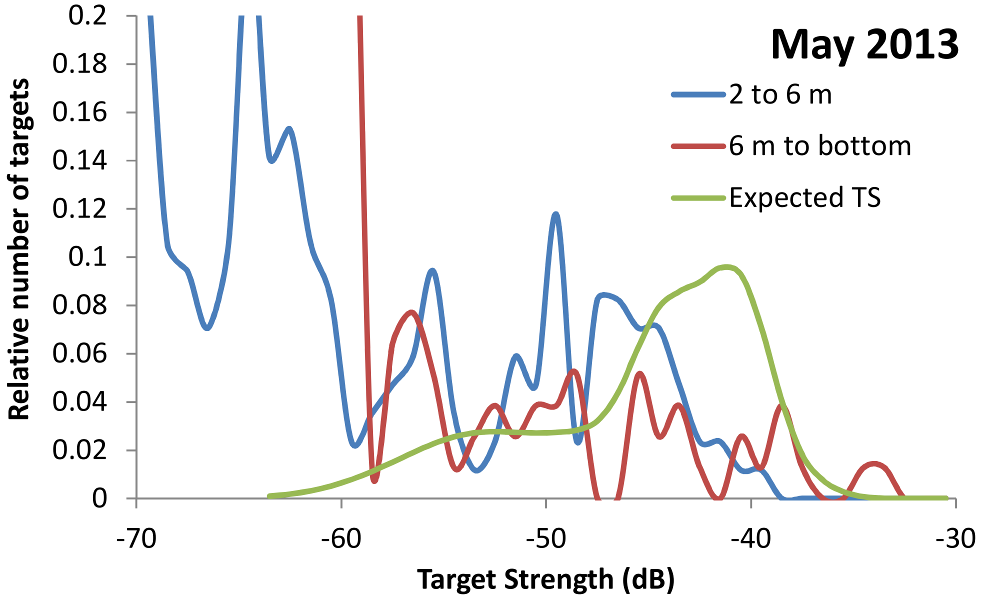


Figure 3. Observed and expected target strength distributions for the May 30, 2013 and October 22, 2013 acoustic surveys of Onondaga Lake. Bubbles were not present in 2013 in contrast to previous years' surveys. "Observed" is the frequency distribution of the targets observed using acoustics in different depth layers. "Expected" is the target strength frequency distribution (normalized to one) of the gill net catches which are representative of 2-6m depth as modeled by the probability density function in Brooking and Rudstam (2009).



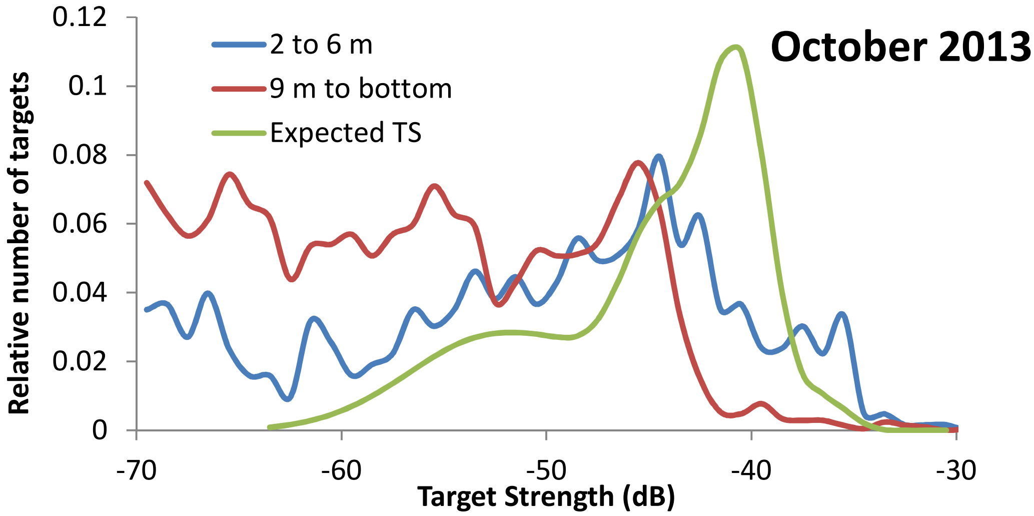


Figure 4. Length distribution of alewife in vertical gill nets from May and October 2013 as well as Spring surveys from 2010-2012.

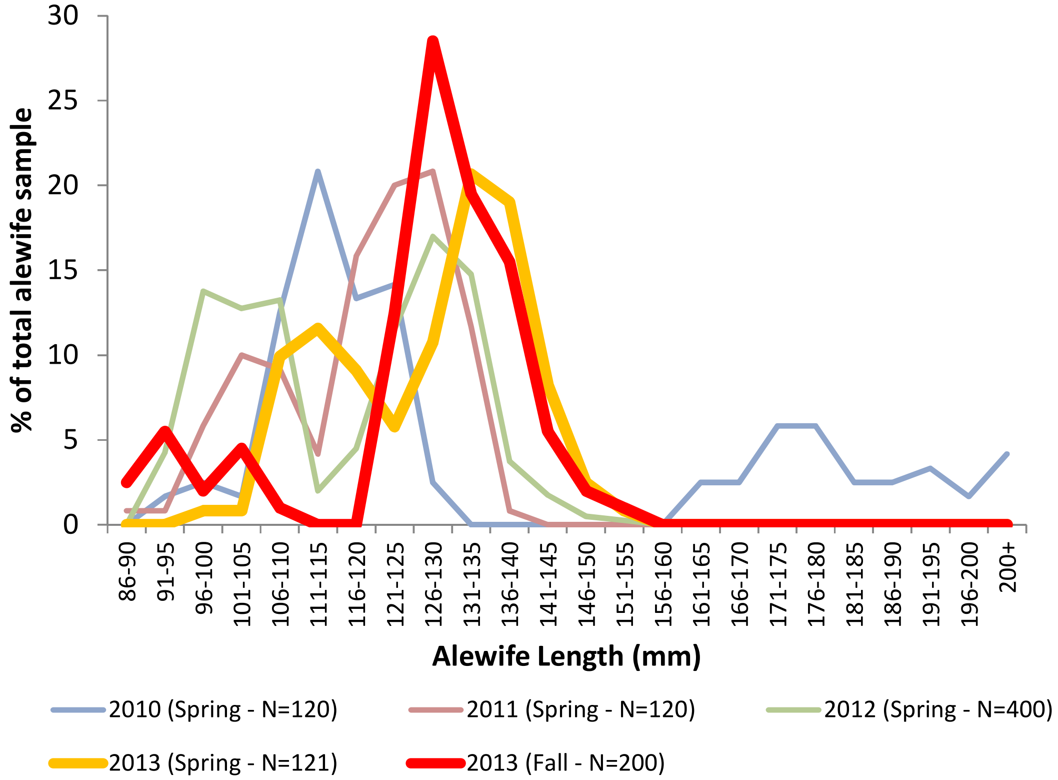


Figure 5. Alewife densities obtained with hydroacoustics (Acoustics, fish/ha) and the gill net catch of all fish species per hour (Net catches, Catch/hr) from May-June surveys in 2005 to 2013 and an October survey in 2013. Alewife densities were derived from hydroacoustic and net catch data. Error bars for net catches represent the range observed in the four nets. Net catch data for 2012 includes only three nets: one net that was only 3 meters deep was excluded from this graphic.