An evaluation of a possible technique for mitigating unionid mollusks mortality caused by zebra mussels: a case study in Douglas Lake, MI

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Abstract

Zebra mussels (*Dreissena polymorpha*) have had consider ecological effects on many lakes of the Great Lakes Region, including Douglas Lake (Northern Lower Peninsula in Michigan, USA). People inhabiting the University of Michigan Biological Station of Pellston, MI, during the summer have been cleaning clams along the shores of South Fishtail Bay for five years when the opportunity arises. This study examined whether clams along South Fishtail Bay were healthier than clams from other parts of the lake, possibly because people clean these clams regularly. Clams from South and North Fishtail Bays were surveyed. The species, length, thickness, mass, and percent coverage by zebra mussels were determined for each clam found. The weight of zebra mussels attached to each clam was also determined. A 1-tailed T-test was used to analyze whether populations of clams differed in mass, length, or the mass of mussels each clam carried. The *Lampsilis siliquoidea* from South Fishtail Bay were significantly larger than those from North Fishtail Bay, but this was not the case for *Ligumia recta*. The lengths of both species were not significantly different between the two bays. Clams from South Fishtail Bay of both species had significantly fewer zebra mussels on them compared to clams from North Fishtail Bay. Results support the hypothesis that South Fishtail Bay has healthier clams than North Fishtail Bay. Clams from South Fishtail Bay are heavier compared to clams from North Fishtail Bay of comparable length. People cleaning the clams may contribute to this observed difference in masses, since clams are regularly cleaned on South Fishtail Bay in the summer and not so in North Fishtail Bay.

Introduction

Since their arrival into North America, zebra mussels (*Dreissena polymorpha*) have caused a great deal of both economical and ecological disturbance. Zebra mussels are an invasive species originating from the Black and Caspian Seas and were first introduced into Lake St. Clair of the Great Lakes region, most probably due to larvae in the ballast water of ships emptying into the lake (Bronmark and Hansson 2005). These zebra mussels have greatly expanded in range and magnitude since their introduction and, as a result, have had a great impact on many native species in North American lakes; particularly the unionid clams.

Populations of many clam species native to the Great Lakes region have been greatly reduced or even extirpated ever since the introduction of zebra mussels (Schloesser et al. 1997). Zebra mussels need hard surfaces to latch onto with their byssal threads (Bronmark and Hansson 2005) in order to survive. Thus, one of the primary ways that zebra mussels interfere with unionid clams is by direct fouling, whereby the zebra mussel latches onto the shell of the unionid (Strayer 1999). This causes a series of problems for the clams because the position and placement of the zebra mussel on the shell of the clam may limit or interfere with valve movements of the mollusk if zebra mussels are placed between the valves of the clam (Mackie 1991; Schloesser et al. 1996). This would result in the inability of the unionid to properly attain food, reproduce, respire, and excrete; it also exposes the clam to predators, parasites, and disease (Mackie 1991; Strayer 1999).

The added mass of the zebra mussels attached to the unionid shell also interferes with the ability of the clam to survive. One study found clams that carried their own mass in zebra mussels (or greater), not necessarily clams that carried greater numbers of zebra mussels, would eventually become extirpated (Ricciardi et al. 1996). This added weight of the zebra mussels may contribute to the immobility of the clam. It may also cause the clam to remain dislodged, thereby allowing the clam to only lie flat on the lake ground and become smothered by the sediment of the lake. Thus, this added weight contributes to mortality of clams by preventing them from performing the tasks they needs to survive (Schloesser et al. 1996).

The ideal solution for alleviating this disturbance to unionid clams by zebra mussels would be to completely eliminate zebra mussels. However, as Strayer (1999) suggests, there currently is not any feasible way of controlling zebra mussel populations in large habitats. Strayer (1999) speculated that zebra mussel populations sharply decline following an initial outbreak. Therefore if unionids could be temporarily protected during the initial outbreak, it would be possible for unionids to later coexist with zebra mussels. One study has shown that unionids can coexist with zebra mussels in a natural refugia, as could be seen by the lower unionid mortality rates in nearshore areas versus higher unionid mortality in deep water areas of the same study area (Schloesser et al. 1997).

One possible method of temporary protection of unionids from zebra mussels would be to clean zebra mussels from unionid shells. Shloesser (1996) determined in his brief yearlong study that fairly regular cleaning could successfully reduce mortality of unionids. His study found that 42% of the cleaned clams survived after that year, whereas none of the uncleaned clams survived.

In the present study, clam health was examined in various locations along Douglas Lake in Pellston, MI. In Douglas Lake, four different species of clams are present: *Anodonta grandis*, *Lamsilis siliquoidea*, *Ligumia recta*, and *Ligumia naruto*. Since 2005, people at the University of Michigan Biological Station have been cleaning zebra mussels from clams that they have encountered along the shores of South Fishtail Bay, whereas other shores of Douglas Lake are not as heavily populated and do not receive this sort of treatment regularly. The purpose of this study is to examine whether the consistent cleaning of native clams by inhabitants of this camp influences the health of the clams along South Fishtail Bay. This study also examined the rate of zebra mussel reattachment to a clam after the clam has been cleaned. Based upon the results that Schloesser (1996) found, it would be expected that clams found along South Fishtail Bay along the University of Michigan Biological Station might be healthier than clams found along other shores of Douglas Bay where people are not regularly cleaning clams.

Methods

Clams were surveyed on North and South Fishtail Bays of Douglas Lake (Figure 1). On South Fishtail Bay, the survey began from the east side of the Lakeside Lab dock and extended to the last faculty cabin. Around 200 people inhabit South Fishtail Bay in the summers. Each year, people are advised to clean clams when the opportunity arises. People do not visit North Fishtail Bay as regularly and therefore it is unlikely that clams from this bay are cleaned as often as clams from South Fishtail Bay. Otherwise, the aquatic habitats along the shore of North and South Fishtail Bays have a similar amount of coverage surrounding the shore area. Neither of the two shores are frequently passed through by a large number of motorboats nor substantially polluted.

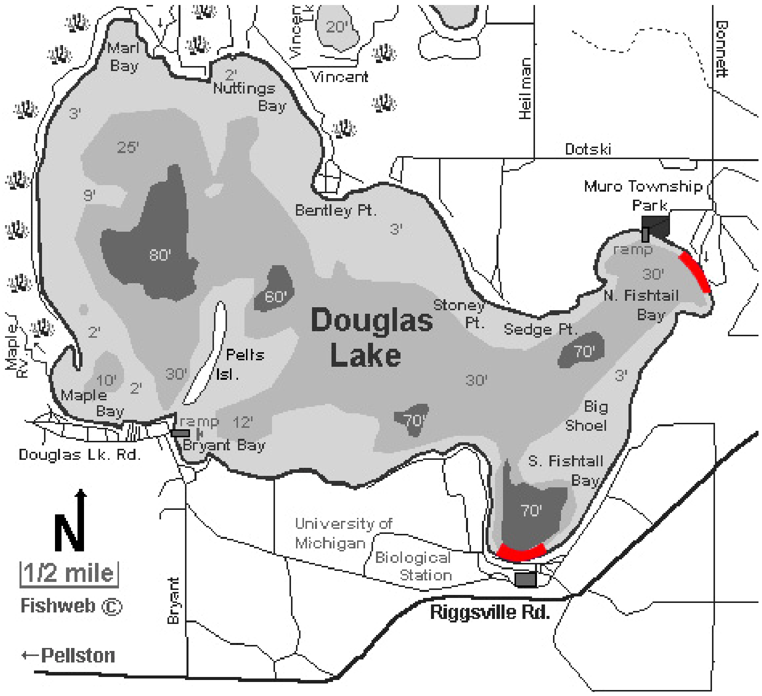

Figure 1: Map of Douglas Lake with surveyed areas marked in red.

Beginning from mid July till mid August of 2010, all living clams along North and South Fishtail Bay were collected, regardless of whether they had zebra mussels on them or not. First, the species of the clam was identified using the guidelines stated by Burch (1975) as well as Heard and Burch (1966). Then, the percent coverage by zebra mussels was visually determined for the clams. Once these were determined, the zebra mussels were cleaned from the shell of the clam and placed into a plastic Ziploc sandwich bag. The plastic bag was labeled so it could later be recalled which clam the zebra mussels were cleaned from. The mass of the clam without the zebra mussels was then measured in grams (g) using a 300 g spring scale. The length (longest end of the clam) and thickness of each clam was also measured in centimeters (cm) using a plastic caliper. The mass of the zebra mussels that came from each individual clam was later determined using a digital scientific balance. Health in this study was quantified by measuring mass as a result of length of the clam.

In order to evaluate rate of reattachment of zebra mussels to a clam after the clam has been cleaned, a pen was constructed to observe the rate of reattachment. The 3-meter by 3-meter square pen was constructed on July 28, 2010 using four wooden stakes and chicken wire on a nearshore area west of the Lakeside Lab dock along South Fishtail Bay that not part of the survey area. Six *L. siliquoidea* and three *L. recta*, which were collected on South Fishtail Bay after the survey was conducted, were placed into the pen roughly evenly spaced apart from each other. Next, 200 grams of zebra mussels, which is roughly 600 individuals, were collected from South Fishtail Bay and scattered randomly within the pen. Zebra mussels were scattered within the pen because the amount of time it takes for zebra mussels to reattach to clams is not known; so adding zebra mussels to the pen may allow for zebra mussels to readily reattach. Then, for the next two weeks, the percent coverage of each clam was measured. The number of zebra mussels attached to each clam was also determined.

The species composition differences between North and South Fishtail Bays were reviewed using a chi-square test. Data from the surveys on both North and South Fishtail Bays were compared to one another based on category (i.e. mass, length, thickness, percent coverage, mass of zebra mussels attached to clams) using a 1-tailed T-test. The null hypothesis of this study was that the population of clams on South Fishtail Bay would be of equal or lesser size than clams on North Fishtail Bay. The alternate hypothesis was that the clams on South Fishtail Bay were larger than clams on

North Fishtail Bay. Relationships between length and mass were also determined for each species of clam found. For the zebra mussel reattachment data, the progress and change in percent coverage was also qualitatively evaluated.

Results

On the shores of both North and South Fishtail Bays, three species of clams were found: *Anodonta grandis*, *Lampsilis siliquoidea*, and *Ligumia recta*. The proportions of each clam found in the South Fishtail Bay population were not significantly different from the North Fishtail Bay clam population (chi-square=0.532290865; df=2; critical value= 5.99, $p>0.05$). Similar proportions of each type of species of clam were found in both North and South Fishtail Bays. The sample size of *A. grandis* was too small ($n=7$) to perform statistical analysis.

No significant difference in mass was found between *L. recta* of North and South Fishtail Bays. However, the *L. siliquoidea* collected on South Fishtail Bay were significantly larger in mass compared to those found on North Fishtail Bay (Table 1). In both species, the length of the shell did not significantly differ between the clams of North and South Fishtail Bays (Table 2).

Table 1: Differences in mass (g) of clams between North and South Fishtail Bays

	Lampsilis siliquoidea		Ligumia recta	
	South Fishtail Bay	*North Fishtail Bay*	*South Fishtail Bay*	*North Fishtail Bay*
Number	20	19	18	12
Mean	32.85	22.73684211	27.55555556	26.08333333
Variance	536.6605263	149.871345	585.5555556	329.3560606
Observations	20	19	18	12
Pooled Variance	348.4928165		484.905754	
Hypothesized Mean Difference	0		0	
df	37		28	
t Stat	1.691022427		0.179395254	
P(T<=t) one-tail	0.049620396		0.42945963	
t Critical one-tail	1.687093597		1.701130908	
P(T<=t) two-tail	0.099240793		0.858919259	
t Critical two-tail	2.026192447		2.048407115	

Table 2: Difference in length (cm) of clams between North and South Fishtail Bays

	Lampsilis siliquoidea		Ligumia recta	
	South Fishtail Bay	*North Fishtail Bay*	*South Fishtail Bay*	*North Fishtail Bay*
Number	20	19	18	12
Mean	5.889473684	5.489473684	6.65	6.508333333
Variance	2.326549708	0.865438596	2.130882353	0.59719697
Observations	19	19	18	12
Pooled Variance	1.595994152		1.528363095	
Hypothesized Mean Difference	0		0	
df	36		28	
t Stat	0.975901861		0.307482676	
P(T<=t) one-tail	0.167812818		0.38037575	
t Critical one-tail	1.688297694		1.701130908	
P(T<=t) two-tail	0.335625635		0.760751501	
t Critical two-tail	2.028093987		2.048407115	

Mass of a clam was exponentially related to its length for both species. Exponential regressions were used rather than linear because the R^2 values were greater using exponential regressions than linear regressions for all trendlines. The mass of *L. siliquoidea* was increasing at a greater rate as length increased in South Fishtail Bay compared to in North Fishtail Bay (Figure 2). Especially in larger clams, *L. siliquoidea* from South Fishtail Bay tended to weigh more than *L. siliquoidea* of comparable length in North Fishtail Bay. For *L. recta*, the mass of clams was increasing at a similar rate as length increased in South and North Fishtail Bays (Figure 3). The three *L. recta* clams with the longest shells were found in South Fishtail Bay.

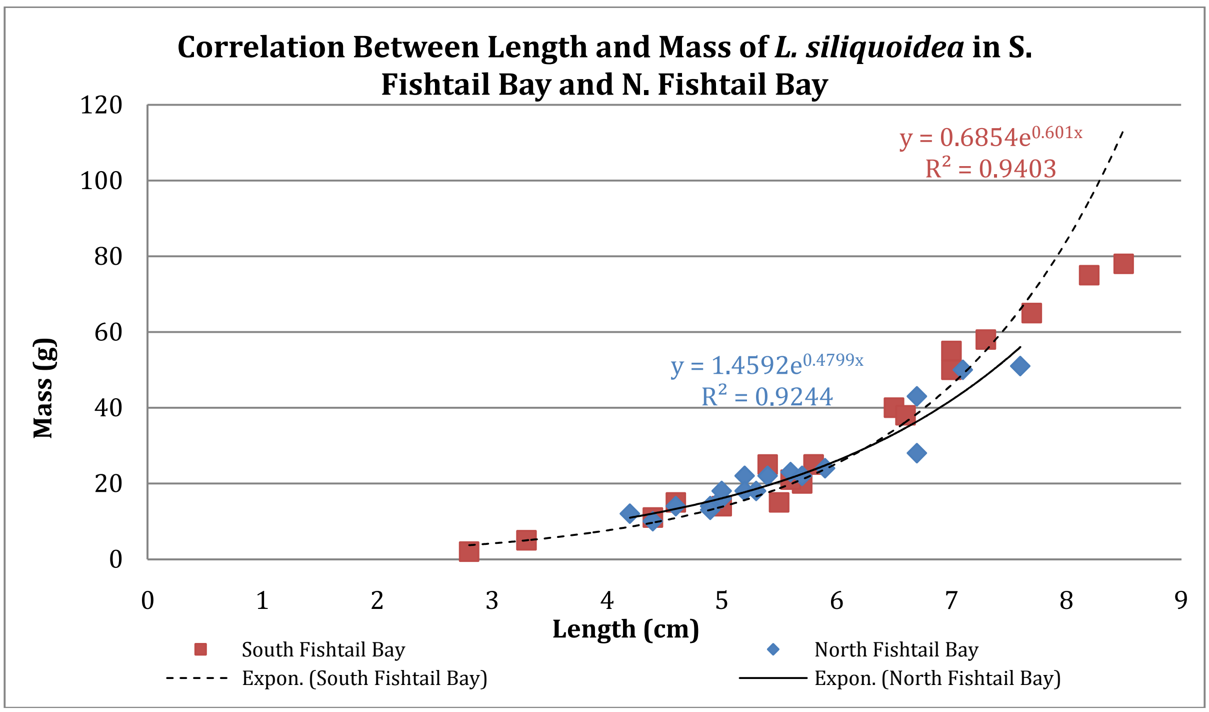

Figure 2: Mass (g) as a result of length (cm) in L. siliquoidea from North and South Fishtail Bays. Exponential regressions are shown.

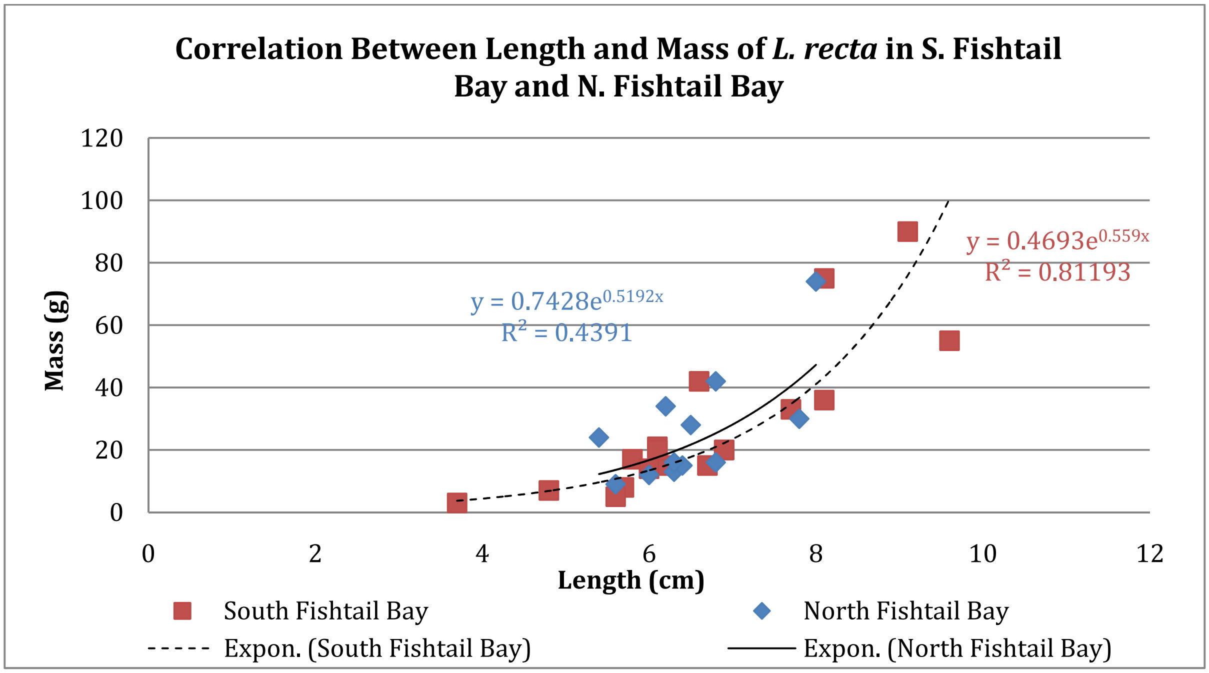

Figure 3: Mass (g) as a result of Length (cm) in L. recta from North and South Fishtail Bays. Exponential regressions are shown.

The mass of zebra mussels found on clams in North Fishtail Bay was significantly greater than the mass of zebra mussels found on clams from South Fishtail Bay for both *L. siliquoidea* and *L. recta* (Table 3).

Table 3: Difference in the mass (g) of zebra mussels carried by clams between North and South Fishtail Bays

	Lampsilis siliquoidea		**Ligumia recta**	
	South Fishtail Bay	*North Fishtail Bay*	*South Fishtail Bay*	*North Fishtail Bay*
Number	20	19	18	12
Mean	16.845	36.63555556	17.89111111	39.9675
Variance	87.85826842	1079.595414	320.359281	1977.777257
Observations	20	18	18	12
Pooled Variance	556.1785873		971.4877715	
Hypothesized Mean Difference	0		0	
df	36		28	
t Stat	-2.582916137		-1.900533875	
P(T<=t) one-tail	0.007003734		0.033851982	
t Critical one-tail	1.688297694		1.701130908	
P(T<=t) two-tail	0.014007468		0.067703964	
t Critical two-tail	2.028093987		2.048407115	

Zebra mussels colonized on clams at an average rate of about 0.4 zebra mussels per day (Figure 4). Based upon qualitative observation, the zebra mussels that attached to the shells of clam tended to be very small (roughly 5-10 millimeters in length). These are possibly younger zebra mussels. It did not appear that zebra mussels placed in the pen reattached to the clams, since most of the mussels dispersed in the pen appeared larger.

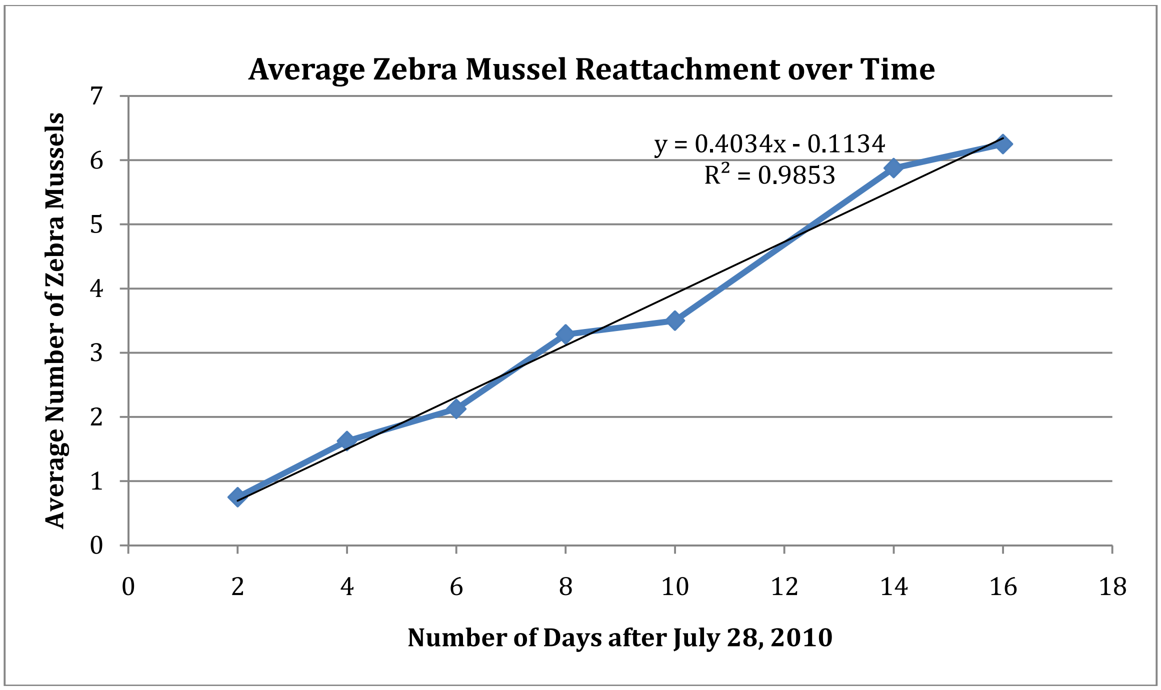

Figure 4: Number of zebra mussels colonizing on native clams to Douglas Lake over time. Trendline represents the average attachment rate of zebra mussels.

Discussion

Data from this study supported predictions based on the original hypothesis that clams from South Fishtail Bay may be healthier than those found on North Fishtail Bay. *L. siliquoidea* from North Fishtail bay tended to weigh less than those of comparable shell sizes on South Fishtail Bay, where University of Michigan Biological Station residents were known to regularly clean zebra mussels from clams during the summer. Thus, the *L. siliquoidea* that were cleaned displayed healthier characteristics compared to clams that had a lesser likelihood of being cleaned. This data was also consistent with the results found by Schloesser (1996), that clams which were cleaned more regularly were healthier than clams that were not cleaned as regularly.

The differences in mass between the two populations of *L. siliquoidea* may be attributed to different levels of glycogen content, which are the primary source of energy storage (Haag et al., 1993). Significant reductions in these stores could critically effect the ability of native unionids to reproduce and survive; zebra mussel encrustation on shells is one source of stress that is known to deplete glycogen energy stores of unionid clams (Haag et al., 1993). In order to sustain the burden of zebra mussels, clams must use the energy available in glycogen stores.

Results from this study were also consistent with the hypothesis that zebra mussels negatively influence health of clams. Both *L. siliquoidea* and *L. recta* from North Fishtail Bay were encrusted with greater masses of zebra mussels compared to clams found on South Fishtail Bay. Therefore, unionid clams from North Fishtail Bay need to expend more energy in order to sustain this greater mass of zebra mussels. This may be a reason why *L. siliquoidea* from North Fishtail Bay were significantly lighter. On the other hand, *L. siliquoidea* from South Fishtail Bay could invest more energy into survival and reproduction because these clams may have greater amounts of glycogen stores. Thus *L. siliquoidea* from South Fishtail Bay would be more fit.

The masses of *L. recta* were not significantly different between the two bays, even though there were significantly more zebra mussels on *L. recta* of North Fishtail Bay. This indicates that mass of *L. recta* may be less sensitive to the presence of zebra mussels compared to *L. siliquoidea*. One study found that mortality was higher in clams of the Lampsilinae subfamily compared to other clams within the same lake because Lampsiline shells were much lighter and therefore changes to the center of gravity caused by zebra mussels make it more difficult and energetically expensive to maintain proper positioning in the sediment (Haag et al. 1993). Shell morphology of *L. recta* may be more withstanding than that of the more sensitive *L. siliquoidea*, thus allowing the L. recta to expend less energy when zebra mussels are encrusted upon its shell.

Assuming that cleaning the clams on South Fishtail Bay contributes to the health of the clam, it is also possible that L. recta may not differ significantly in mass between the two bays because people easily overlook them. *L. recta* have long and thin dark brown shells, which could be less conspicuous than the *L. siliquoidea* with lighter and more rotund shells. Thus, if *L. recta* were positioned in the sediment to look more like a twig in the water rather than a clam, *L. recta* could easily missed by people and therefore would be cleaned less frequently. An in depth study of the morphological advantages of L. recta shells would need to be pursued in order to determine if this is a viable explanation.

Habitat differences sometimes may account for differences observed in data, such as the differences in average mass observed between clams of North and South Fishtail Bay. However, because the habitats of South and North Fishtail Bays were comparable enough to support a similar proportion of clam species, the differences in habitat may not have been significant enough to cause the difference in mass of clams between the two bays. One aspect that was markedly different in South Fishtail bay was the presence of people who consistently cleaned the clams when clams were encountered. Considering the results Schloesser (1996) found, it is possible that the cleaning of these clams may positively influence the health of clams.

This study found that even after ridding the clams of zebra mussels, zebra mussels still recolonized on the shells of clams rather quickly. Some zebra mussels appeared on clamshells in as little as two days. This quick regeneration time may be due to the high fecundity of zebra mussels (Mackie 1991). Although results showed that cleaning the clams does not permanently alleviate them from the burden of zebra mussels, clams may still receive some benefit from being cleaned. Cleaning the zebra mussels from the shells of clams could temporarily relieve clams from the burden of carrying zebra mussels, allowing them to rebuild energy stores more easily than clams that do not receive any temporary relief from zebra mussels.

The cleaning of zebra mussels from clams along the shores of Douglas Lake may benefit the health of the native unionids by providing more opportunities to build up glycogen energy stores necessary for survival and reproduction. Populations of clams on North and South Fishtail bays should continue to be surveyed in order to see if trends observed in this study continue. If long clams from South Fishtail Bay continue to have consistently greater masses than clams from North Fishtail Bay with comparable length, this may suggest that people at the University of Michigan Biological Station cleaning clams does have a positive impact on native clam populations. In addition, if the masses of clams continue to grow over time, this may suggest that clam populations may successfully survive and reproduce even in the presence of zebra mussels.

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