

THE EFFECTS OF ZEBRA MUSSEL (*Dreissena polymorpha*) PRESENCE ON ROCK
SUBSTRATE ALGAL CONCENTRATIONS IN INLAND LAKE SYSTEMS

Cristine Santanna

University of Michigan Biological Station

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Abstract

The possible commensal relationship between benthic algae and zebra mussels occupying the same rocky substrate was studied at Douglas Lake in Pellston, Michigan. Chlorophyll a tests were used to analyze benthic algae concentrations on three different treatments: rocks with live zebra mussels, rocks with dead zebra mussels, and rocks with no zebra mussels with expectations to find that rocks with zebra mussels have higher benthic algae concentrations than rocks with no zebra mussels, and rocks with live zebra mussels have higher benthic algae density than rocks with dead zebra mussels. The study was divided into field survey, field study and laboratory study. In the field survey, I observed a trend that showed higher benthic algae concentration on rocks with zebra mussels; however, it was statistically insignificant. I compared the chlorophyll a concentration found on rocks with live and dead zebra mussels with rocks without zebra mussels for the field and laboratory studies, and found a significant difference in the field study, which showed that rocks with zebra mussels had higher benthic algae concentration. Finally, I compared rocks with live zebra mussels and dead zebra mussels and found an insignificant difference between the two treatments for the field and laboratory study, even though the trends showed a higher concentration of benthic algae on rocks with dead zebra mussels. Since rocks with zebra mussels showed a higher concentration of benthic algae in general, a commensal relationship between the two organisms is possible.

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INTRODUCTION

Commensalism occurs when one organism is positively affected by a direct interaction with another, while the other is completely unaffected by it. Interactions usually have a positive or negative effect on each organism because often one organism must exploit the other in order to benefit itself, which makes commensal relationships between organisms rare and therefore important for the scientific community to increase understanding of organisms' behavior.

Zebra mussels (*Dreissena polymorpha*), an invasive species now found in the freshwater ecosystems of the Great Lakes, having come to North America via ballast water from the Caspian Sea in 1986 (Cecala et al. 2008), have been viewed as pests which negatively engineer ecosystems since their introduction: they have been linked to increased water clarity in the Great Lakes and decreased populations of native organisms (Cecala et al. 2008, Ricciardi et al. 1998, Stewart et al. 1998). Zebra mussels have contributed to increased water clarity because they are extremely efficient filter feeders (Ricciardi et al. 1998, Kurdziel 2009) which remove virtually all the seston from the water column increasing the amount of sunlight penetration and leading to huge explosions of benthic primary production via increased benthic algae populations (Cecala et al. 2008). The mussels also increase the amount of nutrients available to benthic algae and these two factors often lead to lake eutrophication (Davies and Hecky 2005, Cecala et al. 2008). *Dreissena polymorpha* negatively impact many organisms in freshwater

ecosystems: they exclude native gastropod, chironomid, and net-spinning caddis fly species from rocky substrate (Stewart et al. 1998), they effectively smother native mussels by completely encrusting them (Ricciardi et al. 1998), and they out compete native mussels because of their extremely efficient filter feeding (Ricciardi et al. 1998, Kurdziel 2009).

Although there are many studies that have focused on these and other negative impacts of the introduction of zebra mussels, positive impacts have also been shown. One positive relationship occurs between zebra mussels and snails (*Lithasia obovata*); in this interaction, snails received nutrients from zebra mussels while no effect on the mussels was observed (Greenwood et al. 2001). Other studies have concluded that total organic matter is more concentrated in areas with zebra mussel populations (Stewart et al. 1998) and that zebra mussels excretion is rich in phosphorus (Ozersky et al. 2009), which is the main limiting resource for lake ecosystems (Boegman et al. 2008), suggesting this invasive species could be involved in other commensal relationships from which some native species, including benthic dwellers that use dead zebra mussel shells as refuges (Stewart et al. 1999), could benefit. Significant increases in benthic algal production due to high levels of live zebra mussel densities have also been found (Bierman et al. 2005) and this poses a possibility for a commensal relationship between zebra mussels and algae.

The purpose of this study was to determine if indeed a positive relationship occurs between zebra mussels and benthic algae communities on rock substrates in an inland lake ecosystem. Because there is usually higher algal productivity in the presence of zebra mussels (Bierman et al. 2005, Davies and Hecky 2005, Cecala et al. 2008), and

because these shells have been known to serve as a refuge for benthic dwellers (Stewart et al. 1999), I predict that lake areas with rock substrate containing live or dead zebra mussels will have higher benthic algal concentrations than exists on rocks without zebra mussels. Also, because phosphorous is a limiting resource in many lakes (Boegman et al. 2008) and live zebra mussel excretions contain high concentrations of phosphorous (Ozersky et al. 2009), I predict that algal concentrations will be highest in areas with live zebra mussels.

METHODS

Field Survey

In a rocky littoral zone of Douglas Lake in Pellston, Michigan, off the south central shore known as Grapevine Point that was already host to both zebra mussels and algae communities, I randomly selected a total of six rocks, ranging from 4x7cm to 10x15cm of length and width at the longest and widest points, to meet the following conditions: three rocks had live zebra mussels attached and three rocks lacked zebra mussels. I marked a random area of each rock with a 1cm diameter cork borer and collected all algae within the marked area by scraping it with a pocket knife into a petri dish. I separately blended the algae collected from each rock with a recorded amount of deionized water until each mixture was homogenous, and then I filtered it through Millipore HA filters. I folded the filters in half and wrapped each separately in aluminum foil to avoid algae contact with light, and I placed each into a freezer at -20° C to wait chlorophyll a analyzation to quantify the algae present. Chlorophyll a testing was performed by the University of Michigan Biological Station's Lakeside Laboratory, in Pellston, Michigan.

Field Study

In the same area in which my field survey took place, I established nine 30x55cm plots at about a half meter depth, where both zebra mussel and algae communities were present. I removed all rocks and other hard substrates from the plots. I selected forty five rocks (thirty without zebra mussels and fifteen with zebra mussels at a density of approximately 50% cover) from the lake with the same size range as those in my field survey and I scraped them clean of algae and everything else other than zebra mussels using a toothbrush. I placed five rocks with live zebra mussel into three plots and five rocks with no zebra mussel into three different plots. I placed the remaining clean rocks in a bucket to air dry. Once the rocks were dry, I attached dead zebra mussel shells to them, using epoxy glue, at approximately the same density as on the naturally occurring zebra mussel encrusted rocks (approximately 50% cover), and once the glue was dry, I added five of them to each of the remaining plots. After ten days, I collected one random rock from each plot and repeated the same procedure that I described in the field survey to test for chlorophyll a. The plots with dead zebra mussel shells attached were only exposed to the lake water for the last seven of these ten days due to the time required to dry the rocks and to glue the shells and let the glue dry completely.

Laboratory Study

In a boat well stream lab trough in Lakeside Laboratory at the University of Michigan Biological Station, I duplicated the lake plot arrangements. I set up nine 30x55cm plots with a 1cm deep sandy substrate and at about 26.5cm water depth in the trough with constant Douglas Lake water input to and output from the trough at a rate of about 4L/min. to provide nutrients for benthic algae growth and food for the live zebra

mussels. I placed five completely clean rocks (same procedure as in the field study) into each of the first three plots. I placed five rocks with dead zebra mussel shells attached (same procedure as the in field study) into the following three plots. And I placed five rocks with live zebra mussels (same procedure as in the field study) into each of the last three plots. After ten days, I collected one random rock from each plot to measure benthic algae growth (same procedure as in field survey and field study). Again, I collected the rocks with dead zebra mussel shells attached after exposure for only the last seven days due to preparation time.

I used independent samples t-tests to compare the benthic algal concentrations on rocks: 1. field survey comparing rocks with and without zebra mussels; 2. field study and laboratory study comparing rocks with live and dead zebra mussels to rocks without any zebra mussels; 3. Field study and laboratory study comparing rocks with live zebra mussels to rocks with dead zebra mussels.

RESULTS

For the field survey, the difference between the amounts of chlorophyll a found on the rocks with zebra mussel and without any zebra mussel was not significant ($t= 1.22$, $df = 3.995$, $p= .29$). Rocks with zebra mussel had higher algal concentration than rocks without zebra mussel (Figure 1).

The number of benthic algae detected by chlorophyll a tests between rocks with zebra mussels (alive and dead) and rocks without any zebra mussels for the field study was significantly different ($t=2.75$, $df=5$, $p= .041$) The mean quantity of benthic algae collected from rocks with zebra mussels from the field study was $0.36 \mu/\text{cm}^2$, while the mean quantity of benthic algae collected from rocks without zebra mussels was $0 \mu/\text{cm}^2$.

However rocks with zebra mussels (alive and dead) and without zebra mussels did not significantly differ in their algal concentration ($t = .71$, $df = 6.8$, $p = .5$). Rocks with live and dead showed higher algal concentration than rocks without zebra mussels (Figure 2).

There was no significant difference between the amounts of benthic algae on rocks with live zebra mussels and rocks with dead zebra mussels ($t = 1.52$, $df = 2.8$, $p = 0.232$), the concentration of benthic algae present on rocks without zebra mussels was higher than the concentration of benthic algae on rocks with live zebra mussels. The difference in the amount of benthic algae on rocks with live and dead zebra mussels in the laboratory study was also insignificant ($t = 0.451$, $df = 2.05$, $p = 0.69$). The concentration of benthic algae found on the rocks from the laboratory study with live zebra mussels was lower than concentration of benthic algae found on rocks with dead zebra mussel (Figure 3).

DISCUSSION

According to my first hypothesis, benthic algae concentration should be greater on rocks with zebra mussels present (dead or alive) than on rocks without any zebra mussel. For the field study, the difference between rocks with zebra mussel and without was significant, which supports my hypothesis. Stewart et al. (1999) supports the idea that zebra mussels provide refuge for benthic organisms (including algae) and Ozersky et al. (2009) suggests that zebra mussels' excretions are rich in phosphorus, a limiting resource in lake systems. Another limiting factor in lake systems is the depth of light penetration in the water, which is inversely proportional to seston concentration (with lower densities in lakes colonized by zebra mussels due to their filter feeding), thus promoting benthic algae growth (Ricciardi et al. 1998, Stewart et al. 1998, Cecala et al.

2008, Kurdziel 2009). The study conducted in the laboratory did not show the same significance as the one in the field, thus, it did not support my hypothesis. The trend showed by the laboratory study on the mean amount of chlorophyll a measured between rocks with zebra mussel present (dead or alive) and no zebra mussels indicated that even if the difference was not significant, there is still a higher population of benthic algae on rocks with zebra mussels. Possible reasons for the difference in the results from the field and laboratory studies are: difference in the current rate, the input and output of lake water into the trough was too high or too low compared to the lake systems; possible different amount of nutrient and algae concentration between the water cycled through the trough and the water where the plots were. The field survey showed a similar result, even if the difference in the amounts of chlorophyll a between the rocks with live zebra mussels and no zebra mussels was not significant, the trend presented by the data shows that rocks with zebra mussels had a higher concentration of benthic algae and it is in accordance with my first hypothesis that predicted higher benthic algal density on rocks with zebra mussels. The trend is also consistent with previous studies by Stewart et al. (1999), Bierman et al. (2005), and Davies and Hecky (2005), who found that zebra mussels had a positive impact on algae populations. Possible reasons to explain why the difference in the amounts of chlorophyll a between the rocks with live zebra mussels and no zebra mussels was not significant are: the sample size was too small the sampling area was too small.

My second hypothesis predicted that rocks with live zebra mussels would contain a higher concentration of benthic algae than rocks with dead zebra mussel due to the phosphorus input from their excretion (Ozersky et al. 2009). For both field and laboratory

studies, I did not find a significant difference between the amount of chlorophyll a for these treatments; thus my hypothesis is not supported. Very interestingly, the trend for both studies showed that rocks with dead zebra mussels had a higher benthic algae density than rocks with live zebra mussels, which indicates that the refuge offered by the mussels (Stewart et al. 1999) may be of more importance than the phosphorus input. The rocks tested from the laboratory study with dead zebra mussels had a very high amount of benthic algae compared to any other rock sampled (except the field survey rocks with zebra mussel, which were able to accumulate benthic algae for a longer period of time). This difference could be explained by the possible different concentrations of seston in different lake areas (water cycled through the trough could have higher seston concentration than the water where the field study plots were set up) in Douglas Lake. Another factor that might have affected the results was the water depth difference between field and laboratory studies (field study plots were more than twice as deep as the laboratory plots), and the amount of sun light exposure (plots at the lake were shaded by trees but had some direct sunlight during the day, while laboratory plots were close to windows but sheltered all the time).

The field study showed a significant difference between rocks with zebra mussels and without zebra mussels, which indicates that zebra mussel have a positive effect on benthic algae growth on substrate rocks. Even if the difference between the amount of chlorophyll a present on rocks with live zebra mussels and dead zebra mussels was not significant, the trend shows that the refuge offered by dead zebra mussels possibly had more impact than the possible input of phosphorus by zebra mussels since the rocks with dead zebra mussels had higher benthic alga density.

FIGURES

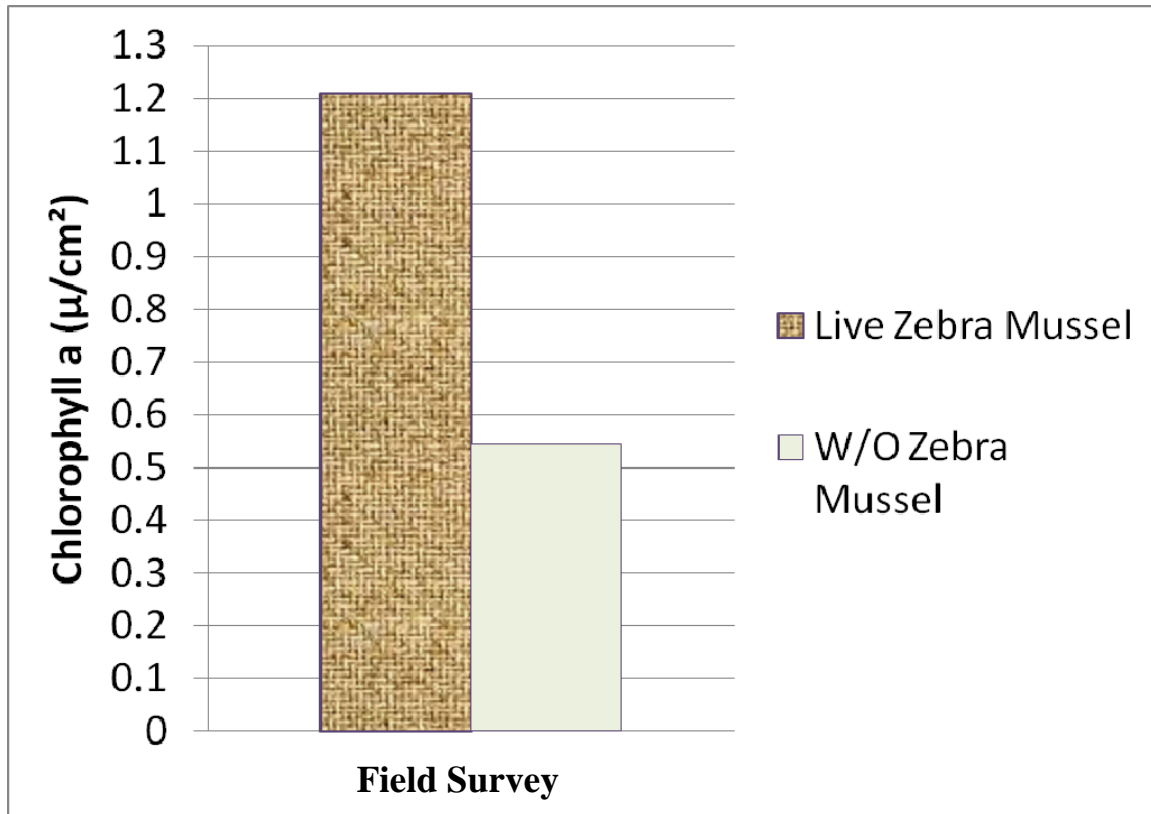


Figure 1. Chlorophyll a concentrations for rocks with live zebra mussels (mean=1.21 μ/cm^2) and without zebra mussels (mean=0.54 μ/cm^2) in the field survey. Average chlorophyll a (μ/cm^2) was more than 2 times greater for rocks with live zebra mussels than rocks with no zebra mussels, but this difference was not significant ($t= 1.22$, $df = 3.995$, $p= .29$).

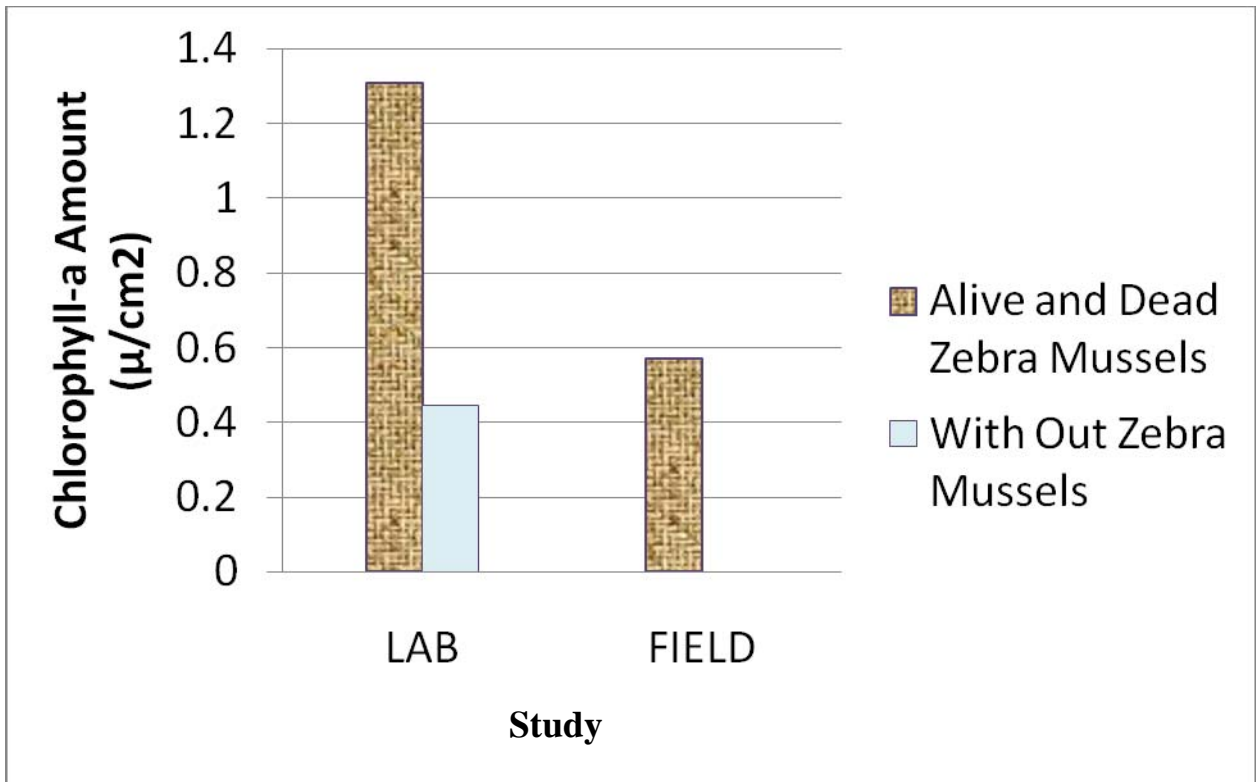


Figure 2. Comparison of the amount of chlorophyll a found on rocks with alive and dead zebra mussels in contrast with rocks with no zebra mussels in the laboratory and field studies. Rocks with alive and dead zebra mussels had significantly higher benthic algae concentrations than rocks without mussels in the field study ($t= 2.75$, $df = 5$, $p= .041$). Rocks with alive and dead zebra mussels did not have significantly higher benthic algae concentrations than rocks without mussels in the laboratory study ($t = .71$, $df = 6.8$, $p=0.5$).

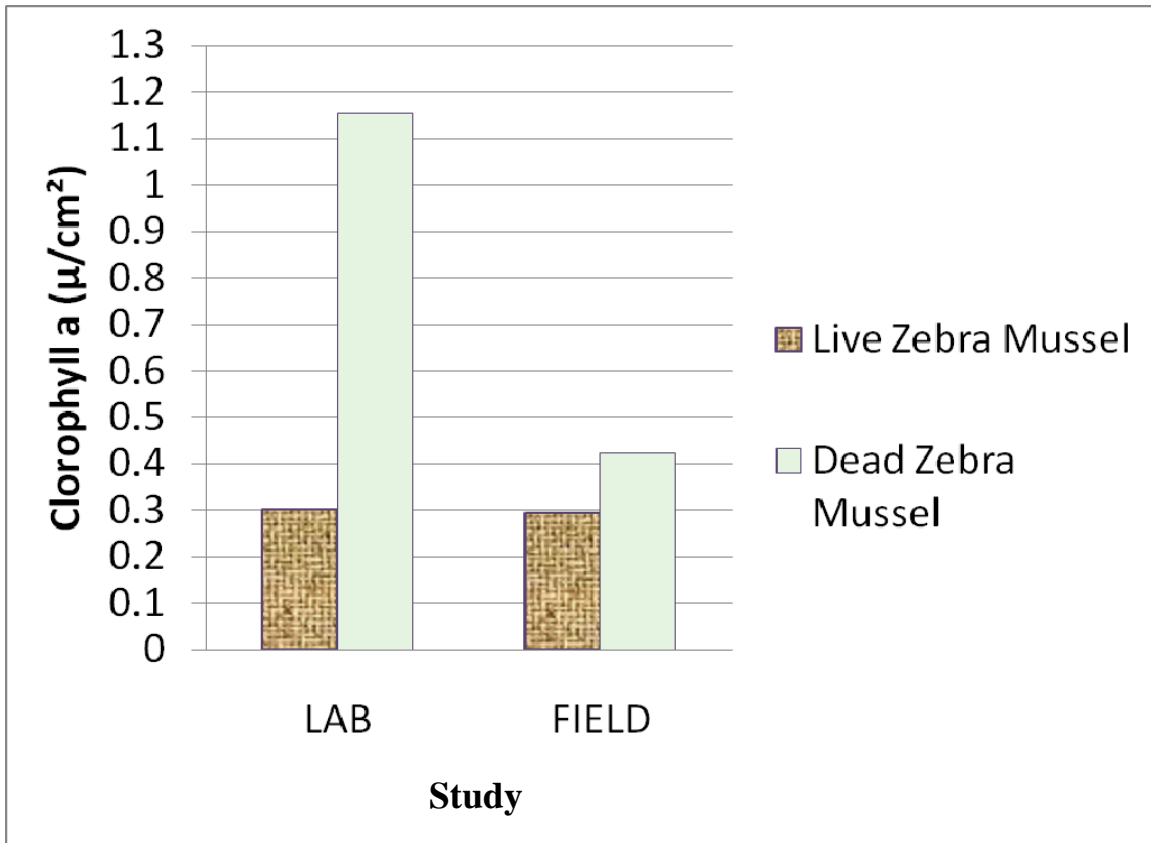


Figure 3. Comparison between the amount of chlorophyll a found in rocks with live zebra and dead zebra mussel in the laboratory and field study. The amount of chlorophyll a found on rocks with dead zebra mussels was higher for both studies. Rocks with live zebra mussels did not have significantly higher benthic algae concentrations than rocks with dead mussels in the field study ($t = .451$, $df = 2.8$, $p = .232$). Rocks with live zebra mussels did not have significantly higher benthic algae concentrations than rocks with dead mussels in the laboratory study ($t = 1.52$, $df = 2.8$, $p = .232$).

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