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Alewife (*Alosa pseudoharengus*) abundance in Onondaga Lake, 2010. A report to Onondaga County.

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Abstract: The alewife (*Alosa pseudoharengus)* population in Onondaga Lake was surveyed May 20, 2010 using small mesh pelagic gill nets and hydroacoustics (123 kHz split beam). Catches in vertical gill nets ranged from 73 to 147 fish/hr with the majority of fish caught being alewife (99%). Other species included three golden shiners and one rock bass. Average length and weight of alewife was 135 mm (range 95-219 mm) and 26.5 g. There were two length groups of alewives in the net catches: 69% of the fish were in the 95-130 mm size group (age-1) and 31% were 160-220mm (age-2 to 4). This indicates a large year class in 2009 and a return to the relatively slow growth rates of age-0 fish observed in 2005-2007. Older fish were larger due to high growth rates in 2008. As in 2008 and 2009, acoustic densities in May 2010 again affected by bubbles in the water column released from the sediment. We removed bubble targets by assuming all targets larger than -47 dB to be alewife, and applying a target strength (TS) distribution derived from controlled measurement in a net cage to estimate the number of smaller targets that were likely alewife. Our estimate is 912 alewives/ha (approximate SE 170 fish/ha) and a biomass of 24.2 kg/ha. This represents an increase from around 100 fish/ha in 2008 and 2009, but densities are lower than in 2005-2007 (1600 – 2300 fish/ha). The proportion of age-1 alewife was high (69%) in 2010 indicating a strong 2009 year class. Bubbles remain a problem for acoustic estimates in this lake, a problem that began in 2008. We reanalyzed the 2008 survey to remove bubbles and be consistent with the approach used in 2009 and 2010. However, the presence of bubbles adds uncertainty to the densities estimates in 2008-2010. Inspection of echograms from 2005 to 2007 indicates that bubbles were not a problem those years.

Introduction.

Alewife, *Alosa pseudoharengus*, increased dramatically in Onondaga County's electrofishing samples in 2003 and remained high in 2004 to 2007 (OCDWEP 2008, Wang et al. 2010). This increase was due to a strong 2002 year class. As these young fish grew through the summer of 2002, alewife biomass increased 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/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. These years also showed diminished water clarity in the spring. 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 2010 spring survey of alewife. It also reevaluates the 2008-2009 surveys using the methods applied in 2010 to avoid inclusion of bubbles in alewife abundance estimates.

Materials and methods

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. The proportion of age-1 fish were estimated from aged fish and size distributions. Alewives were aged using whole otoliths extracted from a subsample of the fish.

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 14.0 km). The survey was conducted on the night of May 20-21, 2010 between 21:18 and 00:41. 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 0.5 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 but the presence of bubbles precludes meaningful analysis of the side-looking data.

Acoustic data were recorded directly to a laptop computer in the field and analyzed with the EchoView software (version 4.9, Myriax Inc. Hobart, Tasmania, Australia). The unit was calibrated in June 2010 with a standard -39.5 dB 38.1 mm tungsten carbide sphere. 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 0.85 dB and TS-Offset of 0.04 dB, both for 0.2 ms pulse length). This calibration was very close to the calibration in 2009. All data were visually inspected for consistent bottom detection, interference from surface bubbles and aquatic vegetation and corrected when needed. Surface noise was minimal. The ambient noise level measured was -121 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 0.5 m below the surface. Therefore, the acoustic analysis is restricted to depth below 2 m from the surface.

Target density in May 2010 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) with -60dB as the lower TS threshold of interest. In situ TS distributions were obtained with EchoView using targets within 6 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 calculations are made in the linear domain and back transformed to dB unit when appropriate.

In 2010, there was substantial bubble production in all areas of the lake (similar to 2009 and 2008). 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 data from five regions 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 2010. This approach was used in several other lakes by Brooking and Rudstam (2009) and Rudstam et al. (in press).

Comparison of expected alewife TS and the measured bubble TS revealed substantial overlap for TS smaller than -47 dB (Figure 2). Therefore, we calculated the proportion of the measured targets larger than -47 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 then 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 -47dB using the equations in Brooking and Rudstam (2009).

Alewives were caught between the surface and 2 m depth in the vertical gill nets; depths that were not surveyed with acoustics. 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 (see Rudstam et al. in press).

Results

Net sampling. A total of 782 fish were caught in the gill nets (Table 1, 73 to 147 fish/hr, average 98 fish/hr). This is the second highest catch rates since 2005 (Table 2). Other fish species caught in 2010 include three golden shiners and one rock bass. Alewife represented 99 % of the catch (98 – 100%). Catches in the three depth layers averaged 20 % (0-2m), 38% (2-4m) and 42 % (4-6m) (Table 1). The average percent catch in each depth layer is based on the average observed at the four net sites. 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 than 160 mm and fish smaller than 130 mm (Figure 1). The smaller length mode consisted of age-1 fish, and represented 69% of the catch. Average length of all measured alewife was 135 mm (N=120, range 95-219 mm). The size of age-1 fish were smaller than in previous years, whereas the size of age-2 and older fish were larger (Table 3, Figure 1). Average length of age-1 fish was 111 mm (Table 3). 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 length distribution suggest that growth rates of age-0 fish returned to the rates typical for abundant alewife population in productive lakes (Rudstam et al. in press). Both age groups were in good condition; dry weight ratio declined only slightly from 30-33% in 2009 to 26-31% in 2010.

Acoustic data. About 13% of the targets were larger than -47 dB, the size we used to separate alewife from bubbles. Fish density derived from these data and the net catches ranged from from 280 to 1365 fish/ha in the seven transects (Table 4). This includes estimated density in the top 2 m of the water column (average fish density in the top 0-2m was estimated to 204 fish/ha). Mean density was 912 fish/ha with an approximate SE of 171 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 26.5 g (Table 1), the alewife biomass would be 24.2 kg/ha (Table 4). Alewife biomass in 2010 was lower than in 2005-2007, but 4 times higher than in 2009 (Table 5).

Discussion.

Densities obtained from the 2010 survey were higher than in 2008 and 2009, but lower than in 2005 – 2007 (Table 5). Net catches also increased in 2010 compared to 2008 and 2009 and was the second highest on record. Most of the alewives caught were from the 2009 year class.

The high growth rates of alewife and the return of large zooplankton to Onondaga Lake in 2008 were consistent with the observed decline in abundance in Onondaga Lake. Similarly, the return to a *Bosmina* and cyclopoid dominated system in late summer of 2009 is consistent with the observed increase in age-1 alewife in the spring of 2010 (from the 2009 year class). Unfortunately, the presence of bubbles increases uncertainty in our acoustic estimates from 2008 to 2010.

The densities for 2008 and 2009 presented here were recalculated based on the procedure to account for bubbles used for the 2010 surveys. We also inspected echograms from the 2005, 2006 and 2007 surveys for presence of bubbles and found none. We did switch echosounder in 2008 from a Simrad 70kHz unit to a Biosonics 123 kHz unit, but limited data from 2007 with both units did not reveal bubble echoes in either frequency. It is most likely that alewife declined during the winter of 2007-2008 before the spring 2008 survey. This would be consistent with the shifts in zooplankton community composition and the subsequent high growth rates during 2008.

In last year's report, we predicted that the decline in alewife in 2008 and 2009 would be short lived because alewife can produce large year classes even at low density. Strong year classes of alewife can form even when the population of spawners is low in the Great Lakes (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. 2010). Similarly, alewife exploded to high abundance in Lake Champlain in only a few years after invading the lake (Simonin et al. 2012) and build to high abundance in Canadarago Lake even though walleye predators were abundant (Rudstam et al. in press). Thus, declines in alewife may have been a welcome change for Onondaga Lake in 2008 and 2009, but the species was unlikely to stay at low densities. The results presented here for the spring of 2010 as well as the observed shift in zooplankton confirmed this prediction for Onondaga Lake. Alewives are again abundant and have strong top-down effects on the zooplankton community.

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 May 20, 2010. Nets were set after dark and retrieved 2 hours later. Proportion by depth layer is based on alewife only. 99% of the fish caught were alewife.

	Net 1	Net 2	Net 3	Net 4	Averages
Latitude N	43° 04.938'	43° 05.384'	43° 06.552'	43° 05.994'	
Longitude W	76° 12.618'	76° 11.775'	76° 13.707'	76° 14.285'	
Soak time (h)	2.0	2.0	2.0	2.0	2.0
# fish caught	294	180	146	162	195.5
Water depth (m)	8	7	8	7	
Catch / hour	147	90	73	81	97.7
Proportion 0-2m	0.24	0.26	0.17	0.13	0.20
2-4m	0.39	0.41	0.42	0.28	0.38
4-6m	0.37	0.33	0.41	0.59	0.42
Alewife					
Catch / hour	147.0	88.0	73.0	81.0	97.2
Mean Length (mm)	126.6	141.0	133	141	135.4
Range of lengths (mm)	95-192	99-219	93-199	107-212	95-219
Mean Weight (g)	11.5	25.1	22.0	47.6	26.5
Golden shiner					
Catch / hour	0	1.5	0	0	0.38
Mean Length (mm)		130			
Rock bass					
Catch / hour	0	0.5	0	0	0.12
Mean Length (mm)		128			

Table 2.–Average fish catches in the vertical gill nets with variable mesh size set in Onondaga Lake in 2004-10. 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 2010 are in Table 1.

Date	**5/17 2005**	**6/4 2006**	**6/6 2007**	**6/4 2008**	**6/4 2009**	**5/20 2010**
Soak time (h)	2.4	5.6[a]	2.3	2.0	2.1	2.0
Proportion (0-2m)	0.38	0.43	0.42	0.37	0.23	0.20
(2-4m)	0.41	0.24	0.31	0.46	0.44	0.38
(4-6m)	0.21	0.32	0.27	0.17	0.33	0.42
Alewife (#/h)						
Catch/hour	75.4	56[a]	95	66	42	97
Mean length (mm)	149	132	153	145	170	135
Min length (mm)	108	110	104	115	123	95
Max length (mm)	164	169	195	176	204	219
Mean weight (g)	33.7	24.9	28.4	28.0	49.2	26.5
Other sp. (#/h)						
Gizzard shad	0	6.7	1.0	0	0	0
White perch	0.1	0.1	0.4	1.4	0.3	0
Yellow perch	0	0	0.5	0.1	0	0
Walleye	0	0	0	0.2	0	0
Emerald shiner	0	1.4	0	0.1	0	0
Golden shiner	0	0	0	0	0.4	1.5
Smallmouth bass	0	0	0.2	0.2	0	0
Pumpkinseed	0	0	0	0	0	0
Brown trout	0.1	0.02	0	0.1	0	0
Channel catfish	0	0	0	0	0	0
Longnose gar	0	0	0	0	0.5	0
Rock bass	0	0	0	0	0	0.12
Rainbow smelt	0	0	0	0	0.2	0

a) One net left overnight for 12 hours. Excluding that net yields a catch per hour of 64 fish/hr

Table 3 Age and length-at-age of alewife in Onondaga Lake from 2005 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
2010	60	24	10	6	0	50
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		

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. Results from acoustics estimate of alewife in Onondaga Lake May 20, 2010, using a 123 kHz split beam unit. Fish Density includes the whole water column accounting for alewife in the surface layer (see methods). ABC is the area back scattering coefficient. Target Density is calculated from ABC/σ_{bs}, where σ_{bs} is the backscattering cross section of all targets > -60dB and includes bubbles. Target Density does not include 0-2m. Fish density is based on the proportion of those targets assumed to be alewife (larger than -47dB) and corrected for surface (density in 2-6m multiplied by 0.25), and the lower tail of the TS distribution from alewife (multiplier 1.36). Mean values are weighted by transect length or number of targets. Biomass is the mean fish density multiplied with the average weight of alewives caught in gill nets.

Transect #	Transect Length (m)	Average TS (dB)	ABC (m^2/ha)	Target Density (#/ha)	Fish Density (fish/ha)
1	2477	-49.1	0.056	4573	1204
2	2322	-48.0	0.032	2063	362
3	2448	-48.8	0.056	4311	1365
4	1490	-46.0	0.036	1470	280
5	2309	-50.2	0.065	6771	1314
6	1737	-51.1	0.036	4693	610
7	1233	-47.5	0.036	2023	902
Mean	2002	-48.8	0.046	3799	912 (SE 171)
Biomass (kg/ha)					24.2

Table 5. Results from May-June acoustic-gillnet surveys of alewife in Onondaga Lake 2005 to 2010. Bubbles were not present in the 2005-2007 surveys, but occurred from 2008 onwards. Lower limit used in calculations are given (TS minimum).

	# net sites	Soak time (h)	Average proportion alewife % (range)	Alewife catch per net-hour Total (range)	Age-1 (%)	0-2 m % (range)	TS minimum (dB)	Abundance 2m-bottom (fish/ha)	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

Figure 1. Length distribution of alewife in vertical gill nets in May-June sampling of 2005 to 2010.

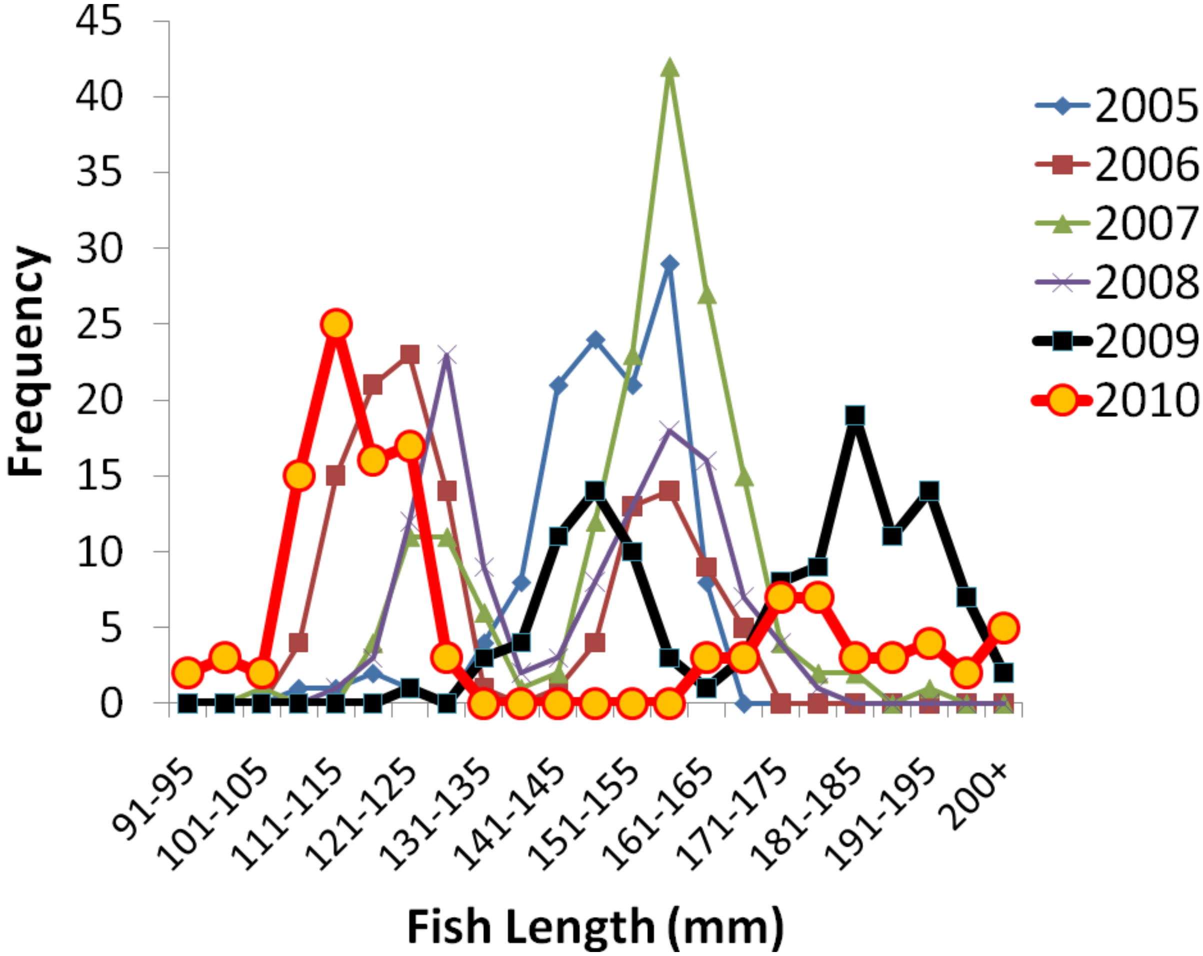

Figure 2. Probability density functions for the observed and expected TS distributions in Onondaga Lake. "Bubbles" represents the target strength of targets identified as bubbles in stationary acoustics surveys in June 2010 (based on 1258 single targets). "Overall" is the observed TS distribution from the survey (based on 3881 single targets). "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).

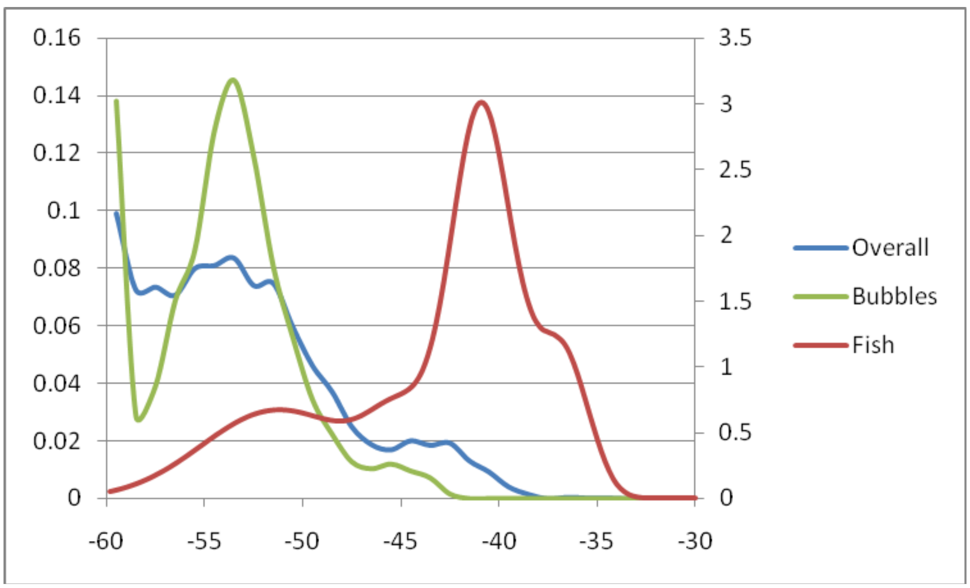

Figure 3. Alewife densities obtained with hydroacoustics (Density, fish/ha) and the gill net catch per hour (Net Catch, Catch/hr) from May-June surveys in 2005 to 2010. Error bars for net catches represent the range in observed in the four nets.