An Assessment of the Effects of Zebra Mussel Presence on Clam Health: a case study in Five Northern Michigan Lakes

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Abstract

Zebra mussel presence in the waterbodies of the Great Lakes Region continues to have large effects on the aquatic ecosystems they inhabit, specifically in relation to a decrease in unionid clam populations. We performed a study to determine how zebra mussels impact clam health, which we evaluated based on the mass and length of the clams. We surveyed five lakes: Larks Lake and Wycamp Lake, which have no zebra mussels, Douglas Lake and Burt Lake, which still contain zebra mussels, and Round Lake, which has zebra mussels but has been treated with Zequanox to control the zebra mussel population. At each lake, we collected clams and recorded their weight, using a 100-gram spring scale, and length, using a manual caliper. Looking at the weight versus length of each lake, Larks Lake had the steepest slope (m = 17.64), while Round Lake had the smallest slope (m = 10.30) (Fig. 1). The lengths of the smallest clams in each lake were significantly different from each other except for Larks and Douglas Lake (p-value = .294) (Table 1). The lengths of the largest clams in each lake showed more variation – Round and Douglas Lake, Wycamp and Larks Lake, and Wycamp and Round Lake did not have large clam lengths that were significantly different from each other (p = .761, p = .834, p = .090) (Table 2). Using weight versus length as a measure of clam health, we concluded that clams in lakes without zebra mussel presence were healthier than clams in lakes with continued zebra mussel presence. Our data suggest that this invasive species of mollusc has detrimental effects on native unionid clams in inland lakes in northern Michigan.

Introduction

Zebra mussels (*Dreissena polymorpha*) are small molluscs commonly found in Europe (Griffiths et. al. 1991). They were found in June of 1988 in Lake St. Clair, but it is likely that they were introduced into Lake St. Clair in 1986 from ballast water discharge of a large ocean vessel (Griffiths et. al. 1991). Since its introduction, zebra mussels have become an invasive species spreading through many waterbodies in the Great Lakes region because these molluscs rapidly produce offspring, and they are easily carried through the ballast water of commercial ships and fishing boats (Griffiths et. al. 1991). While the effects of zebra mussels on unionids in the Great Lakes has been studied extensively, there is less published data on the impact of zebra mussels on unionids in inland lakes. Zebra mussels have an impact on multiple aspects of the water they inhabit. For example, one study found that areas containing zebra mussels showed a rapid decline in algal biomass, which is an important primary producer to support food chains of aquatic organisms (Heath et. al. 1995).

Unionid clams are particularly affected by zebra mussels. Waters with clams and zebra mussels show a high rate of unionid clam death, especially in the initial invasion period (Schloesser et. al. 1998). Zebra mussels tend to latch onto any hard surface in the vicinity, including clam shells, and then secure themselves with byssal threads, or filaments. As zebra mussels accumulate on the shell, they form a dense group of shells that are difficult to detach from the clam (Roberts 1990). Burrowing is an effective defense mechanism for clams against zebra mussels because these molluscs cannot survive at the low oxygen levels found deeper in the sediments, and the act of burrowing can shake zebra mussels off of the clam shells (Nichols and Wilcox 1997). However, clams require soft sediment to burrow and areas with coarse sand-gravel are not ideal for burrowing (Nichols and Wilcox 1997). The fouling, or overgrowth, of zebra mussels on clams interferes with the normal valve function, meaning the opening and closing of the shell, which is necessary for respiration (Strayer and Smith 1996). Additionally, impaired valve function and subsequent inability to close the shell increases clam vulnerability to predators and disease (Mackie 1991). As the amount of zebra mussels increases further, the molluscs remove nutrients from the water, leaving little to no nutrients for the clam, which is likely to starve, lose weight, and die (Mackie 1991).

We collected data on clams in five different inland lakes near Pellston, MI (45.5528° N, 84.7839° W) in order to evaluate their health in relation to the presence or absence of zebra mussels in the lake. Larks Lake (45.6044° N, 84.9326° W) and Wycamp Lake (45.6565° N, 84.9596° W) have no history of zebra mussels. Round Lake (46.1509° N, 86.7416° W), Douglas Lake (45.5770° N, 84.6929° W), and Burt Lake (45.4408° N, 84.7112° W) all have zebra mussels in the recent past and present. However, Round Lake is unique because it was treated with Zequanox. The biopesticide Zequanox has shown potential for controlling zebra mussels in shallow-water areas of lakes without significantly decreasing the water quality (Whitledge et. al. 2015). We collected length (shell width) and weight measurements as a representation of clam health because adult shells make the live animals heavier, possibly due to increased shell mass or greater ability to hold water (Gimin et. al. 2004). Smaller clams have lower ratios of weight to length, and larger clams have higher ratios of weight to length.

If zebra mussel presence has had an impact on clam health in the waterbodies near Pellston, then there should be a steeper slope between weight and length in lakes with no zebra mussel presence than in lakes with continued zebra mussel presence. Also, we would expect that the average lengths of the small clams are approximately equal for all the lakes, but the average lengths of the large clams are greater in lakes without zebra mussels. The purpose of this study was to determine how zebra mussels impact clam health, which we evaluated based on size of the clams.

Materials and Methods

Clam Survey

We conducted our study in five lakes near Pellston, Michigan, United States of America. Two of these lakes have no history of zebra mussels, two of them have zebra mussels currently, and one of them has zebra mussels but has been treated with Zequanox to control zebra mussel growth. The process of searching each lake to find clams differed among the lakes based on a preliminary survey of the number of clams observed in each lake. However, the process of collecting clams and recording data was the same for all the lakes. Each surveyor utilized a glass bottom bucket or scuba diving gear to look for clams at the bottom of the lake. Only live clams that could not be opened were collected. We recorded the length (longest length) of the clam using a manual caliper and the weight of the clam using a 100-gram spring scale. After the measurements were collected, clams were returned to the approximate area where they were found. At Larks Lake and Round Lake, we set up transects 10 meters apart along a line running parallel to the shore. Each surveyor made a transect that reached a water depth of one meter perpendicular to the line. Then, each surveyor looked for clams within 1 meter of each side of the transect. We sampled a much larger section of Douglas Lake, approximately 400 meters of the shoreline to one meter of water depth because Douglas Lake has served as a managed refuge and contains a very small population of living clams. The survey in Wycamp Lake was performed without transects because clam density was very high. We kept track of the areas in which clams were found so that we could return them, but without transects, our area of study was approximately 50 meters in length until one meter of water depth. Zebra mussels colonized Burt Lake approximately 25 years ago. While unionids were present in a study 7 years ago, we were unable to locate any unionids after surveying through an area of 100 meters in length until one meter of water depth.

Statistical Analysis

To analyze the clam data, we utilized R version 3.6.0 to run a linear regression of weight versus length for each lake to determine if there was a difference in slopes between lakes with zebra mussels and lakes without zebra mussels. The spring scale utilized to find weight of the clam was not highly accurate, so the group of largest clams had the highest length and the group of smallest clams had the smallest length. For this data, we utilized R version 3.6.0 to run an analysis of variance (ANOVA) to determine if any of the average lengths of large clams were significantly different from each other and if any of the average lengths of small clams were significantly different from each other. Additionally, we ran a Tukey Post-Hoc test to determine which of the lakes had clams with lengths that were significantly different from the lengths of clams in other lakes.

Results

There were no clams found in Burt Lake, so no data were recorded. According to the linear regression, the slope of the length versus weight graph was greatest at Larks Lake (slope = 17.64), followed by Wycamp lake (slope = 16.25), then Douglas Lake (slope = 11.76), and finally Round Lake (slope = 10.30) (Fig. 1).

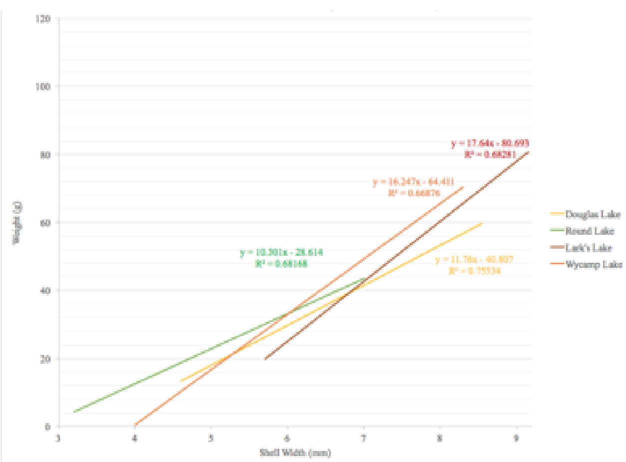

Figure 1. Regression data of clam length versus weight in each lake. (Douglas: $R^2 = .76$, Round: $R^2 = .68$, Larks: $R^2 = .68$, Wycamp: $R^2 = .67$)

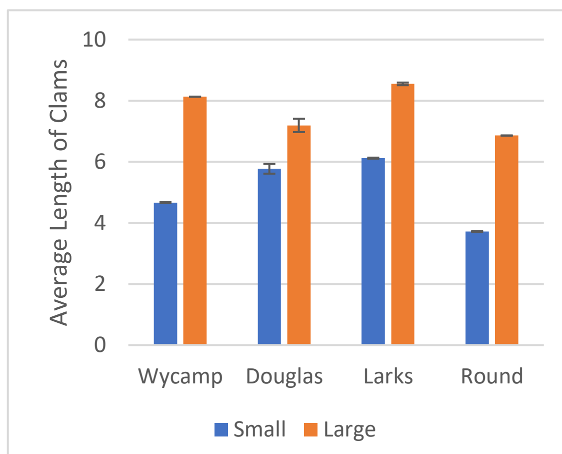

Figure 2. Average length (± SE) of the small and large clams at each lake.

Table 1. Results of the Tukey test that compares the average length of small clams in each lake.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
hdata$Location	3	26.197	8.732	53.23	1.51e-08	***
Residuals	16	2.625	0.164			

	diff	lwr	upr	p adj
Larks-Douglas	-0.47	-1.2029182	0.2629182	0.2939738
Round-Douglas	-2.87	-3.6029182	-2.1370818	0.0000000
Wycamp-Douglas	-1.93	-2.6629182	-1.1970818	0.0000065
Round-Larks	-2.40	-3.1329182	-1.6670818	0.0000004
Wycamp-Larks	-1.46	-2.1929182	-0.7270818	0.0001748
Wycamp-Round	0.94	0.2070818	1.6729182	0.0100375

Table 2. Results of the Tukey test that compares the average length of large clams in each lake.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
hdata$Location	3	15.919	5.306	8.535	0.0013	**
Residuals	16	9.948	0.622			

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	diff	lwr	upr	p adj
Larks-Douglas	2.18	0.7532143	3.6067857	0.0024075
Round-Douglas	0.49	-0.9367857	1.9167857	0.7611827
Wycamp-Douglas	1.76	0.3332143	3.1867857	0.0133329
Round-Larks	-1.69	-3.1167857	-0.2632143	0.0176899
Wycamp-Larks	-0.42	-1.8467857	1.0067857	0.8336700
Wycamp-Round	1.27	-0.1567857	2.6967857	0.0900930

The results of the ANOVA showed that there were significant differences between the average length of small clams at each lake and the average length of large clams at each lake ($p < 0.05$, $df = 3$) (Fig. 2). The Tukey test conveyed that all of the lakes had significantly different average lengths of small clams except for Larks and Douglas Lake (p-value = .294) (Table 1). The lengths of large clams showed less significant differences. Round and Douglas Lake, Wycamp and Larks Lake, and Wycamp and Round Lake did not have large clam lengths that were significantly different from each other (p = .761, p = .834, p = .090) (Table 2).

Discussion

This study provides some evidence of differences in clam health between lakes with no zebra mussels and lakes with zebra mussels. The results were consistent with our hypothesis about the linear relationship between weight and length, and that there would be a stronger relationship seen in lakes without zebra mussels. However, the results did not support our hypothesis about the relationship between small clams and large clams because we found that the small clams had more variable sizes while the large clams had a more uniform distribution of size across the lakes.

Larger weight to length ratios of unionid clams tend to be an indicator of clam health (Merritt 2010). The absence of zebra mussels in Larks Lake and Wycamp Lake account for the larger ratio of weight to length because these clams are not dealing with the effects of zebra mussels. The presence of zebra mussels in Douglas Lake and Round Lake support the smaller ratios of weight to length because these clam populations have been outcompeted for nutrients and negatively impacted by zebra mussels. It is surprising that Round Lake showed a smaller ratio of weight to length because, in 2014, it was treated with Zequanox, an EPA registered molluscicide known to be toxic to zebra mussels (Luoma 2019). Even though there were many clams in a small area, the clams in Round Lake are smaller than clams in the other three lakes, which may be an indication of the negative impact from zebra mussel infestation. One study found that unionid clams suffer mortality rates upwards of 90% when they are attached to a mass of zebra mussels that is greater than or equal to their own mass (Ricciardi et. al. 1996). Additionally, it is unlikely that the Zequanox is affecting unionid clam health because this biopesticide has already been shown to have a minimal impact on unionid clams (Luoma 2019). The complete absence of clams in our study area in Burt Lake where clams were once found (Burlakova et. al. 2014) is indicative of the harsh effects of zebra mussels on clam populations; one study found that just ten zebra mussels attached to a clam can significantly decrease the clam population size in a waterbody (Ricciardi et. al. 1996).

Variation among clam sizes may be related to the type of sand at the bottom of the lake, temperature of the water, and water depth (Hanson et. al. 1988). The effects of these three factors are difficult to separate. In our study, the variation among small clam lengths may be attributable to changes in one or more of these factors, and further studies could be performed on the effects of climate change on clam growth. The lesser, but still present, variation among large clam lengths may also be explained by these factors. However, the decrease in variation may suggest that one or more of these is a limiting factor on clam growth.

In a study done at the Biological Station in 2010, researchers found that cleaning zebra mussels off the clams in two areas around Douglas lake aided in improving the fitness of the clams (Merritt 2010). The focus of the two studies was different. The 2010 study was focused on how human removal of zebra mussels affected clam health (Merritt 2010). Our study was focused on how the presence/absence of zebra mussels affects the health of the clams in inland lakes. However, the results were similar in that they both supported the hypothesis that little to no zebra mussel presence is conducive to healthier clams.

This study of clam health in different lakes with variable zebra mussel presence is relevant to investigations into the effects of these invasive molluscs on native unionid clams. It may also be important for determining how to proceed with clam conservation efforts, such as reducing numbers of zebra mussels in infested lakes versus studying water depths and temperatures in lakes without zebra mussels. Additionally, if the invasive zebra mussels can have such a large effect, there may be important impacts of other aquatic invasive species, which can lead to further studies into the effects of invasive species on native organisms in aquatic ecosystems.

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