Alewife (*Alosa pseudoharengus*) abundance in Onondaga Lake, 2009. A report to Onondaga County.

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Abstract: The alewife (*Alosa pseudoharengus)* population in Onondaga Lake was surveyed June 4, 2009 using small mesh pelagic gill nets and hydroacoustics (123 kHz split beam). Catches in vertical gill nets ranged from 24 to 66 fish/hr with the majority of fish caught being alewife (98%). Other species included white perch, golden shiner, longnose gar and the second record of rainbow smelt for Onondaga Lake. Average length and weight of alewife was 170 mm (123-204 mm) and 49.2 g. There were two length groups of alewives in the net catches: 39% of the fish were in the 120-160 mm size group assumed to be age-1 fish and 61% were in the larger, 160-210 mm size group aged as between age 2 and age 5. Size distributions and age structure in 2009 indicate reproduction in 2008 and substantial increase in growth rate during 2008. Acoustic densities in June 2009 were difficult to obtain due to prevalence of bubbles in the water column. Our estimate is 170 fish/ha and a biomass of 8.3 kg/ha, which are likely biased high. This represents a decrease of an order of magnitude since the spring 2005 survey when the population was estimated to be 2240 fish/ha with a biomass of 76 kg/ha.

Introduction.

Alewife, *Alosa pseudoharengus*, increased dramatically in Onondaga County's electrofishing samples in 2003 and remained high in 2004 to 2007 (OCDWEP 2008). This increase was due to a strong 2002 year class. As these young fish grew through the summer of 2002, alewife biomass likely increased. The dramatic decline in large *Daphnia* and large calanoid copepods from the lake in the fall of 2002 coincided with this increase. Additional year classes of alewife were produced in 2004 – 2007 and the abundance of alewife remained high through the spring of 2007 (over 1600 fish/ha) (Wang et al. in press). Large *Daphnia* and the associated spring clear water phase were mostly absent from the lake between 2003 and 2007, although the smaller *Daphnia retrocurva* was present in 2007. It is likely that these changes in lower trophic levels were caused by increased alewife planktivory in 2002 to 2007 (Brooks and Dodson 1965, Harman et al. 2002, Wang et al. in press). In 2008, large *Daphnia* and calanoid copepods returned to the lake, and so did the spring clear water phase. Interpretation of these changes needs to include the possible effects of the alewife population. This report presents the results of the 2009 spring survey of alewife and compares the densities and size structure obtained during that survey with surveys in 2005 to 2008.

Materials and methods

Acoustics.

Onondaga Lake was surveyed using a 123 kHz split beam echo sounder (Biosonics DtX, full half-power beam angle 6.8^o, 0.2 ms pulse length, pulse rate 2 ping/sec) along seven roughly parallel SW to NE transects (total transect length 8.8 km). The survey was conducted on the night of June 4, 2009 between 21:22 and 23:55. Spatial location of the data was measured with a GPS that recorded latitude and longitude directly to the acoustic data stream. One transducer was towed at 0.35 m depth looking downwards. A second transducer was mounted side-looking on the other side of the boat to survey fish close to the surface that are not available to the down-looking unit. The side-looking data are not yet analyzed.

Acoustic data were recorded directly to a laptop computer in the field and analyzed with the EchoView software (version 4.7, Myriax Inc. Hobart, Tasmania, Australia). The unit was calibrated by the manufacturer in April 2009 and with a standard -39.5 dB 38.1 mm tungsten carbide sphere on June 3, 2009, the day before the survey. Separate gains were applied to the echo integration (measured as area backscattering coefficient, ABC) and target strength (TS) data based on this calibration (Sa-Offset of 0.99 dB and TS-Offset of 0.03 dB, both for 0.2 ms pulse length). All data were visually inspected for consistent bottom detection and corrected when needed, as well as for interference from surface bubbles and aquatic vegetation. There was little wind and a full but hazy moon. Surface noise was minimal. The noise level measured in passive mode was -117 dB (Sv domain). This is low enough to register fish with a TS of -60 dB without bias at all depth present in Onondaga Lake (maximum depth 19.5 m). Analysis was done for each transect from 2 m depth to the bottom. The near-field of this transducer is approximately 1.5 m and the transducer was mounted on a rigid pole 0.35 m below the surface. Therefore, the acoustic analysis is restricted to depth below 2 m from the surface.

Fish density from June 2009 was calculated from the average measured in situ TS and ABC following the standard operating procedure for Great Lakes acoustics (GL-SOP, Parker-Stetter et al. 2009, Rudstam et al. 2009). In situ TS distributions were obtained with EchoView using targets within 12 dB beam compensation with other settings as in the GL-SOP. Appropriate depth varying thresholds were applied to the Sv data (-66dB TS threshold in EchoView). All averages and calculations are made in the linear domain and back transformed to dB unit when appropriate.

In 2009, there was substantial bubble production in all areas of the lake. This was the case even though oxygen was present to the bottom. This complicates acoustic analysis as returns from bubbles are difficult to separate from returns from fish. To do this, we first isolated rising bubbles in five regions of the lake in data collected while stationary. Bubbles are easily identified in stationary data as targets rising towards the surface. The TS distribution of bubbles was calculated from all bubble targets analyzed in these five regions. Second, the alewife catch in the gill nets were converted 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 groups 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 2009. This approach worked well for a number of New York lakes analyzed by Brooking and Rudstam (2009).

Comparison of expected alewife TS and the measured bubble TS revealed substantial overlap for TS smaller than -45 dB. Therefore, we calculated the proportion of the measured targets larger than -45 dB and estimated the density of these targets (assumed to be alewife) from the density of all targets larger than -60 dB. The alewife density was further multiplied by 1.36 to account for the smaller alewife targets that could not be separated from bubble targets. This value represent the ratio between all expected targets from this alewife population and the expected number of targets larger than -45dB. We developed a similar approach to separate age-0 and older smelt in Lake Champlain (Parker-Stetter et al. 2006).

Fish density is the upper 0-2 m that is not sampled with downwards looking acoustics was estimated from the proportion of fish caught in 0-2 m in the vertical gill nets relative to the catch in 2-6 m. Catches in 2-6m was assumed to be representative of the acoustics fish density (fish/m^3) in the water column.

Fish were sampled using vertical gill nets set at four locations (Table 1). The 6 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, 25mm bar mesh). This set of mesh sizes will catch alewife between 50 and 240mm (Warner et al. 2002). The nets were set from the surface to 6 m depth for approximately 2 hrs in water with bottom depth between 6 and 8 m (Table 1). Fish were identified to species and depth of catch recorded in 2 m intervals. A random subsample of 30 alewives or all individual (other species) were measured (total length in mm, weight in g) from each net site.

Results and Discussion.

Net sampling

A total of 373 fish were caught in the gill nets (Table 1, 23 to 65 fish/hr, average 42.7 fish/hr). Other fish species caught include golden shiner, white perch, longnose gar, and rainbow smelt (second record from Onondaga Lake; the first reported by Gandino 1996). Alewife represented 98 % of the catch (94% -99%, Table 1). Catches in the three depth layers averaged 23 % (0-2m), 44 % (2-4m) and 33 % (4-6m) (Table 1). The average percent catch in each depth layer is based on total catch/hr of all alewife in the four nets. These catches suggest similar depth distribution as in past years with a comparatively even distribution of fish in the top 6 m of the water column.

The alewife size distribution had two distinct modes: fish larger and smaller than 160 mm (Fig. 1). The smaller length mode is most likely age-1 fish, and represented 39% of the catch (similar proportion of age-1 fish as in 2008). Average length of all alewife was 169 mm (N=120, range 123-204 mm). This was substantially larger than in previous years (Table 3). Average length of the smaller age group was 143 mm. Although we did not have a sample of the smaller size group to age, the larger size group included age 2, 3 and 4 fish (Table 3). Therefore, we assume the smaller fish were age 1. Alewives typically reach lengths of 60 to 90 mm by September of their first year of life in New York inland lakes (Rudstam and Brooking 2005), but can get larger, up to 140 mm, in productive lakes with large zooplankton (Oneida Lake and Canadarago Lake). The growth of all age groups of alewife in 2008 was higher than in any year since 2002. Percent dry weight from both the age-1 and older fish indicates high fat content and good condition (dry weight 30-33% of wet weight).

Acoustic data.

Only a small percentage of acoustic targets were larger than -45 dB, the size we used to separate alewife from bubbles. Most of the observed targets in the lake appear to be bubbles (Fig. 2), but there was also a smaller peak between -70 and -64dB in the transect data that may represent invertebrates or fish larvae (Rudstam et al. 2002). This small peak was not present in rising bubbles.

Density of targets >-45 dB was low, ranging from 33 to 229 fish/ha (Table 4). This density is multiplied by 1.36 to account for expected smaller targets and by the estimated density in the 0-2m depth layer. Average fish density in the top 0-2m was estimated to 18 fish/ha from the density of fish in the water column. This value is calculated as follows. The average density of fish/m3 is 0015 fish/m^3 in 2 m and deeper water. Catch per hour of gill net in 0-2 m of water is 60% of the same catch in 2-6m of water. Therefore, density in 0-2 m is 0.0015 * 0.60 * 2 (2 m depth layer) * 10,000 (m^2/ha). This calculation was done separately for each transect with the density obtained in that transect. Adjusted densities ranged from 52 to 347 fish/ha among transects (Table 4), with a mean of 169 fish/ha and a SE of 39 fish/ha (N=7). The mean is weighted by transect length. Assuming all of these fish were alewife and the measured average weight of alewife of 49 g (Table 1), the alewife biomass would be 8.3 kg/ha (Table 4). These alewife densities are an order of magnitude lower than in previous years (2005-2007, Wang et al. in press).

Discussion.

Densities obtained from the 2009 survey were substantially lower than in 2005 – 2007 (1632 to 2328 alewife/ha, Wang et al. in press) and are consistent with a decline in net catches in 2009 and 2008 compared to 2007 (Fig. 3, Table 2). The acoustic densities are now comparable to the low values obtained in Canadarago Lake when we first observed alewife in that lake (Brooking et al. 2008) and substantially lower than estimated abundance of age 1 and older alewife across the Finger Lakes (Fitzsimons et al. 2005).

The high growth rates of alewife and the return of large zooplankton to Onondaga Lake in 2008 are consistent with the observed decline in abundance in Onondaga Lake. Although standard analysis of the acoustic data from 2009 was not possible due to the presence of bubbles, we consider our numbers the best possible given this data and further consider them to be biased high as some of the targets considered fish may have been bubbles. If the real number of alewife is even lower than our estimate, this will further reinforce the trend inferred from this survey.

Did this decrease happen in 2008 or through over winter mortality in 2008-2009?. The acoustic survey in 2008 was also plagued by bubbles and we argued that the estimates for 2008 could be biased high, possibly substantially so (Rudstam and Snyder 2008). The in situ TS measured in 2008 were too low given the catch in the gill nets, which raised concerns about the identity of the observed targets in 2008. We discussed four possible explanations for the low in situ TS of alewife in 2008, 1) equipment malfunction or improper calibration, 2) the transducer was towed at an angle relative to the fish resulting in smaller TS due to tilted orientation of the fish relative the transducer beam, 3) presence of fish smaller than 50 mm that were not caught in the vertical gill nets, and 4) inclusions of bubbles in the estimate. Given the results from 2009 and the similarity between the TS distribution from 2008 and the bubble TS distribution from 2009, it is most likely that bubbles were included in the alewife estimate of 2008. We will attempt a similar analysis to 2009 for the 2008 data to resolve this issue.

The high growth rate in the 2009 season follows a return of the larger zooplankton that occurred in 2008. We predict that large *Daphnia* and calanoid copepod densities will also be high in 2009, at least in the spring and summer. The decline in alewife was unexpected and we currently have no explanation for this dramatic return to low alewife abundance in Onondaga Lake. We are very interested in the cause of this decline, both because alewife affect water clarity in Onondaga Lake (Wang et al. in press), and because alewife can disrupt food webs and negatively affect native fish species (Madenjian et al. 2008). However, we note that it is more likely that alewife will produce another strong year class is the next few years in Onondaga Lake than that they will remain at low abundance into the future. Strong year classes of alewife can form even when the population of spawners is low (O'Gorman et al. 2004, Schaeffer et al. 2005). This is true also for Onondaga Lake, where a relatively small population produced the strong 2002 year class (Wang et al. in press). Similarly, alewife exploded to high abundance in Lake Champlain in only a few years after invading the lake (Simonin 2010). Thus, declines in alewife may be a welcome change for Onondaga Lake, but it is doubtful they will remain at low abundance.

Acknowledgment

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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 June 4, 2009. Nets were set after dark and retrieved 2 hours later. Proportion by depth layer is based on alewife only.

	Net 1	Net 2	Net 3	Net 4	Averages
Latitude N	43° 05.994'	43° 06.552'	43°04.946'	43° 05.384'	
Longitude W	76° 14.285'	76° 13.707'	76°12.644'	76° 11.775'	
Soak time (h)	2.13	2.1	2.15	2.17	2.14
# fish caught	51	78	100	144	93.2
Water depth (m)	6.5	8	8	6	
Catch / hour	23.9	37.1	46.5	66.4	43.5
Proportion 0-2m	0.04	0.43	0.20	0.20	0.23
2-4m	0.50	0.35	0.51	0.41	0.44
4-6m	0.46	0.22	0.28	0.39	0.33
Alewife					
Catch / hour	22.5	36.7	46.0	64.5	42.4
Mean Length (mm)	168.1	173.9	169.5	167.6	169.8
Range of lengths (mm)	133-198	138-201	123-204	139-204	123-204
Mean Weight (g)	48.1	52.8	48.3	47.6	49.2
White perch					
Catch / hour	0.5	0	0.5	0	0.3
Mean Length (mm)	242		142		
Golden shiner					
Catch / hour	1.0	0.5	0	0	0.4
Mean Length (mm)	93	86			
Rainbow smelt					
Catch / hour	0	0	0	0.5	0.2
Mean Length (mm)				94	
Long nose gar					
Catch / hour	0	0	0	1.5	0.5

The gar were not measured and released in the field

Table 2.–Average fish catches in the vertical gill nets with variable mesh size set in Onondaga Lake in 2004-08. Four nets were set in each survey, with the exception on July 18, 2007 were only two nets were set. Details on the sets for 2008 are in Table 1.

Date	**10/7/2004**	**5/17/2005**	**6/4/2006**	**6/6/2007**	**7/18/2007**	**6/4/2008**	**6/4/2009**
Soak time (h)	3.42	2.45	5.61	2.34	1.08	2.02	2.14
Proportion (0-2m)	0.35	0.38	0.43	0.42	0.28	0.37	0.23
(2-4m)	0.37	0.41	0.24	0.31	0.40	0.46	0.44
(4-6m)	0.28	0.21	0.32	0.27	0.32	0.17	0.33
Alewife (#/h)							
Catch/hour	58.51	75.4	56.4	94.9	143.5	66.0	42.4
Mean length (mm) (range)	148 (132-165)	149 (108-164)	132 (110-169)	153 (104-195)	150 (110-173)	145 (115-176)	170 (123-204)
Mean weight (g)	29.8	33.7	24.9	28.4	26.8	28.0	49.2
Other species (#/h)							
Gizzard shad	3.1	0	6.7	1.0	0	0	0
White perch	0.1	0.1	0.1	0.4	0	1.4	0.3
Yellow perch	0	0	0	0.5	0.5	0.1	0
Walleye	0	0	0	0	0	0.2	0
Emerald shiner	0	0	1.4	0	0	0.1	0
Golden shiner	0.1	0	0	0	0	0	0.4
Smallmouth bass	0	0	0	0.2	0	0.2	0
Pumpkin seed	0	0	0	0	0.5	0	0
Brown trout	0	0.1	0.02	0	0	0.1	0
Channel catfish	0.1	0	0	0	0.5	0	0
Longnose gar	0	0	0	0	0	0	0.5
Rainbow smelt	0	0	0	0	0	0	0.2

Table 3 Age and length-at-age of alewife in Onondaga Lake from 2004 to 2009. All ages were assigned using otoliths.

Age	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
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	

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 (see Figure 1)

Table 4. Results from acoustics estimate of alewife in Onondaga Lake June 4, 2009, using a 123 kHz split beam unit. Density includes the whole water column accounting for alewife in the surface layer (see text). ABC is the area back scattering coefficient. Density is calculated from ABC/σ_{bs}, where σ_{bs} is target strength in the linear domain (back scattering cross section: $\sigma_{bs} = 10^{(TS/10)}$). Target density refers to all targets, including bubbles. Fish density is based on the proportion of those targets assumed to be alewife and corrected for surface and the lower tail of the TS distribution from alewife (see text). Biomass is the fish density multiplied with the average weight of alewife caught in gill nets.

Transect #	Transect Length (m)	Average TS (dB)	ABC (m^2/ha)	Target Density (targets/ha)	Fish Density (fish/ha)
1	941	-51.71	0.0495	7336	226
2	1862	-50.87	0.0487	5952	347
3	699	-52.42	0.0465	8130	151
4	1475	-51.71	0.0234	3465	138
5	1003	-52.63	0.0384	7034	166
6	1585	-52.39	0.0197	3411	52
7	1227	-53.02	0.0137	2745	58
Mean	1258	-52.11	0.0342	5439	169
Biomass (kg/ha)					8.3

Figure 1. Length distribution of alewife in vertical gill nets in May-June sampling of 2005 to 2009.

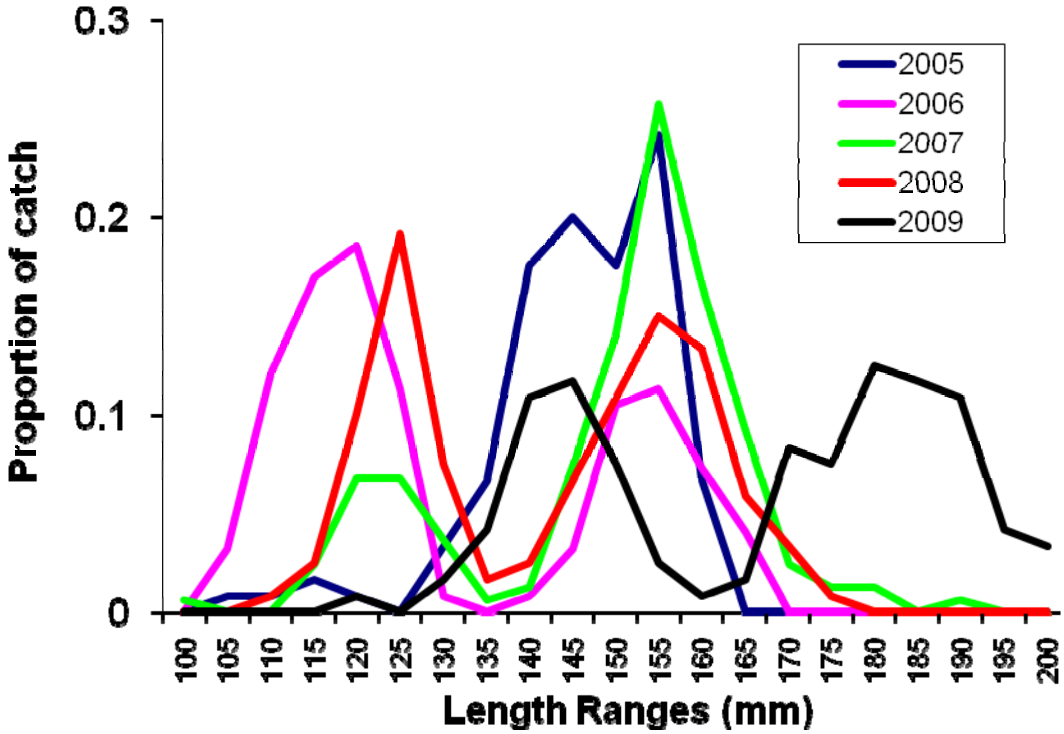

Figure 2. Probability density functions for the observed and expected TS distributions in Onondaga Lake. "Bubbles" represents the target strength of targets identified as bubbles in stationary acoustics surveys in June 2009 (based on 2861 single targets). "Transect" is the observed TS distribution from the survey (based on 12879 single targets). "TS fish" is the expected TS distribution from the alewife population caught in vertical gill nets using the probability density function in Brooking and Rudstam (2009).

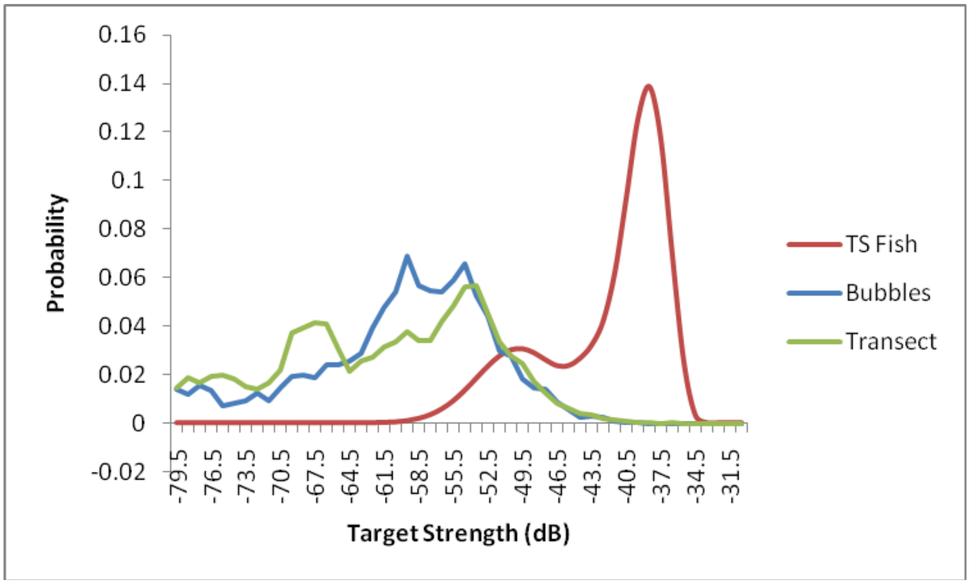

Figure 3. Alewife densities obtained with hydroacoustics (Density) and the gill net catch per hour (Gillnets) from May-June surveys in 2005 to 2009. Error bars represents one SE. Note that the 2008 acoustic survey needs to be revisited to remove bubbles included in the density estimate.