Zequanox: A Potential Solution to Zebra Mussels

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Abstract: Zebra mussels are an invasive species that are very harmful to the environment and therefore cost society a considerable amount of money. Most of the previous attempts to eliminate zebra mussels were either ineffective or caused damage to other organisms. Zequanox is a biopesticide made by Marrone Bio Innovations, and its ultimate purpose is to eliminate zebra mussels. However, Zequanox can change the water quality for very short periods of time and can harm other aquatic organisms in large doses. After extensive research on this controversial subject, Zequanox has been found to be a viable option if used in regulated doses.

Introduction

Zebra mussels (*Dreissena polymorpha*) are an infamous invasive species in the United States. Originating from the Caspian Sea in Europe and arriving in the United States by ballast in ships in 1988, zebra mussels spread throughout the Great Lakes and the Mississippi River. They have rapidly spread to over 20 states in the United States, readily attaching themselves to hard surfaces like boats and motors and then releasing in other lakes (National Park). Issues associated with zebra mussels, such as clogged pipes and polluted drinking water, will not be resolved without active means of prevention. Zequanox, a biopesticide that comes "from a strain of the naturally occurring bacteria *Pseudomonas fluorescens*" (*P. fluorescens strain* CL145), has been found to be a productive and efficient way to kill zebra mussels (Whitledge et al., 2014). Zequanox is unique in the fact that it is not made from synthetic chemicals and solutions, yet it is still an effective pesticide for zebra mussels.

The concern is that Zequanox could not only kill off the harmful invasive mussels, but also affect the water quality, harm native aquatic life, and change the ecosystem. This article will weigh the effects of zebra mussels and Zequanox while considering an important question: Is there too much risk in using Zequanox so that we must find another solution, or even simply live with the infestation of zebra mussels? I will conclude that the answer to the question is this: Zequanox is a viable solution to eliminate zebra mussels because it does little or no damage in multiple areas. The problem of zebra mussels in the United States is more harmful than the potential side-effects of Zequanox.

Zebra Mussels

Zebra mussels are damaging in multiple dimensions. Because of their ability to reproduce so rapidly, they are almost impossible to control. The Virginia Department of Game and Inland Fisheries (2016) declared that an adult female zebra mussel can produce up to a million eggs each year, and it is very likely to find a square meter area with 100,000 to 1,000,000 zebra mussels. The National Oceanic and Atmospheric Administration (n.d.) agrees that up to 700,000 have been found per square yard area on boats, pilings, and pipes. This rate of reproduction is extremely hard to control.

One very important risk that follows the takeover of zebra mussels is the quality of drinking water. Okanagan WaterWise warns that "these invasive mussels promote toxic algae which would pollute our drinking water and also clog drinking water intake and distribution systems" (2012). Additionally, Okanagan Waterwise warns that addressing these drinking water problems could cost millions of tax dollars to fix. Therefore, without prevention, zebra mussels will continue to multiply, causing more and more drinking water intakes to be clogged.

Zebra mussels also pose a threat to fish and other aquatic organisms. Because they filter out many microscopic organisms, they are also taking away a major food source from fish (Virginia, 2016). In fact, the National Oceanic and Atmospheric Administration declares that "fish stocks and conditions have declined in many of the Great Lakes." When the fish decide to eat the zebra mussels, fish waste energy crushing their shell for a result lacking in nutritional value (National Oceanic, n.d.). Along with that, "Zebra mussels attach themselves to native mussels so the natives can't eat, breathe, or reproduce" (National Park, n.d.). The Government Accountability Office estimates that zebra mussels will cause native mussel species to decline to as much as 50 percent in the next 10 years, with up to 140 extinct species (Western, 2010). Because zebra mussels will be killing off many different bottom-dwelling species by taking their food, the mussels will also be killing many other animals that eat those bottom-dwelling species, having a significantly negative impact on the food chain.

Zebra mussels will be, and are, an enormous financial cost to the United States. For example, the United States will lose close to $3.7 million from lost boat sales and required maintenance on docks and marinas, and a boat owner will have to pay between $1,000 and $2,500 a year for maintenance (Okanagan, 2012). These values are minor compared to some that have been recently recorded. "U.S. Congressional researchers have estimated that Dreissenid mussel infestations in the Great Lakes area has cost the power industry $3.1 billion between 1993-1999, with an economic impact to industries, businesses and communities of more than $5 billion," and "[a]verage costs from 1989-1994 for facilities with a Great Lakes basin water intake were over $4 million per respondent for zebra mussels" (Western). If their spread continues, these costs will continue to occur because of the continuous maintenance. The Missouri Department of Conservation expects damage costs due to zebra mussels in North America to be in the billions in the next decade (2010).

Zequanox

Zebra mussels undoubtedly cause many problems, without giving any benefit, which is why Zequanox is being considered to fix the problem. Zequanox is a naturally made pesticide by Marrone Bio Innovations and targets zebra and quagga mussels (Whitledge et al., 2014). It is made from a natural bacteria strain called *Pseudomonas fluorescens* CL145A which is commonly found in soil and water, and it protects plants from disease while helping them grow (Ganeshan and Kuman, 2005). Zequanox is used in the form of a dried powder and is administered directly into the infested body of water (Meehan, 2014).

Zequanox seems to be good substitute compared to other products that have been tested to kill zebra mussels. Unlike other chemicals, zebra mussels do not see Zequanox as a danger and will readily ingest it. Once this happens, the Zequanox will deteriorate the lining of the zebra mussels' stomachs, ruin their digestive system, and cause death (Marrone, n.d.). Zequanox also kills zebra mussels more quickly than do other products.

Meehan's Study

There are many known benefits to using Zequanox; however, this article examines whether the benefits outweigh the costs of this pesticide. Sara Meehan conducted a study to research some of the areas of concern, such as water quality and the health of other aquatic organisms being introduced to Zequanox. Meehan divided the study area into two treatment groups and a control group each containing naturally settled and seeded mussels. Treatments 1 and 2 were treated with Zequanox, while the control was not. Aeration devices were used to administer oxygen into the water, keeping the levels of dissolved oxygen (DO) in the water fairly constant in Treatment 1. Because Meehan knew that Zequanox can alter the levels of DO in water, she wanted to see if the results of use of aeration devices in Treatment 1 would give differ from results in Treatment 2, which wouldn't have aeration devices. If DO levels become too low, aquatic animals may not have enough oxygen to go through the process of respiration, resulting in their mortality (Murphy, 2007). Meehan also observed different parameters of water quality like turbidity and total organic carbon (TOC) during her study.

Turbidity is a measure of haziness in the water, while TOC is the amount of organic matter in the water; both of which can affect the carbon cycle (Murphy, 2007) and aquatic organisms that rely on the quality of the water to survive.

The mortality rate of seeded mussels in Treatment 1 was 75% and only 56% in Treatment 2. The difference in mortality between the two could have resulted from the decrease of DO in Treatment 2, causing the mussels to avoid ingesting the Zequanox. Additionally, naturally settled mussels had a mortality rate of 46% in Treatment 1 and 65% in Treatment 2. The aeration devices being placed so close to the naturally settled mussels could have disturbed them enough to avoid ingesting the Zequanox, causing a lower mortality rate in Treatment 1. Temperature and pH levels in the treatment groups did not differ considerably from those in the control group. Furthermore, there was an increase in turbidity in both treated areas, an increase in TOC in both treated areas, and a decrease in DO levels in Treatment 1. However, turbidity, TOC, and DO levels all returned to normal within 24 hours.

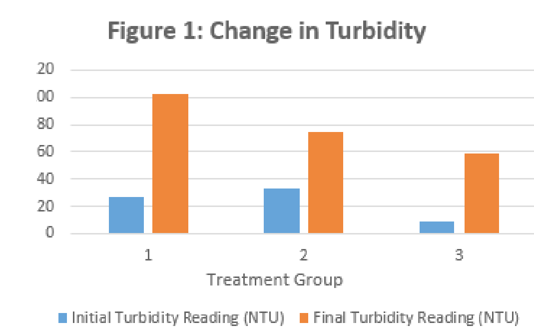
Meehan also studied different species and families of aquatic organisms following Zequanox exposure. She placed many organisms such as nonbiting small flies (*Chironomus*), aquatic sowbugs (*Asellus aquaticus*), mayflies (*Ephemerella ignita*), blue mussels (*Mytilus edulis*), freshwater mussels (*Anodonta*), water fleas (*Daphnia pulex*), European freshwater crayfish (*Austropotamobius pallipes*), and freshwater snails (*Lymnaea peregra*), and brown trout (*Salmo trutta*) in different concentrations of Zequanox and monitored them. The results showed that all the organisms tested except Salmo trutta had little to no mortality at a concentration of 100-200mg/L being administered every 12-24 hours for 72 hours. However, even lower concentrations of Zequanox lead to a high mortality rate for *Salmo trutta*.

Whitledge et al. Study

To further investigate whether Zequanox is a viable solution to the zebra mussel problem, this paper will analyze another study: Gregory E. Whitledge et al. explain and interpret their research on the effects of Zequanox in two different sets of controlled environments. In the 2012 trial, Whitledge et al. studied three pairs of control groups and experimental groups of equal area. The experimental group was treated with Zequanox, and the control group was not. To determine whether the surface the zebra mussels are attached to will affect their mortality rate while being treated with Zequanox, zebra mussels were tested from a log that was submerged into the treated area (wood substrate), the bottom of the lake (benthic substrate), and rigid mesh chambers placed in the treated areas.

Zebra mussels attached to the benthic substrate had a mean mortality rate in the treatment plots of 42.6% one day after treatment, and 91.7% one week after treatment. Additionally, the control plots had a mortality rate of 0.41% one day after treatment, and 4.5% one week after treatment. Similarly, zebra mussels attached to wood substrate had a mean mortality rate in the treatment groups of 37.9%, and 1.7% in control groups one day after treatment. Two weeks after treatment, zebra mussels placed in the mesh chambers had a mean mortality rate of 97.1% in treatment groups, and 11.1% in control groups. With these results, Whitledge et al. conclude that the type of substrate does not influence the mortality rate; therefore, Zequanox is effective in killing zebra mussels attached to all the common types of surfaces they are typically found.

In the 2012 trial, Zequanox concentration did not exceed 124 mg/L. Figure 1 shows how turbidity changed from the addition of Zequanox.



Whitledge, Gregory et al. (2014)

Twenty-four hours post-treatment, the average turbidity reading for the treatment groups was 9 NTU compared to 1.2 NTU in controls groups. DO levels decreased 24 hours after initial treatment, but the DO levels were insignificant on the overall water quality observations because they quickly returned to normal levels once the barriers were removed. Levels of pH in the experimental groups were also fairly constant with the control groups. Additionally, water samples from the treatment groups and the control groups were tested for BOD, Chlorophyll a, Phosphorus, Nitrogen, and Ammonia, and all were either undetectable or the same as in the control groups.

In the 2013 trial, Whitledge et al. wanted to investigate how effective Zequanox would be if it were to be injected approximately 0.3 meters above the bottom of the lake. These results elude to how quickly and efficiently Zequanox spreads while also killing zebra mussels around the area that it was administered. Whitledge et al. comment on the results of this trial:

> At 1-d post-treatment, settled mussel mortality averaged 0.8% in control samples, 82.9% at locations < 5 m from Zequanox SDP application points, 11.1% at locations > 5 m from application points, and 73.6% at locations shallower than application points . . . ; mortality was significantly higher at locations < 5 m from application points and in shallow areas within the area enclosed by the barrier compared to control sites.

With that information, Whitledge et al. conclude that Zequanox is most effective in killing zebra mussels up to 5 meters from where it is injected. This means that Zequanox only needs to be administered close to the bottom of the treated area, and it will still be just as effective as if it were administered at many different depths.

The average turbidity reading for the treatment area at the substrate was 177.7 NTU, and 26.5 NTU at the surface. The reading in both areas combined decreased to 46.6 NTU 17.5 hours following treatment. A decrease in DO levels was observed as it was in the 2012 trial, with 7.2 mg/L inside the barrier, and 8.5 mg/L outside of the barrier. However, unlike in the 2012 trial, DO levels returned to normal within 2 hours of barrier removal.

Discussion

Zequanox has been shown to be extremely effective in killing zebra mussels. Results show that mean mortality rates in treatment groups are significantly higher than in controls group. This gives one reason to investigate the other effects Zequanox may have.

These studies were done under extreme conditions, as the researchers did tests with large concentrations of Zequanox, concentrations that would not be permitted in open water. Zequanox use in open water cannot exceed a concentration of 200mg/L and will usually be used at a concentration of 150 mg/L (Meehan, 2014). The required smaller amounts of Zequanox indicate that in reality Zequanox might not be as harmful as the tests lead on, because it will be so diluted.

With that said, Zequanox will be harmless to most fish if regulations are followed. Mortality rates in fish occur in concentrations above 200 mg/L, meaning that fish would only experience death in hypothetical situations. Fish are not affected by the Zequanox; they are affected by the changes in water quality like levels of dissolved oxygen, again showing that following regulation will resolve this problem. *Salmo trutta* mortality is definitely a factor in this argument, as it occurs even in low concentrations. When deciding where and how to use Zequanox, *Salmo trutta* will have to be taken into consideration. Additionally, strategies could be developed to detour the *Salmo trutta* away from treated areas.

Even though turbidity, TOC levels, and DO levels changed with the use of Zequanox, they all returned to normal levels within 24 hours of being administered. This indicates that Zequanox does not permanently change water quality. This change was observed in high concentrations whereas lower concentrations had less of a change. Thus, if regulations are followed, these small changes will be even smaller.

One of the reasons that Zequanox is being used to kill zebra mussels in the first place is because zebra mussels are financially detrimental. It is rational to ask whether it is cost efficient to be using Zequanox, or if it causes more debt than it is worth. With this said, a booklet addressed to the Douglas County Commissioners asserts that “Steve Hirsh, DNR, estimated in an email to John Reynolds on March 25th that anticipated Zequanox treatment costs are currently $10,000 per acre” (Lindquist et al., 2011). With this information, it can be determined that a product like this does not come without a cost.

Although it is very expensive, it is very effective and could alter the negative effects caused by zebra mussels in many lakes around the United States. In theory, if the Zequanox works well enough to eliminate zebra mussels and they do not spread further, they should no longer be costing the United States any money. Although this scenario isn't totally realistic, it demonstrates that Zequanox is going to significantly decrease the financial burden even without a 100% mortality rate.

Conclusions

In conclusion, Zequanox should be used to kill zebra mussels. From the studies that confirm the harmless effects to water quality and other native aquatic organisms, it is clear that Zequanox has less harmful effects than do zebra mussels. It has also been predicted that Zequanox use will cost the United States a lot less financially compared to zebra mussels, making it the best option monetarily. Zequanox is a superior solution to this destructive problem.

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