Silence of the clams: The effect of *Driessena polymorpha* (zebra mussels) removal and the health of Douglas Lake Unionidae

Judy Jinn

University of Michigan Biological Station
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Professor Pillsbury

Abstract

Dreissena polymorpa (zebra mussels) are a concern in many waterways throughout the United States. They have begun to choke out native fauna such as clam species in the Great Lakes Region. This study researched the effects of continuous removal of *D. polymorpha* from shells of native unionid species, *Anodonta grandis* (giant floaters), *Lampsilis siliquoidea* (fatmucket clams), *Ligumia recta* (black sand mussel), and *Ligumia nasuta* (eastern pondmussels) in North and South Fishtail Bay of Douglas Lake (Pellston Michigan, USA). It also examined the rate of *D. polymorpha* attachment to clean unionids. Routinely cleaned *L. siliquoidea* had significantly higher mass (p=.0496), but not longer shells (p=.168). Routinely cleaned and uncleaned *L.recta* had no difference in length or mass (p=.429 and p=.307). The mass of *L. siliquoidea* and *L. recta* was correlated with the length of their shells in both routinely cleaned and uncleaned areas. *Dreissena polymorpha* were found to attach to unionids at a rate of six new individuals per unionid every two weeks. Cleaning native unionids appears to have a significant effect on the health of *L. siliquoidea*, but not on *L. recta.*

Key words: *Dreissena polymorpa, Lampsilis siliquoidea, Anodonta grandis, Ligumia nasuta, Ligumia recta*,health, attachment

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Introduction

Introduction of *Dreissena polymorpha* (zebra mussels) during the late 1980s to the Great Lakes region in the past has been catastrophic (Nalepa *et al.* 2009). Invasive species such as *D. polymorpha* are responsible for the extinction and endangerment of native species (Dextrase & Mandrak 2005). Their rapid rate of reproduction shifted the ecosystem, displaced original benthic organisms, and changed predatory behavior (Beekey *et al.* 2004).

A single *D. polymorpha* can spawn up to 6 million eggs a year (Ram *et al.* 1996). The plankton stage then travels quickly to new areas through estuaries and by attaching to boats and boat trailers (Johnson *et al.* 2001). Recreational boat use spread *D. polymorpha* populations to most waterways within a decade of its initial discovery (Johnson *et al.* 2001).The planktonic form attaches itself to any hard substrate in the water including boats, docks, other mollusks, other unionids, and even other zebra mussels (Herbert *et al.* 1991). Within a year, *D. polymorpha* can reach sexual maturity and begin to spawn again (Ackerman *et al.* 1994).

Dreissena polymorpha were soon discovered in Douglas Lake (Pellston, Michigan, USA). The University of Michigan Biological Station situated on South Fishtail Beach began researching the invaders and their effects on local fauna. Douglas Lake's shorelines are mostly comprised of soft sediments, restricting where adult *D. polymorpha* can attach (Stoermer 1977). This forced *D. polymorpha* to encrust pebbles in shallow waters, logs, and even plants. The native species of unionids (clams) quickly became encrusted with *D. polymorpha* where they are not buried beneath the sand. At times, they were so infested that the entire unionid had become surrounded by *D. polymorpha* and the unionid was unable to close its shell. Residents of the Biological Station began removing *D. polymorpa* in 2005 from unionids living in the station's beach in an attempt to save the native species (Pillsbury, personal communication).

Douglas Lake had four native species of unionids, *Anodonta grandis* (giant floaters), *Lampsilis siliquoidea* (fatmucket clams), *Ligumia recta* (black sand mussel), and *Ligumia nasuta* (eastern pondmussels). All four species have a parasitic larva stage which use fish as hosts before metamorphosis to their adult stage (Arey 1921, Tucker 1928, Khym & Layzer 2000, Wolfe 2007). Adult unionids bury themselves in shallow, sandy waters to filter feed.

Dreissena polymorpha crowding on unionids may impede filter feeding, reproduction, and movement (Appledorn & Bach 2007). They often crowd onto native unionids until they block the siphon which is used for feeding, killing it. Unionids also slowly move and dig using a powerful foot. A heavy infestation of *D. polymorpha* can also spread laterally across the sand surrounding a unionid "cementing" it in place. *Dressena polymorpha* also have the ability to slowly pry a unionid from the sand if enough alsoattach to surrounding hard substrates. This leaves the unionid exposed on top of the sand and vulnerable to changing water levels and predators (Riccardi *et al.* 1995).

This study explored the effect of removing *D. polymorpha* from the four species at Douglas Lake. Unionids in North Fishtail Bay, not subject to constant *D. polymorpha* removal, were predicted to be smaller than the unionids by station grounds. The study also found data on the speed in which *D. polymorpha* attached to unionids which had been cleaned.

Materials and Methods

The University of Michigan Biological station was located in Pellston, Michigan, USA. Living unionids were collected in the waters of the main camp grounds in South Fish Tail Bay from the boat house docks to the last cabin at the edge of the residential area (Figure 1). They were collected from shore to the steep drop off (shown in figure 1 as 70' and 30').The area was three feet at the deepest point, clear, sandy, and devoid of vegetation. Unionids found in South Fishtail Bay were compared to those found in the beach of North Fish Tail Bay at Camp Knight where *D. polymorpha* are not actively removed from unionids (see figure 1). The shallow areas of North Fishtail Bay extended about twice as far as the area in South Fishtail Bay. The waters were three feet at the deepest point, clear, and had a patch of reeds (~20 sq. m) in the middle of the sample area.

Unionids collected were assigned a spreadsheet number for organizational purposes. *Dreissena polymorpha* were removed and placed into whirl-paks labeled, using a pen, with their corresponding unionid number. Each bag of *D. polymorpha* was massed using a digital scale after unionid collection was completed. Cleaned unionids were placed into a small plastic bag and weighed using a 0-500g spring scale. Calipers were used to measure the longest distance from anterior to posterior end. The species was identified before replacing the unionid into the same area it was found. Data were put into Microsoft Excel and analyzed to find any significant differences between unionids in South Fishtail Bay and North Fishtail Bay. Each species of unionid was analyzed separately. One-tailed t-tests were performed with the null hypothesis that unionids in South Fishtail Bay would have the same or lower mass than North Fishtail Bay's unionids. Alternatively, unionids in South Fishtail Bay would have larger mass than unionids in North Fishtail Bay.

The study also examined the rate of *D. polymorpha* attachment to unionids. On the west side of the boat docks at the Biological Station a 3mx3m pen was made. Chicken wire with holes large enough that *D. polymorpha* could enter or exit, but native unionids could not was used. In the surrounding area, 9 unionids were collected, six *L. siliquoidea* and three *L. recta*. The *D. polymorphao* were removed from each unionid. Unionids were then assigned a letter, written on its shell using a Sharpie marker. Unionids were placed into the pen starting July28 within their own 1m square. 200g of zebra mussels which were not attached to any substrate or each other, were then scattered within the pen. Every two days for two weeks, the number of *D. polymorpha* on the shell of each unoinid was recorded. This data was also put into Microsoft Excel and a correlation was used to determine the speed of reattachment.

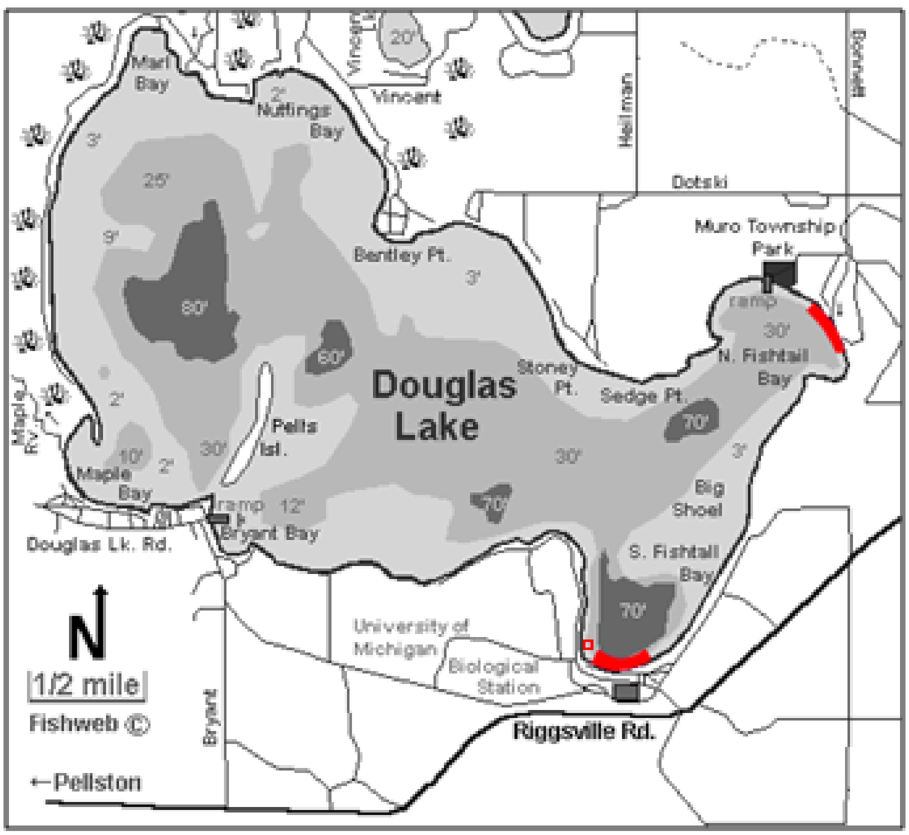

FIG. 1. Douglas Lake. Locations of clam collection and reattachment pen highlighted in red.

Results

Seventy-eight unionids, comprised of three species, *Anodonta grandis*, *Lampsilis siliquoidea*, and *Ligumia recta* were found. Only 7 specimens of *Anodonta grandis* were collected. They were not used in the statistical analysis due to small sample size. The number of species found in each bay was approximately the same. To ensure accuracy when comparing South and North Fishtail Bay, a Chi-squared test was performed to show the number of each unionid species found was approximately the same (Chi squared value = 0.532290865, df = 2, critical value = 5.99).

Lampsilis siliquoidea in South Fishtail Bay were significantly heavier than those found in North Fishtail Bay (Table 1).

Table 1. – T-test statistics: comparison of lengths of *Lampsilis siliquoidea* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	32.85	22.73684211
Variance	536.6605263	149.871345
Observations	20	19
Pooled Variance	348.4928165	
Hypothesized Mean Difference	0	
df	37	
t Stat	1.691022427	
P(T<=t) one-tail	0.049620396	
t Critical one-tail	1.687093597	

Lampsilis siliquoidea in South Fishtail Bay were not significantly smaller or larger in length than those found in North Fishtail Bay (Table 2).

Table 2. – T-test statistics: comparison of lengths of *Lampsilis siliquoidea* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	5.889473684	5.489473684
Variance	2.326549708	0.865438596
Observations	19	19

Pooled Variance	1.595994152
Hypothesized Mean Difference	0
df	36
t Stat	0.975901861
P(T<=t) one-tail	0.167812818
t Critical one-tail	1.688297694

Examination of lengths of shells and mass of corresponding unionid revealed a linear relationship did not accurately describe the relationship. Instead, a strong exponential relationship was found between the length and mass of *L. siliquoidea* in both bays. Mass as a response to the length of shells was greater in *L. siliquoidea* found in South Fishtail Bay (Figure 2).

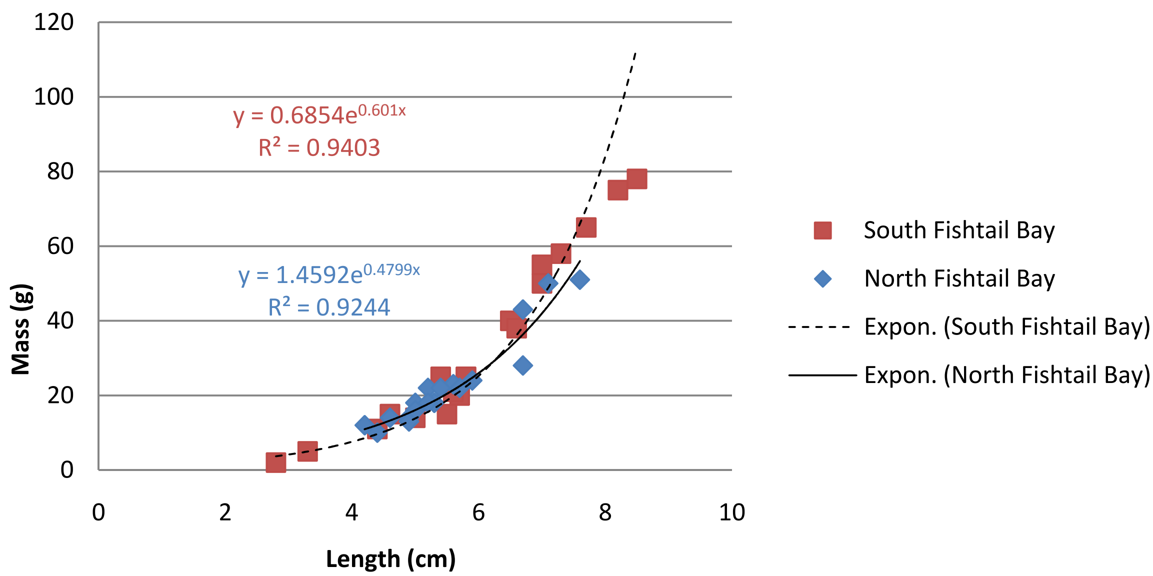

FIG. 2. Exponential correlation between length and mass of *L. siliquoidea* in S. Fishtail Bay and N. Fishtail Bay.

There was no difference in mass or shell length of *L. recta* in South Fishtail Bay and North Fishtail Bay (Table 3 and Table 4).

TABLE 3. – T-test statistics: comparison of mass of *Ligumia recta* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	27.55555556	26.08333333
Variance	585.5555556	329.3560606
Observations	18	12

Pooled Variance	484.905754
Hypothesized Mean Difference	0
df	28
t Stat	0.179395254
P(T<=t) one-tail	0.42945963
t Critical one-tail	1.701130908

TABLE 4. – T-test statistics: comparison of lengths of *Ligumia recta* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	6.65	6.508333333
Variance	2.130882353	0.59719697
Observations	18	12
Pooled Variance	1.528363095	
Hypothesized Mean Difference	0	
df	28	
t Stat	0.307482676	
P(T<=t) one-tail	0.38037575	
t Critical one-tail	1.701130908	

Ligumia recta also had a strong exponential relationship between the length and mass in both bays. Mass in relation to the length of shell was slightly greater in South Fishtail Bay than in North Fishtail Bay, represented by the higher power for South Fishtail Bay.

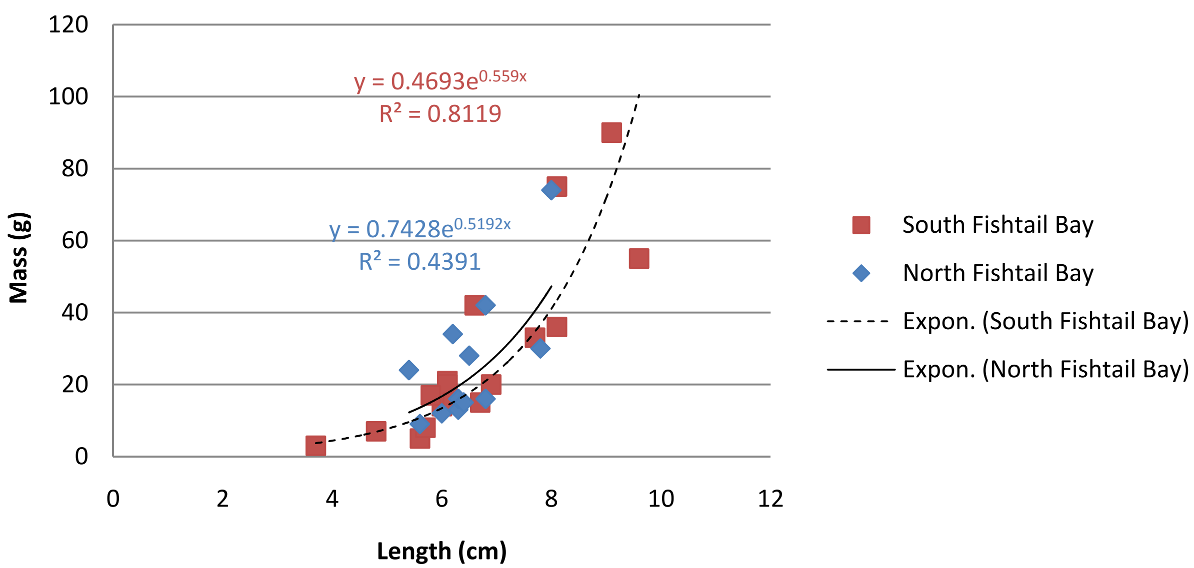

FIG. 3. Exponential correlation between length and mass of *L. recta* in S. Fishtail Bay and N. Fishtail Bay.

The average mass of *D. polymorpha* collected from the shells of *Lampsilis siliquoidea* in South Fishtail Bay was significantly less than those collected in North Fishtail Bay (Table 5).

TABLE 5. – T-test statistics: comparison of mass of *Dreissena polymorpha* found on the shells of *Lampsilis siliquoidea* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	16.845	36.63555556
Variance	87.85826842	1079.595414
Observations	20	18
Pooled Variance	556.1785873	
Hypothesized Mean Difference	0	
df	36	
t Stat	-2.582916137	
P(T<=t) one-tail	0.007003734	
t Critical one-tail	1.688297694	

Mass of *D. polymorpha* found on shells of *L. recta* was also significantly less in South Fishtail Bay (Table 6).

TABLE 6. – T-test statistics: comparison of mass of *Dreissena polymorpha* found on the shells of *Ligumia recta* in South Fishtail Bay and North Fishtail Bay.

	South Fishtail Bay	*North Fishtail Bay*
Mean	17.89111111	39.9675
Variance	320.359281	1977.777257
Observations	18	12
Pooled Variance	971.4877715	
Hypothesized Mean Difference	0	
df	28	
t Stat	-1.900533875	
P(T<=t) one-tail	0.033851982	
t Critical one-tail	1.701130908	

The *D. polymorpha* attachment study showed a linear increase of *D. polymorpha* on the shells of the unionids over the course of two weeks (Figure 4). One *L. recta* unionid was lost early into the experiment eight unionids were used to find the average number of attached *D. polymorpha* because. No data was taken on the 12th day after July 28th.

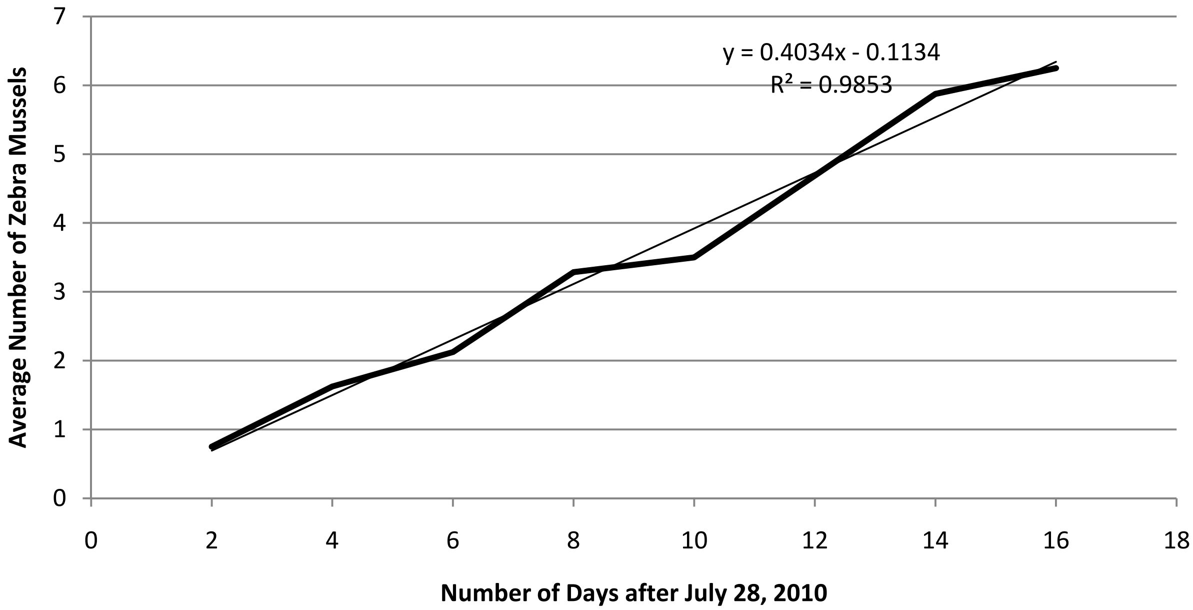

FIG. 4. Time versus average number of *D. polymorpha* attachment found on shells.

Discussion

D. polymorpha infestations can reduce food intake resulting in lower food reservoirs (Haag *et al.* 1993). Thin-shelled unionids, such as *L. siliquoidea,* are heavily affected by *D. polymorpha* infestation (Haag 1993). T-tests showed the two bays had unionids of similar length. Mass, however, was significantly different, showing unionids had higher mass within South Fishtail Bay. The correlation, therefore, showed that for each increase in length of shell, the masses of *L. siliquoidea* in South Fishtail Bay were becoming significantly larger than those found in North Fishtail Bay. *Dreissena polymorpha* were also found in significantly higher numbers on unionids in North Fishtail Bay. The comparison of correlation found between length and mass for *L.siliquoidea* between the two bays was very encouraging. *D. polymorpha* removal may be having a positive effect on the health of native unionids.

Although the *L. siliquoidea* had a significant difference in their mass, *L. recta* did not show a similar relationship. The correlation showed that the rate of change in mass of *L. recta* in relation to length of shells was only slightly higher in South Fishtail Bay. *Dreissena polymorpha*, however, were still found in higher numbers on *L.recta* in North Fishtail Bay. *Ligumia recta* may have managed to maintain their mass despite having *D. polymorpha* attached to their shells. Alternatively, *L. recta* may not be benefitting from removal of *D. polymorpha*.

Reproduction is extremely stressful on species such as *L. siliquoidea*. Mortality is highest during the breeding season (Haag 1993). With the added stress of *D. polymorpha* reducing the mass and health of unionids, mortality would be even higher during breeding season. *D. polymorpha* removal from unionids has been shown to increase reproductive fitness (Schloesser 1996).The higher mass of *L. siliquoidea* in South Fish Tail bay gives hope that a sustainable population could still flourish and repopulate the lake.

The attachment study showed *D. polymorpha* reattach almost immediately to clean unionids. During the two weeks of observation, an average of six *D. polymorpha* were found attached to unionids. The speed of attachment suggests unionids could be covered to a degree that would affect their health within a few months. Loss of energy reserves would decrease the chance of survival during winter (Riccardi *et al.* 1995). Although *D. polymorpha* were quick to reattach, constant cleaning throughout a summer would allow a unionid to regain lost mass.

Notably, many of the newly attached *D. polymorpha* were small, less than 1cm in length. Smaller *D. polymorpha* may move around easier and find it easier to attach to hard substrates. These *D. polymorpha* are probably immature. If removed from shells, it is possible they would wash onto shore and die before reaching sexual maturity. Large zebra mussels (over 1cm) which were placed into the pen with native unionids were not seen in the pen again. Further studies should explore what happens to previously removed *D. polymorpha* and whether or not they reattach to other substrates or die.

Increasing numbers of *D. polymorpha* have begun to drive native unionids to extinction (Ricciardi *et al.* 1998). In an attempt to save species, new methods of *D. polymorpha* control are crucial.

Data in the study has shown the simple act of cleaning native unionids of invasive species may be making an impact.

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