REPORTS:

An estimation of the density, abundance, biomass and species composition of the Otsego Lake pelagic fish community and zooplankton and alewife phosphorus regeneration

David Warner*, Lars Rudstam**, and W.N. Harman

ABSTRACT

The alewife (Alosa pseudoharengus) is now the dominant fish in Otsego Lake. This study addresses two previously unexamined aspects of the alewife community: abundance and trophic impacts. Although previous monitoring of the pelagic fish community has provided some information concerning the seasonal distribution of alewife, no accurate estimates of abundance have been made. This study, through the use of hydroacoustic technology, trawling, and gill netting, provides this information. Measurements of zooplankton community structure and density allowed estimation of the role these animals play in nutrient cycling. Alewife density in September, 1996 was 6,796 fish/ha. with smelt present at 20.8 fish/ha. Alewife biomass was 51 kg/ha, or 87 metric tons. Fish were concentrated in the upper 12 meters of the water column. Zooplankton density was 77 animals/liter, with rotifers dominating the community. Initial estimates of the phosphorus content for zooplankton and alewives were 58.1 kg and 1538 kg respectively. Volumetric regeneration rates (during stratification) for zooplankton and alewives were 0.19 and 0.084 μg P·L⁻¹·d⁻¹ respectively. These regeneration rates indicate zooplankton and alewives may be important sources of nutrients for phytoplankton.

INTRODUCTION

In approximately ten years the alewife has become the dominant fish species of Otsego Lake. It is believed these fish were illegally introduced in 1986 (Foster, 1989). Of the issues faced by those currently developing a lake management plan, alewife introduction and its trophic impacts are of paramount importance. The changes in Otsego Lake limnology since alewife introduction are detailed by Harman et al. (1997). This study is the first step in a project intended to provide information about the interaction among alewives, zooplankton, and phosphorus cycling in Otsego Lake. To do this it is necessary to first accurately estimate alewife abundance. Additional research will provide information regarding the distribution and abundance of alewives in the lake throughout the summer. Kraft (1993) indicated these factors were influential in determining the role of Lake Michigan alewives in the cycling of phosphorus during the 1970's. Alewives of Otsego Lake behave similarly to those in the Great Lakes and other waters of New York (Smith, 1985; O’Gorman et al., 1991) in that they concentrate in inshore areas shortly after stratification and stay inshore until late July or mid August.

*Graduate student: SUNY Oneonta, Biology Department.
**Senior Research Associate: Cornell University Biological Field Station, Bridgeport, NY.
Concentration of these fish in epilimnetic waters during a period in which primary productivity depends on nutrient regeneration may have the effect of increasing algal production (Brabrand, 1990). Mean zooplankton size has been depressed in other lakes with alewives (O’Gorman et al., 1991; Johannsson and O’Gorman, 1991, Makarewicz et al., 1995). This likely reduces the rate and capacity of grazing by the zooplankton community (Knoechel and Holtby, 1986). In essence, the abundant alewife population is likely having both bottom-up (nutrient regeneration) and top-down (planktivory) impacts on the lake. Phosphorus regenerated by alewives and zooplankton is likely readily available for utilization by phytoplankton. Grazing on zooplankton by alewives has the effect of reducing zooplankton size. This reduction in size may increase the rate of phosphorus regeneration by zooplankton and reduce the grazing efficiency of the zooplankton community. The net result in Otsego lake appears to be a large pool of phosphorus in phytoplankton and fish, with the linkage between the two large pools (zooplankton grazing) operating at low efficiency because of decreased grazing on phytoplankton.

METHODS

Acoustic sampling was conducted following guidelines found in MacLennan and Simmonds (1992) and Brandt (1996). Pelagic fish abundance was estimated using a SIMRAD EY 500 split-beam echo-sounder. The transducer was suspended over the side of the vessel at a depth of 30 cm. Acoustic data was collected at a steady speed along a straight-line south to north transect and a north-to-south transect zig-zag between major shoreline points (Figure 1). This data was stored digitally on a laptop computer, and later analyzed using SIMRAD EP500 echo processing software and a spreadsheet application. Concurrent with acoustic data collection, seven vertically suspended 12 meter gill nets were used to provide an estimate of the proportional abundances of the various pelagic fish species in the lake. As an addition to the gill net collections, fish were collected ten days later using a 3 meter Isaacs-Kidd mid-water trawl towed at 4.5 miles per hour, at depths between the surface and the thermocline (0-15m).

Fish size and biomass data collected from the above netting methods were combined with data obtained throughout the summer of 1996 using a four foot Pennsylvania trap net in order to predict the expected minimum and maximum size of alewives and smelt. Fish were measured to the nearest millimeter (n=839) and a random sample was weighed to the nearest 0.01g (n=317) within one hour of capture.

Proportional abundances of alewives and smelt from the gill net catch were used to differentiate between these two species in the acoustic data. Density and abundance were calculated as follows:

\[ D_s = D_t \cdot P_s \]

where \( D_s \) = species-specific density
\( D_t \) = density of all pelagic fish combined
\( P_s \) = proportion of total fish density of given species, as predicted from species size range data from netting.
Figure 1: Zooplankton sample site (TR4-C) and transects used for September 16th acoustic sampling.
Numeric fish abundance was estimated by multiplying the areal density (fish/ha) of each species by the lake surface area. SIMRAD echo-processing software and a spreadsheet application were used to estimate the relative density and abundance of size classes within species based on target strength (decibels) distribution as calculated with the echo-processing software. Using a general relationship between fish target strength and length, \(TS=20\log_{10}\text{length}_{cm}^{-6}\) (Lindem and Sandlund, 1984) we estimated total alewife biomass by multiplying numerical alewife abundance by the mean alewife weight.

Phosphorus (P) content and regeneration rate by alewives were estimated using methods prescribed by Kraft (1993). Weight-specific regeneration values of 1.7, 0.95, and 0.39 \(\mu\text{g P/mg dry weight}^{-1}\cdot\text{d}^{-1}\) were used for age-0 (young-of-the-year), age-1 and adult age classes respectively. Lake-wide regeneration was calculated by multiplying the rate for individual young-of-the-year (yoy), age 1, and adult fish by the acoustic estimate of lake-wide abundance for each age class. Phosphorus content of the phytoplankton community was estimated based on the assumption that in the absence of detectable SRP, nearly all the P found is in particulate form (Harman et al., 1997). The fraction of water column total phosphorus (TP) pooled in zooplankton on September 5, 1996 was subtracted from the estimated mass of P in the pelagic zone on this same date to estimate the fraction of P pooled in the phytoplankton community.

As part of a bi-weekly sampling program initiated in May 1996, zooplankton were collected on September 5, 1996 from TR4-C, a center-lake location from surface, 4, 8, and 12 meter depths using a 10 liter Vandorn bottle. One liter was collected from each depth and concentrated to a final volume of between 25-40 ml using a 63\(\mu\)m nitex plankton cup. Zooplankton in three one-ml subsamples were identified to species, enumerated, and measured. Phosphorus content of zooplankton was estimated by multiplying the pelagic population by P content for each taxon. Phosphorus content values were taken from Taylor and Lean (1991). Regeneration by zooplankton was estimated by multiplying the lakewide pelagic number of each genus by the regeneration rate of 1.7 \(\text{P/mg dry weight}^{-1}\cdot\text{d}^{-1}\). This rate was established by Scavia (1988) for Lake Michigan zooplankton and was also found in Wetzel (1983) for mixed epilimnetic cladocerans, copepods, and rotifers. Dry weights were based on values from Wetzel and Likens (1991).

RESULTS

Gill net catch consisted of 61, 38, 207, and 2 age 0, age 1, age 2, and age 3 alewives respectively. In addition, 5 golden shiners, 1 rock bass, and 1 smelt were captured. Table 1 contains mean length and weights of fish by gear type. The density of fish that fall in the size range for alewives, smelt, and golden shiners (3 of the species captured in the gill nets) was between 5,400 and 8,500 fish/ha with a mean of 6,951 fish/ha (CI=0.05). The gill net catch was dominated by alewives. The majority of the alewives captured were between 100-120 mm in length. Figure 2 shows the length frequency distribution of alewives captured from June to September 1996. Smelt comprised only 0.3% of the gill net catch and 2.3% of the trawl catch, while golden shiners made up 1.6% of the gill net catch. From the proportions of alewives, smelt,
and golden shiners in the gill nets, this translates to 6,796 alewives, 20.8 smelt, and 111 golden shiners per hectare.

The density of the pelagic zooplankton community was 77 organisms/liter. Rotifers were dominant, especially *Polyarthra vulgaris*. A combination of four species (in descending order of numerical abundance) including *P. vulgaris*, *Keratella cochlearis*, *Kellicottia longispina*, and *Asplanchna priodontus* comprised 65% of the community numerically. The crustacean community was dominated by *Bosmina longirostris*, followed by *Dacyclops bicuspidatus* and *Ceriodaphnia reticulata*. Figure 3 depicts proportional abundances of the various species captured.

Annual phosphorus (P) regeneration by alewives is estimated to be 1.498 kg during the stratification period, or 0.08 μg P·L⁻¹·d⁻¹. The alewife population contains approximately 1.538 kg of phosphorus. The zooplankton population contained 58.1 kg of P and regenerated 3,306 kg during stratification, or 0.19 μg P·L⁻¹·d⁻¹. In comparison, the phytoplankton community contained 1,197 kg of P. Of the P contained in living organisms, 2.0%, 42.9%, and 55.1% was in zooplankton, phytoplankton, and fish respectively (Figure 4).

Table 1: Average lengths and weights for fish captured with different gear types in Otsego Lake from June to September 1996.

<table>
<thead>
<tr>
<th>species</th>
<th>trap net</th>
<th>gill net</th>
<th>trawl</th>
<th>seine</th>
</tr>
</thead>
<tbody>
<tr>
<td>alewife</td>
<td>108 mm, 8.5g</td>
<td>93.9 mm, 7.5g</td>
<td>102 mm, 5.1g</td>
<td>107 mm, 7.5g</td>
</tr>
<tr>
<td>golden shiner</td>
<td>NA</td>
<td>147 mm, 39.3g</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>smelt</td>
<td>NA</td>
<td>95 mm, 3.5g</td>
<td>41 mm, NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**DISCUSSION**

This study has provided new information pertaining to the abundance and composition of the Otsego Lake pelagic fish community. It must be noted that this study is preliminary in some respects. This is the first attempt to estimate the role of Otsego Lake alewives and zooplankton in phosphorus regeneration. As with any study based on acoustic data, absolute description of the composition of the pelagic fish community is difficult because of the overlap in sizes of different species and the uncertainties in target strength relationships. Use of data from gill nets on one date and location for verification of acoustic data does not account for possible spatial variation in fish distribution. Seasonal distribution patterns of the alewife community must be further examined to refine the analysis of their role in phosphorus regeneration. The location of fish (inshore versus offshore) is of vital importance to the impact they have on the lake. The location of fish within the water column may be important as well. The use of published phosphorus content for fish and zooplankton along with Kraft’s (1993) regeneration model likely introduces error because the P content information and model are not specific to Otsego Lake organisms or conditions.
Figure 2: Length-frequency distribution of alewives from Otsego Lake captured with gill nets, trap net, trawl, and seine in 1996.

Figure 3: Proportional abundances of zooplankton species captured on September 5th, 1996 from TR4-C in Otsego Lake
Figure 4: Percentages of phosphorus pooled by living organisms in the pelagic zone (0-12m) of Otsego Lake in September 1996.

Figure 5: Comparison of areal densities of pelagic fish in 3 New York Lakes. Values for Otisco and Cayuta Lakes from Brooking et al. (1995).
Areal densities (figure 5) of alewives in Otsego Lake, Otisco Lake, and Cayuta Lake (Brooking et al., 1995) are 6,951, 1,815, and 8,168, fish/ha respectively. The biomass of pelagic fish in Otsego Lake is approximately 87 metric tons (0.6 g/m³). The 1987 biomass of the Lake Michigan pelagic fish community was 366,900 metric tons (0.15 g/m³) (Argyle, 1992) in a volume of water nearly 13,000 times greater than in Otsego Lake. The biomass of the Otsego Lake pelagic fish community is lower than that found by Brooking et al. (1995) in Cayuta Lake (128 kg/ha) but higher than that found in Otisco Lake (28 kg/ha). The mean length and weight of alewives in Otsego Lake is lower than in Otisco or Cayuta (Figures 6 and 7). Alewives from Otisco and Cayuta were captured in October. Because the sampling in Otsego Lake occurred in September, yoy alewives would be expected to have a lower mean length and weight. The difference in sampling dates should not have as much impact on mean length and weight for adult alewives. Overall it appears that alewife growth in Otsego Lake is slow. Mean lengths for yoy, age 1, age 2 and age 3 alewives were 53, 82, 110, and 139 mm respectively.

The phosphorus regeneration rate for zooplankton during stratification is twice that for alewives. Kraft (1993) found that the quantity of P regenerated by zooplankton in Lake Michigan during the 1970's was similar to the quantity regenerated by alewives. It is possible that the difference in quantities in Otsego Lake is a result of the very low mean size of zooplankton and subsequently higher metabolic rate of these organisms. The zooplankton community composition provides additional significance to the quantity of P regenerated by zooplankton. Otsego Lake is dominated by small rotifers. The absence of large zooplankton can increase algal sedimentation as a result of increased algal standing crop (Taylor, 1984). Our estimate of P regeneration during the stratification period by zooplankton and alewives is more than the annual external phosphorus load estimated by Albright (1996). Consideration should be given to the length of time it would take for regenerated P to equal the quantity pooled by phytoplankton. Based on estimates from this study it would take 32.4 days for P regenerated by zooplankton and alewives to equal the amount contained in phytoplankton. The estimate of the quantity of P contained in the phytoplankton community is probably high because P content of non-living seston was not measured. This over-estimation results in a higher value for the time required to replace algal P content completely. Regeneration rates provided in this paper are estimates and as such serve only as indication that further research is an important step in the right direction. Further refinement of the estimation processes may provide additional information and understanding of the relationship between phytoplankton, zooplankton, alewives, and phosphorus.

ACKNOWLEDGMENTS

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Figure 6: Comparison of mean alewife yoy lengths and weights for 3 New York Lakes. Data for Otisco and Cayuta Lakes from Brooking et al. (1995).

Figure 7: Comparison of mean adult alewife lengths and weights for 3 New York Lakes. Data for Otisco and Cayuta Lakes from Brooking et al. (1995).
REFERENCES


