INTERACTION BETWEEN ASSOCIATION AND EXPOSURE IS CORRELATED WITH MEAN SIZE OF BASAL *CREPIDULA FORNICATA* IN NAHANT, MA

Audrey Seiz
Department of Biology, Clark University, Worcester, MA 01610 USA
(aseiz@clarku.edu)

Abstract The Atlantic slipper snail, *Crepidula fornicata*, is a filter-feeding gastropod. *C. fornicata* is a sequential hermaphrodite with a unique reproductive behavior that involves smaller, mobile male slipper snails stacking on top of larger female slipper snails. This association allows males to release sperm in close proximity to fertile females. This study examined the mean size of basal *C. fornicata* in mid-tide tidal pools in Nahant, MA. The purpose of the study was to determine if association (unstacked or stacked), exposure (exposed tidal pools or sheltered tidal pools) or the interaction between the two variables altered the mean size of basal *C. fornicata*. Unassociated basal *C. fornicata* had a smaller mean size than associated basal *C. fornicata* in both exposed and sheltered tidal pools. The interaction between exposure and association significantly altered the mean size of basal *C. fornicata*, and the basal *C. fornicata* with no associations was larger in sheltered tidal pools; however, the basal *C. fornicata* with associations was smaller in sheltered tidal pools.

Keywords*: Crepidula- associations- size-interaction*

Introduction

Crepidula fornicata, commonly known as the Atlantic slipper snail, is found in the intertidal and subtidal zone of North America and has been introduced in several parts of Europe, including Ireland and France, as well as the Pacific coast of North America (Collin 1995). *C. fornicata* is a sessile filter-feeding gastropod that attaches itself to hard substrates, such as rocks or bivalves (Thieltges 2005). This gastropod employs a fascinating reproductive strategy known as sequential hermaphroditism, which is also seen in shrimp, annelids and other mollusks (Proestou et al. 2008). Slipper snails develop as males and then transition to females once they reach a critical size (Proestou et al. 2008 ; Cam et al. 2009; Hoch and Cahill 2012). In order to reproduce, the small, mobile males form associations (or stacks)— composed of up to twelve individuals—on top of a larger female. These stacks can remain associated for a short period of time (days or weeks) or a long period of time (months or years) (Collin 1995; Thieltges 2005; Proestou et al. 2008; Henry, Collin and Perry 2010). The process of *C. fornicata* egg fertilization involves males externally releasing sperm into the water column. Following this event, female slipper snails filter in the sperm from the surrounding environment to internally fertilize their eggs. Stacking increases an associated male's chance of fertilizing eggs, because it is more likely that the sperm from a male in close proximity to female will be used to fertilize the eggs (Ambrogio and Pechenik 2009; McNeill et al. 2010).

Previous studies focused on *C. fornicata* as an introduced species, studying its distribution and effects on ecosystems, or the size-sex ratio in *C. fornicata* populations

(Collin 1995; Ambrogio and Pechenik 2009; McNeill et al. 2010). The present study focused on: (1) Is the mean size of basal *C. fornicata* significantly different when the organism has associations? (2) Is the mean size of basal *C. fornicata* significantly different in exposed tidal pools versus sheltered tidal pools? (3) Is the mean size of basal *C. fornicata* significantly different when examining the interaction between association and exposure?

Materials and Methods

Study Organism

Crepidula fornicata is a marine mollusk with a single, uncoiled, oval-shaped shell (Figure 1). The shell of *C. fornicata* is generally smooth with a few sporadic growth lines. The shell is arched but has no dorsal point, although the shell does have a posterior apex. *C. fornicata* shell color generally ranges from grey to cream with occasional brown or red spots. The Atlantic slippersnail has an internal, posterior shelf that covers one-fourth to one-half of the interior of the shell, which separates its foot from the rest of its body (Henry, Collin and Perry 2010).

Figure 1. Photograph of *Crepidula fornicata* (circled in black) in Nahant, MA.

Study Area

The study was conducted in Nahant, MA (42.4264° N, 70.9194° W) — a city located in eastern Massachusetts on a peninsula surrounded by the Atlantic Ocean (Figure 2). The specific stretch of rocky intertidal zone used for the study was next to Northeastern University's Marine Science Center (Figure 3).

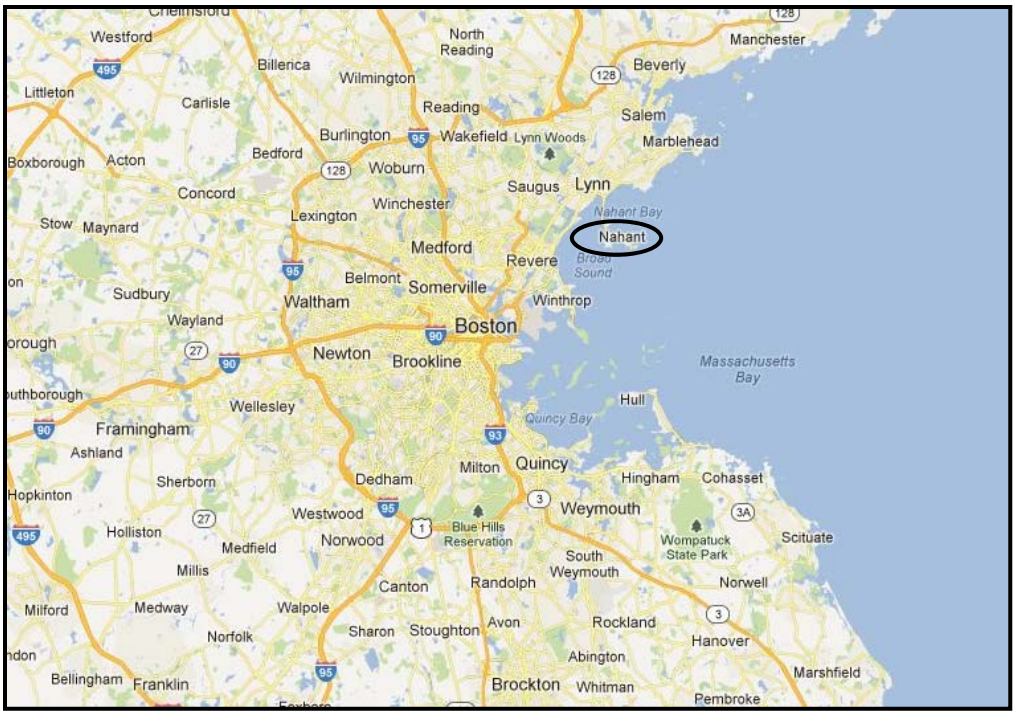

Figure 2. Image from Google Maps of eastern and central Massachusetts with the city of Nahant circled.

Figure 3. Photograph of the Nahant rocky intertidal zone.

Experimental Methods

C. fornicata were randomly measured on September 15th, 2012 and October 26th, 2012 in five different mid-tide tidal pools in both exposed and sheltered areas in Nahant, MA. The shell lengths of *C. fornicata* were measured in millimeters using a small, plastic,

metric ruler. A total of 114 *C. fornicata* shells in sheltered mid-tide tidal pools and 113 *C. fornicata* shells in exposed mid-tide tidal pools.

Statistical Analysis

A contingency analysis was used to test if there were significant differences in the frequency of basal *C. fornicata* associations in exposed versus sheltered tidal pools using the software program JMP. A Two-way ANOVA was used to determine if there were significant differences in basal *C. fornicata* size in terms of the main effects of association or exposure or the interaction between association and exposure.

Results and Discussion

There was no significant difference in the frequency of associations between exposed and sheltered tidal pools (Chi-Squared Test= 0.018, p=0.89). In both the exposed and sheltered regions of the intertidal, mean size of the basal *C. fornicata* found in association was significantly greater than unassociated *C. fornicata* (Figure 4; $F_{1, 224}$=129.83, p<0.001). The mean size of basal *C. fornicata* was not significantly different in exposed versus sheltered areas (Figure 4; $F_{1, 224}$=0.7099, p=0.4004). There was a significant interaction between association and exposure: the mean size of basal *C. fornicata* with no associations was larger in sheltered tidal pools, whereas the mean size of basal *C. fornicata* with associations was smaller in sheltered tidal pools (Figure 4; $F_{1, 224}$= 5.9183, p=0.0158).

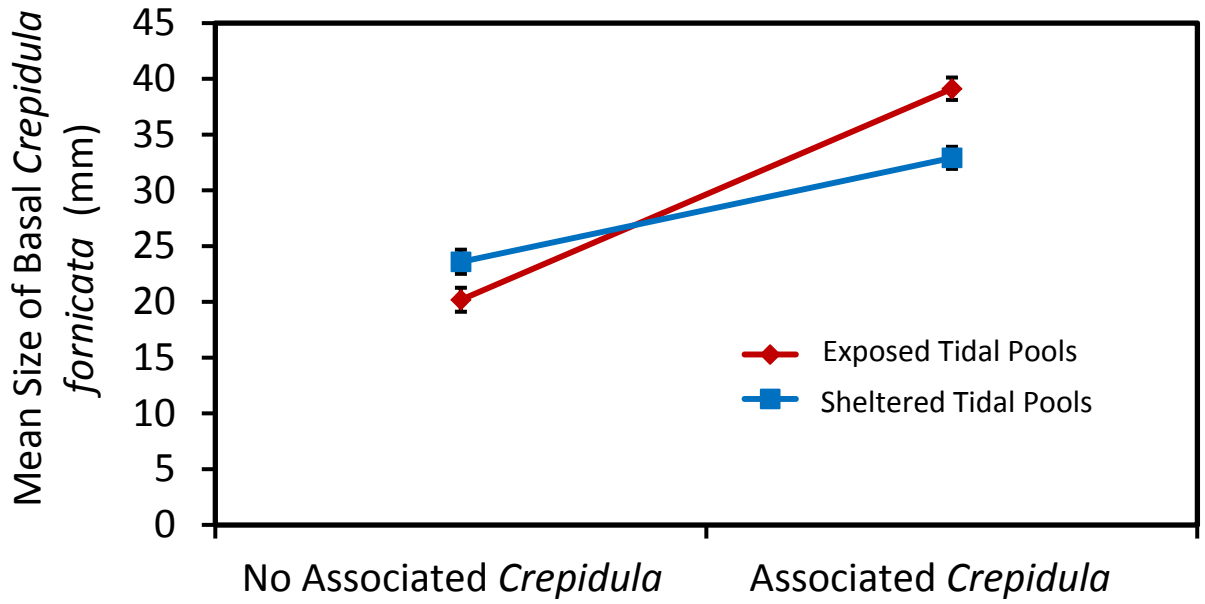

Figure 4. Mean size of basal *Crepidula fornicata* with or without associations in both sheltered and exposed tidal pools. Errors bars indicate the standard error of each mean value.

The size at which association occurs is influenced by an organism's age as well as growth rate. In this study, basal *C. fornicata* in associations were larger than individuals without associations. This mean size difference of basal *C. fornicata* with and without associations was likely a reflection of different age classes, because older *C. fornicata* had more time in the tidal pool to grow, develop and form associations. Other studies of gastropods determined that the increased wave action of exposed intertidal areas either stunted the growth of marine gastropods or crushed individuals over a certain size (Shanks and Wright 1986; Blanchette 1997; Branch and Odendaal 2003). Unlike the results of these studies, this study determined that it was advantageous for associated *C. fornicata* in exposed tidal pools to be large, and the associated basal *C. fornicata* were about 6mm larger in exposed versus sheltered tidal pools. The large size of associated basal *C. fornicata* in exposed environments is important because it increases the foot size and adhesion ability of the organism to the substrate. This enables the basal *C. fornicata* to still form associations needed for procreation without being dislodged by high levels of wave actions. The associated basal *C. fornicata* were able to reach such large sizes because the increased wave action in exposed areas readily replenished food for filter-feeding organisms.

The difference in individual mean size of unassociated *C. fornicata* in sheltered and exposed areas were smaller than the difference in the mean size of associated basal *C. fornicata* in sheltered and exposed areas. Although sheltered individuals had a larger size than exposed individuals, this difference was slight and may be due to disparities in the age of the individuals measured.

Future research is needed to explore the sex and age of the basal *C. fornicata* both with and without associations. Also, it would be interesting to determine the sex of the associated *C. fornicata* to investigate the sex-ratio of the associations. Finally, further research should measure the shell lengths of both male and female *C. fornicata* in Nahant, MA to establish if there is an evident size threshold that provokes the transition from male to female sex.

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