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Feasibility of Introduced Species into the Westhampton Lake for Pollution Control

Abstract

Westhampton Lake, located at the University of Richmond in Virginia is a man made lake that feeds into the James river. The lake itself suffers from pollution and above average nutrient loads from external sources. There have been efforts to try to reduce some pollution from the lake but this research proposes and explores the viability of introducing species into the lake for the same purpose. Two types of animals proposed for introduction into the lake are common carp (Cyprinus carpio) and freshwater mussels (Bivalvia: Unionidae). Sterilized common carp are proposed as a short term solution to removal of invasive plant species (can not reproduce and would need to be replenished) because of their foraging ecology to eat undesirable plant species. Freshwater mussels have the potential to filter through e.coli and nutrients that are in excess in the lake. Freshwater mussels are also suffering from dwindling populations and so reintroducing them into the Westhampton lake would be overall beneficial to their survival in Virginia. Research into the nutrient levels of the lake proved that Westhampton Lake has nutrient levels in the range of what mussels could survive in. Common carp, however, would have too many risks associated with their introduction to be recommended. Common carp forage in a way that breaks up soil and could release nutrients into the water and would also likely favor eating native rooted plants as opposed to the invasive duckweed we would be seeking for them to target. Therefore, it is proposed that there be a trial introduction of mussels in enclosed cages in the lake so their health and growth could be monitored before introducing a larger population. Common carp as a means of invasive plant species management should not be pursued.

Introduction

Many consider the Westhampton lake to be a focal point of campus, emblematic of the university itself, showcased on pamphlets and web pages to represent what the beautiful campus has to offer. While the lake is hailed as an important component to our campus identity, upon first glance, there are some obvious factors that hinder the overall aesthetics of the lake. The water is turbid and impossible to see through. Depending on the time of year, if you want to walk around the lake on the trail that surrounds it, you may find yourself more focused on dodging goose droppings than enjoying the fresh air. If someone wanted to use the lake for recreational fishing, they may find that there are a relatively small amount of fish, and usually undesirable ones. Because of the lake's condition, the species and types of organisms that can survive in the lake are limited.

High concentrations of these nutrients in the water also make for the ideal conditions to spur outbreaks in plant life like duckweed and filamentous algal blooms (Vadeboncoeur, et. al. 2020). When filamentous algal blooms occur in a lake, the algae creates a carpet over the littoral habitat which drastically reduces biodiversity and any other type of plant attempting to grow in that same zone (Vadeboncoeur, et. al. 2020). Because higher levels of pollution and nutrient loads are ideal for these algal blooms, finding ways to remove these plants themselves or altering the composition of the lake so that it is less supportive of algal blooms would be crucial to reducing the degradation caused by these species and to help restore the littoral habitat (Vadeboncoeur, et. al. 2020). Another problematic species is duckweed, which thrives in environments with high levels of phosphorus and nitrogen (Liu, et. al. 2017). Duckweed poses a threat because of its invasive nature that tends to create a dense layer on the water's surface that prevents any other species from sharing the same habitat (Vymazal, 2008). When duckweed invades in this way, it can limit the amount of oxygen entering the water and sunlight that can reach phytoplankton, further reducing biodiversity (Vymazal, 2008). For these reasons, it is beneficial to find methods to remove both duckweed and filamentous algae either by manual removal or by reducing the suitability of their habitat.

A frequently hypothesized method of duckweed and algae removal is to introduce species of invasive carp that have been sterilized. This method offers a non-permanent and cost effective possibility for removing these problematic species from the lake (Snodgrass 2008). Invasive carp are known to eat away at a plethora of plant species in a water system so the idea is to release a few fish periodically and let them go to work on manual removal of the duckweed (Snodgrass 2008). There are some species of carp that target desirable plant species, and some even eat mussels, so evaluating whether or not these carp would be beneficial is crucial ("Black Carp" 2022). This research seeks to determine whether or not common carp will target the species we are attempting to remove and if they will be destructive to the ecosystem.

There are also non-migrating Canada Geese present on the lake year round that contribute to the lake's pollution through their feces that are either directly dropped directly into the lake or get swept up in the lake through stormwater runoff. Canada Goose feces generally cause large amounts of phosphorus and nitrogen to be loaded into a habitat, two elements that alter the types of biota that can survive in a water system (Dessborn, et. al. 2016). Canada geese also contribute larger than normal amounts of salmonella and e. Coli into a water system (Elmberg, et. al. 2017). According to data collected on the Westhampton Lake, there high enough levels of E. coli to suggest that goose feces could be impacting the water quality ("Westhampton Lake water quality")

There are 77 species of freshwater mussels native to Virginia alone, but more than half of these species are federally endangered (Jones 2015)). In response to their rapidly declining populations, there are extensive efforts by both citizen-run and government-run organizations to help re-establish and support the reintroduction of mussels into their native ecosystems (Jones 2015). Because of this, freshwater mussels pose a viable option to reintroduce in the Westhampton lake that will have the potential to benefit the survival of freshwater mussels in Virginia as a whole. There are risks associated with introducing species, and so specific considerations should be made to try to limit inbreeding and genetic drift in these small founder populations (Hoftyzer, et. al. 2008). Another crucial consideration for mussel survival is the presence of acceptable host fish species for mussel larvae to implant on and grow on (Denic, et. al. 2015).

In addition to their threatened status, freshwater mussels also have a high potential to absorb large loads of nutrients. It has been suggested that there is a direct link between the nutrient cycling processes that occur in a lake and the freshwater mussels present within it, and that they both impact one another (Strayer 2014). It has also been found that mussels can absorb considerable amounts of E. coli from water (Ismail, et. al. 2015). Some mussels can even filter through up to 10 gallons of water in a day, which quickly and efficiently helps the lake to naturally filter through pollutants ("Native Freshwater mussels" 2007). For these reasons, if viable, mussels could be a beneficial filter feeder to reduce both excess nutrients caused by pollution and harmful bacterias like e. Coli.

There are paved paths surrounding the entirety of the lake, a portion with a main road being uphill from it, and a larger portion with a campus road around it. Richmond gets temperatures below freezing in the wintertime, and all of these roads are diligently treated with road salt to reduce the freezing point and de-ice the slipping hazards. Because of each of these roads, there are road salts that get leaked and run-off into the lake directly leading to high levels of nitrates in the water. This is very harmful because even small concentrations of chlorine in waterways can severely harm aquatic species ("How road salt harms the environment" 2018). Because of this, chlorine levels need to be examined and evaluated for their potential harm for freshwater mussels.

The main research question being addressed through this work is:

1. Is there any viability to adding organisms (i.e. sterilized common carp, freshwater mussels) to the lake to reduce pollution or any other factors that could be limiting the quality of the ecosystem?

Methods

Westhampton Lake is a man-made lake centered in the University of Richmond campus in Richmond, Virginia. The lake serves a few purposes, first as an important element of the James River watershed that flows into the James River itself, and also as a beautiful focal feature for the campus to surround. Because of this, there is a desire to both keep the lake as beautiful as possible as well as keep it productive in its role within the James river watershed. Figure 1 is an aerial view of the Westhampton lake, with four locations within the lake marked A through D. Each of these sites are the locations where the Environmental Studies Department at VCU collects water quality data on a monthly basis. The data collected at these areas include E. coli levels, nitrogen, chloride, and phosphorus, and ammonia concentrations.

Figure 1: aerial view of the westhampton lake with four labeled sites for water quality collection.

For freshwater mussels, the key factors that are considered regarding the feasibility of their introduction are as follows:

1. Are there fish species currently living in the lake that could serve as hosts for the larval stages of mussel growth?
2. Are the chlorine levels in the lake too high for mussel survival?
3. Are the ammonia levels in the lake too high for mussel survival?

(1) Through environmental DNA testing kits conducted in July of the year 2020, there is a list of the different fish species that live in the Westhampton lake (JonahVentures 2020). Each of these fish species will be searched through a database that lists all of the mussel species that are able to use the fish as a host for their larval stage ("Freshwater mussel host database" 2022). This list will then be filtered to show only the species of mussels that are able to survive in this geographic region by cross-referencing them with a study that examines the different mussels that can survive in the area (Jones 2015).

(2) water quality data collected and provided by the Environmental Studies Department of VCU has monthly readings of different nutrients at four different sites around the Westhampton Lake and this will be used to determine the normal and peaked levels of chlorine within the lake ("Westhampton Lake water quality"). These chlorine levels will be researched within the literature as to whether or not these levels are too high for mussel survival or not. (3) additionally, levels of ammonia recording within the westhampton that are recorded by VCU will be researched to determine whether or not the current ammonia levels in the lake are of a range that can sustain mussel growth ("Westhampton Lake water quality"). If all of these requirements are met, freshwater mussels will be listed as feasible for introduction and next steps will be proposed for introducing them into the lake.

For common carp, the key factors that are considered regarding the feasibility of their introduction are as follows:

1. Will common carp target the plant species we are seeking for them to eat?
2. Are there other aspects of carp ecology that could negatively impact the lake, rendering them unfeasible?

(1) Existing literature will be researched to determine preferred types of plants and animals that common carp are likely to consume and will be examined as to whether or not introducing common carp will support the goals of the project.

(2) Extensive research into common carp will be conducted to determine whether or not there are aspects of carp ecology and ecology of the Westhampton lake that would clash with one another rendering the carp a harmful species. If both requirements are met, common carp will be listed as feasible for introduction and next steps will be proposed for introducing them into the lake.

Results

Freshwater mussels:

1. Are there fish species currently living in the lake that could serve as hosts for the larval stages of mussel growth?

The table below shows each of the fish species found in the Westhampton Lake through an environmental dna testing kit (JonahVentures 2020). Accompanying each fish species are the mussel species that have been observed as using that fish species as a host for their larval stage. Shown in the table below, there are two fish species that have no observances of freshwater mussel larvae using them as a host. The other four species of fish have a list of a few species of freshwater mussels that would be able to use them as a host species.

Fish species present in lake July 2020	**Viable mussel species that can infest fish species found in James River Watershed**
Gizzard shad	Rock pocketbook, spike, washboard
Bluegill	Spike, creeper, washboard, flat floater
Largemouth bass	Spike, creeper, washboard, flat floater
Eastern mosquitofish	No compatible mussels
Florida largemouth bass	No compatible mussels
Warmouth	Flat floater, paper pondshell, washboard

Table 1: fish species found in Westhampton Lake from an environmental dna testing kit and the mussel species that are able to use each fish species as a host. Included in the list of mussel species are only those that are geographically suitable for that area.

2. Are the chlorine levels in the lake too high for mussel survival?

While chlorine is usually an element that can cause toxicity to aquatic species, prevailing literature shows that chlorine spikes are less likely to cause changes in the survival of mussels (Valenti et. al. 2006). The literature suggests that since mussels are more tolerant to chlorine than most other fish and plants species, if other species of fish are surviving in the lake with the current levels, then the water is suitable enough for mussel growth.

3. Are the ammonia levels in the lake too high for mussel survival?

The water quality data collected at Westhampton lake can be shown in the boxplots in figure 2. From the graph, it can be seen that ammonia peaks as high as the .30-.37 mg/Liter range, but has most of its data, in the interquartile range, in the .075 - .175 mg/Liter range ("Westhampton Lake water quality"). The peaks are exceeding the range of ammonia which freshwater mussels can survive but mussels can survive in the more frequently recorded range of ammonia in the Lake ("Effects of Ammonia on Freshwater Mussels in the St. Croix River" 2002).

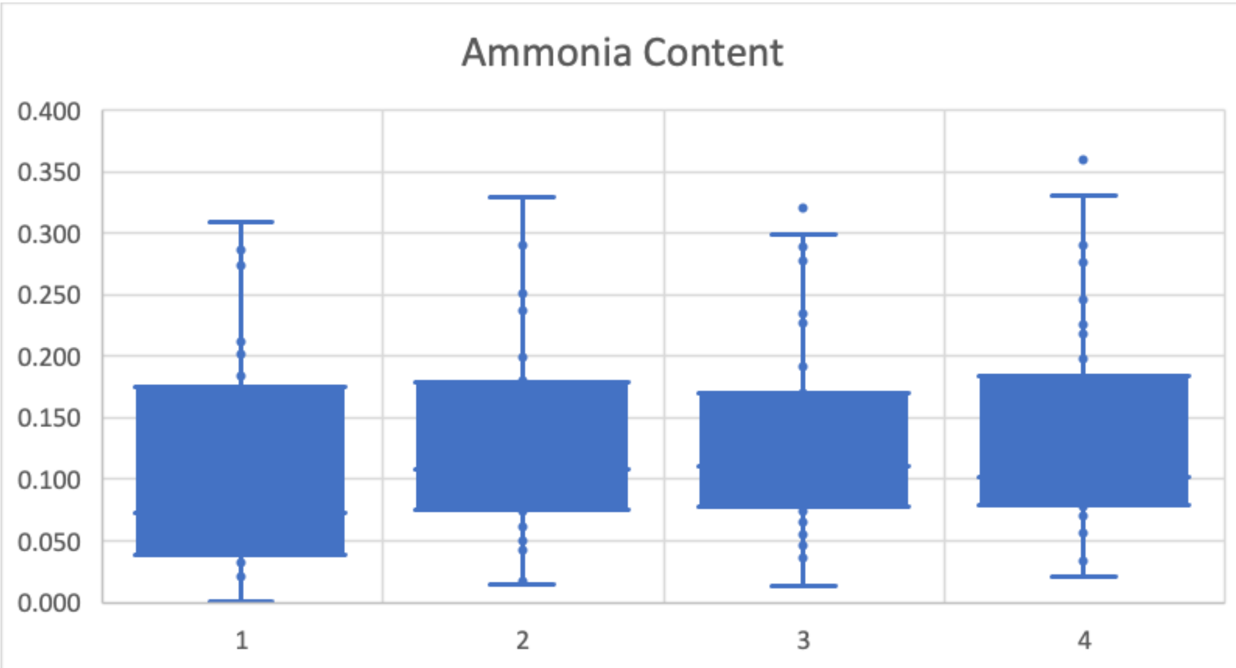

Figure 2, box plot showcasing the ammonia concentrations found at the four collection sites around the Westhampton Lake.

Common Carp:

1. Will common carp target the plant species we are seeking for them to eat?

Common carp are an omnivorous species and are known to eat a multitude of different plant and animal species. Rather than species like duckweed, the existing literature suggests that the carp will take preference to the different zooplankton and macroinvertebrates in the lake, and thus introducing them into the lake will risk the carp targeting a completely different group of species than what is intended (Rahman 2014).

2. Are there other aspects of carp ecology that could negatively impact the lake, rendering them unfeasible?

Extensive research into common carp introduced several problematic and probable outcomes once the fish are introduced. First, because of the way carp can break up soil while foraging for food, they will likely release more nutrients like phosphorus and nitrogen into the water on a continual basis (Qiu, et. al. 2019). Additionally, carp will produce waste that could also raise the nitrogen and phosphorus levels of the lake since it will be turning sediment nutrients into soluble versions (Qiu, et. al. 2019).

Discussion

As it can be interpreted from table 1, there are a few species of freshwater mussels that can be introduced into the lake that would also have different fish species as host options (JonahVentures 2020). Therefore, it can be concluded that there are adequate amounts of host individuals for the larval stage of mussel growth, if the right species of mussels are used. Because there are a high number of fish species that are able to serve as hosts to the mussels, this is very promising to the survival of mussels for more than one generation. Being able to reproduce for mussels relies on the availability of host species being present for their larval forms to parasitize. Additionally, while chloride levels are relatively high in the Westhampton

Lake, existing literature suggests that chloride levels are not problematic for freshwater mussels survival if other species of plants and animals are also able to survive in the same ecosystem (Valenti et. al. 2006).

While the other aspects of the lake quality are conducive to successful mussel growth, the only potentially problematic aspect of the water quality are the levels of ammonia found in the lake. The interquartile range of the boxplots for each collection site are within the range of what is possible for mussel survival. However, the upper limits tend to be out of the range of what is safe for freshwater mussels to survive in. This could be due to a few different causes. Since the data shows that ammonia is spiking and lowering over time, it is probable that something periodic like algal blooms that can occur in the Westhampton lake are what is causing the spikes, rather than a consistent source. After an algal bloom occurs and crashes, there are usually observed ammonia spikes because the algae served as a sink for large loads of ammonia (Sergeant 2014). This is why the algal blooms could potentially be the cause of the periodic spikes in ammonia concentrations. Therefore, getting the Westhampton Lake into ranges that will be suitable for freshwater mussels ammonia-wise could be a matter of reducing algal blooms. Some causes of algal blooms are eutrophication which is the excess of nutrients present in a body of water (Sellner, et. al. 2003). Like it is mentioned in the introduction, there are easily identifiable causes of these large amounts of nutrients being added into the lake. This includes but is not limited to addressing the problem of non-migrating geese on campus and limiting their stay on campus as a means of limiting the nutrients they add to the lake and finding ways to combat the duckweed and other covering plant species that limit oxygen being allowed into the water. In total, there is potential for introducing freshwater mussels into Westhampton Lake as a method for improving the water quality of the lake, as long as ammonia levels are continued to be monitored and improved.

In terms of next steps, there is existing research on potential methods for mussel introduction into Westhampton Lake. As apart of an environmental studies senior capstone project at the University of Richmond, student Henry Hurt proposed adding a trial sized amount of freshwater mussel species into the lake enclosed in cages that would not allow for them to disperse (2019). This method would allow for mussels to have a trial period in the lake, so that researchers could see their growth and health while living in the Westhampton Lakes's water. This will act as a middle step on the way to introducing a larger population of mussels to ensure that freshwater mussels are actually able to survive in the water before excessive time and resources are used to implement them. The research presented here went into the water requirements of freshwater mussel survival to show potential feasibility before actually adding mussels to the lake in the methods that Hurt described.

Due to the results found supporting the idea that carp would be more problematic to the ecosystem than beneficial, moving forward with common carp introduction is not suggested. Alternatively, the benefits of nitrogen and phosphorus removal by freshwater mussels could potentially help the nutrient levels in the lake so that the water will eventually be unsupportive of massive algal blooms and overpowering duckweed in the way that it is now. Therefore, while it is not feasible to introduce common carp into the ecosystem, the problems that the carp were seeking to solve could alternatively be solved by the introduction of freshwater mussels.

Introducing mussels into the lake has the potential to move forward the research regarding the reintroduction of mussels as a means of helping re-establish their populations. If mussels are reintroduced into the Westhampton lake, this study area could be used as a case study of either a failure or a success of reintroducing mussel species into a body of water for purposes of nutrient filtering. If the mussels are successfully established in the lake, it would also be important to continue monitoring the nutrient levels of the lake over time to determine the extent of which freshwater mussels are able to help the nitrogen and phosphorus levels of the lake. Lower concentrations of both nutrients could also help diminish the algal blooms and duckweed, yielding more oxygenated water in the lake and higher biodiversity. Clearly, a successful reintroduction of mussels in the Westhampton lake would yield a plethora of measurable results that have the potential to inform researchers on what freshwater mussels can do to help polluted bodies of water.

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