# The effects of habitat and current on the shell morphology of the freshwater snail, *Elimia livescens*, in Northern Michigan streams

Abigail R. DeBofsky

University of Michigan Biological Station

EEB 381 General Ecology

August 18, 2010

Prof. Cathy Bach

## Abstract

Snail shell morphology is a salient property of snail adaptations that is dependent on a variety of environmental factors. The purpose of this study was to observe the differences in snail shell thickness, size, and length-to-width ratio, or apex proportion, in both riffle, or higher current, and pool, or little to no current, environments of streams, and to understand how these differences were dependent on current levels in the freshwater snail, *Elimia livescens*. To test these factors, snails were collected in riffle and pool sites within two streams and snail shell thickness at the aperture, length, and width were recorded. Thickness was found to be significantly greater in riffle environments than pool environments, and shell thickness was positively correlated with current level. The apex proportion and shell size did not appear to be affected by current. Overall, of the aspects of shell morphology studied, thickness appeared to be the most influenced by current.

# The effects of habitat and current on the shell morphology of the freshwater snail, *Elimia livescens,* in Northern Michigan streams

Abigail R. DeBofsky, University of Michigan Biological Station

## ABSTRACT

Snail shell morphology is a salient property of snail adaptations that is dependent on a variety of environmental factors. The purpose of this study was to observe the differences in snail shell thickness, size, and length-to-width ratio, or apex proportion, in both riffle, or higher current, and pool, or little to no current, environments of streams, and to understand how these differences were dependent on current levels in the freshwater snail, *Elimia livescens*. To test these factors, snails were collected in riffle and pool sites within two streams and snail shell thickness at the aperture, length, and width were recorded. Thickness was found to be significantly greater in riffle environments than pool environments, and shell thickness was positively correlated with current level. The apex proportion and shell size did not appear to be affected by current. Overall, of the aspects of shell morphology studied, thickness appeared to be the most influenced by current.

## INTRODUCTION

Throughout the world, the dynamic environments of organisms have led to adaptations to allow survival in the harshest conditions. Within each environment, natural selection favors morphologic traits that benefit organisms, increasing their fitness within particular populations and leading to higher frequencies of the traits within those populations. Both biotic factors and abiotic factors can produce selective pressures that can affect the morphology of organisms.

Crowl and Schnell (1990) determined that biotic factors, such as levels of predation and availability of biomass, are influential in the shell morphology of freshwater snails; however, their results fail to address the importance of all abiotic factors. Trussell (1997) found that snails have larger shells in stream pool areas and smaller shells in stream riffle areas, and as water current increased, this size decrease became more dramatic. Johnson and Brown (1997) also demonstrated that current affects snail shell size, but found a different trend than did Trussell (1997); their results indicated a direct relationship between shell size and current strength due to environmental stresses of in higher current. Minton et al. (2008) also found support for a direct relationship between these variables proposing that larger shells protect snails from damage due to high currents, and that large shells are correlated with large feet, which help snails hold onto substrate in high currents. Additionally, Raffaelli (1977) demonstrated that thickness is also affected by current strength; shells in areas of high current with higher risk of shell injury due to dislodgement tend to be thicker. With greater shell thickness and size, the risk of shell destruction is minimized if the snail becomes dislodged in a strong current environment; and with large feet the risk of becoming dislodged when exposed to high-current conditions is reduced (Raffaelli 1977, Trussell 1997, Minton et all 2008). In addition to shell size and thickness, current has also been shown to affect other traits of shell morphology; smaller shells with sharper points in high flow riffles are more energetically favorable and selected for because of hydrodynamics that create a laminar flow of water (Vermeij 1993). However, squatter shells, or shells that are shorter and wider, have also been found to be more advantageous in high current environments to reduce drag (Trussell 1997).

In addition to water current, calcium levels affect snail shell morphology; calcium levels in the environment act as limiting factors and selective pressures on snail shell morphology (Rundle et al. 2004). Higher levels of calcium allow snails to build thicker shells to protect against predation; in the presence of predator chemical cues and a high availability of calcium, a snail's shell becomes thicker and develops a narrower aperture (DeWitt et al. 1999, Rundle et al. 2004). Although snails primarily intake calcium from their food, a portion of the snail shell calcium is derived from the water column (Glass and

Darby 2008), and water column calcium levels are directly related to pH level (Hunter 1989). In the presence of low pH levels and low calcium concentrations, snail shells are more prone to erosion, but low pH does not limit calcium uptake. In experimental manipulations of calcium levels at a fixed low pH, high levels of calcium have been shown to repair the erosion, indicating that calcium levels and pH are both important factors in determining snail shell morphology (Glass and Darby 2008).

In this study I attempted to determine how water current in two Northern Michigan streams affect shell morphology in the freshwater snail, *Elimia livescens*. Based on the findings of Raffaelli (1977), Johnson and Brown (1997), and Minton et al. (2008), I expected that within riffles, snails should have thicker and larger shells to better protect them against damage and to allow for a larger foot to better grasp the substrates in higher current environments. Finally, based on Vermeij's findings (1993), I expected the snails in the stream riffles to have more streamlined, or narrow, shells for a more energetically favorable method of countering the effect of stronger current.

## METHODS

I collected data at Wycamp Creek off of Wycamp Rd. in Cross Village, MI and at Little Carp River at Munger Rd. in Bliss, MI; the two streams were approximately 13.1 km away from each other (Fig. 1) and chosen based on locations indicated by Burch (1993). The source of Wycamp Creek is Wycamp Lake, while the source of Little Carp River is Lake Paradise. In each stream, I collected one water sample for calcium ion level analysis; calcium ion concentrations were measured through chemical analysis in Lakeside Lab at the University of Michigan Biological Station in Pellston, MI. I also measured pH, dissolved oxygen level, conductivity, and temperature with electronic handheld readers (Fisher Scientific, Accumet Portable AP10 pH Meter, fishersci.com; YSI Incorporated, Model 50B Dissolved Oxygen Meter, YSI.com; YSI Incorporated, Model 30 Conductivity/Salinity/Temperature Meter, YSI.com) in each stream to control for differences in these abiotic factors between the different streams. Water current was determined by measuring the time taken for an orange to travel a meter in each of the three riffle and three pool plots per stream My sample plots were approximately 8-16 m$^2$ each, and selected such that I could collect 100 snails per plot at Wycamp Creek and 50 snails per plot at Little Carp River using glass bottomed buckets. The reduced amount of snails collected at Little Carp River was due to time constraints associated with project deadlines. For each snail collected, I measured, with digital calipers, the length, width at the widest point, and thickness of each shell at its aperture (Fig. 2). I used length multiplied by width to establish a size index, thickness at the aperture to establish shell strength, and length divided by width to calculate an apex proportion index to establish hydrodynamic resistance.

A two-way analysis of variance (ANOVA) was used to determine whether the snail shell size, thickness, and apex proportion was affected by stream and/or habitat (riffle or pool plot) within the streams, and to determine if the interaction between the streams differed. Additionally, linear regressions were used to examine correlations between current level in all habitats within the two streams and shell size, thickness, and apex proportion.

# RESULTS

Overall, the current in Little Carp River was not significantly different from the current in Wycamp Creek (t=-.587, df=10, p=.570). Additionally, the calcium concentration, pH, and dissolved oxygen level were similar between the two streams, while conductivity and temperature differed slightly between the two streams (Table 1); however, no statistical analyses were performed.

There was a significant difference in the sizes of snails from the two rivers; snails in the Little Carp River were significantly larger than snails in Wycamp Creek (Table 2). There was no significant difference between snail shell size and the habitat in which they live (pool or riffle) (Table 2); however, snails in pools were slightly smaller than snails in riffles (Fig. 3). There was no significant interaction between stream and habitat in influencing size (Table 2), as the shells were larger in the riffles in both of the two streams (Fig. 3). In addition, size and current were not significantly correlated ($R^2$=.05, df=11, p=.483) (Fig. 4).

Additionally, there was a significant difference between snail shell thickness and the rivers in which they are found (Table 2); snail shells were thicker at the aperture in Little Carp River than in Wycamp Creek (Fig. 5). Snail shells were also significantly thicker in riffles than pools (Fig. 5) (Table 2), and there was no significant interaction between stream and habitat in affecting size (Table 2), as the shells were thicker at the aperture in the riffle sites of both streams (Fig. 5). Furthermore, an increased snail shell thickness increased linearly with increasing current (Table 2) ($R^2$=.640, df=11, p=.002) (Fig. 6).

Finally, the snail shell apex proportion did not differ significantly between riffles and pools (Table 2). The difference in apex proportions between the two rivers was significant, as apex proportion was significantly larger in Little Carp River than Wycamp Creek. The significant interaction between habitat and stream resulted from the pools having a larger apex proportion at Wycamp Creek, while riffles had a larger apex proportion at Little Carp River (Fig. 7). Linear regression also indicates no trend between current and apex proportion; apex proportion is not dependent on current ($R^2$=.048, df=11, p=.493) (Fig. 8).

## DISCUSSION

My findings that snails in riffles were not significantly larger than snails in pools did not support my hypothesis that snails should be larger in riffles than in pools. This finding was inconsistent with the results obtained by Johnson and Brown (1997), which found that larger snails have an adaptive advantage in higher current areas because of stress involved with a higher current. Additionally, with bigger shells, the foot should be larger to help the snails better attach to rocks in the presence of faster water flow (Minton et al. 2008). Furthermore, my findings that snails in Little Carp River were larger than snails in Wycamp Creek were not consistent with my hypothesis, indicating that possibly an additional selective pressure was acting upon shell size. Based on the work of Crowl and Schnell (1990), perhaps predation or competition for biomass in differing streams are stronger forces acting upon snail shell size than current speed. Moreover, I found that conductivity was higher in Little Carp River than Wycamp Creek (Table 1); Chetelat et al. (1999) found that conductivity is positively correlated with biomass, while Crowl and Schnell (1990) found that shell size is positively correlated with biomass availability. Based on these studies, the greater snail size in Little Carp River might be attributed to the higher conductivity.  The two rivers showed no significant interaction with regard to size between pools and riffles, which was expected, as this shows the trend is consistent between the streams and not limited to one population of snails.

The significant difference in snail shell thickness between pools and riffles in both streams supported my hypothesis that thicker shells would be more favorable in increased current levels. My findings were consistent with Raffaelli (1978) in that thicker shells would be more resistant to damaging effects of becoming dislodged in a high current environment and therefore would be found in a higher current environment. Additionally, my results for this variable were supported both by the significant difference between riffles and pools from the two-way ANOVA and the significant linear regression between current and thickness. Although the two rivers were used as controls, a significant increase in snail shell thickness in Little Carp River may have resulted from the same selective pressures between streams as was suggested with shell size. In addition, perhaps Little Carp River has higher water current speeds, on average, than Wycamp Creek, making it more advantageous to have thicker shells overall. The lack of significant interaction between stream and habitat in influencing thickness was expected, as this shows the trend is not limited to one population of snails.

The lack of significant difference between riffles and pools in the snail shell apex proportion was not consistent with my hypothesis. I expected the proportion to be larger in snails in the riffle area based on the findings of Vermeij (1993), which concluded that a narrower shell would be more hydrodynamic and energetically favorable. My results;

however, were also not supported by Trussell (1997), who found that squatter shells are more favorable in high current environments in order to reduce drag. I saw no trend in the overall proportion of the length to width between pools and riffles, but a significant difference in the apex proportion between the two streams. This finding was also inconsistent with the results of Kemp and Bertness (1983), which found that snails in low-density environments are expected to have rounder, wider shells than snails in high-density areas. Although this variable was not measured, snails were present in much higher densities in Wycamp Creek than in Little Carp River, indicating that snail density may not have been a significant force acting upon snail apex proportion either.

Although I expected that an increase in calcium ion concentrations would lead to an increase in snail shell thickness, limitations in equipment available at the University of Michigan Biological Station make this association difficult to discern. Using the provided equipment, calcium and magnesium concentrations could not be separated from each other, so the effect of calcium ion concentration could not be independently analyzed. Additionally, the two concentrations were relatively similar, but because magnesium and calcium were measured together, the relative proportions of each element were unknown. I expected a concurrent neutral pH with high calcium ion concentration; however, pH levels between the two streams were almost identical, so pH alone would likely not be a factor influencing shell morphology. Possible sources of error included a bias for selecting larger snails during collection; however, this bias would be reflected in both habitats and in both streams, and would ultimately not have a significant effect on data. Furthermore, snails were collected on different days; varying water current conditions may have altered snail distribution, although this likely had an insignificant effect as well.

Based on this study, it is evident that current has a profound effect on the morphology of snail shells. My findings showed that snail shell thickness is dependent on current, as thickness significantly differed with changing current environments, suggesting that thickness is more dependent on this measured environmental conditions than shell size or shape. While these results provide a significant starting point in understanding snail shell morphology, future work should focus on the effects of calcium ion concentration and conductivity on shell thickness and size, and predation, snail density, and competition for resources on overall shell morphology.

## LITERATURE CITED

Burch, J. B., and Y. Jung. 1993. Freshwater snails of the University of Michigan Biological Station. Walkerana 6:1-218.

Chételat, J., F. R. Pick, A. Morin, and P. B. Hamilton. 1999. Periphyton biomass and community composition in rivers of different nutrient status. Canadian Journal of Fisheries and Aquatic Sciences 56:560-569.

Crowl, T. A., and G. D. Schnell. 1990. Factors determining population density and size distribution of a freshwater snail in streams: effects of spatial scale. Nordic Society Oikos 59:359-367.

DeWitt T., A. Sih, and J. Hucko. 1999. Trait compensation and cospecialization in a freshwater snail: size, shape and antipredator behaviour. Animal Behaviour 58:397-407.

Glass N., and P. Darby. 2009. The effect of calcium and pH on Florida apple snail, *Pomacea paludosa* (Gastropoda: Ampullariidae), shell growth and crush weight. Aquatic Ecology 43:1085-1093.

Hunter, R. D. 1990. Effects of low pH and low calcium-concentration on the pulmonate snail *Planorbella trivolvis*—a laboratory study. Canadian Journal of Zoology 68:1578-1583.

Johnson, P. D., and K. M. Brown. 1997. The role of current and light in explaining the habitat distribution of the lotic snail *Elimia semicarinata* (Say). Journal of the North American Benthological Society 16:545-561.

Kemp, P., and M. D. Bertness. 1984. Snail shape and growth rates: evidence for plastic shell allometry in *Littorina littorea*. Proceedings of the National Academy of Sciences 81: 811-813.

Minton, R. L., A. P. Norwood, and D. M. Hayes. 2008. Quantifying phenotypic gradients in freshwater snails: a case study in *Lithasia* (Gastropoda: Pleuroceridae). Hydrobiologia 605:173.

Raffaelli, D. G. 1978. The relationship between shell injuries, shell thickness and habitat characteristics of the intertidal snail *Littorina rudis* maton. The Journal of Molluscan Studies 44: 166-170.

Rundle, S. D., J. I. Spicer, R. A. Coleman, J. Vosper, and J. Soane. 2004. Environmental calcium modifies induced defenses in snails. The Royal Society 271:67-70.

Trussell, G. C. 1997. Phenotypic Plasticity in the Foot Size of an Intertidal Snail. Ecology 78:1033.

Vermeij, G. J. 1993. Evolution and escalation: an ecological history of life. Princeton University Press, Princeton, New Jersey, USA.

Formatted: Left

# FIGURES AND TABLES

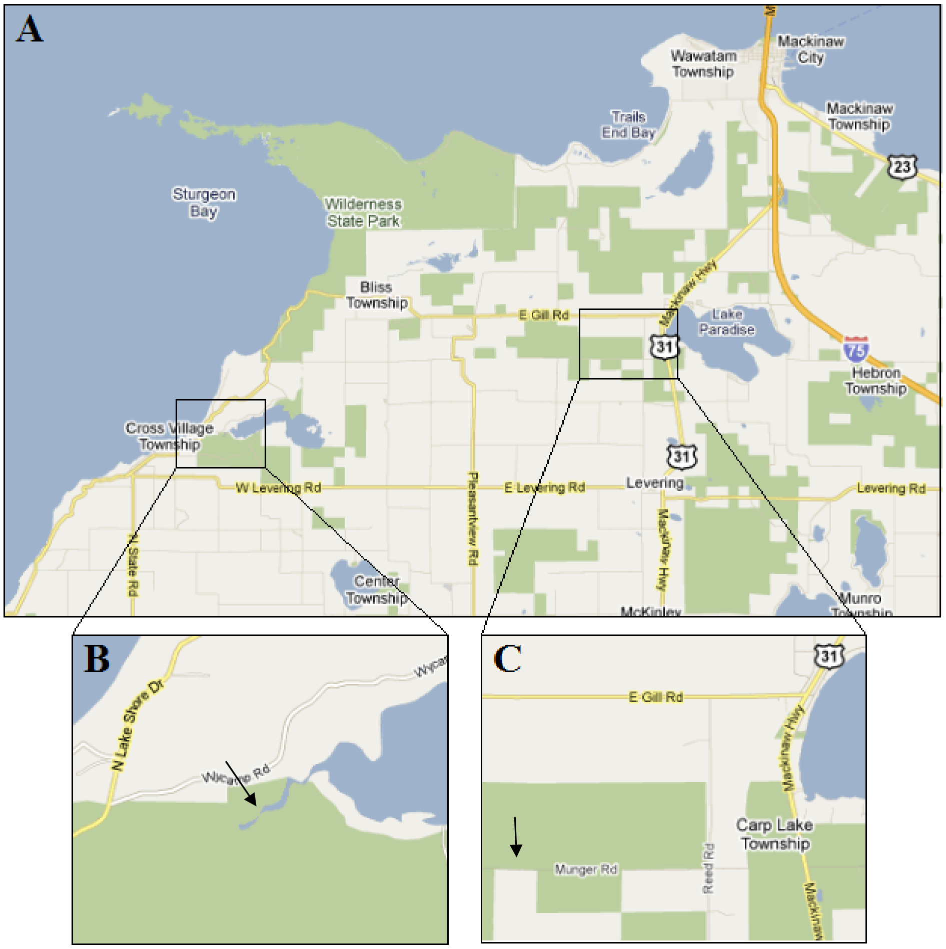

Figure 1: Our two study sites were located approximately 13.1 km apart in Northern Michigan (A): Wycamp Creek off Wycamp Road near Cross Village, Michigan (B) and Little Carp River on Munger Road in Bliss, Michigan (C).

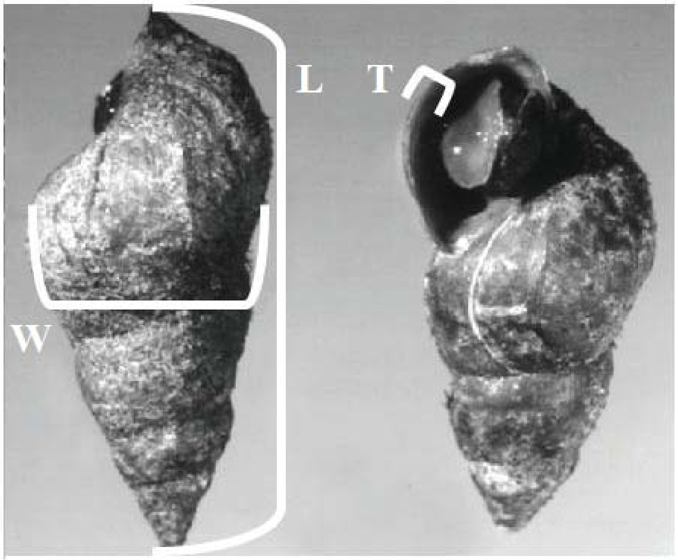

Figure 2: We measured the length (L), width at the widest point (W) and thickness at the aperture (T) of the snail shell.

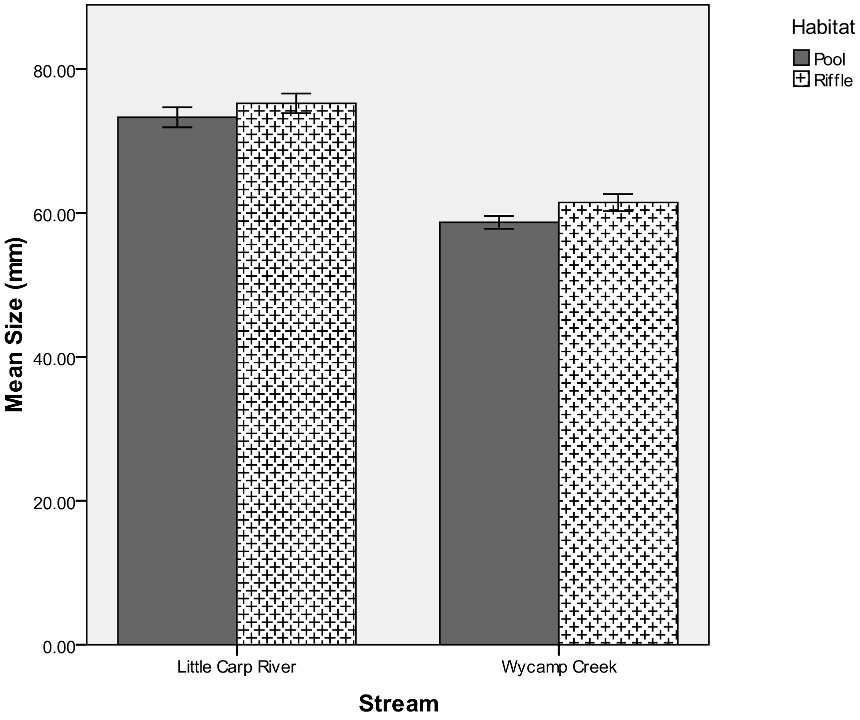

Figure 3. The mean size of snails (length x width), in both pools and riffles in Little River and Wycamp Creek. Snails were significantly larger in Little Carp River than in Wycamp Creek; however the mean snail shell size was not significantly different between pools and riffles (Table 2). The interaction was not significantly different between habitat type and stream (Table 2).

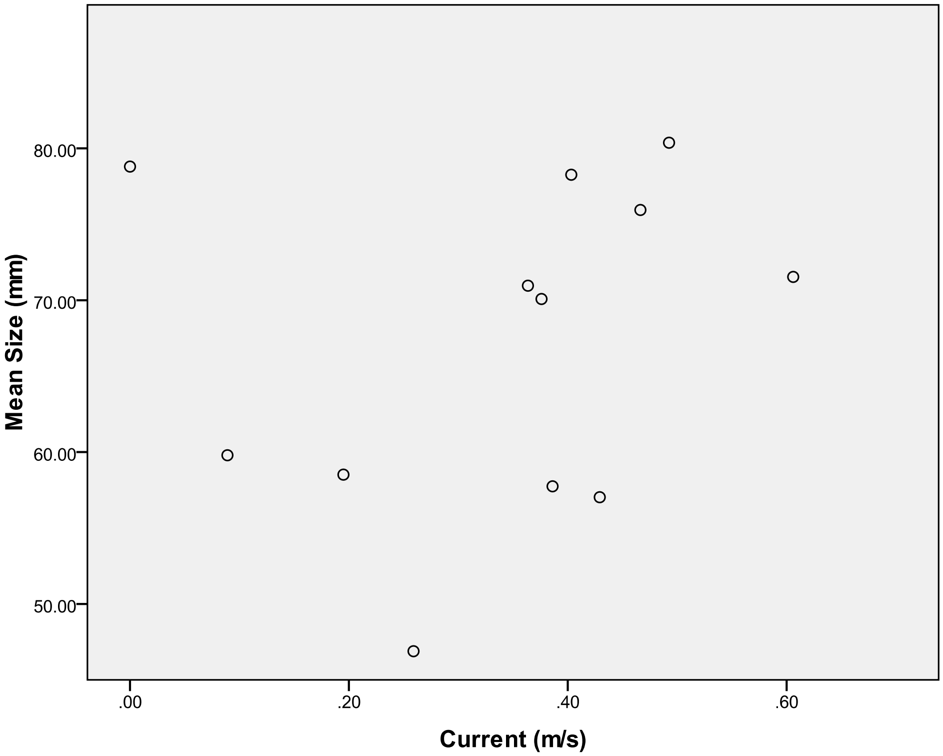

Figure 4. Mean snail shell size at each riffle and pool plot within Little Carp River and Wycamp Creek versus current. There was no significant correlation between the two variables ($R^2$=.05, df=11, p=.483).

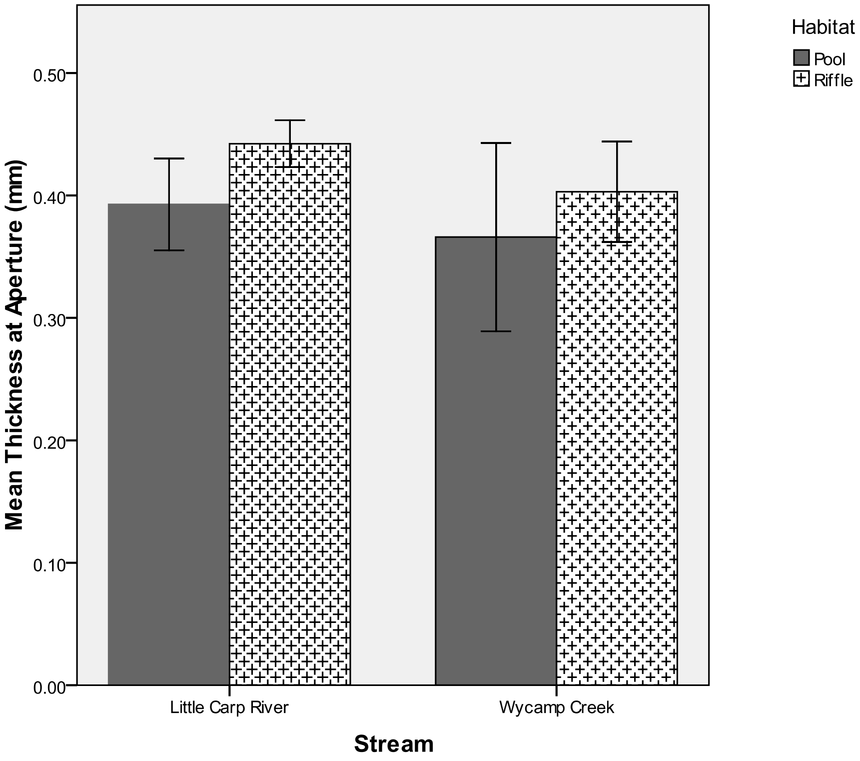

Figure 5. The mean thickness of snail shell aperture in both pools and riffles in Little Carp River and Wycamp Creek. Snails were significantly thicker in Little Carp River than in Wycamp Creek, and the mean snail shell thickness was significantly thicker in riffles than in pools (Table 2). The interaction was not significantly different between habitat type and stream (Table 2).

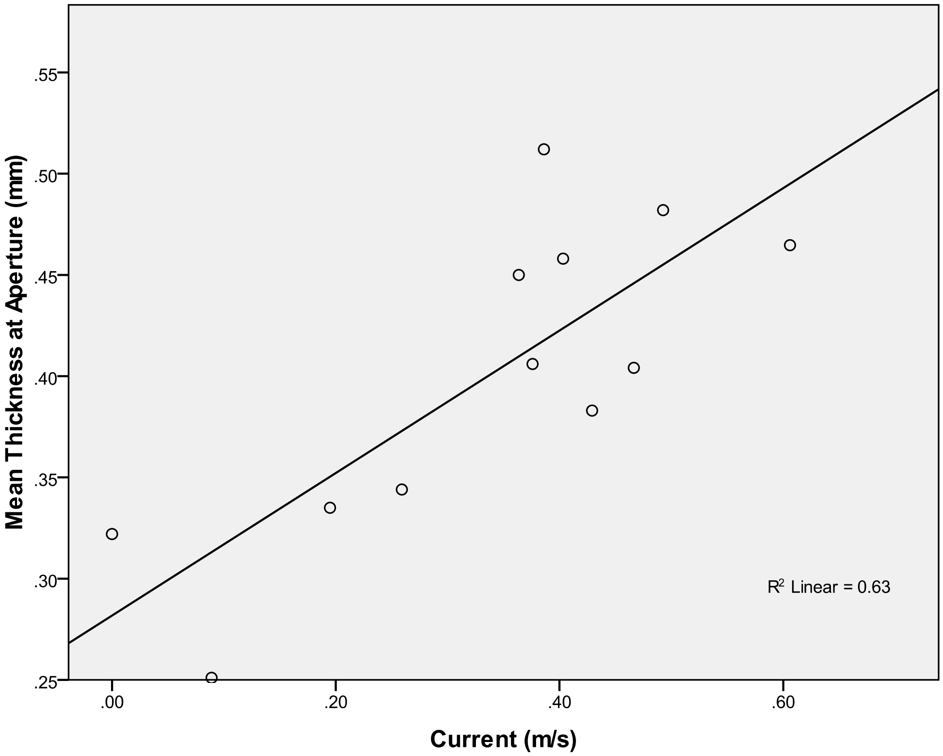

Figure 6. Mean snail shell thickness at each riffle and pool plot within Little Carp River and Wycamp Creek versus current. There was a significant correlation between the two variables ($R^2$=.640, df=11, p=.002). As current increases, thickness increases.

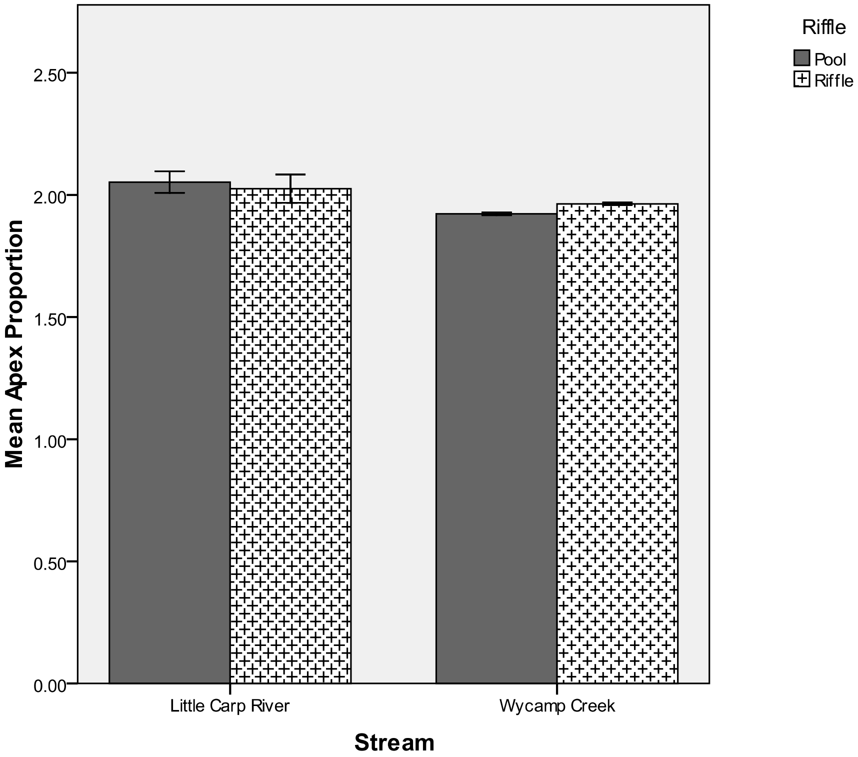

Figure 7. The mean snail shell apex proportion (length/width), in both pools and riffles in Little Carp River and Wycamp Creek. The mean snail shell apex proportion was greater in Little Carp River than in Wycamp Creek (Table 2). Additionally, there was no significant difference between mean apex proportions in the two habitats (Table 2). The interaction between stream and habitat type was significantly different.

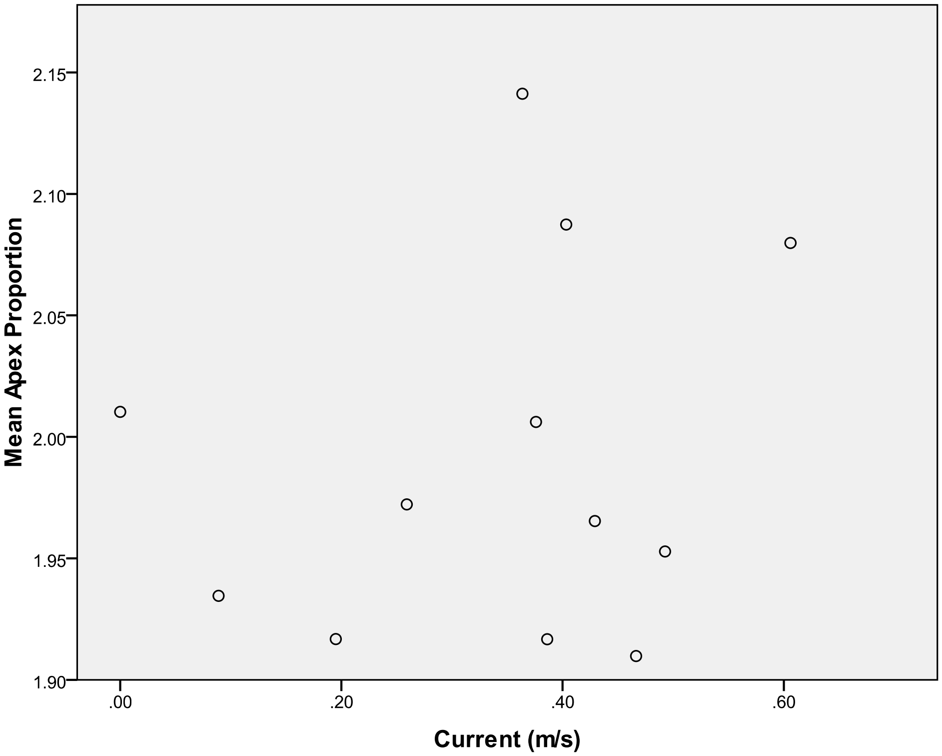

Figure 8. Mean snail shell apex proportion at each riffle and pool plot within Little Carp River and Wycamp Creek versus current. There was no significant correlation between the two variables ($R^2$=.048, df=11, p=.493).

Table 1. Values for abiotic factors (calcium, pH, dissolved oxygen, conductivity, and temperature) at Little Carp River and Wycamp. The results for each factor, except conductivity, between the streams are similar.

| **Factor** | **Little Carp River** | **Wycamp Creek** |
|---|---:|---:|
| Calcium ion conectration (mM) | 1.4 | 1.7 |
| pH | 7.68 | 7.61 |
| Dissolved oxygen (%) | 39.2 | 40.1 |
| Conductivity (µS) | 286.2 | 236.8 |
| Temperature (ºC) | 22.2 | 27.2 |

Table 2. The F-statistic, degrees of freedom, and corresponding p-values from two-way ANOVAs testing for effects of stream, habitat, and stream*habitat for three parameters: size, thickness, and apex proportion of shells.

| **Size** | | | |
|---|---|---|---|
| | F | df | p |
| Stream | 127.787 | 1,896 | <.001 |
| Habitat | 3.48 | 1,896 | 0.062 |
| Stream*Habitat | 0.103 | 1,896 | 0.748 |

| **Thickness** | | | |
|---|---|---|---|
| | F | df | p |
| Stream | 9.006 | 1,896 | 0.003 |
| Habitat | 15.491 | 1,896 | <.001 |
| Stream*Habitat | 0.346 | 1,896 | 0.557 |

| **Apex Proportion** | | | |
|---|---|---|---|
| | F | df | p |
| Stream | 59.703 | 1,896 | <.001 |
| Habitat | 0.361 | 1,896 | 0.548 |
| Stream*Habitat | 7.084 | 1,896 | 0.008 |