Comparison of gill raker morphology of alewife from recent and bygone introductions

Daniel Stich¹ and Chase Ducey²

INTRODUCTION

The alewife (*Alosa pseudoharengus*) is an anadromous species of herring native to North America, but along the east coast of the United States, landlocked alewife populations have become well established in inland lakes mostly due to fish stocking. Anadromous adults typically reach 10 to 12 inches in length, whereas adult size in landlocked populations is highly variable but tends to be much smaller (Palkovacs et al. 2007). A high temperature threshold allows them to comfortably live nearly anywhere and helps them survive as they move along streams and rivers to other bodies of water. A reproductive reaction to predation allows them to establish quickly in a new environment, which can sometimes interfere with the pre-existing ecosystem (Gibson and Myers 2003).

Alewives are planktivores, eating large zooplankton and fry (juvenile fish that no longer feed off their own yolk sacs) by filter feeding, which utilizes gill rakers (bony or cartilaginous processes that project off the branchial arch, which supports the gills). As alewife populations grow, competition for food increases, and the abundance of large zooplankton decreases, resulting in the need for alewife to adapt to smaller types of zooplankton. The need to retain smaller food sizes during filter feeding may exert selective pressure on the morphology of gill rakers used in feeding (Palkovacs et al. 2007). Landlocked alewife tend to have more gill rakers that are more closely spaced than fish of similar size in anadromous populations (Palkovacs et al. 2007), and the number and spacing of gill rakers in landlocked population is correlated with prey sizes (Palkovacs and Post 2009). The objective of this study was to determine if and how alewife gill rakers change in either number and/or spacing as part of this adaptive process in two landlocked populations of alewife in New York lakes following different periods of introduction (historical and recent).

METHODS

Alewives were collected from Canadarago Lake (Otsego County, NY) and Truesdale Lake (Westchester County, NY) during June 2016. Alewives from Canadarago Lake were obtained from the NYS DEC Region 4 fisheries gill net survey; fish from Truesdale Lake were netted from the surface following a fish kill (Jenne 2016). Alewife have been present in Canadarago Lake since their illegal introduction in 1999 (Brooking et al. 2012). Alewife were first documented in Truesdale Lake in 2016 (Jenne 2016), though the date of introduction is not known.

All fish were frozen until the day of processing, at which time they were thawed in water until flexible. The length (millimeters) and mass (grams) of each fish was recorded and a scale

---

¹ Assistant Professor of Biology, SUNY Oneonta.
sample taken from the left side prior to dissection. Scale samples were stored in labeled coin envelopes. The left gill arch was removed from each fish using a scalpel or scissors and severed at each end of the arch so that no rakers were left behind. Gill arches were then stored in a vial containing 70% ethanol. The head of each fish was removed, and otoliths were harvested using tweezers and stored in empty vials.

Prior to measurement, gill rakers were transferred to vials containing 1 ml 70% ethanol and 1 ml glycerin for approximately 1 hour. Next, an equal number of vials were filled with 2 ml glycerin for storage until further processing. A photograph was taken of each gill raker using a dissecting microscope with an Infinity 2 camera attachment. This allowed us to count and measure them easily. The number of gill rakers on each arch was counted and standardized by gill arch length, and the spaces between the first gill rakers on the upper and lower gill arch were measured for each fish. The width of the first gill raker on upper and lower arches also were measured, and the length of the gill arch was measured and standardized by fork length for comparison. A standardized measure of gill raker spacing was calculated for each fish (Palkovacs, Post 2008):

$$GRS = \frac{(L - N \cdot W)}{N}$$

where $GRS$ was gill raker spacing, $L$ was the sum of the lengths of the upper and lower gill arches, $W$ was the average of the widths of the first gill rakers on the upper and lower gill arches, and $N$ was the total number of gill rakers on both arches. Length-standardized gill raker counts were calculated by dividing the total number of gill rakers by the total length of gill rakers.
RESULTS

We collected 86 alewives in total from Canadarago Lake (n = 53), and Truesdale Lake (n = 33). Fish from Truesdale Lake were significantly larger than the fish collected from Canadarago Lake (t-test, t = 1.71, df = 33, p < 0.05; Figure 1). Gill arches in fish from Canadarago Lake were 13% longer (95% CI = 7-19% larger) than gill arches of fish from Truesdale Lake when standardized for fork length (t-test, t = 4.38, df = 33, p < 0.05; Figure 1).

Gill raker spacing in alewife from Canadarago (µ = 16.5, S.D = 3.9) and Truesdale (µ = 15.1, S.D = 0.07) lakes was not significantly different at the 95% confidence level (t-test, t = 1.71, df = 33, p = 0.09). However, standardized gill raker count was significantly greater for fish collected from Canadarago Lake than for fish collected from Truesdale Lake (Wilcox test, W = 1298, p < 0.05; Figure 2). Similarly, gill raker width was significantly narrower for fish from Canadarago Lake than fish collected from Truesdale Lake (Wilcox test, W = 264, p < 0.05; Figure 2).

Figure 1. Comparison of fork length (left) and standardized gill arch length (right) of alewife collected from Canadarago (n = 53) and Truesdale (n = 33) lakes during June 2016. Dark lines indicate medians, box ends represent the inner quartile range, and whiskers show 99% confidence interval.
DISCUSSION

This study demonstrated differences in the morphology of the feeding structures of an invasive species following two different timelines for introduction. This work confirms the work of others who have investigated contemporary evolution of gill raker morphology in planktivorous fishes in other locales (Palkovac et al. 2014). While the alewives in Truesdale Lake had only recently been documented (summer 2016), the alewife population in Canadarago Lake has been established for some time. During the time-course of invasion and population growth, the latter population appears to have diverged further morphologically from what might be expected of anadromous populations than has the more recently introduced population in Truesdale Lake.

We observed a marked difference in the size of individuals within each population, with alewife in Truesdale Lake being generally larger than alewife from Canadarago Lake. Similarly, the gill raker count in Canadarago Lake was significantly greater than in fish collected from Truesdale Lake, despite the fact that fish from both lakes had a similar gill raker spacing. This indicates that fish in Canadarago Lake, with a smaller mean size, have adapted morphologically during a contemporary time frame to fit a larger number of gill rakers in to a smaller space through by decreasing the width of individual gill rakers and increasing the proportional size of the gill arch. This finding is strongly suggestive that the fish have adapted to differences in the plankton communities between the lakes, and indicates alternative evolutionary strategies for optimizing feeding morphology compared to previous findings (Palkovac, Post 2008). Future work describing these communities has the potential to confirm or refute this conjecture. Furthermore, few, if any, studies have examined the consequences of the adaptations for the
actual fitness of this species as related to growth, fecundity, or survival. The ability to link documented differences in gill raker morphology to these metrics has the potential to be useful in the management of invasive alewife populations.

REFERENCES


