Obstruction of the upstream migration of the invasive snail *Cipangopaludina chinensis* by high water currents

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Abstract

The viviparid snail *Cipangopaludina chinensis* is an Asian invasive species in North America. It has been recently reported at UNDERC, and an anecdotic observation was made about its invasion at Brown Creek, where it appears to have stopped on the downstream side of a culvert. We hypothesized that the increase in water current that the culvert creates is what is holding the snail from invading further up. We conducted laboratory trials where snails of different size classes were exposed to a slowly increasing current, so we could see how much current could they withstand before getting flushed out. A field survey was made in order to see the distribution and density of *C. chinensis* around Brown Creek, and another group of snails was exposed to a weaker constant current to see if they showed a preference for upstream migration. We found that the current velocities in the culvert can in fact hold the snails from going upstream, the snails were not as abundant as expected in the creek, and they do not express a preference for upstream or downstream migration. Thus we suggest a culvert, or any other mean of accelerating the water current as a management tool for an invading population of *C. chinensis*.

Introduction

Exotic species are non-native species which produce negative ecological or economic effects in areas where they are introduced (Mills et al. 1994, Vitousek et al., 1997). Most often, invasive species cause these negative effects by quickly expanding both numerically and spatially, often extirpating and displacing native species already present in the environment, having far-reaching effects on ecosystem functioning and biodiversity (Brönmark and Hansson, 2002). In understanding these migration-invasion patterns, we must consider that physical characteristics of the habitat are capable of limiting the expansion of an invading population into a native community. There are many species-specific biotic and abiotic factors which may inhibit, accelerate or otherwise affect the invasion process. These factors should be considered when forecasting future invasion, designing monitoring protocols and developing management tools to control an exotic species.

The viviparid snail *Cipangopaludina chinensis* (Viviparidae) was originally introduced to the United States through the Chinese market, and the first well-established population was reported in 1911 by Hannibal on the corridor between San Francisco Bay and San Jose. This species' native range encompasses from Southeast Asia to Japan and eastern Russia, but in the present day, imported specimens have invaded freshwater bodies across North America, forming isolated but dense populations in about 27 states of the Unites States and in Canada (Amy Benson, 2008). Still today they are imported through the aquarium trade (Rixon et al., 2005)

On the easternmost section of the UNDERC property in Land O' Lakes, MI there is a culvert through which Brown Creek flows, and downstream of it, this invasive species has been reported (Peters, *personal communication*). Some species of freshwater snails have been shown to have a natural tendency to migrate upstream (Schneider and Frost, 1986), so we expect *C. chinensis* to behave accordingly. Anecdotal evidence suggests that the culvert is impeding the snail from migrating upstream, and on the upstream side of the culvert no representatives of the species have been reported. The culvert changes the flow velocity of a creek, and in Brown Creek's case this is more so, since one of the two culverts through which the creek used to flow has been dammed by beavers. This means that the water that used to flow through a 5 m bed now has to fit itself through a 1.8 m wide culvert, meaning an almost threefold decrease in flowing room. We hypothesize that the increase in current the culvert creates is one of the factors that impedes the snails from moving upstream. During this study *C. chinensis* were found inside the culvert; eliminating the hypothesis that the culvert positioning (with an overhanging outlet) may be a physical barrier which the snails could not overcome.

We designed a study to investigate factors that could be limiting the upstream migration of *C. chinensis* in Brown Creek. The snail communities above and below the culvert where characterized multiple times throughout the summer to confirm the absence of *C. chinensis* above the culvert. We tested the maximum current velocity that different size classes of *C. chinensis* could withstand and if *C. chinensis* had a natural tendency to migrate upstream.

Materials and Methods

The questions were evaluated through field observation and laboratory experimentation.

Field Survey

The field portion was a simple survey in Brown Creek that consisted of meter-long dip net (26 cm wide) samplings in three spots across the creek (West shore, center of creek, and East shore) in three transects placed at 2, 10, and 20 meters upstream and downstream of the culvert. Each substrate sample was filtered through two sieves: one for sieving the larger snails (0.5 cm grain), one for the smaller ones (0.75 mm grain), and individuals of all sizes and all species were collected. The specimens collected were then preserved in ethanol and identified to family. Snails in the Viviparidae family were identified to species. These data were analyzed to determine the density and occurrence of *C. chinensis* in Brown Creek.

In addition to surveying snail abundances, I determined the water velocity using a Global Water Flow Probe in and around the Brown Creek Culvert on three sampling periods throughout the summer.

Laboratory Experiments

C.chinensis were collected from Wildcat Lake, and classified into four size classes: Class A (5-10 mm), B (20-25 mm), C (30-35 mm), and D (45-50 mm). The classes were determined by observation, trying to take snails of highly differing sizes, so as to be able to see if shell size affected their ability to hold themselves against a current. For each class, 25 snails were measured, tagged and numbered with a small piece of paper glued to the shell.

My first experiment tested the maximum water velocity which different size classes of C. chinensis could withstand. Modifying from Martel and Diefenbach, (1993) I constructed an experimental flume by housing a metal gutter inside a plastic wading pool. Lake water was delivered to the pool via a 2-inch PVC pipe, controlling the flow using a PVC ball valve.

Snails were placed in the gutter and left undisturbed until the foot was observed to be fully attached to the gutter. The valve was then opened in small notches, each notch representing approximately a 2 km/h increase in current speed. If the snail was able to stay attached to the gutter for one minute, the valve was opened another notch. This process was repeated until the snail detached from the gutter and was flushed down the gutter. Upon detachment, the current velocity was measured at the point the snail was previously attached.

My second experiment tested whether or not *C. chinensis* snails have a natural tendency to migrate upstream. A gutter was placed in a wading pool as was done in the previous experiment. A constant low current velocity (1-2 km/h) was used for this experiment to ensure snails would not be flushed downstream. The gutter was divided into labeled sections and for each snail, a starting position was recorded as soon as the foot was observed to be attached to the gutter, and an hour later the position was recorded. Depending on their behavior, each snail then was determined to prefer either upstream or downstream movement.

Statistical Analysis

I tested for differences in maximum current resilience among different size classes of *C. chinensis* using a blocked one-way analysis of variance. I also tested the ANOVA assumption of normal distribution of the residuals using a K-S Lilliefors test. These tests were conducted using SYSTAT 10. I tested for preference in movement using a chi-square test.

Results

Field survey

C. chinensis was observed during each sampling period downstream of the culvert. However, *C. chinensis* was not present in some dip net samples even when it was noticeably visible in the stream. On the first survey (6/2/2008) they were found in equal densities compared to the other species of snail present (Fig. 1), and relative to other sampling periods, this day was when the greatest densities of this species were observed. In a single meter-long sample, 15 snails were counted, being the majority adults or close to adult size. Moreover, *C. chinensis* was never observed upstream. It is worth noting how the number of snails decreased as the summer went by, suggesting that the population present at Brown Creek fluctuates with time or there is some type of migratory behavior, and that *C. Chinensis* was found only directly below the culvert, suggesting that the culvert is impeding migration.

The culverts themselves were measured for length, width, height (Table 1), and highest current speed. Current velocity readings (Table 2) are limited to the East culvert, since as mentioned earlier, beavers have dammed the West culvert, and there is no water flowing through it.

Resistance to Increasing Current

The sampling for the resistance to current velocities was made in two different days, each two weeks apart. A blocked one-way analysis of variance found a significant difference between the four size classes (df= 3, F= 4.112, p= 0.009). A Tukey's HSD post hoc test indicated that there was only a significant difference between size classes A and D (df= 95, p= 0.012) (Table 3).

Each snail class had a maximum current that one or very few individuals were able to withstand, and when compared to the current measurements done, we can see that a few specimens were able to withstand current velocities equal to or higher than the lowest maximum current reading found in the culvert (Table 2). In Figure 2 we can see how there are 6 data points over the lowest maximum current velocity measured, representing a 6% of the total snail population sampled. In theory this would mean that these snails could go up the culvert under the lowest flow conditions.

Effects of Current in Snail Movement

In the second part of the laboratory work, out of 34 snails evaluated, 18 showed a preference for downstream movement, and 16 for upstream. A Pearson's chi-square test showed no significant ($p \approx 0.75$) difference in the snail movement from an expected (50% upstream 50% downstream) distribution.

Discussion

Culverts have never been appreciated as being helpful for a stream's health, and are generally seen as human interactions with the freshwater ecosystem that are eventually detrimental to the native fauna by blocking their migration routes, separating populations, or in the least, by disturbing the habitat. However, in the case of invasive species management, blocking migration routes can be a positive effect of culverts.

The field survey of our research has demonstrated that there is an apparent interaction between the culvert and the population of *C. chinensis* downstream of it, and it is apparent from our laboratory experiments that the factor that is actually holding snails from invading is the increase in current velocity that the culvert creates. Before discussing this any further, we must note that there is a 6% of snails that theoretically can withstand more current than the maximum we found one of the days. There are certain factors, however, that are not being taking into account in this experiment: the culvert measures 8.5 m long, it is corrugated, which will form eddies and areas of turbulence, and algae has covered practically all the underwater surface of the culvert, diminishing the traction a snail's foot can have. We conducted our experiment in a smooth gutter, where turbulence was minimized, with the intentions of making an ideal setup for a snail to crawl up, so we would get data for a worst-case scenario. Laboratory observations also indicate that after a certain speed, snails were not able to crawl upstream, all they could do was hold themselves in place.

Thus, a culvert is still an option for preventing an invasion of the snail *C. chinensis*, but its effects on the native environment should also be gauged, since any human-induced drastic change that impacts a well-established native community can disrupt their balance (Sanders et al., 2003) and cause the same negative effects they are being protected from. Like any other management tool, it must be consciously evaluated, and even though this species did not show a special preference for upstream migration, each snail still has a 50% chance of moving upstream.

It is interesting enough that there are representatives of each class capable of withstanding high current speeds, so in talking about maximums, any specimen could colonize, but the analysis of variance we did showed us that in general, bigger snails would be able to hold themselves better in higher current speeds. This is of great importance, since the difference between a small snail invading versus a big snail doing so, is that if the big one is a pregnant female, it can start a population fairly easily. This result also suggests that that monitoring efforts should be focused on finding large individuals, which are likely to be the first to invade. The fact that this species is viviparous helps it, because if it had a free-living larva stage, it would probably be washed back into the downstream side before being able to metamorphose. A small fully developed snail, however, is able to get a hold of the substrate and keep on growing in pools on the other side.

We suggest a culvert, or any other way of accelerating the current as a management tool for stopping the invasion of the *C. chinensis.* A well studied case where the maximum and minimum levels of a stream are known should tell if the current velocity is to be able to hold an invading snail population, and as long as it is well managed, the overall environmental impact can be maintained in the minimum.

Tables

Table 1. Dimensions of both East and West culverts in Brown Creek.

	Length (m)	Width (m)	Height (m)
East	8.546	1.79	1.246
West	8.544	1.762	1.262

Table 2. Maximum current speed for the East culvert (West culvert is dammed by beavers), and maximum, minimum, and average currents withstood by each snail class.

Sampling day	Max		
1	14.3		
2	22.06		
3	34.6		
Snail Class		Min	Average
A	16.2	3.3	7.684
B	16.2	2.5	9.592
C	15.9	2.4	8.224
D	16.9	2.2	10.426

Table 3. Pairwise probability comparisons from Tukey's HSD test.

	1	2	3	4
1	1			
2	0.136	1		
3	0.926	0.404	1	
4	0.012	0.776	0.064	1

Figures

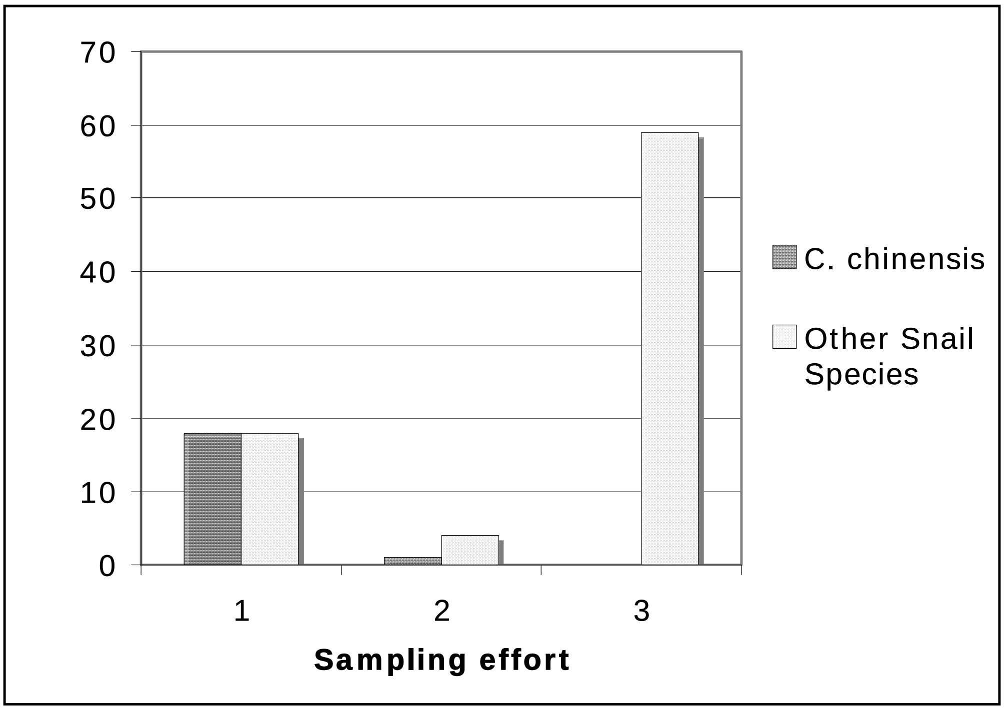

Figure 1. Number of snails found on throughout the summer in the downstream section of Brown Creek

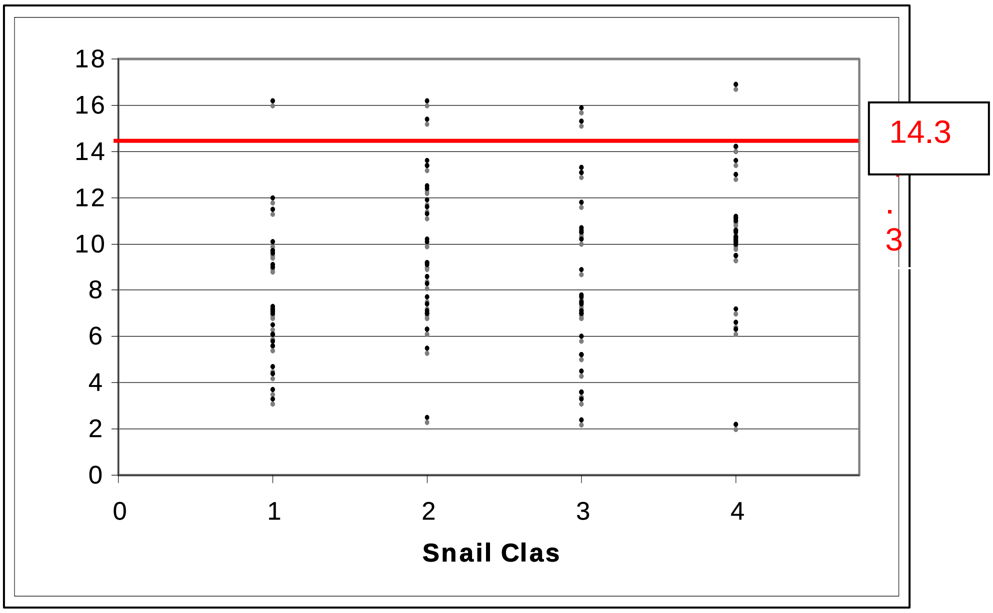

Figure 2. Current resilience per snail class-note Classes A, B, C, and D are Groups 1, 2, 3, and 4, respectively. Red line represents the lowest maximum current velocity obtained in the surveys.

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