IMPACTS OF AN INVASIVE SNAIL ON BENTHIC MACROINVERTEBRATE COMMUNITIES

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Abstract. Invasive species can greatly affect the ecological systems in which they establish. Due to the increasing number of invaders entering new ecosystems, it is necessary to prioritize management of these species based on the amount of ecological and economic damage they cause. *Bellamya chinensis* is an aquatic gastropod native to Eastern Asia, currently present in numerous lakes and wetlands across North America. The purpose of this study was to examine the effects of *B. chinensis* presence on benthic macroinvertebrate communities in freshwater marshes. An initial field survey in six freshwater marshes assessed macroinvertebrate density in both the presence and absence of *B. chinensis*. To further study this relationship, a microcosm experiment was designed to simulate marsh habitats with and without *B. chinensis*. Macroinvertebrate density in the field was only marginally lower in marshes with *B. chinensis* populations. Results suggested that the presence of *B. chinensis* was associated with lower densities of invertebrates within collector-gatherer and scraper feeding guilds. Microcosm results showed that macroinvertebrate density significantly decreased as snail density increased. Periphyton decreased significantly at low densities of *B. chinensis* but, contrary to expectations, increased at higher densities. The impact on benthic macroinvertebrates may signify a greater bottom-up disruption from a *B. chinensis* invasion. Combined results from this study indicate that *B. chinensis* has the capacity to substantially impact North American aquatic ecosystems.

INTRODUCTION

Invasive species are organisms carried by humans that establish and have a negative impact on ecological systems outside their natural geographic range (Strayer 1999; Byers et al. 2002; Lockwood et al. 2007). Over the past decade, biological invasion research has increased exponentially as this problem has become more apparent (Lockwood et al. 2007). This research is needed for a number of reasons. Information on the spread, ecological effects, and control of invasive species is needed to implement effective management strategies (Byers et al. 2002). This research is also important for creating a knowledge base to aid in potential predictions of invader spread. Finally, due to the increasing number of biological invasions, it has become necessary to prioritize management of these species based on the amount of ecological and economic damage they cause.

The Chinese mystery snail, *Bellamya chinensis,* has only recently been looked at as a biological invader. It has been referred to in past literature as *Viviparus chinensis malleatus*, *Cipangopaludina malleata*, *Paludina japonicus* and other names (Smith 2000). This species was first introduced into North America in the 1890s from Eastern Asia (Abbott 1950). Sold in Chinese food markets in San Fransisco, these golf-ball sized delicacies established in California’s artesian belt region by 1900. In the Northeast, *B. chinensis* was first discovered in 1914 in Muddy River in Boston, Massachusetts. It is believed that the snails were introduced to this area and subsequent areas due to their popularity as aquarium snails (Clench 1940). According to Jokinen (1982), populations have since established in all of the northeastern states, as well as in isolated bodies of water across the country and in two of the Great Lakes (Figure 1).

Many life history characteristics and behaviors of *B. chinensis* have been previously studied, laying a solid framework for new research on this organism (Wolfert and Hiltunen 1968; Jokinen 1982). Chinese mystery snails are ovoviviparous—they produce live young rather than eggs—and measure approximately 4.5 mm in length at birth (Wolfert and Hiltunen 1968). This species has a lifespan of three to five years, growing upwards of 50 mm in length, and lives and feeds in the sediments of aquatic ecosystems (Jokinen 1982). *B. chinensis* is unusual in that it can filter feed as well as browse attached particles using its radula. The primary method of feeding is radular rather than by filtration. Its diet consists of green algae, blue-green algae, diatoms, flagellates and decaying organic matter.

B. chinensis lives in lentic bodies of fresh water with sandy or muddy sand substrates, including wetlands and marshes. These complex ecosystems are important for soaking up large amounts of water, reducing spring flooding, filtering pollutants from the watershed, and acting as spawning grounds for numerous species of fish (Thorp and Covich 1991; Custer et al. 2000). Marshes are also the habitat of many larval insects, including species from the orders Diptera, Ephemeroptera, and Odonata. These larvae are an important part of the marsh food web, providing food for fish, waterfowl, and invertebrates (Bazter and Wissinger 1996). Odonata are mainly predators, while Diptera and Ephemeroptera tend to fall into the collector/gatherer or scraper feeding guilds (Figure 2). Collector/gatherers and scrapers feed on decomposing fine particulate organic matter and periphyton, respectively (Bouchard 2004). This diet is very similar to the diet of *B. chinensis*, which may make these native macroinvertebrates particularly sensitive to an invasion (Figure 3). Little research has been completed on the impacts of *B. chinensis* to these ecosystems.

I designed this study to examine the impacts of *B. chinensis* on benthic macroinvertebrate communities in freshwater marshes. I conducted a field study of six wetlands to compare the benthic communities in the presence and absence of *B. chinensis.* I then implemented an experiment in which I manipulated the population density of *B. chinensis* in simulated wetland microcosms. I hypothesized that macroinvertebrates in the collector/gatherer and scraper guilds will have lower populations in habitats with *B. chinensis*. This research will provide new scientific knowledge on the impact of an invasive species and how it affects native animal communities, guiding management of this species.

METHODOLOGY

Study Sites

The field aspect of this research used six New York wetlands (Figure 4). The three wetland areas without *B. chinensis* were Thompsons Pond in Stissing, NY, Fowler Pond in Millbrook, NY, and Buttercup Marsh between Pine Plains and Stanfordville, NY. All locations were in Dutchess County, NY. The survey also included three bodies of water known to contain *B. chinensis*. These three sites included Duck Pond in the Mohonk Reserve outside New Paltz, NY, Bashakill Marsh in Wurtsboro, and Hunns Lake in Stanfordville, NY.

Field Survey

I first surveyed the composition of macroinvertebrates in marshes with and without *B. chinensis*. Three invaded and three non-invaded marshes were sampled using a benthic corer because of its ease of use and quick collection (Turner and Trexler 1997). Samples were taken in shallow areas with fine substrate because this is the microhabitat preferred by *B. chinensis* (Clench and Fuller 1965). The organisms in these areas would, according to the hypothesis in this study, be most sensitive to competition by the invader. Sediment cores were put into water-tight containers, labeled and taken to the lab to determine invertebrate composition. Using a sieve, animals were sorted, and then identified to order.

In addition to macroinvertebrates, invaded marshes were surveyed for *B. chinensis* densities. Snails were collected from 0.25 m^2 quadrats and measured with calipers. Specimens were placed in 10-mm categories based on shell length and the percentage of snails in each category was determined. This shell-size distribution was used as a reference point in the set up of a microcosm experiment. A *t*-test was run for both macroinvertebrate and snail densities to test for differences between invaded and non-invaded marshes.

Microcosm experiment

To further investigate the effects of *B. chinensis*, I replicated competition in a newly invaded marsh through use of a microcosm experiment. Due to the invasive nature of *B. chinensis*, it would not be appropriate to experiment with this species in a non-invaded marsh in nature, and therefore a microcosm setup was the most practical alternative. The microcosms consisted of sixteen sheep-watering tanks in a four-by-four configuration. Four tanks were subsequently not used because of water contamination issues. Each tank of the remaining twelve tanks was set up to simulate the silty, shallow portion of a marsh with no history of invasion by *B. chinensis*. This setup included the addition of submerged vegetation and sediment containing a representative assemblage of macroinvertebrates.

In this experiment, the two treatments and a control were established with four replicates each. The control group had no *B. chinensis* specimens, while the two treatment groups had a low and a high density of *B. chinensis*. These densities were 10 snails/m^2 and 80 snails/m^2, respectively. I determined stocking densities from the field survey results. Treatments were randomized within the four-by-four tank configuration to avoid bias caused by uncontrollable differences between tanks. Mesh netting was used to cover the tanks to avoid the addition or subtraction of animals during the experimental period. The microcosm ecosystems were run for approximately four weeks. During this time, environmental factors, such as temperature and pH, were measured. Calcium was measured with a Leeman Labs Inductively Coupled Plasma Spectrometer (Teledyne Technologies, Los Angeles, CA) in the Institute of Ecosystem Studies Analytical Laboratory.

At the end of the experimental period, I removed, sampled the benthic layer of each tanks to determine the macroinvertebrate density. Sediment samples were run through a 0.5 mm sieve and then placed in a tray for identification and counting. *B. chinensis* specimens were also counted and measured as they were extracted from each tank. After being recorded, the snails were euthanized and disposed of based on protocol for invasive species experimentation.

To gain a more complete understanding of how food resource availability impacts the interactions within this ecosystem, periphyton quantity and quality were determined using ash-free dry matter (AFDM) and chlorophyll a procedures. AFDM was measured to determine the amount of organic matter in the periphyton, thus determining the quantity and quality of this food source. A chlorophyll a procedure was also performed as a measure of the quality of periphyton in each microcosm. To perform these procedures, two ceramic tiles were leaned diagonally against the side of each tank at the beginning of the experimentation period. After the four week period, periphyton was scraped from a 4 cm^2 area of the tile. Using the procedures and calculations outlined by Steinman and Lamberti (1996), I determined the AFDM and chlorophyll a concentration of the periphyton in each tank. I used an analysis of variance (ANOVA) tests to determine statistical significance between treatments.

RESULTS

Field Survey

The population density survey for *B. chinensis* revealed that this organism has the capacity to inhabit a wetland environment at a variable range of densities. Two of the three invaded sites contained snail densities of 8.5 snails/m^2, ranging in length from 16 to 51 mm. In contrast, the remaining site contained a much higher *B. chinensis* density, at 75 snails/m^2. This snail population had a similar range of sizes (10-56 mm).

Benthic samples yielded five macroinvertebrate taxa within each of the survey sites: Diptera, Amphipoda, Oligochaeta, Hirudinea, and Gastropoda (Figure 5). Of these five taxa, organisms in the Order Diptera—specifically family Chironomidae--were in the collector/gatherer and scraper guilds. Collector/gatherer and scrapers inhabited non-invaded marshes at a mean density of 4.19 individuals per site, compared to a mean density of 2.50 collector/gatherers and scrapers at sites with *B. chinensis.* Although this difference was only marginally significant (p=0.089), I suspected the high variability of nature and the low number of replicates may have masked the actual trends. A power analysis confirmed this suspicion, and it was determined that 24 total replicates would be required to determine a significant trend at p=0.05.

Microcosm experiment

Similar to the field survey, organisms from Diptera, Amphipoda, Oligochaeta, Hirudinea, and Gastropoda were collected from the microcosm tanks. Individuals from the Order Ephemeroptera were also found. However, this taxon, as well as Gastropoda and Oligochaeta were too rare and variable to be considered in the analysis. Two taxa within the Order Diptera were found—Chironomidae and *Chaoborus*—and were analyzed separately. While mean population density of each taxon was lowest in tanks with the highest population density of *B. chinensis*, there were only statistically significant differences between treatments for organisms in the genus *Chaoborus* (Figure 6). While Chironomidae is in the collector/gatherer feeding guild, *Chaoborus* is a planktivore. Total macroinvertebrate density was also analyzed (Figure 7). An analysis of variance revealed that total macroinvertebrate density was significantly lower in treatments with higher *B. chinensis* density (p=0.047).

I found that periphyton AFDM was significantly denser (p=0.049) in the control and high snail density treatments than in the low snail density treatment (Figure 8). Chlorophyll a analysis suggested a similar trend: low snail densities contained less algae than the control or high snail density treatments (p=0.053).

One unexpected result from this experiment was the change in water chemistry across different treatment tanks over the four week period. After only two weeks, the water hardness—a measurement of calcium content—was significantly lower in tanks with higher densities of *B. chinensis*. Measurements at the end of experimentation showed a similar relationship, (p=0.016) across all three treatments (Figure 9). There was also physical evidence of a calcium deficiency within high-density tanks. Multiple *B. chinensis* specimens were observed with holes in their shells, a phenomenon known as pitting.

DISCUSSION

Before scientists can determine a strategy to deal with non-indigenous species, they must first have a well-rounded knowledge base on that species (Byers et al. 2002). One aspect of this knowledge base involves assessing the impact of this species on the native species. In this study, I examined macroinvertebrate densities and aspects of their primary food source, in an effort to determine the magnitude of the impact of *B. chinensis* in this study area.

I expected a reduction in food resources, based on the idea that higher snail densities would increase the amount of pressure on these resources. This was seen in the microcosms with no mystery snails, with significantly more periphyton at the end of four weeks than treatments with 10 snails/m^2. However, the effect of increasing the snail density to 80 snails/m^2 was contrary to this trend, with the high density treatment exhibiting significantly higher levels of periphyton than the low density treatment. As a possible explanation to these observations, Jokinen (1982) discussed two different feeding methods that *B. chinensis* uses, citing radular feeding as a primary method and filter feeding as an alternative. What these microcosm results suggest is that there may be a behavioral mechanism that causes *B. chinensis* to switch from eating algae to filter-feeding when periphyton levels reach a certain threshold. In her study, Jokinen goes on to assert that gastropod feeding and nutrition is a poorly explored area. This statement is supported by these results of apparent contradictory feeding habits of *B. chinensis*.

Macroinvertebrate density and composition depend on a number of factors in nature, only one of which is availability of resources. Due to the complexity of these relationships, I was not able to determine statistical significance for collector/gatherer and scraper macroinvertebrates in the field survey. However, both the field survey and the microcosm results provided moderately strong support for my hypothesis. The results did indicate that as whole, the benthic macroinvertebrate community is significantly smaller in habitats invaded by *B.*

chinensis. I would suggest that a larger-scale survey would reveal that *B. chinensis* does significantly impact macroinvertebrates of similar trophic levels by competing with them for food resources.

The microcosm experiment further suggests a relationship between *B. chinensis* and the benthic macroinvertebrates. Although total collector/gatherer and scraper densities were not significantly affected by *B. chinensis* density, certain taxa appeared to be more sensitive to an invasive species infringing on a food resource. It was unexpected that *Chaoborus*, a plankton-consuming dipteran, would be one of the more sensitive taxa in this experiment. Combined with the periphyton data, this suggests that the food web interactions are much more complicated than first thought. Further study in the areas of phytoplankton and *B. chinensis* are strongly suggested.

Another impact of high *B. chinensis* density was found to be dissolved calcium levels. Snails in the high density tanks were observed with damage on the shell surface, known as pitting (Jokinen 1982). This phenomenon is known to occur with gastropods in soft water conditions. This result implies that *B. chinensis* may not only impact the biotic factors in a wetland ecosystem, but also certain abiotic factors. More research needs to be done on this aspect of *B. chinensis* impact before I can determine the effect it has on native ecosystems.

Conclusions and Recommendations

Results from the microcosm and field aspects of this experiment, combined with previous microcosm data on water chemistry changes (Kroiss 2006, personal communication), indicate that *B. chinensis* has ecological impacts. Although this species may seem benign, it may change water chemistry and decrease primary consumers.

Resource managers are required to make choices about how to spend their limited financial means (Byers et al. 2002). From this research, I would posit that *B. chinensis* is not a high priority for extensive removal program due to the fact that ecosystem disruptions are not as drastic as that of other species. Resource management finances should be spent on more pressing ecological issues. However, measures to prevent spread of *B. chinensis* should be pursued.

One way that we can prevent the spread of *B. chinensis* is by educating the public. *B. chinensis* does not spread to bodies of water by its own locomotion, but rather requires human assistance. Education initiatives will help to quell future invasions of this species into ponds, lakes and wetlands. I recommend the following educational points:

- Learn to identify snails
- Do not move snails
- Do not dispose of aquarium snails into bodies of water

A removal program is not recommended for *B. chinensis*, as it may exacerbate the problem. Recent research suggests that external stressors cause *B. chinensis* females to spawn at a faster rate, producing more offspring with less biomass (Prezant *et al*. 2006). Therefore, a poorly executed removal program may cause an increase in *B. chinensis* births, thus increasing the population. If resource managers follow these suggestions, we may be able to keep *B. chinensis* from further invasions.

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APPENDIX

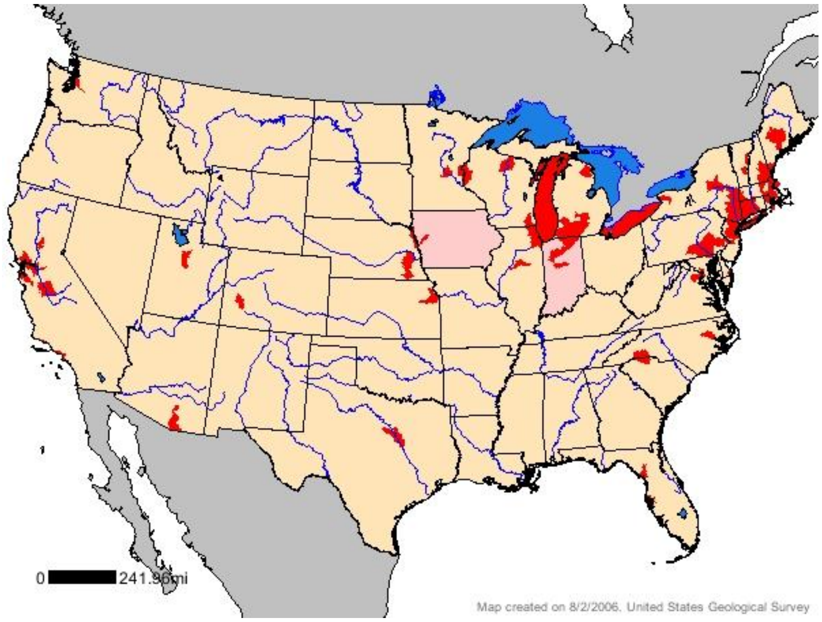

FIGURE 1. Map of known established populations of *B. chinensis* in the continental United States. Known invasions indicated by red areas. Courtesy of the United States Geological Survey, 2006.

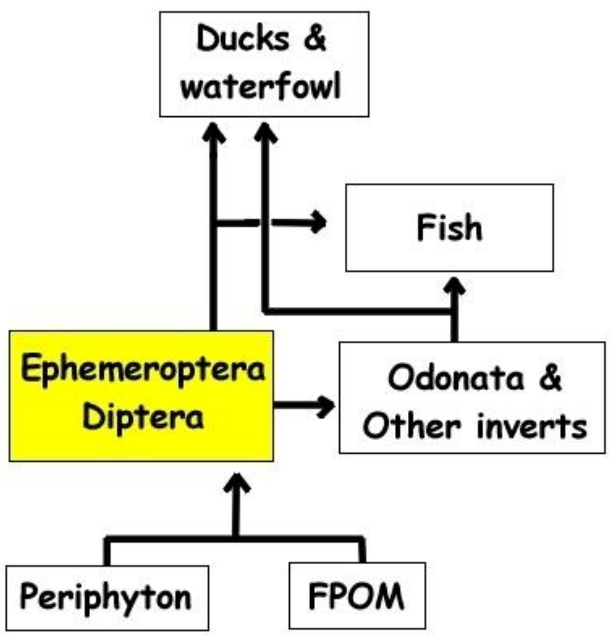

FIGURE 2. A proposed food web, focusing on importance of marsh macroinvertebrates (Merritt and Cummins 1996).

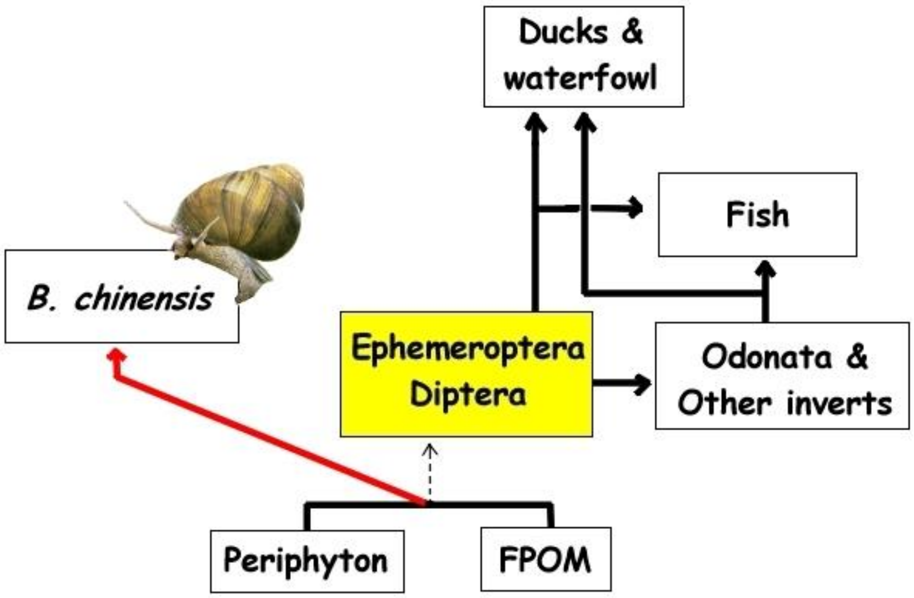

FIGURE 3. A proposed mechanism for food web disruption by *B. chinensis* (modified from Merritt and Cummins 1996).

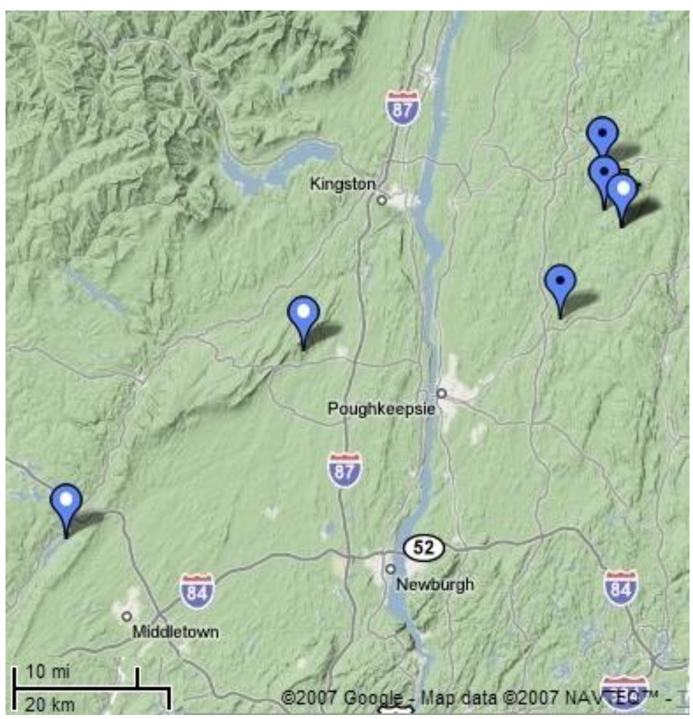

FIGURE 4. Map of study sides in New York, USA. Sites with populations of *B. chinensis* indicated by white dot. Sites without *B. chinensis* indicated by black dot. Sites (from top): Thompsons Pond, Buttercup Marsh, Hunns Lake, Fowler Pond, Duck Pond, Bashakill Marsh. Courtesy of Google Maps, 2007.

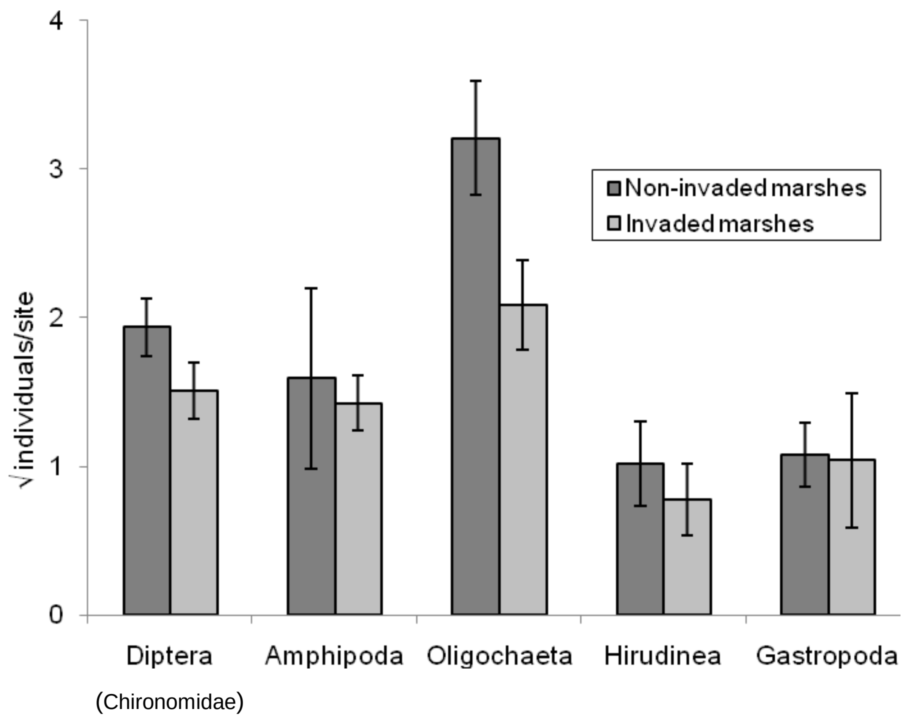

FIGURE 5. Mean macroinvertebrate densities (+/- 1 s.e.) associated with *B. chinensis* establishment from field survey.

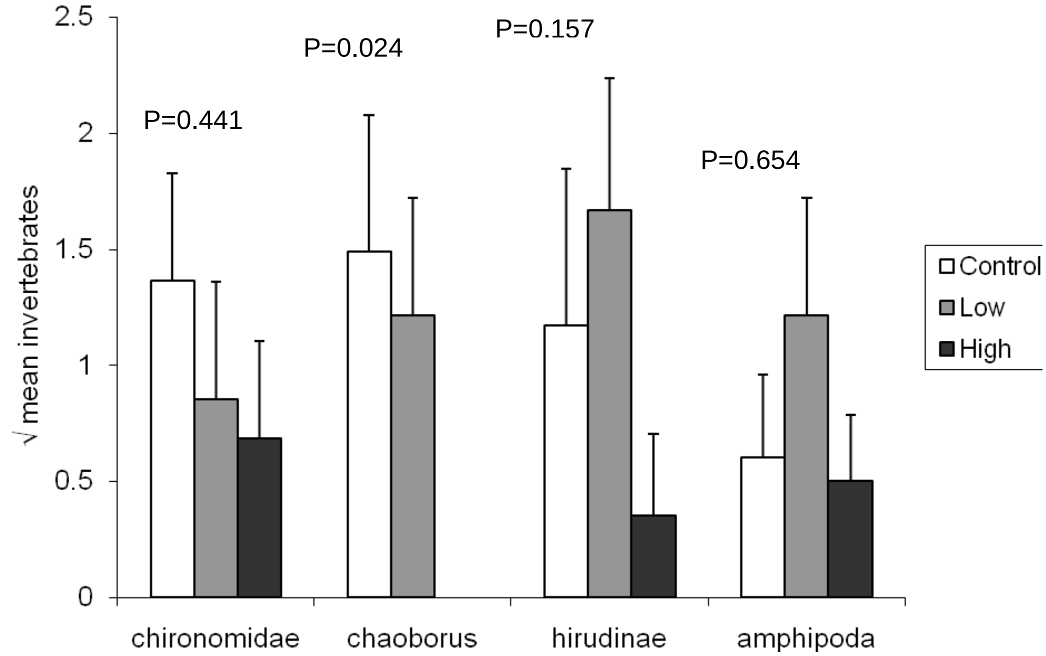

FIGURE 6. Mean macroinvertebrate densities (+/- 1 s.e.) by taxa associated with *B. chinensis* treatment groups in microcosms.

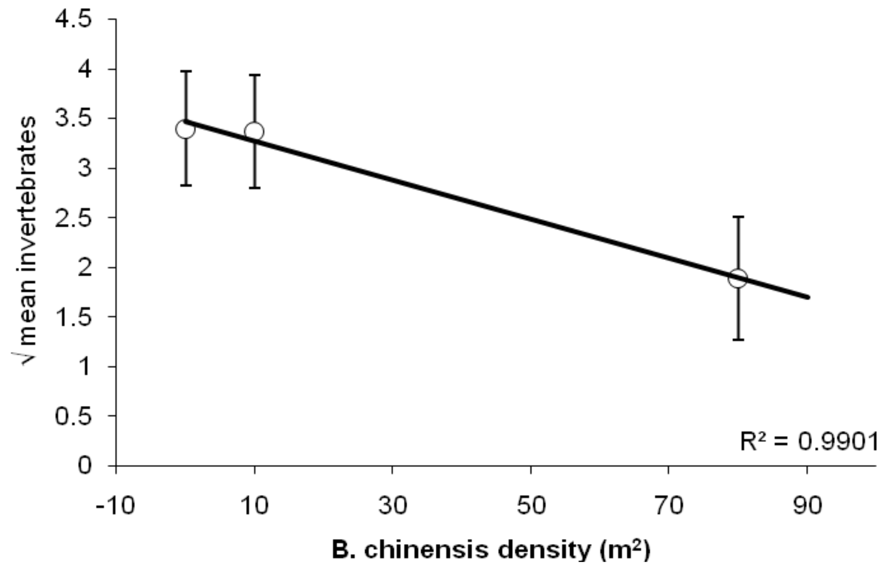

FIGURE 7. Mean macroinvertebrate density (+/- 1 s.e.) associated with *B. chinensis* population density in microcosms (p=0.047).

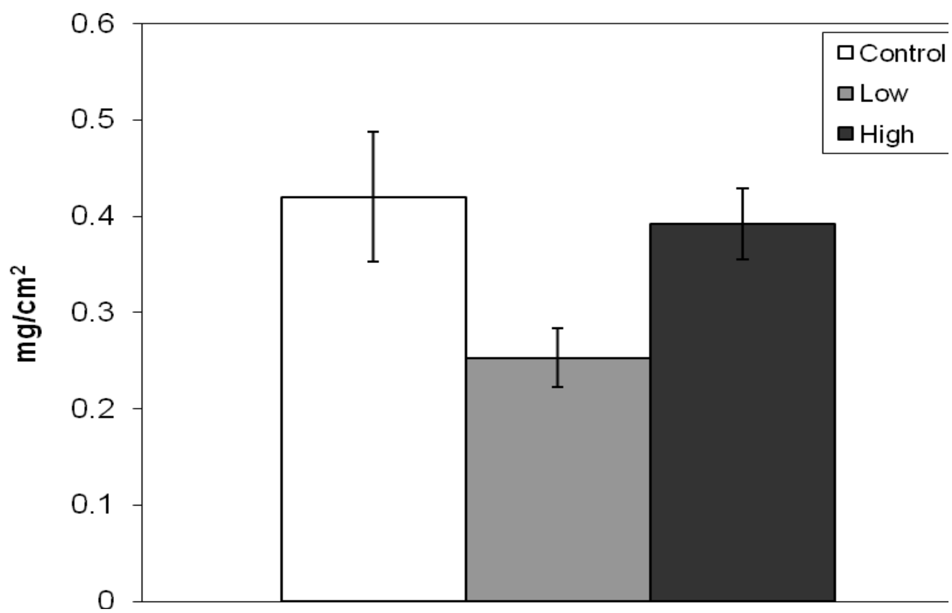

FIGURE 8. AFDM concentration in mg/cm^2 (+/- 1 s.e.) associated with *B. chinensis* treatment groups in microcosms (p=0.049).

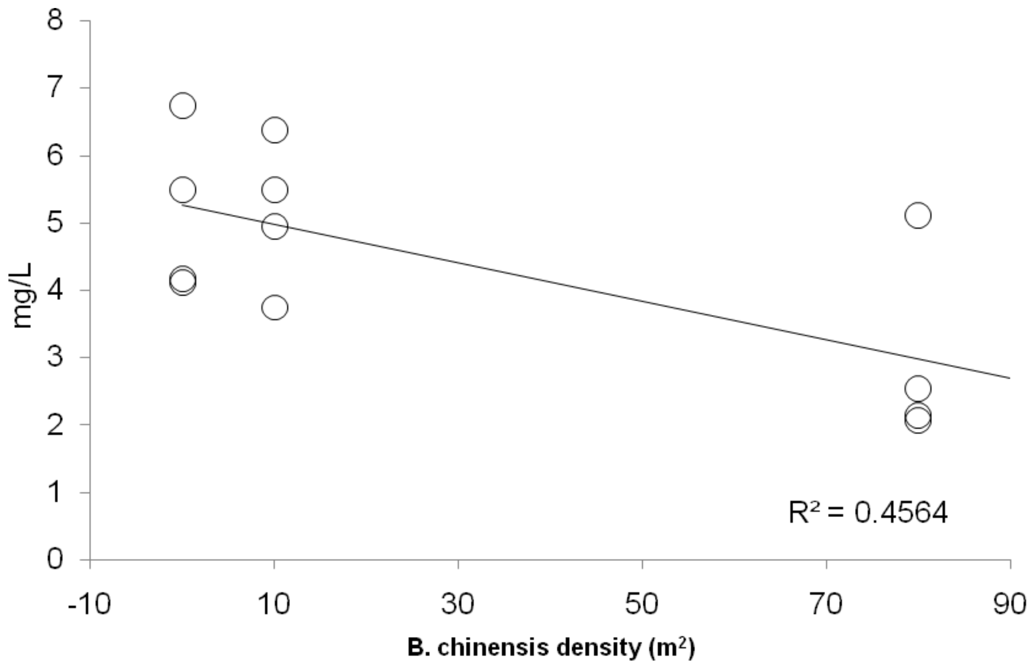

FIGURE 9. Calcium concentration in mg/liter (+/- 1 s.e.) associated with *B. chinensis* density in the microcosm study (p=0.016).