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# Movement Patterns of the Common Periwinkle Cenchritis muricatus in the Rocky Supralittoral Zone of San Salvador, Bahamas

Luke Stannard

Donna Howard

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Luke Stannard, Donna Howard

Research Mentors: James McClintock, Ken Marion, and Robert Angus

**Abstract**

*Directional movement patterns of adults of the littorinid periwinkle Cenchritis (Tectarius) muricatus were documented over a five and half day period in May 2008 at low, mid, and upper supralittoral (the region above the intertidal zone that is wet only by occasional sea spray) sites on the northwestern rocky coast of San Salvador, Bahamas. Daytime surface temperatures on the rocky substrata were extreme ranging from 24 to 48 ˚C. Snails at all three sites generally moved only short distances (approximate mean = 1 cm/hr). Nonetheless, snails at the mid-level site moved significantly greater distances than did snails at either the low or upper sites. There was a significant increase in distances moved following a rain event (approximate mean = 2 cm/hr). Moreover, at upper and lower sites, snails moved greater distances during the night than during the day. These findings suggest that snails increase the distances they move when surface substrata temperatures are low due to rainfall or a reduction in exposure to sunlight (night). This likely reflects a mechanism to reduce physiological stress due to desiccation as mucus is lost during locomotion. Selection for increased movements during these periods may be valuable in terms of meeting nutritional requirements as C. muricatus grazes on microalgae that occur on the rocky substrata.*

## Introduction

Supralittoral habitats of the Caribbean islands are well known to be characterized as physically stressed environments. Extreme tropical temperatures exert considerable desiccation stress on gastropods and other marine organisms that occupy this zone (Little 1989; McMahon and Britton 1991; Gochfeld and Minton 2001). For example, daytime temperatures in rocky supralittoral habitats of San Salvador, Bahamas may attain temperatures as high as 48 or even 50 ˚C (McClintock et al. 2007; present study). These supralittoral habitats are also rarely wetted even during extreme high tides, although they may periodically receive spray during strong storm winds or coastal surge events associated with hurricanes. To further exacerbate the situation the Caribbean region is characterized by intense periods of aridity which impose further desiccation stress on supralittoral marine life.

Gastropods that occur in supralittoral habitats possess a variety of mechanisms to mitigate the effects of thermal and desiccation stress including aspects of shell morphology such as pigmentation, small size, degree of ornamentation, and possession of an operculum (Vermeij 1973, Heath 1975, Britton 1995). Moreover, gastropods that occur in these regions may produce mucus seals that secure them tightly against the substrate (McMahon and Britton 1991) and possess behaviors that facility the occupation of shaded microhabitats (Garrity and Levings 1984).

*Cenchritis muricatus* (Linnaeus, 1758) is the most common gastropod in the supralittoral zone of the rocky shores in the Caribbean (Lewis 1960; Fraenkel 1968; Lang et al. 1998; Minton and Gochfeld 2001; Gochfeld and Minton 2001; Emson et al. 2002). Several studies have shown that *C. muricatus* generally move limited distances (Lang et. al. 1968; Burgett et al. 1987; McClintock et al. 2007). It has been suggested that individuals move directionally toward the sea during night hours when air temperatures are less extreme (Kaplan 1988). In contrast, Gochfeld and Minton (2001) noted a lack of directional movement and found that movements were not correlated with diurnal, tidal, or lunar cycles.

In the present study we further investigated the behavioral ecology of *Cenchritis muricatus* in order to determine whether there were differences in movement patterns (distances) during day and night periods at three discrete levels of the rocky supralittoral zone. Moreover, an opportunistic rain day event allowed an evaluation of whether individuals move greater distances during periods of substrate wetness.

## Materials and Methods

The study site was located on the north shore of the island of San Salvador approximately 1 km west of the Gerace Research Centre (24° 3' 0", -74° 31' 0"). The site was comprised of weathered, deeply pitted, limestone. There was very little vegetation growing on the study site, however, the upper two thirds of the transect did contain *Rhachichallis americana*, *Strumpfia maritime*, and *Borricchia aborescens* (Cornel and Cornell 1982).

In order to examine the movement patterns of *C. muricatus*, three study sites were established at locations 2.1, 3.1, and 4.4 m above mean lower low water (MLLW). These sampling sites were chosen so as to represent supralittoral heights that were employed in a previous study to examine movement patterns in this gastropod (McClintock et al. 2007). A 50 x 50 cm quadrat (divided into 10 x 10 cm sectors with fine nylon line) was placed with its lower edge parallel to the shore line on to the substratum, and its location on the rocky substrata permanently marked using finger nail polish. This allowed the same exact site to be resampled during the study.

At each of the three sample sites, 15 snails were haphazardly selected and marked within the quadrant. Snail marking consisted of using super glue to attach a 3 x 3 mm piece of numbered plastic to the apex region of each snail shell. In addition, a small dot of red fingernail polish was placed on the shell apex in order to facilitate relocation of each individual on the rocky substrata .

The initial locations of each of the 15 snails within each sample site quadrant were recorded. Subsequent positions of each snail were recorded at 12 hour intervals over a five and half day period (eleven 12 hour periods). Measurements were recorded in the early morning and late evening so as to allow an evaluation of distances of movement during day versus night hours. At each 12 hr interval, surface substrata temperatures were recorded at each site using a thermometer

Distances moved by each snail when occupying the quadrant were based on its position relative to its most recent position (12 hr earlier). Once snails moved outside of the quadrant, each subsequent measurement of its distance moved was based on the distance from its position to the corner of the quadrant nearest its location.

**Statistical Analyses**

An Analysis of Variance (ANOVA) was used to compare the mean distances snails moved over 12 and 24 hour periods at the three supralittoral sites. A Tukey Post Hoc test was employed to conduct pair-wise comparisons. Prior to analysis with ANOVA and Tukey Post Hoc tests, all data was normalized using a log transformation.

**Results**

Snails at the mid–level site moved significantly greater distances per 12 hr than did snails at the high ($P< 0.01$) or the low site ($P = 0.05$) (Fig. 1). There was no significant ($P > 0.05$) difference between the distances moved by snails at the high and low site.

A rain event occurred on day 1. As such, we restricted our comparison of day versus night movements to full days that occurred on days 2, 3, 4 and 5 of our study. When 12 hr periods of movement coincident with night were compared to those during daylight, at the upper and lower sites snails moved significantly ($P < 0.05$) (Fig. 2). There was no significant difference ($P > 0.05$) between day and night distances moved at the mid-level site.

We compared distances moved on a day by day basis (24 hr periods) for the five full days of our study to evaluate the impact of the rain event that occurred during our study. Shown in Figure 3 are distances moved per day which varied significantly from one another (ANOVA: $P < 0.001$). Pairwise analysis indicated that distances moved during day 1 (rain event) were significantly ($P < 0.05$) greater than days 3, 4 and 5. While there was no difference between day 1 and 2, day 2 was significantly ($P < 0.05$) greater than day 4.

Mean substrate surface morning and evening temperatures were 38.5 °C± 4.8 °C (n = 6) and 27.0 °C± 2.4 °C (n =5), respectively.

**Discussion**

Similar to other studies our qualitative observations indicated that *Cenchritis muricatus* occurred in high abundance in the supralittoral zone of San Salvador, Bahamas (Lewis 1960, Frenkel 1968, Lang et al. 1998, McClintock et al. 2007). Our experimental results indicated that snails at low, mid and high level study sites moved on average short distances (approximately 1 cm per hr). These limited movements are similar to what has been reported in other studies with *C. muricatus* and likely reflect the extreme conditions under which they live (Lang et al. 1968, Burgett et al. 1987, McClintock et al. 2007). While distances of movement were generally low, we did detect significant differences between our suppralittorial sites. *Cenchritis muricatus* moved greater distances at the mid-level infralittoral site (3.1 m above MLLW). The basis for this pattern could be related to several factors. Snails at the high site may move less than those at the mid site due to the increased stress associated with heat on the upper reaches of this zone. In contrast, snails at the low site may move less than mid-level snails because their food source, microalgae, is likely to occur at greater density closer to the sea. Thus, they would need to graze less to acquire a similar amount of nutrition. Mid-level snails may move further to optimize grazing under a thermal stress regime that facilitates greater movement than the upper site. A number of studies have suggested that heat stress is an important factor in the restricting movement behaviors *C. muricatus* (McMahon 1990, Britton 1995, Lang et al. 1998).

Contrary to previous studies (Lang et al. 1998, Gochfeld and Minton 2001, Emerson et al. 2002, McClintock et al. 2007), our study revealed significant differences between night and day distances of movement for two of the three sites examined (low and upper site). For snails in the upper site it may be advantageous to reduce dramatically (6 fold decrease) their movements during the day to avoid desiccation stress. We found morning temperatures (taken when the study sites were fully exposed to the sun) were almost twice those of evening temperatures (taken when the study sites were shaded). In contrast, snails at the lower site may have the luxury of meeting their nutritional needs during night time hours and thus avoiding movements during the day time. This would allow them to avoid day time heat stress and potential increased susceptibility to predation (as locomotion inhibits firm attachment to the substrate). Snails at the mid-level site did not move more at night than during the day, but moved greater distances overall than snails at low or high sites suggesting the demands of nutrition and heat stress outweigh the benefits of reducing their day motion.

Although there was only a single day of rain during the study, its impact on the movements of snails when compared to more typical dry days was dramatic. We found that during the rain day when the substrata was wet, snails moved on average 2 to 3 times greater distances than on dry days. This supports previous observations that *C. muricats* moves greater distances when substrates are moist from storms (Gochfeld and Minton 2001; Emson et al. 2002). Interestingly, snails on day 4 of our study moved the shortest distance overall and this coincided with the hottest day of the five and half day study. Temperatures reached 48 ˚C on this day. That snails moved the greatest distance during a period of rain and the shortest distance on the hottest day reflects the tremendous heat related stress that *C. muricatus* must cope with in the infralittoral habitats San Salvador. The present study, and those of others on movements in this species, would suggest that heat stress is the single most important factor governing the movement patterns of *C. muricatus* in the Caribbean.

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## Figure Legends

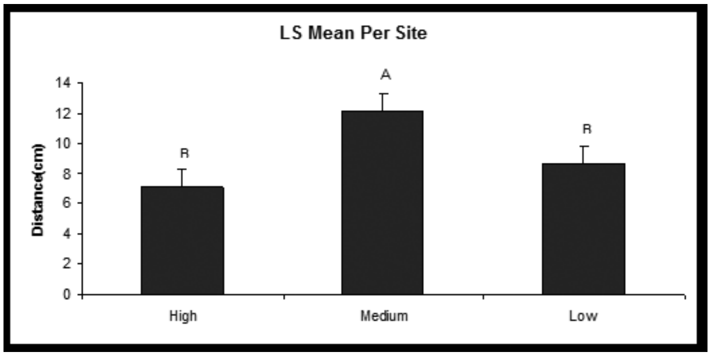


Figure 1: Least squares (LS) mean ± 1 SE for 12 hr incremental distances over a five and half day period for the littorinid gastropod *Cenchritis muricatus* at three supralittoral sites (2.1, 3.1 4.4 m above MLLW) on San Salvador, Bahamas. Different capital letters on top of bars indicate statistically significant differences.

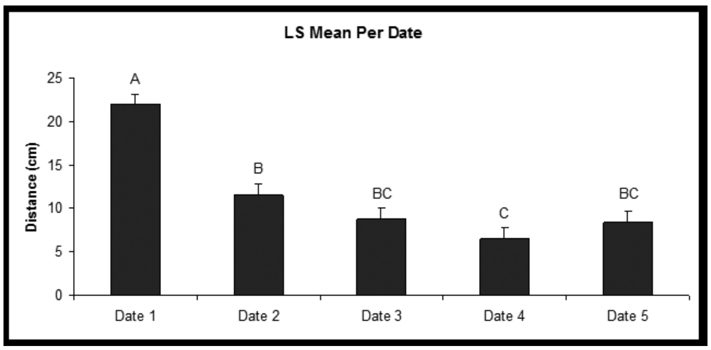


Figure 2: Least squares mean ± 1 SE during the day (open bars) and night (closed bars) over a five day period for the littorinid gastropod *Cenchritis muricatus* at three supralittoral sites (2.1, 3.1 4.4 m above MLLW) on San Salvador Island, Bahamas. Asterisks indicate significant differences.

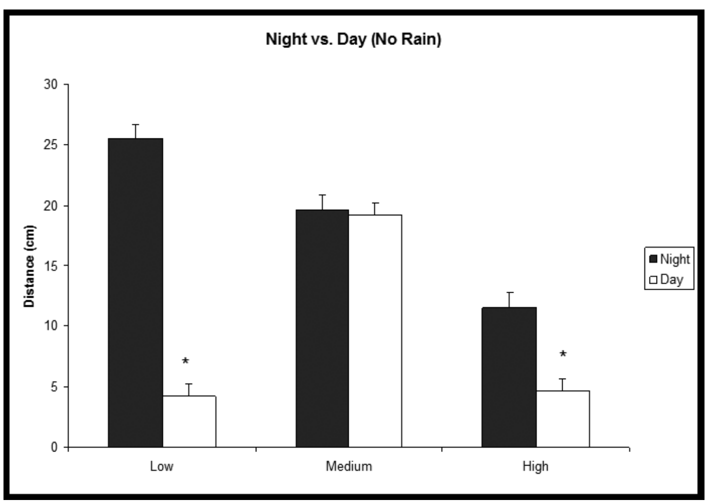


Figure 3: Least squares mean ± 1 SE distances moved over five days (24 hr) in the littorinid gastropod *Cenchritis muricatus* for all sites combined. Day 6 is not presented as it was sampled only in the morning hours. Different capital letters on top of bars indicate statistically significant differences.