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Population dynamics and habitat selection of giant floater mussels (*Pyganodon grandis*) in a lake infested with invasive milfoil (*Myriophyllum spicatum*)

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Abstract

Invasive species may facilitate the survival of native species by providing appropriate habitat in the absence of native pond vegetation. The aim of this project was to study the distribution and population dynamics of freshwater mussels in a lake infested with Eurasian watermilfoil (*Myriophyllum spicatum*) in southeastern Minnesota, USA. We recorded a total for 44 individual giant floater mussels (*Pyganodon grandis*) between four transects: 2 transects were infested with watermillfoil, and 2 transects were unvegetated with open substrate. The objectives of this study were to 1) compare distribution of mussels between plots with vegetated substrate and plots without vegetation, 2) measure individual mussel size, age, and sex, and 3) make projections about the survivability of mussels in areas invaded by non-native species. We found more individuals in the vegetated plots (33) than in plots with open substrate (11), of which 57% were female and 43% were male. Individuals ranged from 1 to 6 years of age, and females tended to be older than males. The increased presence of mussels in transects with vegetation indicates that watermilfoil may provide a more suitable habitat for mussels, necessitating further research on the positive impacts of invasive species on native species.

Keywords: mussel, invasive species, habitat, lake ecology

Introduction

Invasive aquatic plants may facilitate the survival of freshwater bivalve populations throughout the loss of native pond plant species, necessitating understanding of mussel habitat selection and factors that contribute to the longevity of mussel populations. Freshwater mussels provide a variety of ecosystem services and are an essential food source for many lake predators, but their populations are declining throughout North America (Williams et al. 1993). Mussels perform many important services in lake systems such as nutrient recycling and storage, food web modification, and can function as environmental monitors by regulating services such as water purification (Vaughn 2018). Continued reductions in freshwater mussel populations foreshadows a loss of these essential services and detrimental effects to many lake ecosystems.

As sedentary animals with complex life cycles, freshwater mussels are sensitive to a variety of environmental disturbances (Davis and Sietman 2015). Freshwater bivalves are among the most threatened groups of animals, with more than 65% of freshwater bivalve species considered endangered in North America (Nobles and Zhang 2015). Two of the largest threats facing mussels in the Twin Cities area of Minnesota are invading forces of zebra mussels (*Dreissena polymorpha*) and Eurasian watermilfoil (*Myriophyllum spicatum*) (Dillon 2000). Zebra mussels are known to outcompete and threaten native species of bivalves, but the effects of Eurasian watermilfoil on mussels are largely unknown (Mallex and McCartney 2018).

Eurasian watermilfoil is often classified as an invasive species to midwestern lakes in the United States. Invasive species are loosely accepted as having rapid population growth and domination of an area, and concomitant displacement of native species. Eurasian watermilfoil can tolerate a large range of temperatures, depths, and turbidites, which contribute to its success as an invasive species (Gräfe 2014, Smith and Barko 1990). Controlling populations of Eurasian watermilfoil can cost millions of dollars annually by requiring removal methods such as aquatic herbicide application, dive suction removal, or water and biological control (Liao et al. 2015). Continued high removal costs make it unlikely that watermilfoil can be removed from all infested lakes in the Twin Cities area, necessitating a better understanding of the costs and benefits its presence may offer ecological communities in these lakes.

To assess the effects Eurasian watermilfoil may have within one particular lake, we sought to study differences between areas of the lake infested with watermilfoil and areas without substantial vegetation. The objectives of this study were to 1) compare distribution of mussels between plots with vegetated substrate and plots without vegetation, 2) measure individual mussel size, age, and sex, and 3) make projections about the survivability of mussels in areas invaded by non-native species. We hypothesized that mussels would be more abundant in transects without watermilfoil due to increased light, thus potentially containing more algae and phytoplankton. We hypothesized that ratios of males and females would not differ significantly between transect type as reproduction would be most influenced by general lake pH. Analysis of these factors will allow a clearer understanding of the impact Eurasian watermilfoil has on mussel diversity and population dynamics.

Methods

Site Selection: We conducted this study in Firemen's Clayhole (DOW 10022600), Chaska, Minnesota, USA. This lake has a surface area of roughly 3.64 hectares, and is roughly 4.5 meters deep at the deepest point. The average pH was 8.60, and average temperature was 18.49°C. Firemen's Clayhole was selected for the known presence of giant floater mussels in a region of substantial extirpation by other freshwater mussel species (Davis and Sietman 2015). Physical and chemical properties of the lake were measured using a Eureka Manta+ m.35. Area was measured in Google Earth.

Mussel Survey: We established four 10x5 meter transects along the shore of Firemen's Clayhole, as freshwater mussels are known to prefer shallow waters (Dillon 2000). Two of the transects contained Eurasian watermilfoil (*Myriophyllum spicatum*) on sediment substrate, and two transects were unvegetated with open sediment substrate (Figure 1). Transects were established along the north and south shores to avoid roads along the east and west borders of the lake. We walked the transects with soft-booted waders to detect any mussels that were not visually identifiable, and we combed transects using a standard metal rake to pull bivalves from the sediment. We recorded length, width, depth, and distance from shore for each individual found. Mussels were aged to the closest year by counting shell ring depositions, and sexed via visual comparison of length and width against hinge position. We surveyed the four transects three times over a two month period to avoid sampling bias based on weather conditions.

Data Analysis: Data was recorded in Google Sheets and analyzed using RStudio v4.0.3. Mussels with the same dimensions, sex, and age were removed to only include 1 sample to prevent double counting of individual mussels. Mussels were divided into three age groups of young (1-2 years), middle aged (3-4 years), and old (5+ years) for analysis purposes. Analysis was conducted by contingency, correlation, and analysis of variance. For the purpose of this study, significance is defined as $p \leq 0.05$.

Results

Overview: We found a total of 44 individual mussels among all four transects, all of which were giant floater mussels (*Pyganodon grandis*). 33 mussels were found in the transects with watermilfoil, 11 were found in the transects with open unvegetated substrate (Table 1). Of the 44 individuals, 30 (68.2%) were female and 14 (31.8%) were male (Table 1). Proportions of males and females were not significantly different between vegetated plots and open substrate plots (Table 1, $p>0.71$).

Mussel Survey: Shell width was significantly correlated with shell length (Figure 2, $p<0.01$). Mussels were between 1 and 6 years of age, with the majority of mussels between 3-4 years of age (Table 2, $p>0.17$). Breakdown of age class showed no significant differences between male and female ages (Table 2). Age did not affect the habitat selection between transects with vegetation or open substrate (Table 3, $p>0.46$). Shell length and width were not correlated with age ($p>0.40$). Mussels were found at an average depth of 60.84 cm in vegetated transects and at 67.73 cm in open sediment transects, which was not significantly different ($p>0.11$). In both transect types, mussels were found an average of 2.5 meters from shore. Mussel length and width did not significantly differ between vegetated and open sediment transects ($p>0.21$).

Discussion

Vegetated transects contained substantially more mussels than open substrate transects. The implications for habitat creation and longevity raise questions about how watermilfoil can function as an alternative to native pond vegetation in infested waters. Watermilfoil is an invasive species that affects water clarity and quality, and may also impact community structure (Smith and Barko 1990). Invasive species carry a negative connotation through most ecological discussions, yet the presence of watermilfoil may facilitate the longevity of giant floaters within Firemen's Clayhole if native lake species are less abundant.

Comparison of transect types: Of the 44 individual mussels found, 75% (33) were found in transects with watermilfoil (Table 1). As the age distribution of mussels was not dependent on habitat type, watermilfoil provides a suitable habitat for bivalves of all age classes to a greater extent than open substrate habitats (Table 3). Watermilfoil mobilizes sediment nutrients into the water column, which may be beneficial to algal and phytoplankton communities, the main food sources of freshwater mussels (Smith and Barko 1990, Davis and Sietman 2015). Additionally, watermilfoil vegetation may provide natural cover from mussel predators such as diving birds, making mussels less visible in the substrate against plant roots (Smith and Barko 1990). Invertebrates and fish tend to be more abundant in vegetated habitats than in open water, most likely due to the benefits of shelter and soft substrate that aquatic plants provide (Wiley et al.

1984, Kilgore et al 1989). While native plants such as some varieties of *Potamogeton* were minimally present in the vegetated transects, watermilfoil was the most abundant, thus creating the largest amount of shelter for other organisms.

Sex and Size: There were significantly more female mussels than male mussels between the four transects (ANOVA, $p<0.01$). Lake pH has previously been reported to impact sex ratios in freshwater bivalves within Minnesota, with lower pH lakes skewed towards male dominance and higher pH lakes skewed towards female dominance (Downing 1997). Firemen's Clayhole had an average pH of 8.60, which is above the 7.5 pH threshold for male dominant populations as recorded by Downing (1997). Length and width were strongly correlated, suggesting sufficient growth over time. Length and width are not correlated with age, as mussel growth varies by external environmental factors, and size is not a reliable method to age bivalves (Neves and Moyer 1988). Mussels were in normal size ranges that indicated the individuals of the population were healthy, although food is most likely not overabundant. Mussels were found between 1 and 6 years of age, suggesting recruitment is occurring within the population. 68.2% (30) mussels were between 3-4 years of age, indicating that while younger mussels were found, giant floaters are not reproducing at high rates to account for the lack of older (5+ years of age) mussels (Table 2).

Conclusions: Vegetated habitats contain more mussels than open substrate habitats. Invertebrates are known to prefer vegetated habitat over open water, which this study agrees with (Wiley et al. 1984). A high lake pH of 8.5 skewed the sex ratio to favour female mussels over male mussels (Downing 1997). Eutrophication and other anthropogenic interactions via the nearby roads might contribute to unequal sex ratios in Firemen's Clayhole. A range of mussel ages were present, but the population was heavily dominated by mussels between 3 and 4 years of age, which may require intervention to encourage recruitment of future generations of mussels to ensure the longevity of the giant floater population. Watermilfoil seems to be an acceptable replacement for native vegetation against habitats without vegetation.

Future Direction: The implications of positive impacts from invasive species like the watermilfoil necessitates further research into the costs and benefits associated with watermilfoil. Future studies may examine changes to physical and chemical properties of the lakes, and community structure surrounding watermilfoil. More data is needed to solidify the findings of this study. Further research may examine the relationship between watermilfoil and mussel populations across a variety of lakes and different mussel species. Analysis of nutrient availability and algal matter is necessary to more fully understand giant floater habitat selection. Additionally, direct comparisons between Eurasian watermilfoil and native lake vegetation such as *Potamogeton spp*. must be conducted to fully understand the benefits or detrimental effects that may accompany the presence of watermilfoil on invertebrate community structure.

Regions such as Chaska, Minnesota are facing extirpation of mussels with up to 77% of mussel species extirpated from the region (Davis and Sietman 2015). Conservation efforts are necessary to maintain existing populations, and management strategies must be considered to encourage population growth to prevent further biodiversity loss. Although the giant floater remains common throughout Minnesota, they may suffer a similar fate to other species of freshwater bivalves should management strategies ignore the invading forces that may threaten *Pyganodon grandis* in the future.

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Appendix

Figure 1. A map of the study site. Firemen's Clayhole with rough transect boundaries shown for the four study transects. Image sourced from Google Earth.

Table 1. Contingency of mussel sex and substrate type. Mussel sex was not contingent on habitat type (X=0.13986, p=0.7086).

	Open	**Vegetated**	**Total**
Male	4 (9.1%)	10 (22.7%)	14 (31.8%)
Female	7 (15.9%)	23 (52.3%)	30 (68.2%)
Total	11	33	44

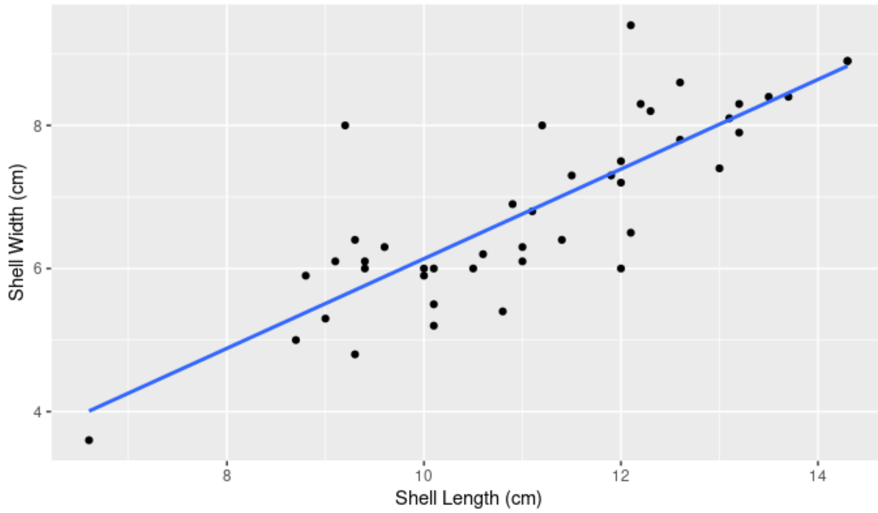

Figure 2. Shell length is correlated with shell width. Bivalve shell length increases with shell width (r = 0.828, $p<4.33*10^{-12}$).

Table 2. Contingency of mussel sex and age class. Mussel age class was not contingent on age class (x= 3.4362, p=0.1794).

	Young	**Mid Aged**	**Old**	Total
Male	5 (11.4%)	9 (20.5%)	0 (0.0%)	14 (31.8%)
Female	5 (11.4%)	21 (47.7%)	4 (9.1%)	30 (68.2%)
Total	10 (22.7%)	30 (68.2%)	4 (9.1%)	44

Table 3. Contingency of substrate type and mussel age class. Habitat selection was not contingent on mussel age class (x= 1.51111, p=0.4697).

	Young	**Mid Aged**	**Old**	Total
Open	2 (34.5%)	7 (15.9%)	2 (4.5%)	11 (25%)
Vegetated	8 (18.2%)	23 (52.3%)	2 (4.5%)	33 (75%)
Total	10 (22.7%)	30 (68.2%)	4 (9.1%)	44