Why does the Caribbean Periwinkle Escape Rock Surrounded by Seawater?

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INTRODUCTION

Previous unpublished observations of the rocky shore knobby periwinkle (Cenchritis muricatus) above high tide marks uncovered a surprising behaviour - these periwinkles would leave a dry rock when surrounded by seawater, but not in other situations. This behaviour seems non advantageous, as periwinkles normally do not forage, travel or hide in seawater. Earlier experimental findings displayed that all individual periwinkles would leave a rock when surrounded by seawater overnight, none would leave when surrounded by freshwater, and around half would do so when exposed to a mix of sea- and freshwater. These responses are unexpected based on the general ecology or behaviour of periwinkles.

The knobby periwinkle, also known as the beaded periwinkle, is a terrestrial species of marine origin. Periwinkles are common above the high tide mark, away from direct wave action.[1] Invertebrate inhabitants face challenges along rocky shores due to large gradients of salinity and potential desiccation. These difficulties have led to a variety of morphological and behavioural adaptations. They feed on green algae like Cladophora and Enteromorpha, as well as organic particles covering rocks.[2] Periwinkles exhibit nocturnal feeding behaviour when the rocks are damp, but they may also forage during the day after rain while remaining inactive on dry, hot rocks. Periwinkles show remarkable tolerance to desiccation and exhibit higher survival rates than other marine-origin rocky shore animals.[3]

Since periwinkles do not naturally occur in saltwater, their tendency to leave a rock surrounded by seawater poses an ecological puzzle. Triggers for this behaviour may include insufficient food resources, risk of flooding, or increased predation. The aim of this research is to explore how periwinkles can assess their environment and migrate based on perceived threats.

METHODS

This study took place at the Discovery Bay Marine Lab (DBML) in the University of the West Indies located in Discovery Bay, Jamaica. Experiments were run from December 28th, 2023, to January 10th,

2024. Periwinkles were collected from coastal rocks near the sea, freshwater, or brackish water pools at sites around the DBML. Rocks were chosen close to the sea to ensure experimental conditions were like those individuals already experienced in the wild. Two primary collection sites were near the lab boardwalk pier and boating dock.

Figure 1. *Map of the Discovery Bay Marine Lab where specimen collection occurred.*

The knobby periwinkle was the most abundant species at the study sites, often found in groups on rocks near the splash zone. Four experiments were conducted where rocks were placed in seawater and freshwater tanks halfway submerged, with periwinkles added to the dry areas. After 24 hours, the periwinkles that left the rocks were counted, interpreting their departure as a response to unsatisfactory conditions. Subsequent experiments tested rock size, texture, and orientation to refine and validate the results.

RESULTS

Periwinkles left their home rock more often when surrounded by seawater than freshwater (Fig. 3A, Table 1), though this effect varied across experiments (Fig. 3B). Interestingly, when the water depth was >60 cm, migration rates did not differ between freshwater and seawater (Fig. 4) which suggests that water depth, possibly linked to wave action or water level movement, influenced their behaviour.

Overall, salinity interacted with other factors (Table 1), but these interactions showed inconsistent effects on periwinkle migration. The variation between experiments suggests that certain factors, like water depth, may have a more significant role in periwinkle behaviour. Other observations such as the interaction between rugosity and salinity, reduced the role of migration chance, suggesting potential protective effects from wave impact.

Figure 2. *The beaded periwinkle (C. muricatus) shells. From Bailey-Matthews National Shell Musemu (https://www.shellmuseum.org/post/shell-of-the-week-the-beaded-periwinkle). Photos by James F. Kelly. Licence – none required.*

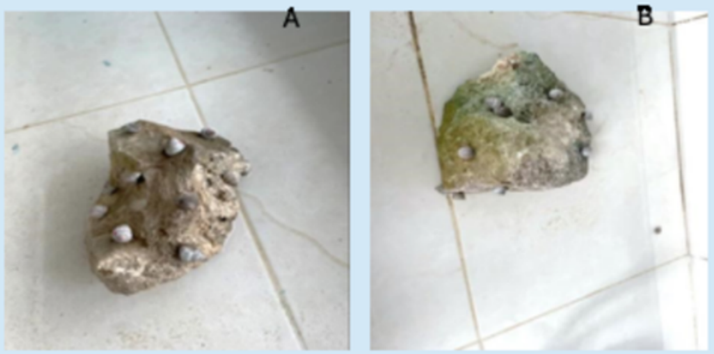


Figure 3. *Wet-lab experimental setup - rocks with periwinkles. Freshwater (A). Seawater (B).*

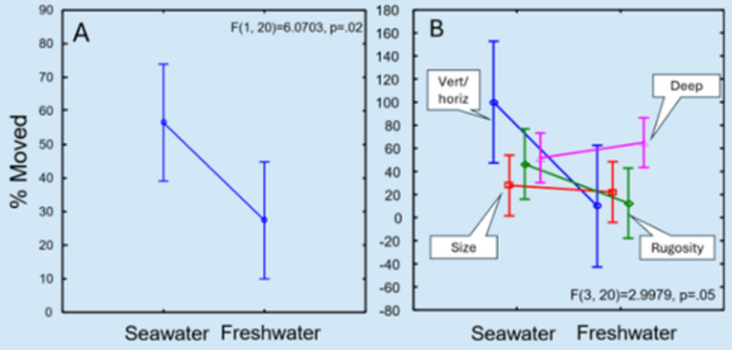
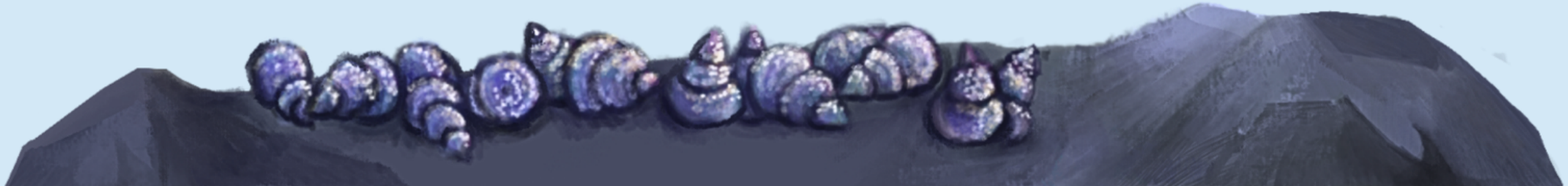


Figure 4. *A - Mean periwinkle numbers moved over all the combined experiments. B – different treatments (individual experiments) were significantly different but not individually.*

Table 1. Factorial ANOVA results on periwinkle migration response to sea/freshwater rock island environment across the four experiments. Note that the interactions between the Experiment and Salinity were significant at an alpha-level of 0.1.

	SS	Df	MS	F	P-value
Intercept	32184.04	1	32184.04	50.53258	0.000001
Experiment	6786.20	3	2262.07	3.55170	0.0329
Fresh/Salt	3866.14	1	3866.14	6.070	0.0229
Experiment*Fresh/Salt	5728.09	3	1909.36	2.998	0.0549
Error	12737.94	20	636.90		



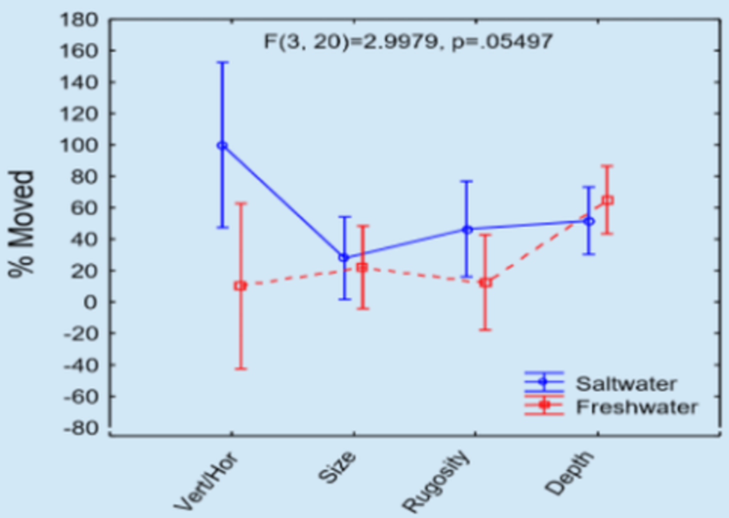


Figure 5. *Water salinity effect on periwinkle movement across the experiments (x-axis).*

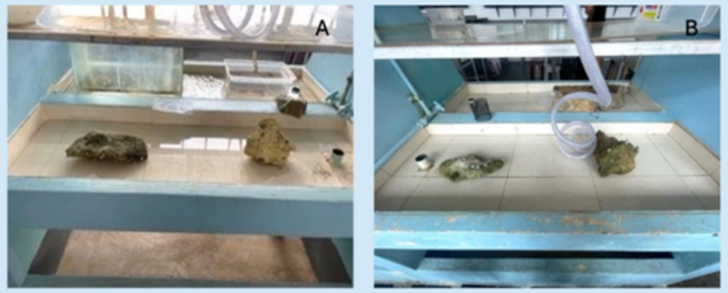


Figure 6. *Experiment 1: Rock Orientation. Wet-lab setup to assess the influence of rock position on periwinkle movement. n = 28 (n=7 per rock). A wet lab setup in the seawater environment testing a horizontal rock compared to a vertical rock (A). The freshwater environment setup compares a horizontal rock to a vertical rock (B). Water levels were maintained around 1cm.*

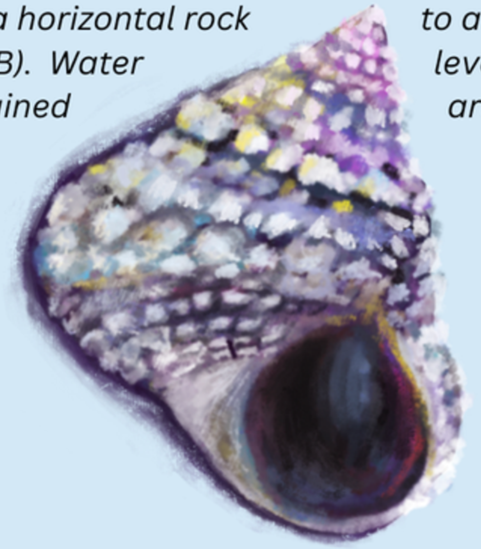


Figure 7. *Experiment 2: Rock size. Wet-lab setup to assess the impact of a small, medium, and large rock on periwinkle migration. (A) In the seawater tank, the large rock had a surface area of 50.14 cm^2 per periwinkle (n=28). The medium rock had a surface area of 53.25 cm^2 per periwinkle (n=20). The small rock had a surface area of 48.00 cm^2 (n=5). (B) In the freshwater tank, the large rock had a surface area of 49.95 cm^2 per periwinkle (n=40). The medium rock had a surface area of 45.80 cm^2 per periwinkle (n=15). The small rock had a surface area of 48.75 cm^2 per periwinkle (n=6). Water levels were maintained around 1cm.*

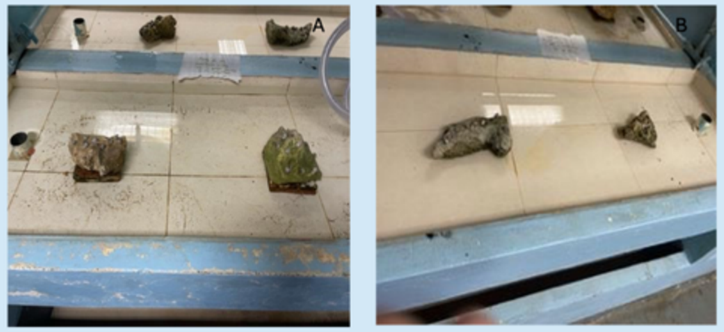


Figure 8. *Experiment 3: Rock terrain. Wet-lab setup to assess the effect of rock surface rugosity on periwinkle behaviour. A flat rock (n=10) and a cracked rock (10) in seawater (A). A flat rock (n=10) and a cracked rock (10) in freshwater (B). Water levels were maintained around 1cm.*

Figure 9. *Experiment 4: Rock depth. Outdoor experimental setup to assess the tidal threshold that periwinkles can withstand. A 60cm long coral rock was placed with 11cm exposed (n=10). A time-lapse camera attached to a pole driven into the sea sediments recorded periwinkle movements.*

DISCUSSION

While we were unable to link periwinkle responses to specific local features such as rock size, rugosity, or orientation (horizontal or vertical), the role of salinity in triggering periwinkle escape from rocks surrounded by seawater remains to be a clear, consistent, yet unusual behaviour. At the immediate scale, this behaviour is puzzling, as leaving dry rocks and crossing seawater to reach another location is an extreme risk. Any reports of knobby periwinkles entering the sea as part of their normal behaviour is unknown. However, this behaviour might reflect a risk inferred from broader-scale studies, such as Piovia-Scott (2009), which found that shores with high wave exposure had lower periwinkle densities in the supratidal zone than more protected ones.[4]

This escape behaviour may be representative of adaptive evolutionary responses to risk cues such as seawater submersion or being washed into the ocean. For instance, as periwinkles are common on dry rocks projecting into the sea but still connected to the shore, it is possible that periwinkles react to being surrounded by seawater, which could be a cue for escape.

This study's findings were more variable than an earlier outdoor experiment at the same facility by previous students. The previous experiment involved rocks placed in bowls surrounded by shallow freshwater or seawater, while the present study was conducted in lab tanks with running water. Differences in environmental conditions, such as thermal, light, and wind variations might have contributed to more pronounced behavioural responses outdoors. In nature, periwinkles do not enter seawater unless forced, and freshwater pools signal good foraging conditions. Thus, the escape behaviour may be an adaptive response to rising seawater levels, which are linked to increased wave energy.[4] This study highlights the challenges of interpreting behavioural experiments. When local factors do not directly correspond to the species' natural behaviours, small-scale experiments may confound our understanding of broader ecological adaptations rather than enhance them.[5]

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