BIOLOGICAL SCIENCES

Relationship Between Snail Shell Size and Distance on Substrate

Cassandra Liong

The intertidal zones of Hawai'i are an ever-changing environment where habitating organisms are subject to highly variable conditions. Due to such changes, these organisms have been forced to evolve to keep up with the environment over time. Despite the many beaches and intertidal zones that are easily accessible in Hawai'i, little is known about the snails of the genus Littorina *and* Nerita picea *living on the substrate in these areas. The shells of snails serve as protection against predators in the intertidal area and have varying sizes and shapes. This research examined whether the size of snail shells are connected to the location of a snail in the intertidal zone, and whether snails that experience stronger wave action have different shell types. With a sample of these snails found on a rocky substrate, the distance between the base of a cliff and the observed location of the snails was measured in relation to the size of the snail shell. After conducting a correlation test and checking the statistical significance of the data, no significant relationship was observed between the two variables. In addition, there was little variance observed in the sizes of the snail shells measured. The findings suggest that shell size does not change in respect to where snails live in the intertidal zone. Further research could be conducted with an increased sample size and measuring other variables such as the snail shell thickness or height to observe if other relationships are present between the size of snail shells and their habitat.*

Introduction

The intertidal zones of Hawai'i are home to many organisms that must be able to survive ever-changing conditions of the environment, from waves to sunlight exposure. These constant changes have resulted in adaptations in the organisms that live in this environment. Some of these organisms include the snails that live on the rocky substrate of tidal pools, specifically those in the genus *Littorina* and *Nerita picea*. Over time, stress from the highly variable intertidal habitat influenced the evolution of the organisms that inhabit the area, such as the periwinkles or *Littorina*. The gene pool of these organisms is limited due to recruitment from a similar pool and little larval dispersal, which suggests that evolution occurred simultaneously, resulting in similar adaptations in differing habitats (Johannesson 2003). There is little species variation for the organisms that live in the rocky shore due to constant temporal changes to the habitat. This results in predators being the main regulator of the population size of other species. In addition, there are many harsh environmental elements present that create an unforgiving habitat such as varying temperatures, wave action, and differences in substrate (Johannesson 2003).

Cassandra Liong is a first-year Marine Biology student from Southern California. She hopes to be able to complete her undergraduate degree with a minor in Earth Science and has completed this research paper for her BIOL 265L Ecology & Evolutionary Biology Lab. Through this project, Cassandra has found her interest in marine invertebrates and will be working with the Bishop Museum in the summer of 2023 to continue researching the topic. In the future, she hopes to be able to study coral reef ecology as well as do research on bioluminescent organisms. She hopes that people will be able to have a better understanding and appreciation of marine biology and species endemic to Hawai'i after reading her paper.

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The species *Littorina littorea* (periwinkle) is native to Europe and was introduced to Hawai'i, seen on the West Coast as early as 1937 (Smithsonian 2023). A similar snail in appearance is the *Echinolittorina hawaiiensis* which is endemic to Hawai'i, in addition to the *Nerita picea* (Black Nerite). *L. littorea* (periwinkle) was likely introduced through the transportation of aquaculture, food, or bait (Brawley 2009). The periwinkle lives in the mid- to low-intertidal and mostly consumes algae and seaweed. This species is prey to crabs and can host parasites. Figure 1 below shows an image of the *L. littorea* periwinkle. The Black Nerite is found in the high intertidal, generally in groups around the *L. littorea* (Gutierrez 2000). This snail also eats algae and is prey to crabs and fish. An image of the Black Nerite can be found below in Figure 2. *L. littorea* is considered an invasive species, competing with other native snail species. The Black Nerite can serve as a vector of animal disease (Brawley 2009). Species of *Nerita* appear in the fossil record with shell shapes similar to shells of current day *Nerita* species. These shell shapes were found in as early as the middle Oligocene and had variants in the late Paleocene in areas of the lower intertidal region (Frey 2010).

Shells of the genus *Littorina* are used by hermit crabs for protection as well as by hydroids that form colonies on the shells (MacKay 1945). The *Littorina* genus is known to have the most variation in shell shape, which may be due to features

Figure 1. *Littorina littorea*/periwinkle found on substrate.

Figure 2. *Nerita picea*/Black Nerite found on substrate.

in the environment (Struhsaker 1968). Despite having varied exposure to waves, shell size and shapes were observed to be similar in different areas. Differences were found between species that had planktonic larvae versus direct development for *Littorina* (Johannesson 2003). Shells are designed to prevent predation but also to combat aggressive conditions brought by the tide, resulting in snails with thin, short, and smaller shells. Changes to shells can happen over relatively short periods of time because of selective pressure, such as predation resulting in thicker and shorter shells. (Johannesson 2003). Shell morphology in *Nerita* is thought to have played a role in the distribution of snails to prevent them from drying out and help them retain moisture (Frey 2010).

There are multiple instances of archaeological data being collected by dating the carbon from marine shells, particularly gastropods. However, there is a lot of variation within the shells found in Hawai'i, posing a significant problem when it comes to dating the shells (Dye 1994). In a study conducted in California through San Diego State University, variations in shell size and shape were observed. This study looked at the location of the snail and how wave exposure would affect two various species of *Littorina.* In areas of increased wave action, species were found to have smaller shell sizes in addition to shorter height (Rugh 1997). Another study conducted in California focused on the range of species of *Littorina,* with temperature being a primary factor. This focused on the niches and interactions between species within the habitats and factors that prevent the species from spreading apart (Yamada 1977). However, several species in Hawai'i have not been observed to be in competition with one another.

In this study, the length of snail shells was observed in relation to the distance between the location of a snail and the base of a cliff. The purpose of this study was to identify whether there was a relationship between these two variables. This information was used to find if shell size increases or decreases with increasing exposure to waves. The base of the cliff was used to create a standard for which to compare the distances of the snails, with snails further from the base of the cliff being more exposed to wave action. Understanding the relationship between shell size and how much the snails are affected by wave action may reveal an ideal snail shell size or if tidal action is a more important element affecting snail size compared to predation or other factors. In addition, gaining more knowledge on what factors affect the size of snail shells can help with the dating of marine shells and better understanding gastropods that lived in intertidal habitats. This study provides more information on snail species in Hawai'i.

Materials and Methods

This study was conducted in a rocky intertidal zone approximately 34 meters east from the end of Beach Road, located south of Diamond Head Road and west of the Diamond Head

Figure 3. View of substrate from Beach Road facing east.

Figure 4. Observer recording distance from cliff base to location of snail on substrate. A helper held the end of the tape measure while the observer walked away from the cliff base

Lighthouse on Oʻahu, Hawaiʻi, shown in Figure 3 below. The beach is accessible through Beach Road and the intertidal area substrate, consisting of sedimentary rock, is about 4.65 meters away from the cliff area north of the beach. The temperature during the time of the study was about 79 degrees Fahrenheit with some cloud cover. There was intermittent wind, and the tide was relatively high and increasing, covering the lower areas of the substrate closer to the road, and splashing areas of the substrate where data was collected. There was little vegetation in this intertidal zone, with mostly rock and some areas with algae.

Materials used for this study included a transect line, a tape measure, and a ruler that were able to read to a tenth of a centimeter. The end of the tape measure was held by one person perpendicularly as close to the base of the cliff as possible to ensure a standard starting point for all measurements. The observer walked a straight line with the measuring tape, perpendicular to the ocean, until they were able to observe a snail, which can be seen in Figure 4 below. From this point, the observer recorded the distance from the cliff base to the location where the snail was observed to the nearest tenth of a centimeter and measured the length of the snail shell to the nearest tenth of a centimeter. This process was continued until all the snails visible on the substrate were measured and as far as was safe to do so. Data was not recorded in areas where the tide was unsafe. These measurements were taken about one meter from the easternmost edge of the rocky substrate seen below in Figure 5.

Photographs were taken of the distance from the base of the cliff to the snails measured with the measuring tape, as well as the snail shell size in case there were any discrepancies in the data in addition to avoiding duplicate data. Data was collected and recorded into an excel sheet with the distance from the cliff base to the snail listed in meters in one column and the snail size

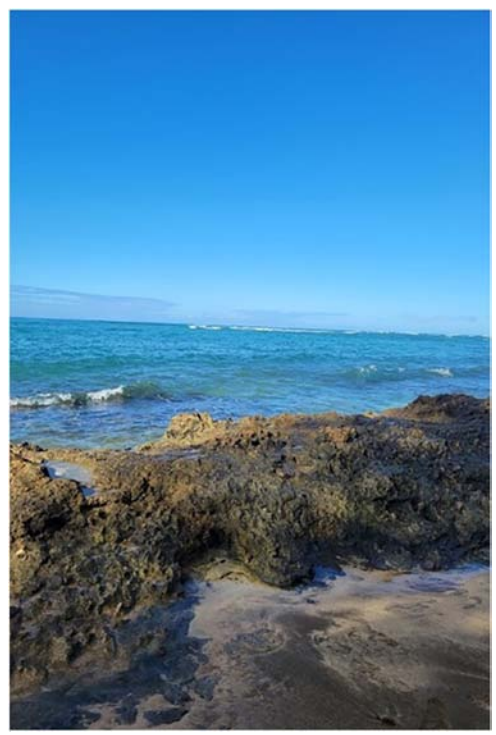

Figure 5. Eastern edge of the substrate (left), image taken from cliff base.

measurement in centimeters in another column. The species of snail was recorded as well as any other significant variations in the snail shells, such as visible cracks. A scatter plot of the points was then created to analyze the data to check for a relationship and statistical significance. A linear correlation analysis was run to test for correlation between the two variables and the strength of this association. In addition, the p value was calculated to check the statistical significance of the data collected. A box and whisker plot was developed to better grasp and analyze the distribution of the sizes of the snail shells within the data.

Results

In total, 50 snails of the genus *Littorina* and *N. picea* were observed, with data collected of the snail's distance from the cliff base in meters and the size of the snail shell in centimeters. Seven of the snails observed were *N. picea* and the other 43 were of the genus *Littorina*. The snails were found on a rocky substrate, oftentimes in groups close together, with one of these groups having seven *Littorina* snails in a cluster. The *N. picea* snails were typically observed alone or in a location near other *Littorina* snails. Many of the snails observed did not move during sampling. Two of the *Littorina* snail shells observed were cracked.

When placed into a linear regression, the R-value of the distance from the cliff base in meters versus size of the snail shell in centimeters was revealed to be 0.252, denoting a slight positive correlation between the distance and size variables. After running a linear correlation analysis, the p value was found to be 0.078. This p value is greater than 0.05, meaning that it can be concluded that there is no statistically significant relationship between the distance of the snail from the cliff base and the size of the snail shell. A plot of the points can be seen below in Figure 6, along with the line of regression running through the data points.

The median snail shell size was found to be 0.93 centimeters with a minimum at 0.32 centimeters and maximum at 1.51 centimeters. The first quartile of data lies between 0.32 and 0.7475 centimeters, the second quartile between 0.7475 to 0.93 centimeters, the third between 0.93 to 1.08 centimeters, and the fourth between 1.08 to 1.51 centimeters. Much of the data is found in the first and fourth quartile. There are no outliers to this data and the data is relatively evenly distributed, with no apparent tendencies to the left or right and even sections within the box and whisker plot. This data has been formatted into a box and whisker plot in Figure 7, with the maximum of 1.51 centimeters on the top.

Discussion

With a p value of 0.078, the data was found to be statistically insignificant, thus rendering our null hypothesis void. Therefore, there is no relationship between the distance from a snail

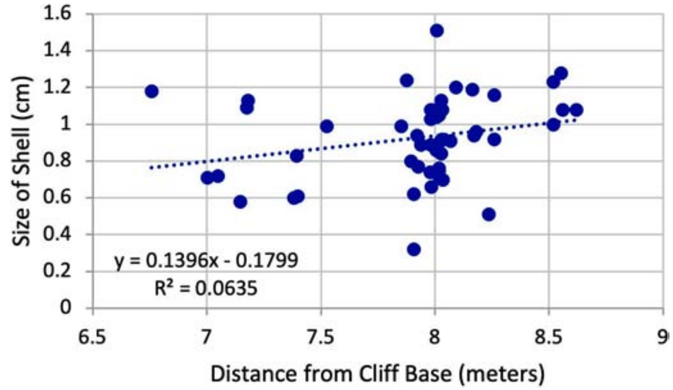

Figure 6. Scatter plot of distance from cliff base in meters versus size of shell in centimeters.

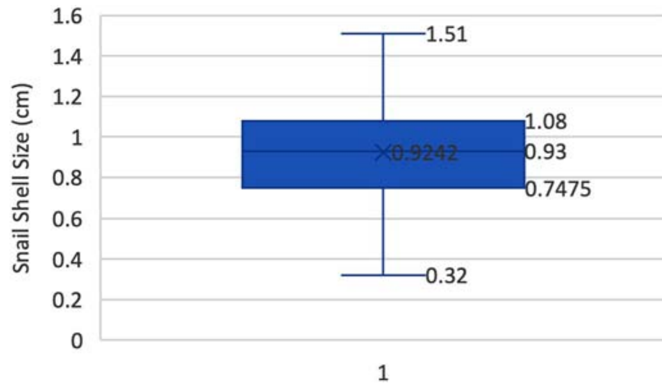

Figure 7. Box and whisker plot of snail shell sizes.

to the cliff base and the size of snail shells. In a previous study done in California, shells were found to be smaller and taller in areas of increased wave action for species of *Littorina* (Rugh 1997). In comparison, the study on mostly *Littorina* snails in Hawai'i did not reveal similar results and there appears to be no apparent correlation between snail shell size and wave activity. It is difficult to determine whether the snail shell size is considered small as there was very little variation among the snail shells measured and there were no previous measurements of snail shells in the area to compare to. However, with much of the data located in the first and fourth quartile, much of the snail shell sizes were in the upper and lower extremes observed. With increased distance from the cliff base, there is more exposure to wave activity, and if there were to be an observed relationship, the size of snail shells would have increased or decreased.

Possible errors may include those in data collection as the snails were measured along a single transect in one location and snails in a different area of the substrate may have exhibited a different relationship from the snails observed in this location. The location being only a meter away from the easternmost edge of the substrate may have affected the types of snails living in that location. In addition, the snails present during that time may not be in that location during a different time of day or under different weather or tide conditions, indicating that there may be different effects temporally. Other errors include that data collection may have been inaccurate or nonrandomized if snails were not observed directly on the transect and discrepancies associated with the measurements changing over time. The snails were observed where it was safe to do so, so other snails located further away from the cliff base where the tide covered the substrate were not included in the study, which may have resulted in different outcomes.

Future studies could include observing the snails over an increased range over a substrate to obtain more randomized data. If there are multiple species, they could be examined separately to see if there is an observed relationship in certain species for snail shell size versus wave action. In addition, the study could be conducted during different times of day to observe the snails during low tide or under variable sun exposure. It is possible that the temperature and weather may affect the location of the snails and if the snails are present in groupings to better retain moisture and avoid drying out as seen in Frey's research (2010). Observing snails in different locations in Hawai'i may show if there is a possible difference between snails on different areas of the island. Crabs were observed to be also present at the substrate during the time of observation, so there is a possibility that the presence of predators may have influenced the number of snails present during the time of observation. Some snails were observed to have cracked shells as well, which leads to questioning if there was observed predation at that site or if there is an apparent upper limit in the size of snail shells. The study done by Green suggests there is a relationship between snail shell weight and length (1932).

In all, there was no statistically significant relationship observed between the distance from the cliff base in meters and the size of snail shells in centimeters at the intertidal area near Beach Road in Oahu during high tide. Snails observed during this time were of the genus *Littorina* and *N. picea,* often found in groups. Majority of the snails were *Littorina* and two of these snails had cracked shells. The distribution of snail shell sizes observed over a given transect on intertidal substrate was relatively evenly distributed with a range of 0.32 to 1.51 centimeters and the majority of data located in the first and fourth quartile.

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