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# Zebra and Quagga Mussels: The Distribution and Dispersion of Invasive Species in Bethlehem, PA

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## Abstract

An invasive species is an organism that is not native to the ecosystem that it is living in and causes harm, and in Bethlehem Pennsylvania they have aquatic invasive species: zebra and quagga mussels. Zebra and quagga mussels are mussels that have been detrimental to the environment and the ecosystem, especially in the great lakes. In order to look at the distribution and dispersion of these mussels, researchers had to dive down to look at them and plot them. It was found that there was preference between hard and soft substrate, which is different than previous findings. It was also found that the mussels that lived on rocks on the soft substrate were zebra mussels. It was also discovered that the zebra and quagga mussels lived in monospecific clumps and that there may be succession that is occuring between the two species in the quarry.

**Keywords:** Invasive species; Living organism; Ecosystem

## Introduction

An invasive species is a type of living organism, or even an organism's seeds or eggs, that are not native to an ecosystem and causes harm. Invasive species also reproduce quickly and spread aggressively. The harm that is caused by invasive species can be done to the ecosystem or to the economy. When invasive species are introduced into an ecosystem, they may not have any natural predators or controls; this leads to them breeding and spreading quickly, taking over an area. Many times native wildlife does not have defenses against the invasive species, or they may not be able to compete with a species that has no predators. "The direct threats of invasive species include preying on native species, outcompeting native species for food or other resources, causing or carrying disease, and preventing native species from reproducing or killing a native species' young" [1]. Two examples of invasive species are the quagga mussel and the zebra mussel. Zebra mussels and quagga mussels are virtually identical, both physically and behaviorally. Zebra and quagga mussels originate from Eastern Europe, and through ships were brought to the Great Lakes in the 1980s. They spread dramatically, outcompeting native species for food and habitat, and by 1990, zebra mussels and quagga mussels were all over the Great Lakes.

The zebra mussel, Dreissena polymorpha, is type of mussel that has a triangular shell, where the height is between 0.4 and 3 centimeters, about 40-60 percent of their length. The quagga mussel is between less than an centimeter and five centimeters in length, just like the zebra mussel, but has a rounder shape. Both zebra and quagga mussels are found in temperate climates and "have been found to tolerate a range of salinities, from 0.6% (Rhine River) to 10.2% (Caspian Sea.)" [2]. The mussels have a two to four week planktonic larvae phase three to five days after fertilization, then their first year of life is led "under optimal conditions". After the initial year, these mussels tend to live two to eight more years. During a zebra mussel or quagga mussels lifetime approximately five million eggs will be laid and over 100,000 of them will reach adulthood [3]. Byssal threads (or ropes) are on the hinge edge of zebra and quagga mussel shells and allow for these mussels to move [4]. These threads are unique to zebra and quagga mussels and are not found on native mussels. Quagga and zebra mussels are prey to various types of birds and fish, but because of the rate in which they are reproducing, and the fact that they're so starvation tolerant, have no preference to the substrate that they are attached to [5], and that they have no known diseases [2], they are rapidly increasing in population.

Zebra mussels and quagga mussels play an enormous role in the ecosystem. Zebra and quagga mussels filter feed, which makes for clearer water. This allows sunlight to get to the bottom of the lake or river that the mussels are in. This creates ideal conditions for algae to grow, which then lead to algae blooms. "Zebra mussels are believed to be the source of deadly avian botulism poisoning that has killed tens of thousands of birds in the great lakes since the late 1990s" [6]. The deaths of over 70,000 aquatic birds has been due to these algae beaches created by the zebra and quagga mussels [3]. Zebra and quagga mussels also devastate other species by stripping the food web of plankton. This affects populations of alewives, salmon, whitefish, and other mussels. "The zooplankton abundance dropped 55-71% following mussel invasion in Lake Erie,... and the total biomass of zooplankton in the Hudson River declined 70% following mussel invasion, due both to a reduction in large zooplankton body size and reduction in microzooplankton abundance" [2]. The decrease in zooplankton may cause an increase in competition, which then would lead to a decreased in the survival of planktivorous fish. Because micro zooplankton is more heavily impacted by zebra mussels, the larval fish population may be more greatly affected than later life stages.

While the effects that the zebra and quagga mussels are having on the environment are enourmous, there is also an ecemonical problem with these mussels. "Multiple economic impacts, including: fisheries (interference with fishing gear, prey for commercial fish, alteration of fish communities), aquaculture (fouling of cages); water abstractions (clogging of water intake pipes); aquatic transport (fouling of ship hulls and navigational constructions). Invasion of the zebra mussels to the North America is causing annual multimillion losses to the economy". Zebra mussels colonize water supply pipes of hydroelectric and nuclear power plants, public water supply plants, and industrial facilities [5]. The colonization of the mussels restrict the flow of water, therefore affecting heat exchangers, condensers, firefighting equipment, and air conditioning and cooling systems. "Zebra mussel densities were as high as 700,000/m2 at one power plant in Michigan and the diameters of pipes have been reduced by two-thirds at water treatment facilities". Small mussels also can get into engine cooling systems causing overheating and damage on boats. Navigational buoys have been sunk under the weight of attached zebra mussels. "Maintenance of pipes clogged with zebra mussels costs the power industry up to $60 million per year and temporary shutdowns due to insufficient water flow can

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cost over $5,000 per hour. The total cost to the United States of the zebra mussel invasion is estimated at $3.1 billion over the next ten years" [7].

In Bethlehem Pennsylvania there is a quarry for divers to swim through sunken boat, buses, and even planes. In this quarry, it is known that there are zebra and quagga mussels. It is thought that these mussels were introduced to increase the visibility in the water, because the mussels are so good at filtering out the plankton. Researchers dove down to see if there were patterns in which the mussels were growing, to see if there was a trend in zebra versus quagga mussels, and to see if succession was occurring. Based on research, it was thought that there was no preference in substrate for quagga or zebra mussels. There was also no evidence that one was out-competing the other, or that one was better at living in certain areas. The researchers dove a fire truck and sunken cylindrical blocks, to see if there was any pattern to where mussels were dispersing. The researchers then mapped out mussels, and took samples of the mussels in the soft substrate using the sunken boat as a reference. Finally, the researchers dove a sunken airplane.

The way that mussels were dispersed and distributed was looked at, and samples were taken. It was hypothesized that there would be no dispersion, for the mussels would be distributed everywhere, covering everything. However, the quagga mussels and the zebra mussels would exhibit regular dispersion from each other, but there would be no pattern to the way in which were laid out. Based on prior research these mussels just cover all substrate.

## Materials and Methods

In order to look at the zebra mussels and quagga mussels in a quarry in Pennsylvania, scuba gear was needed. In order to map where the mussels were, a square grid was used, a compass, and measuring tape. First a sunken firetruck was looked at for qualitative data. The two foot by two foot grid was then used to look at the dispersion and distribution of the mussels. Then in another dive, a sunken boat was used as reference to plot where the mussels would be in soft substrate.

From the tip of the boat a compass was used to find the direction the clumps of mussels were from the boat. The measuring tape was used to find how far away the clumps of mussels were from the boat and how long the diameter of each clump was. From each clump mussels were taken to look at the type of mussels that were in each clump. Then on a separate dive the dispersion and distribution of mussels were looked at on hard substrate on a sunken airplane. On the side of the wing the two foot by two foot grid was used to plot were the mussels were distributed and six feet were measured with the measuring tape and left in-between the plots. Mussels from each plot were taken to find the type of mussel. When deciphering what mussels were which, a microscope was used and a cooler filled with ice was used to preserve the mussels. The way that the mussels were deciphered is based on Figure 1.

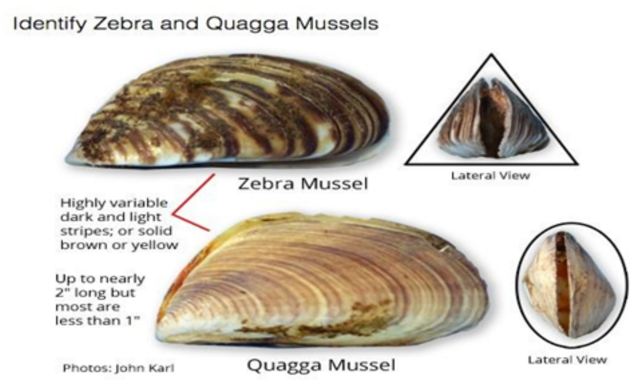


**Figure 1:** The way of identifying the difference between a quagga and a zebra mussel.

## Results and Discussion

Previous research has shown that zebra mussels and quagga mussels show no preference in hard or soft substrate [5]. It was therefore hypothesized that when the sunken objects in the quarry were looked at, they would be covered by the same amount of mussels as the sandy floor bottom. At the quarry the bottom had no mussels on it, except for some clumps that were thought to be on rocks. Figure 2 shows the Images of Mussels on a sunken Fire truck. There were also many large cylindrical blocks that were on the ground. These blocks were covered in mussels, except for the top part that is facing the surface of the water. This was the same for the sunken boat and fire truck. The sides of the boat and fire truck were covered and in the interior, but the parts of the sunken modes of transportation had no mussels on the parts that were facing upward. These findings seem to refute previous studies of these mussels. This is thought to be because the sand would inhibit their filtering process to acquire nutrients. The sunken airplane is suspended in the air from buoys. On the top of the plane there were no mussels, but underneath and on the sides, every inch was covered by mussels. Other explanations for this could be because divers are constantly touching the tops of these sunken objects, but it is likely that sand coming from the bottom is the main cause because there were hardly any mussels that were just on the sand, and not on sand covered rocks.

Shown in Figures 3-5 and Table 1-4 the amount of zebra mussels on soft substrate compared to the amount of quagga mussel of soft substrate was significantly different (Figure 4). This chi squared test revealed that there was a 0.00003% chance that the number zebra mussels found and quagga mussels found was simply by chance. As it is shown in figure 6, there are clumps of the mussels in the sand. Twenty out of the twenty one mussels in the sand measured from the boat were zebra mussels. The clumps varied in size, but the size of the clump could have been the size of the rock that the mussels were on. Where the mussels were living in the sand there were rocks underneath them, however they were surrounded by soft substrate. It was clear that zebra mussels did better in the sandy living conditions. The mussels were visibly moving, each using its foot, to and from the boat to go to other hard substrate surfaces.

**Figure 2:** Images of Mussels on a sunken Firetruck.

| Soft Subtrate | |
|---|---|
| Site | Mussel Type |
| A1 | Zebra |
| A1 | Zebra |
| A2 | Zebra |
| A2 | Zebra |
| A2 | Zebra |
| A3 | Quagga |
| A3 | Zebra |
| A3 | Zebra |
| A3 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |
| A4 | Zebra |

**Table 1:** Raw Data Chart of Soft Substrate.

| Hard Substrate | |
|---|---|
| Site | Mussel Type |
| B1 | Quagga |
| B1 | Zebra |
| B1 | Zebra |
| B2 | Zebra |
| B3 | Zebra |
| B3 | Quagga |
| B3 | Quagga |
| B4 | Quagga |
| B4 | Quagga |
| B4 | Quagga |
| B5 | Quagga |
| B5 | Quagga |
| B5 | Quagga |
| C1 | Quagga |
| C2 | Quagga |
| C2 | Quagga |

| | |
|---|---|
| C3 | Quagga |

Table 2: Raw Data Chart of Hard Substrate.

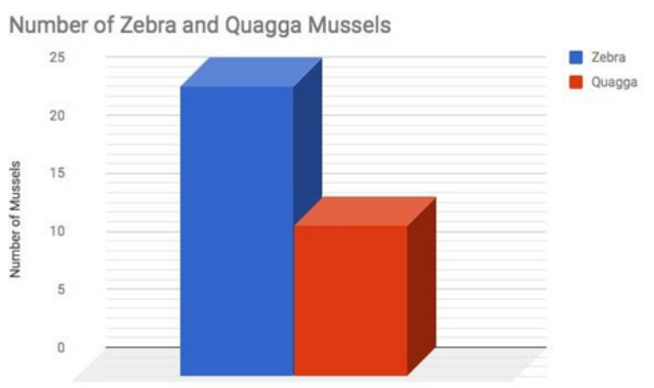


**Figure 3:** This is a chart that shows the total number of zebra mussels compared to quagga mussels, with a sample size of 38 mussels.

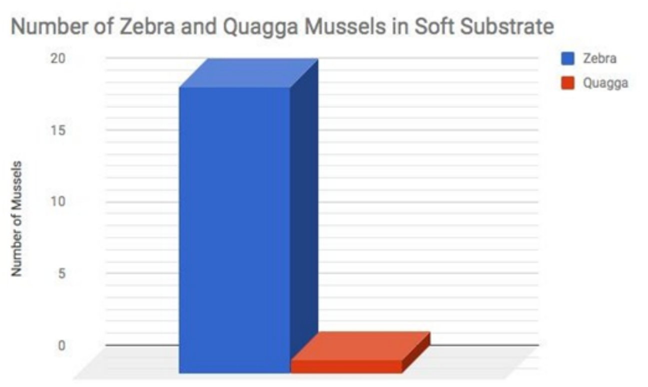


**Figure 4:** This is a chart that shows the number of zebra mussels compared to quagga mussels on soft substrate, with a sample size of 21 mussels. These mussels were found in the sand next to a sunken boat.

In figure 3 -6 and Table 1-4, the amount of quagga mussels that were on the hard substrate compared to the amount of zebra mussels on the hard substrate was not significantly different. This chi squared test revealed that there was a 8.96% chance that the number a zebra mussels found and quagga mussels found was simply by chance. The zebra and quagga mussels that were looked at were on sunken airplanes, boats, and fire trucks, but they were only mapped out from the plane.

Figure 7 demonstrates that on the hard substrate there was each type of mussel found on the side of the wings. In Figure 7 the analysis shows the probability that all four zebra mussels were found together in a clump. There is a 0.7143% chance that all the zebra mussels would be clumped together by chance. The math showing the probability that all four zebra mussels are together on the same half of the wing. The probability that this arrangement would happen, is 0.00000555%. These results show that the distribution and dispersion of these mussels are most likely not by chance (Figure 8). This supports that conclusion that zebra and quagga mussels grow, and stay, in mono specific clumps. This may be the case because the mussels might not move after reproduction. The distribution and dispersion of these mussels also may be due to succession. Either, there could have originally been entirely zebra mussels and now they are being outcompeted by quagga mussels, or it was entirely quagga mussels, and now the zebra mussels are out competing them. Figure 9 shows sightings of zebra mussels in the US.

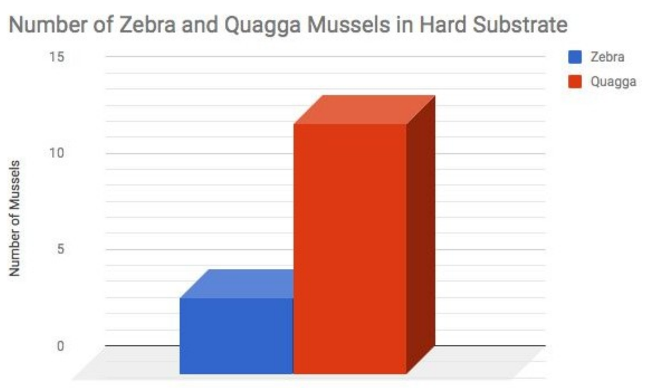


**Figure 5:** This is a chart that shows the number of zebra mussels compared to quagga mussels on hard substrate, with a sample size of 17 mussels. These mussels were found on a sunken airplane.

| | | Experimental | Theoretical |
|---|---|---|---|
| **Total** | Zebra | 26 | 19 |
| | Quagga | 12 | 19 |
| | Chi | 0.02314093131 | |

**Table 3:** This is the chi squared test for the number of zebra mussels compared to quagga mussels found in the quarry, with a sample size of 38. This chi squared test revealed that there was a 2.31% chance that the number a zebra mussels found and quagga mussels found was simply by chance. This shows that there was significant difference between the observed and expected numbers of these two mussels.

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| | | Experimental | Theoretical |
|---|---|---|---|
| Hard Substrate | Zebra | 5 | 8.5 |
| | Quagga | 12 | 8.5 |
| | Chi | 0.08955507441 | |

**Table 4:** This is the chi squared test for the number of zebra mussels compared to quagga mussels found in soft substrate, with a sample size of 21.

This chi squared test revealed that there was a 0.00003% chance that the number zebra mussels found and quagga mussels found was simply by chance. This shows that there was significant difference between the observed and expected numbers of these two mussels.

| | | Experimental | Theoretical |
|---|---|---|---|
| "Soft" Substrate | Zebra | 20 | 10.5 |
| | Quagga | 1 | 10.5 |
| | Chi | 0.000033812725 | |

**Table 5:** This is the chi squared test for the amount of zebra mussels compared to quagga mussels found in hard substrate, with a sample size of 17.

This chi squared test revealed that there was a 8.96% chance that the number a zebra mussels found and quagga mussels found was simply by chance. This shows that there was not significant difference between the number of observed and expected mussels.

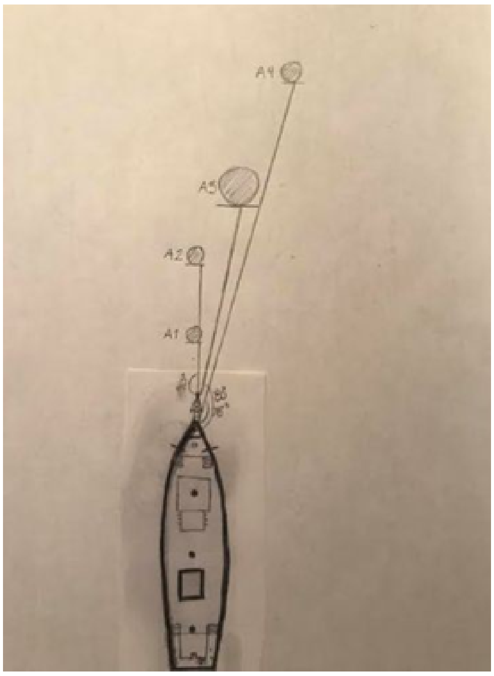


**Figure 6:** This is a scaled drawing of the clumps of mussels relative to the boat. The map scale is six millimeters to one foot.

The first plot, A1, was 3.4 feet away and had a diameter of roughly 1.4 feet. The second plot, A2, was 11.2 feet away and had a diameter of roughly 1.6 feet. The third plot, A3, was 15.4 feet away at an 80 degree angle, and had a diameter of roughly 2.8 feet. The fourth plot, A4, was 25.0 feet away at an 70 degree angle, and he has a diameter of roughly feet.

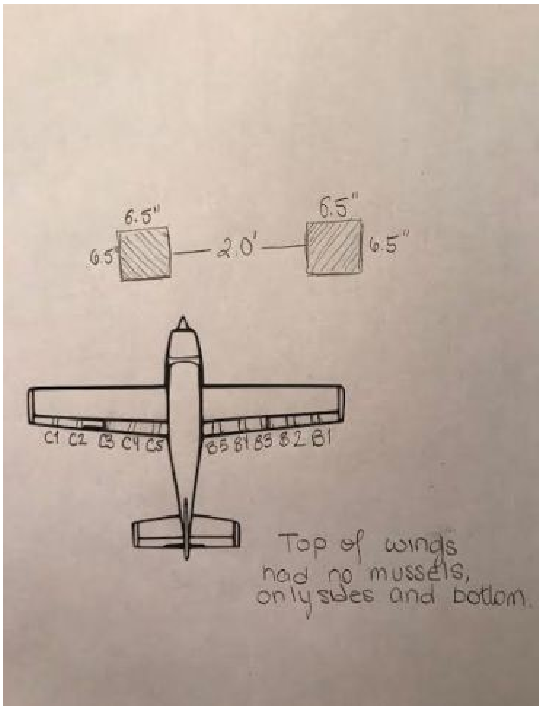


Figure 7: This is a scaled drawing of the location of the zebra and quagga mussels are on hard substrate, which is an sunken airplane. There were no mussels on the top of the plane, only on the sides and on the underside of the plane, and the plane that was suspended from buoys. On the sides of the wings, 6.5 by 6.5 inch plots of mussels were looked at and sampled, with two feet in between each plot. The entire plane was covered with no dispersion pattern.

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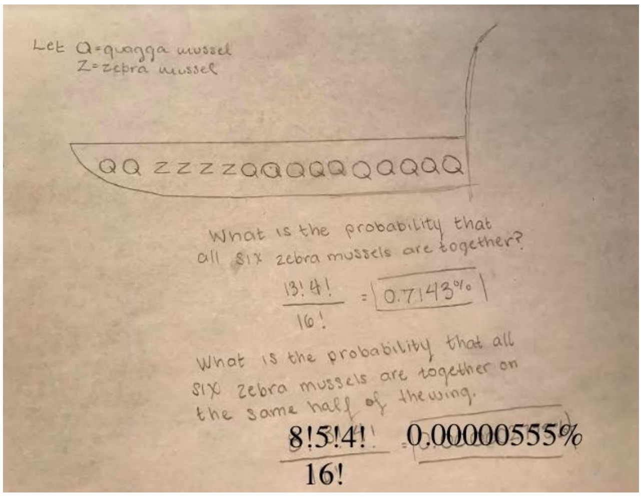


**Figure 8:** The first set of calculations shows the probability that all four zebra mussels were found clumped together.

There is a 0.7143% chance that all the zebra mussels would be clumped together by chance. This is shown by doing (13!4!)/16!, where the 13! represented the way in which the 13 mussels are arranged (the four zebra mussels are one group and then there are the other 12 quagga mussels.) 13! is multiplied by 4! because 4 is the number of zebra mussels that can be rearranged together. This is then divided by the total possible arrangements for the mussels, which is 16!.

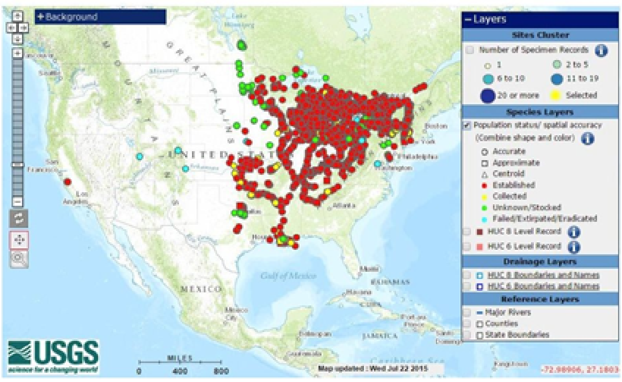


**Figure 9:** This is a graph from the USGS showing where there are confirmed sightings of zebra mussels in the US.

The second set of calculations shows the probability that all four zebra mussels are together on the same half of the wing. This is done by multiplying the number of ways that the mussels could rearrange themselves on one half of the wing (8!) times the number of ways that the mussels could rearrange themselves on one half of the wing, assuming that the zebra mussels are sticking together (5!). This is then multiplied by the number of ways that the zebra mussels could rearrange themselves (4!). All of this is divided by the number of ways that the mussels could be rearranged (16!) to find the probability that this arrangement would happen, which is 0.00000555%.

In this lab there are sources of error. There may be some human error in identifying the mussel, but there is also error, because the amount of mussels taken and looked at is so different in size, that it is hard to get an accurate reading of the number of mussels in the given place. This lab gathered a lot of qualitative data that reflected that there was in fact a difference in preference between the soft and hard substrate. The mussels were entirely on hard substrate. The quantitative data suggests that succession occurred.

## Acknowledgment

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