INTRODUCTION

The ecological make-up of many North American waters has been drastically altered due to the invasive species *Dreissena polymorph*, known commonly as the zebra mussel. Brought in through ballast waters from Europe and Asia, the first recorded *D. polymorph* in North America appeared in Lake St. Clair in 1986 (Hebert et al., 1991). Since then, it has spread throughout the Midwest. *Dreissena polymorph* have many negative effects on native populations of unionids. Zebra mussels require a hard substrate to attach to; they are non-selective in what type, though, and will attach to any unionid (Ludyanskiy et al., 1993). In the upper St. Lawrence River, Ricciardi et al. (1996) found that the combined mass of the attached zebra mussels was significantly heavier than the mass of their host. This burden stresses the unionids in various ways. The zebra mussels may restrict valve movements in the unionids (Schloesser et al., 1994). They also locally minimize available food through competition (MacIsaac, 1996). The weight of them reduces mobility, causing the unionid to sink or become dislodged (Van Appledorn and Bach, 2007). These restrictions lead to the death of most unionids.

In an attempt to combat the hold *D. polymorph* has on the native clam species of Douglas Lake in Cheboygan County, Michigan, USA, residents of the University of Michigan Biological Station have been removing zebra mussels from clams found within the beach waters of South Fishtail Bay-where the station is located-for the past five years (Robert Pillsbury, personal communication). This study was performed to determine whether this practice of "shucking" is helping the native clams in South Fishtail Bay. Past studies have found zebra mussel infestation negatively affects unionid growth (Mackie, 1991). A study done by Burlakova et al. (2000) compared two lakes in North America: Clark Lake and

Vineyard Lake. Clark Lake had a larger infestation of zebra mussels than Vineyard; Clark Lake also had smaller unionids.

This study measured and weighed unionids to determine if shucking has a positive affect on their long-term health. We predicted that unionids in South Fishtail Bay have healthier measurements than those of North Fishtail Bay, which has not experienced any shucking activity. We also identified species in an effort to see if zebra mussels have any preference for one species over another; four species of native clams are found in Douglas Lake: *Anodonta grandis, Lampsilis siliquodea, Ligumia recta,* and *Ligumia naruta* (endangered within the lake) (Heard and Bach, 1966; Donna Hollandsworth, personal communication).

Our goal was to determine whether shucking has had a long-term effect in zebra mussel infestation levels. After being shucked, though, how fast does it take for zebra mussels to colonize a clam? The experimental portion of this study attempted to observe reattachment.

METHODS

The areas surveyed were shallow, sandy beaches extending 3 to 15 meters from shore; beyond that, there is a sharp drop-off into deep water. Figure 1 highlights the beaches surveyed. Surveyors scanned the entire lake floor for all living clams within the survey area. Unionid species were determined by color, size, dimensions and presence or absence of teeth (Heard and Burch, 1966).

Zebra mussels were shucked into a bag and the mass of the unionid was measured in grams using a 500g or 300g spring scale. Length of the clam and the thickness of clam at

its thickest point were measured using manual calipers. Clams were returned to the lake floor and zebra mussels were measured later in a lab using a digital scale.

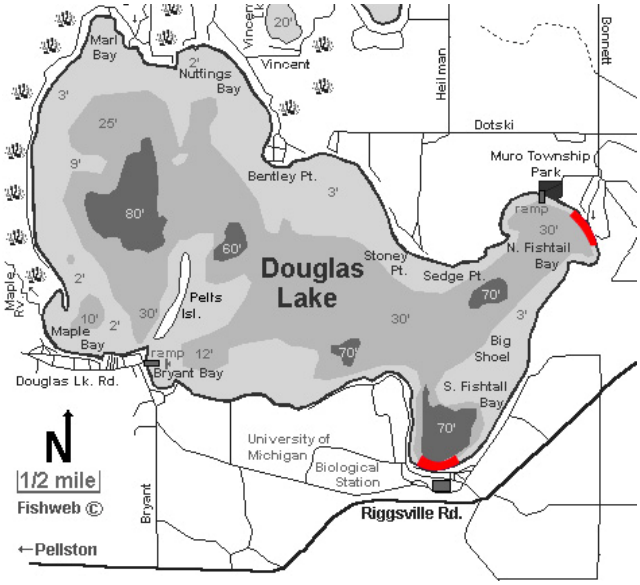

Figure 1: Douglas Lake with surveyed areas highlighted in red.

For the reattachment observation, a pen made of chicken wire was constructed. Placed in the sand of South Fishtail Bay beach, it measured 3 meters by 3 meters. Nine unionids were collected, shucked, individually marked on their shell using a sharpie marker and placed in the pen with uniform spacing between them. Zebra mussels were collected from around the area, 200 g in all which is approximately 4000 zebra mussels (Mackie, 1991), and sprinkled randomly throughout the pen. The number of zebra mussels attached to a clam was counted every other day for 2 weeks.

Data was sorted by species. One-tailed t-tests with equal variances assumed were used to analyze differences in mass, length and zebra mussel mass (per clam) between the two bays. For each variable, the null hypothesis was "there is no difference between the

two bays' measurements". Correlations were run between clam mass and length for the bays. It should be noted that we attempted to collect at a third beach in Maple Bay, but we found only two living clams which was not enough to run statistical analysis on. They are not included in our data.

RESULTS

At South Fishtail Bay, we found 4 *A. grandis*, 20 *L. siliquodea*, 18 *L. recta* and no *L. naruta*. At North Fishtail Bay, we found 3 *A. grandis*, 19 *L. siliquodea*, 12 *L. recta* and no *L. naruta*. Because of the low number of individuals in the species found, *A. grandis and L. naruta* were not included in our statistical analyses. A chi-squared test was run with the null hypothesis of no difference between species proportions between the two beaches. The chi-squared value was 0.5323 (df=2, critical value=5.99). Thus, we failed to reject our null hypothesis.

Lampsilis siliquodea had significantly higher mass ($t=1.69$, $df=37$, $p<0.05$) in South Fishtail Bay ($\bar{x}$= 32.85 g) than in North Fishtail Bay ($\bar{x}$= 22.74 g). The difference between the masses of *L. recta* at South Fishtail ($\bar{x}$=27.56 g) and North Fishtail ($\bar{x}$=26.08 g) were not statistically significant ($t=0.18$, $df=28$, $p=0.43$). Length differences between the two bays ($\bar{x}_{South}$=5.89 cm, $\bar{x}_{North}$=5.49 cm) for *L. siliquodea* was not significant ($t=0.98$, $df=36$, $p=0.18$), nor were they significant for *L. recta* ($\bar{x}_{South}$=6.65 cm, $\bar{x}_{North}$=6.51 cm, $t=0.31$, $df=28$, $p=0.38$). *Lampsilis siliquodea* had significantly less zebra mussel mass attached ($t=-2.58$, $df=36$, $p=0.007$) at South Fishtail ($\bar{x}$=16.85 g) than North Fishtail ($\bar{x}$=36.64 g). *Ligumia recta* also had significantly less zebra mussel mass attached ($t=-1.90$, $df=28$, $p=0.03$) at South Fishtail ($\bar{x}$=17.89) than North Fishtail ($\bar{x}$=39.97).

We plotted length over mass to better understand this relationship. We ran an exponential regression for the species (Table 1 and 2). The plot for *L. siliquodea* shows the significance we found in our t-test in the difference in the regression line slopes. We chose to report our findings using exponential regression because the data fit an exponential trend more than a linear one. The regressions for *L. recta* can be concluded not significant by realizing that both length and mass were shown through the t-tests to be not significantly different for the species between the two bays. Because both the x and y variable were not significant, the trend line of the two variables plotted could not be, either.

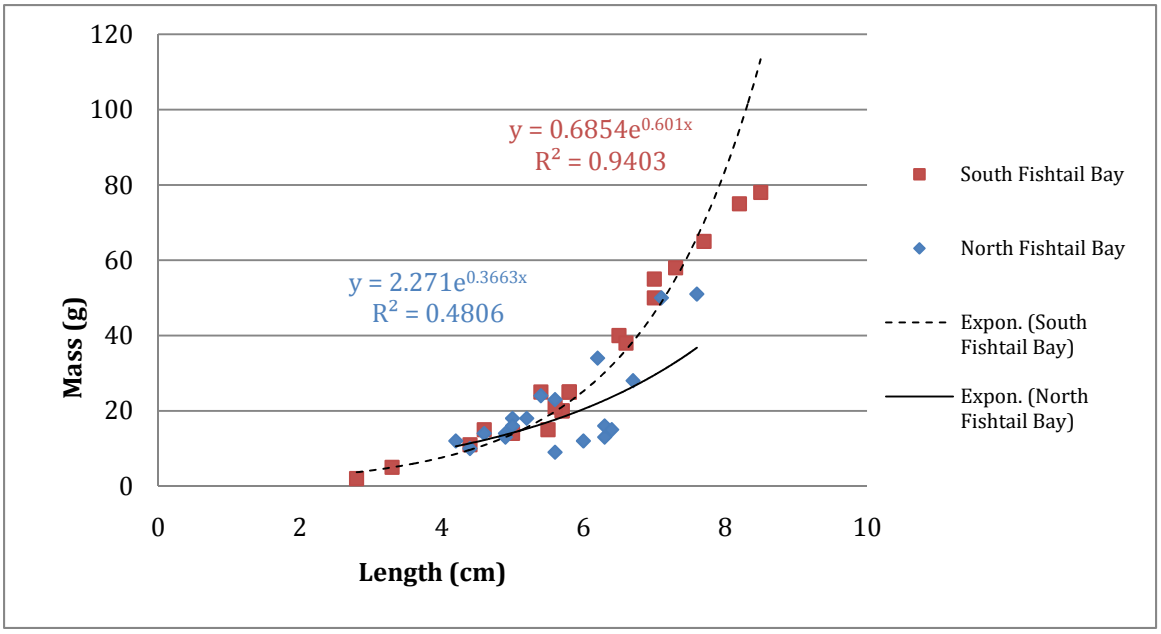

Figure 1: Correlation between length and mass of *L. siliquoidea* in S. Fishtail Bay and N. Fishtail Bay

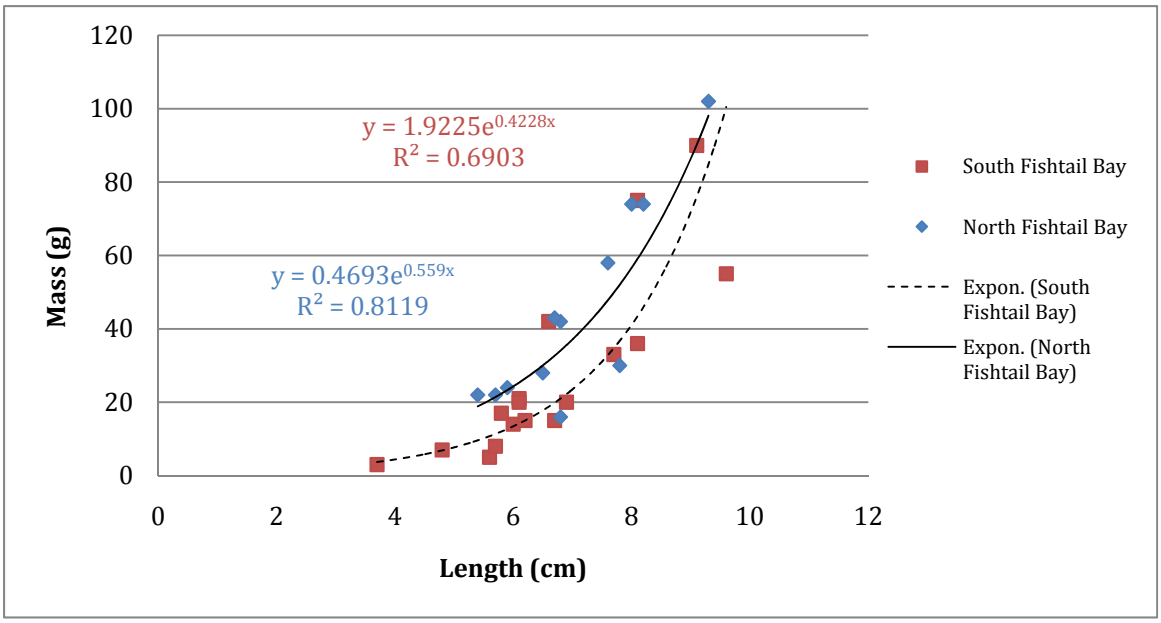

Figure 2: Correlation between length and mass of *L. recta* in S. Fishtail Bay and N. Fishtail Bay

We averaged the number of zebra mussels attached per day to each clam in our pen and plotted a time graph (Table 3). The trend shows that after 2 weeks, clams have on average 6 zebra mussels reattached to them. We observed that the zebra mussels attached to the clams were young and freshly formed mussels just out of their larval stage; none of the clams had the older zebra mussels that were sprinkled into the pen attached to them.

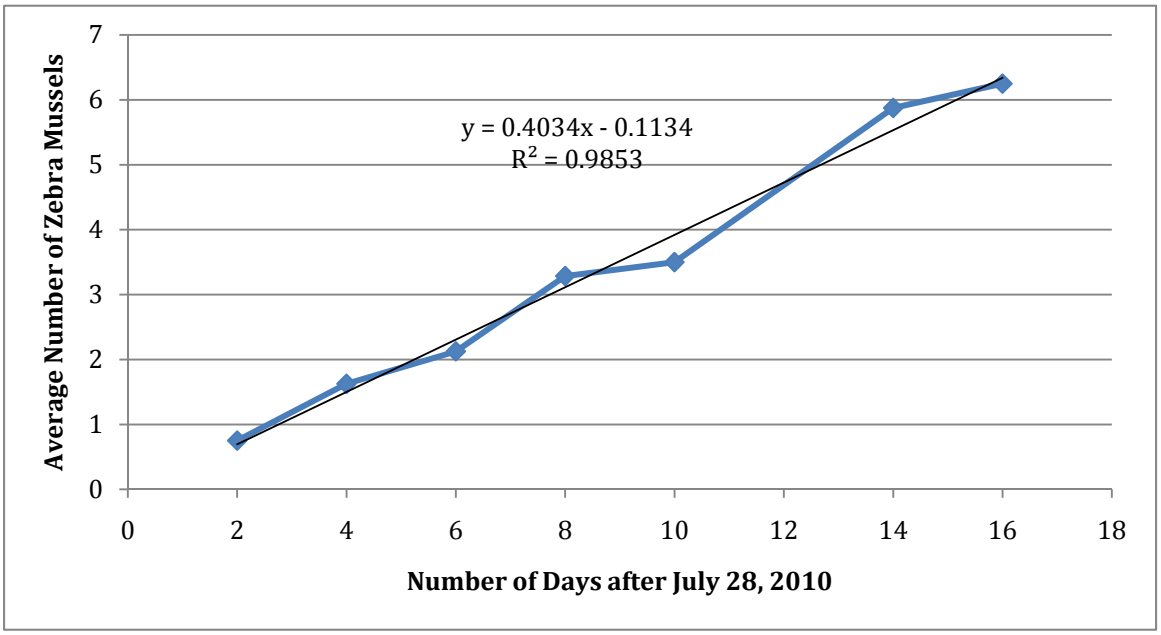

Figure 3: Average number of zebra mussel reattachment over time.

DISCUSSION

Due to their endangered status, the lack of any *L. naruta* was not surprising. The lack of *A. grandis*, though, is alarming. In one day in 2005, 45 *A. grandis* were collected from Douglas Lake (Van Appledorn, 2007). The drop in numbers within 5 years is warrant for worry over the state of this species.

The chi-squared test assured the validity of using the two beaches as equal testing sites. The null hypothesis was not rejected; their species composition is similar enough to assume that their substrate and environments are similar. If they were different, this study's findings would be nullified; there is no sense in comparing the clams of two different beaches because their difference would most likely be due to differing variables and not just difference in shucking history.

The combination of a significant difference in mass but not a significant difference in length for *L. sililquodea* calls for an interpretation. It means a clam in South Fishtail Bay that is of the same length as one in North Fishtail Bay has a greater reserve of animal tissue within. The southern clam is healthier than its northern counterpart. We have two ideas for why there was no difference in mass or length of *L. recta*. Either shucking has no effect on the health of *L. recta* or zebra mussels have no effect on them.

The difference in zebra mussel mass shows that the fairly constant shucking in South Fishtail Bay prevents severe build-up. This ties in to what we found with the recolonization portion of the study. If the rate were extrapolated, it would take 3 to 4 months to amass enough zebra mussels to affect movement and feeding. If shucking is

continued, clams are provided a time in which they can work at full productivity, hopefully ensuring their survival and allowing successful reproduction within this time. If shucking allows at least a few clams to reproduce, the clam population could be maintained. Within a six-week period in August, *Actinonaias ligamentina*, a unionid, were found to expel 80,616 to 1,561,224 eggs and larvae per clam (Moles and Layzer, 2008). Such high fecundity levels per individual ensure a good continuation of progeny.

We suggest the continuation of the shucking practice at the University of Michigan Biological Station to help maintain clam populations and to serve as a model for other lakes. We highly recommend shucking in other lakes where humans often populate sandy beaches. Local organizations could post signs asking visitors to shuck any clam they find during their recreational activities. By including locals and laymen, we may still save our clams from the damaging effects of the zebra mussel infestation.

ACKNOWLEDGEMENTS

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