Alewife abundance, growth, and mortality in Otsego Lake 1996-2002

David M. Warner[1], Mark D. Cornwell[2], Wes Tibbits[2], Mike Gray[2]

ABSTRACT

Alewife abundance in Otsego Lake has been monitored in 11 of the last 14 years using littoral trap netting efforts. Hydroacoustic surveys of alewife (*Alosa pseudoharengus*) density have been conducted in Otsego Lake since 1996 (except for 1998). Alewife density during this period ranged from a low of 968 fish/ha in May 2002 to a high of 14,797 fish/ha in August 2002. The lowest density (May 2002) followed the second highest density (October 2001) and the lowest winter water temperatures ever recorded, suggesting that the effects of low water temperatures (1.6° C throughout water column) and intraspecific competition are important in regulating alewife survival and abundance. Comparisons of fall density with density in the following spring were used to estimate overwinter mortality during three years of this study. These mortality estimates were compared with alewife (ages 1-4) mortality estimated from catch curve analysis. Both methods revealed high mortality relative to alewife populations in other lakes. High mortality is further supported by slow growth and short life span (4 years) of alewives in Otsego Lake. However, our findings also suggest that alewives exhibit a compensatory increase in survival of young-of-year (and potentially fecundity) when adult abundance is low. This compensation may be the result of reduced cannibalism of young-of-year alewives when adult densities are low, as in May 2002.

INTRODUCTION

The Otsego Lake alewife population has been the focus of extensive monitoring efforts intended to provide estimates of their abundance (Gray, 2003; Harman et al., 2002). Alewife abundance has been monitored during summers through the use of daily trap netting in 11 of the last 14 years (Gray and Foster, 2003; Foster, 1996). Gray (2003) revealed variability in a summary of all existing trap net data where he found a wide range of catch-per-unit-effort (CPUE) that did not appear to correspond with other variables. He therefore suggested that trap netting provides only an index of abundance. In 1996, hydroacoustic surveys were initiated in an effort to improve estimates of alewife abundance and to characterize the ecological role they played in Otsego Lake (Warner, 1999; Warner et al., 1997). Early acoustic work was hampered by a lack of knowledge of the acoustic characteristics of alewives, which made it difficult to determine which acoustic targets corresponded to alewives. However, recent work by Warner et al. (2002) provided evidence that previous estimates of the proportion of targets that were alewives were relatively accurate. As part of a walleye (*Stizostedion vitreum*) re-introduction project (Cornwell 2000), additional acoustic surveys have been conducted following the work of

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[1] BFS visiting researcher, summer 2002. Present affiliation: CBFS, Cornell University, Ithaca, NY.
[2] SUNY Oneonta biology MA candidate. Biological Field Station, Cooperstown, NY.

Warner (1999) and Warner et al. (2002). In this paper, existing acoustic abundance estimates are presented to provide a baseline of seasonal and annual patterns in alewife abundance prior to re-establishment of walleye.

MATERIALS AND METHODS

Acoustic data were collected on 16 dates between September 1996 and October 2002. We employed either a Simrad EY500 70 kHz split beam sounder (11.1 degree beam width, 0.2 or 0.6 ms pulse length) or a Biosonics DE6000 120 kHz split beam sounder (7.1 degree beam width, 0.2 or 0.6 ms pulse width). The acoustic systems were calibrated during the survey in all cases except September 1996, when the sounder was calibrated approximately one month after the survey. Calibrations indicated that the effect of the beam pattern on a standard target was well described by the beam pattern applied at the time of data collection. The typical deviation from theoretical values for calibration spheres was <0.6 dB after accounting for the beam pattern within the 6 dB compensation angle. The transducers were deployed athwartships and at a depth between 0.5 and 1 m on either a towed body suspended from a wooden plank or attached to a square steel pipe fastened to the same plank.

Surveys were conducted in a roughly zig zag pattern and covered the majority of the lake in 1996-1999 and in October 2002 (Figure 1A). Beginning in 2000, surveys were conducted in a stratified random design which included parallel and approximately east-west transects (8-10 on average, Figure 1B). All surveys were conducted at night at least one hour after sunset. To reduce the potential effect of moon light on fish behavior (schooling), surveys were conducted only on nights with a waxing, waning, or new moon.

Data were analyzed using either Simrad EP500 (version 5.2) or Sonardata Echoview (version 2.25). Zig zag surveys were divided in approximately equal-ping segments (N=8-10) and analyzed assuming each segment was an independent observation even though geostatistical analyses may have been more appropriate. We chose this method because the early surveys lacked location data. We assumed that similar estimates of mean density would be obtained from either classical or geostatistical methods, but geostatistical methods would result in a lower and best linear unbiased estimate of the variance associated with the mean (Rivoirard et al., 2000; Cressie 1993).

Alewife density was calculated from volumetric scattering (sv), mean backscattering-cross sectional area of individual targets in each layer ($\sigma_{bs,}$ the linear form of target strength), and the mean height (m) of the layer for 10 depth layers (2-6, 6-8, 8-10, 10-12, 12-14, 14-16, 16-20, 20-30, 30-40, and 40-50 m). However, the data collected August 1999 and October 2001 were limited to the top 20 m of the water column, precluding analysis of the three deepest strata. Total density for the water column in each segment was obtained by summing the density within each stratum. Mean density for the lake was obtained by calculating the average of the densities for each transect or segment. The loss of data below 20 m in August 1999 and October 2001 had little influence on mean abundance because the vast majority of alewife targets are above 20 m.

Densities calculated included all fish with target strength between –61 and –37 dB (Warner et al., 2002). Additionally, densities in the 2-6 m stratum on 3 June 2002 were reduced by approximately 70% to account for surface noise that resulted from bubble entrainment due to wind.

Interpretation of acoustic survey results requires some knowledge of fish community structure and size/age distribution. To provide this information, netting was conducted concurrent with all but one of the acoustic surveys presented here. Several gears were employed and included a 3-m Isaacs-Kidd midwater trawl, a 1-m larval fish trawl, and variable mesh monofilament gill nets. Netting was conducted concurrent with or within one week of acoustic surveys. To assist in describing age distribution, sagittal otoliths were extracted from 60 fish (30 caught fall 2000 and 30 caught fall 2002) and aged using a stereo dissecting microscope and reflected light. Otoliths were prepared by soaking them in glycerin. Age-at-length was determined from the aged otoliths and used to construct an age-length key. This key was employed (in conjunction with catch data from trawling and gill netting) to estimate the annual mortality rate of age classes 1-4 using the slope of a line fitted to the descending limb of the catch curve (Ricker, 1975). These mortality estimates were contrasted with acoustic overwinter mortality estimates calculated as the percent difference between mean fall and spring density in the winters of 1996-97, 2000-01, and 2001-02.

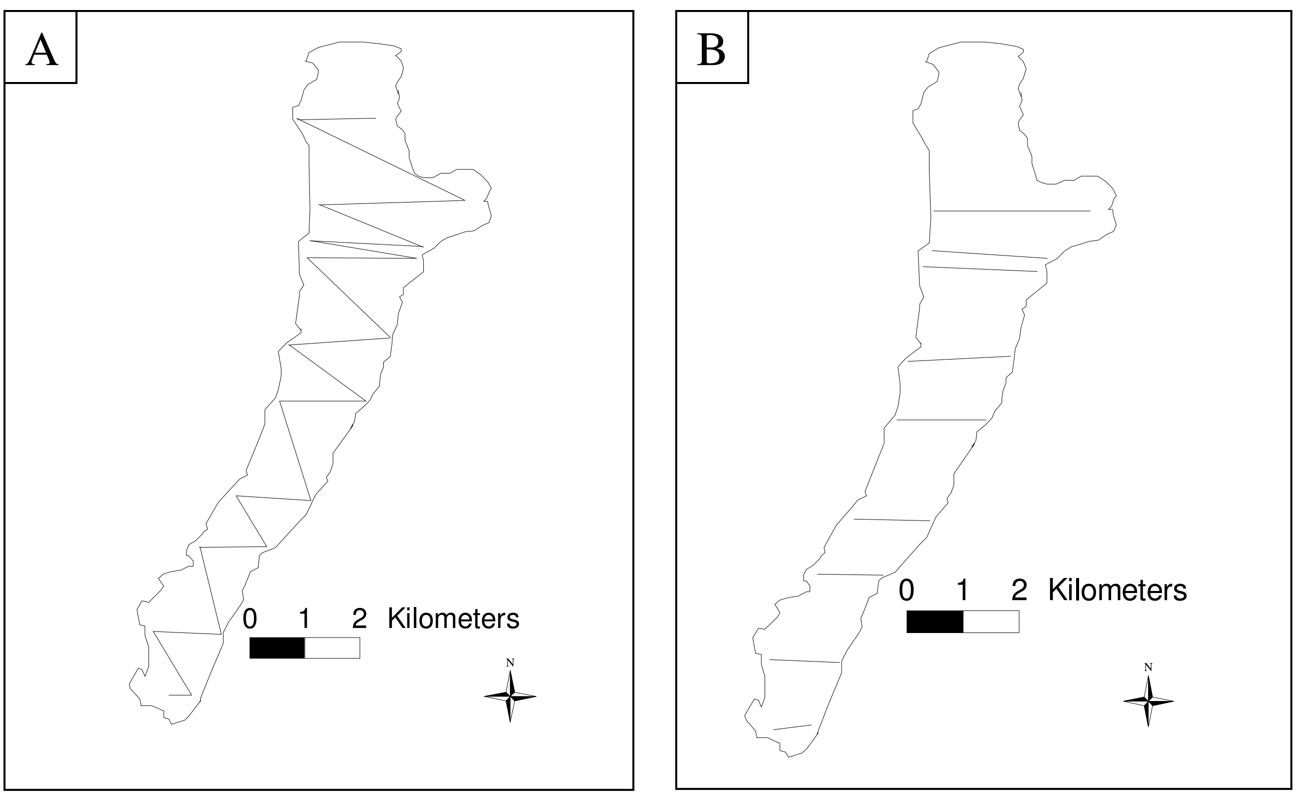

Figure 1. A) Map of Otsego Lake and the acoustic survey transects for surveys before 2000 and in October 2002 and B) acoustic survey transects in 2000-2002.

RESULTS AND DISCUSSION

Estimates of alewife density varied depending on season and year (Table 1). This variation spans an order of magnitude from the lowest mean density (968 fish/ha) observed in May 2002 and the highest (13,381 fish/ha) observed in October 2001. Although estimates of mean density were quite variable and often had wide confidence intervals, other data support our acoustic estimates of the direction (if not magnitude) of changes observed in mean alewife density. First, *Daphnia* was a persistent member of the zooplankton community in 2002 (Martin, 2003), whereas in previous years it was rarely present (Morgan 2001; Warner 1999). Second, mean summer Secchi transparency was higher than it had been since 1995 (Albright, 2003). Lastly, there appears to be a positive relationship between trap net CPUE of alewives (Gray and Foster, 2003) and spring alewife density (Figure 2).

The occurrence of lowest average density in spring (Table 2) is not surprising considering the intolerance alewives have for low water temperatures (Colby, 1973). Colby (1973) found that alewives held in experimental tanks for periods from 26-277 days exhibited behavioral responses to decreases in water temperature including reduced swimming speed, reduced activity, and cessation of feeding. Additionally, Colby (1973) found that alewives began to suffer high mortality when water temperatures were lowered below 3.4° C. Colby (1973) observed average mortality of ~70% (range 50-92) at 2.2° C, while in alewives held in a control tank alewives at 15.6° C suffered 30% mortality.

Date (frequency kHz)	Segments	Mean density (95% confidence interval)
16 September 1996 (70)	10	8,192 (6,631 – 11,211)
22 May 1997 (70)	10	1,892 (36 – 3,747)
6 July 1997 (70)	10	2,637 (1,630 – 3,644)
12 October 1997 (70)	9	8,389 (4,972 – 11,805)
21 July 1999 (70)	10	3,584 (1,613 – 5,553)
22 July 1999 (70)	10	5,675 (4,311 – 7,038)
12 August 1999 (70)	10	8,630 (4,972 – 12,287)
3 June 2000 (70)	9	1,922 (502 – 3,342)
23 July 2000	9	10,468 (5,140 – 15,796)
7 October 2000 (120)	10	3,257 (1,951 – 4,564)
20 May 2001 (70)	9	1,450 (591 – 2,310)
2 August 2001 (120)	8	10,005 (3,836 – 16,175)
14 October 2001 (70)	9	13,381 (5,164 –21,598)
15 May 2002 (120)	8	968 (139 – 1,798)
8 August 2002 (120)	9	14,797 (9,772 – 19,821)
15 October 2002 (70)	8	11,996 (8,745 – 15,246)

Table 1. Date, echosounder frequency, number of survey segments, mean density, and 95% confidence intervals for density from 16 acoustic surveys of Otsego Lake. Density estimates included all fish with target strength between –61 and –37 dB.

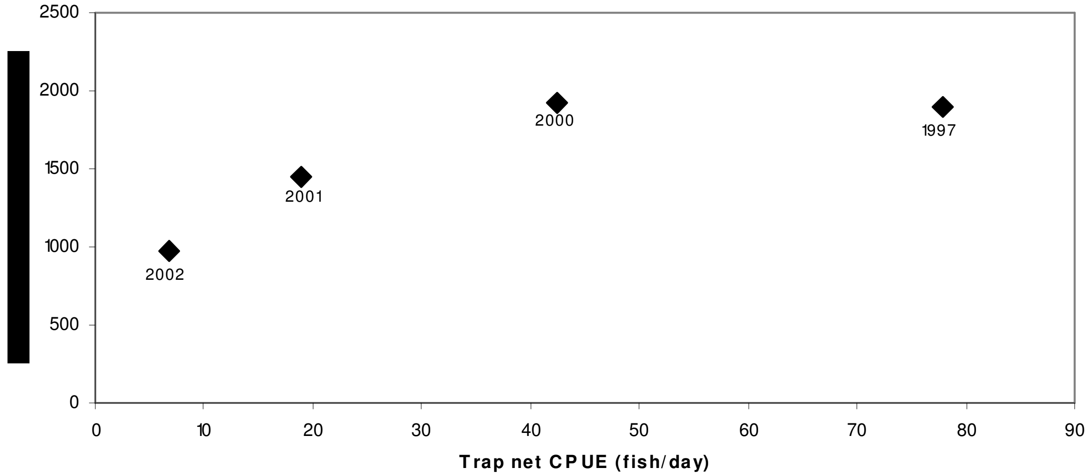

Figure 2. Spring alewife density in Otsego Lake (fish/ha, estimated hydroacoustically) plotted against summer alewife trap net CPUE (fish/day). Data are from the years 1997 and 2000-2002. Acoustic density includes all targets with target strength between –61 and –37 dB.

Season	N	Mean (95% confidence interval)
Spring	4	1,558 (844 – 2,272)
Summer	7	7,971 (4,004 – 11,938)
Fall	5	9,043 (4,148 – 13,938)

Table 2. Mean and 95% confidence intervals for seasonal alewife density and number of acoustic surveys in each season (N) between 1996-2002. Season refers to spring (May-early June), summer (July-August) and fall (September-October). Density estimates included all fish with target strength between –61 and –37 dB.

Alewives appear to face strong intraspecific competition in Otsego Lake. Alewife growth is slow and both maximum size and length at age are low compared to alewives in Lake Ontario and Superior (O'Gorman et al., 1997; Bronte et al., 1991). The extremely low density (relative to other years) observed in May 2002 followed a winter in with the coldest water temperatures ever recorded (Albright, 2003.). That was the first winter since records have been kept (1842) during which Otsego did not freeze. This allowed for circulation throughout the winter, leading to homothermic conditions of 1.6^{o} C by April. In addition to the low temperatures, alewives that survived the winter of 2001-2002 likely faced high levels of intraspecific competition in fall 2001 because the mean alewife density in fall 2001 was the second highest (slightly lower than in summer 2002) observed in the 16 acoustic surveys conducted so far. Brown (1967) found that high levels of intraspecific competition increased susceptibility to stress from low water temperatures, and O'Gorman and Schneider (1986) found that alewives <60 mm total length do not survive their first winter in the lower Great Lakes. It is likely that both low water temperature and intraspecific competition had an interactive influence on alewife survival during winter 2001-2002. Cannibalism is another factor that may regulate survival of young-of-year alewives (Rhodes et al., 1974), and in years of high adult abundance, survival of young-of-year is likely lower than in years with low adult abundance. Our data support this possibility, as the highest alewife density occurred in the summer following the spring when the lowest alewife density was observed.

Alewife mortality is relatively high in Otsego Lake, as evidenced by low maximum age (4 years, Figure 2). Results from two methods of estimating alewife mortality support this conclusion. Estimation of alewife density in successive fall and spring surveys provided the opportunity to calculate rough mortality estimates for three winters (Table 3). Mean density declined between 55 and 93 % (mean = 75%) during the three winters considered. The catch-at-age data from alewives caught in trawls and gill nets in 2000-2002 indicated that the average annual mortality for ages 1-4 was 58 % (Figure 3). The disparity between the acoustic mortality estimates and the catch-at-age estimate may have resulted from the different temporal scales (winter versus annual). Additionally, the overwinter declines observed in the acoustic density estimates may also be elevated because some alewives may be nearshore in water too shallow to sample acoustically during spring surveys. Although acoustic abundance estimates have been used successfully to estimate mortality of Pacific herring, the technique is dependent on spatial segregation of age classes (Stokesbury et al., 2002), which is poorly understood in inland lakes. As a result, it is suggested that future efforts to estimate alewife mortality focus on aging of otoliths and construction of catch-at-age estimates. Both of our methods estimated mortality levels higher than in Lake Ontario (~47 %, O'Gorman et al., 1997), while our estimates of overwinter mortality were similar to annual mortality in Lake Superior (67 %), where most alewife mortality occurs during winter (Bronte et al., 1991).

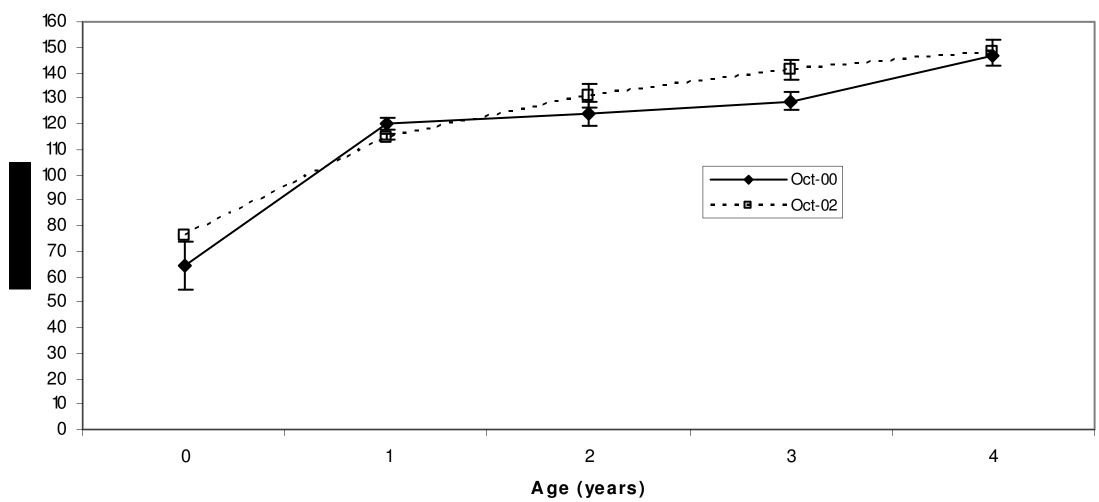

Figure 3. Mean length (mm) at age (years) for Otsego Lake alewives collected in October 2000 and 2002. Paired sagittal otoliths were aged from approximately 30 fish each year. Error bars represent two standard errors.

Years	Fall density (fish/ha)	Spring density (fish/ha)	Difference	% difference
1996-1997	8,192	1,892	6,300	77
2000-2001	3,257	1,450	1,807	55
2001-2002	13,381	968	12,413	93

Table 3. Acoustic estimates of overwinter mortality of Otsego Lake alewives during the winters of 1996-97, 2000-01, 2001-02. Density estimates included all fish with target strength between –61 and –37 dB.

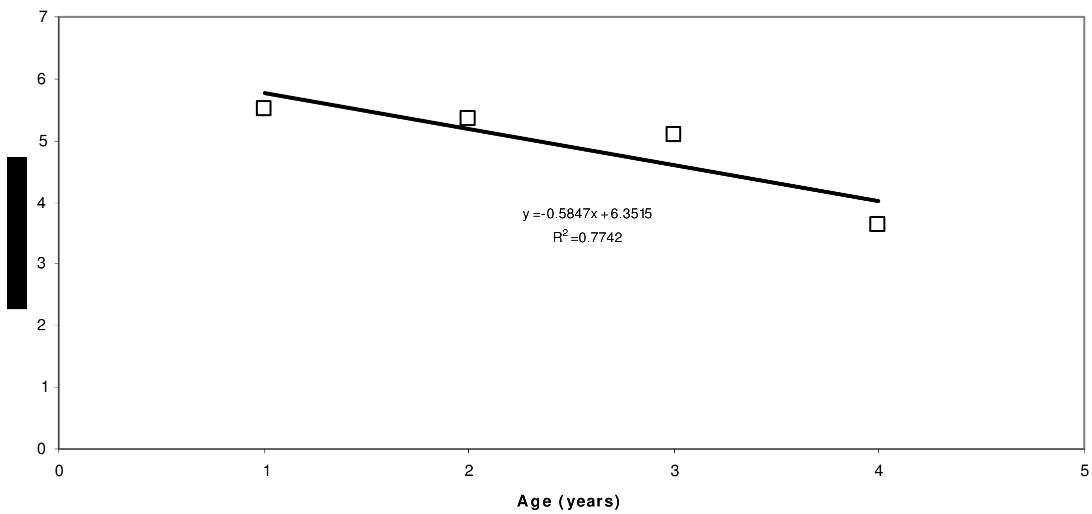

Figure 3. Natural logarithm of catch at age plotted versus age (years) for Otsego Lake alewives aged 1-4 years. Catch data included alewives captured with both trawl and gill net (N = 866) in 2000-2002. The trend line and equation represent the relationship between the two variables, with the equation slope x100 representing the mean annual mortality rate for ages 1-4.

The majority of adult alewife mortality is likely the result of poor adaptation to conditions in Otsego Lake. There is clearly some predation mortality caused by walleye (Cornwell, 2003) and by salmonids. However, we conclude that because of the large variations in density, slow growth and small maximum size, it is likely that alewife abundance is primarily regulated through density dependent processes, which at times interact with the poor tolerance of low water temperatures. This suggests that additional stocking may be necessary to increase predator demand for alewives. Therefore, we recommend continued stocking of predators at increased rates. Furthermore, because predator demand for alewife prey is poorly understood, we suggest that future monitoring efforts include bioenergetic estimates of predator demand for prey (e.g. Warner, 1998). Such estimates would require an improved understanding of the abundance of alewife predators and any seasonal or spatial patterns in overlap with alewives. We also recommend further monitoring of alewife abundance to determine if the high abundance observed in summer and fall 2002 persists in the form of a strong year class.

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