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Internal Volume/Weight ratio preference of *Coenobita clypeatus* in Discovery Bay, Jamaica

INTRODUCTION

The Caribbean Hermit Crab *Coenobita clypeatus* can be found in abundance on the shores of Discovery Bay, Jamaica. Layering of limestone and Pleistocene reef deposits into terraces create an ideal habitat for *C. clypeatus* (Gayle and Woodley, 1998). Because hermit crabs are largely nocturnal, *C. clypeatus* seeks cool, dark places to hide during the day (Morrison and Spiller, 2006). Many cavities and cracks in the limestone provide shelter for the crabs in addition to their shells. In the western Atlantic, *C. clypeatus* is the only species of true land hermit crab (Morrison and Spiller, 2006).

Anomuran hermit crabs take shelter in gastropod shells because of a lack of calcification abilities to protect their soft abdomen (Hazlett, 1981). The use of a shell or other forms of shelter including sponges, dead coral, bamboo and pebbles act as protection from environmental stressors such as predation and desiccation (Osorno et al., 1998; Masunari, 2008). *Coenobita clypeatus* was shown to inhabit fossils of gastropods when shell availability was extremely low (Walker, 1994). In addition to protection, shells also aid in the reduction of water loss due to evaporation and assists in thermoregulation (Greenaway, 2003). Specialized legs and a symmetrically coiled abdomen help Anomura successfully live inside other species' shells (O'Shea, 2014). Hermit crabs have been found to obtain shells by taking them from other hermit crabs or from a dead gastropod or crab. *Coenobita clypeatus* is attracted to the odor of dead crabs as a mechanism to easily find new shells (Hazlett, 1981). The crabs have also been observed collecting and hiding shells in cases of low vacant shell supply (Greenaway, 2003). However, shell switching is the most popular method of changing shells for *C. clypeatus*.

An inspection process is performed by the crabs before selecting a new shell. Hermit crabs examine empty shells by inserting their chelipeds into the shell opening in addition to using their antenna and legs (North, 2011). Preferences for shell selection differ individually. Other dimensions of the potential shells that are investigated are crowding, volume, and weight (Lewis and Rotjan, 2009). Crabs look for the ideal size for their growth at the time. Smaller crabs target shells that are lighter and large enough to grow into while larger crabs are looking for

lighter shells that don't have to be much larger than their current shell since more energy is devoted to reproduction than growing. Shells that are damaged are more likely to be rejected as the crabs are more susceptible to predation and desiccation.

Hermits that engage in shell switching behavior either approach the event aggressively or as a negotiator. Aggressive behavior is exhibited by piggybacking, where a hermit crab will climb onto another crab to assess and potentially steal their shell by quickly rapping their cheliped on the shell of the target (Elwood, 1995). Larger crabs were found to have a higher rate of rapping which increased their success of forcing the old inhabitant out of a shell (Briffa and Elwood, 2002). The winner will release the defender from its shell and extract it, inserting its own body into the newly empty shell. These interactions are not mutualistic, one party does not benefit from the interaction. Negotiating behavior results in a benefit for both parties, such as a small crab in a large shell switching with a larger crab in a shell too small with both benefit from the switch (O'Shea, 2014). The smaller crab will gain the smaller shell that will use less metabolic energy and aid in growth while the larger crab will gain a larger shell where the metabolic focus will turn to reproduction (Osorno et al., 1998).

Piggybacking is also used to create vacancy chains (Lewis and Rotjan, 2009). A single available shell is won by the most dominant crab. Dominance is achieved by multiple crabs engaging in aggressive cheliped pushing (Osorno et al. 1998). Crabs inhabiting damaged shells were found to be more aggressive than others to prevent predation or desiccation success (Lewis and Rotjan, 2008). Chains are very unstable due to the cheliped pushing. Once the chain is initiated by a single crab transferring to the available shell, the rest of the crabs in the chain rush to change shells to the next most viable shell. The shell left behind is seen to be the least desirable shell (North, 2011). Lewis and Rotjan (2009) concluded that vacancy chains result in an overall decrease in crowding individually in a chain, making vacancy chains beneficial for most parties.

Shells are a cumbersome shelter to hermit crabs and a majority of their metabolic energy is spent on carrying shells. Osorno et al. (1998) notes that a heavier shell will also restrain growth and fitness. Smaller crabs with smaller, lighter shells use less energy to move and can budget more energy toward growth (Osorno et al., 1998). In a case of shell switching, these crabs will have the upper hand with a stronger cheliped to produce faster rapping on a defender. Larger crabs benefit the most with larger, lighter shells that provide enough space for their body. With a

lighter shell, these sexually mature crabs can use more energy toward reproduction and finding a mate (Osorno et al., 1998). Overall, males contribute more energy to growth while females focus more energy on reproduction (Sanvicente-Anorve and Hermoso-Salazar, 2011).

Light shells are often a limited resource because hermit crabs are found to prefer low internal volume to weight ratios (Osorno et al., 1998). This study tests whether the *Coenobita clypeatus* that inhabit Discovery Bay, Jamaica follow this pattern. Through both solo and group trials in lab, shell switching behaviors and aggression towards obtaining lighter shells with more volume are observed to confirm this theory. It can be expected to find that there will be an abundance of crabs choosing lighter shells to prevent excess metabolic use that can be directed towards reproduction or growth.

MATERIALS AND METHODS

STUDY SITE

Hermit crabs were collected on the campus of Discovery Bay Marine Lab. Largest aggregations of *C. clypeatus* were found around the edges of the lab building (lat 18°28'00" N, long 77°24'30" W) in May 2017. *Nerita sp.* were collected on limestone outcrops in the intertidal zone. Lab experiments were performed at the Discovery Bay Marine Laboratory.

CRAB COLLECTION

Shell collection began during the day to have the most ideal identifying conditions. Only *Nerita sp.* shells were collected to avoid shell species preference. Shells were considered viable if they were not broken. Collection area was not considered for the acquisition of these shells. A variety of small to large shells (n=X) were chosen at random and brought back to the lab.

Crab collection began the first day in Jamaica and continued until 100 individuals were collected. *Coenobita clypeatus* (n=100) were placed in a ten gallon aquarium and held for 24 hours before initial measurements were taken. Provided in the tank were rocks, pieces of wood and other natural items from their habitat to reduce stress on the crabs. Additionally, sections of paper towel were provided in two places to keep the crabs hydrated.

PRE-TRIAL MEASUREMENTS

Each crab was given an identifier, a written number on their shell. *Coenobita clypeatus* was then weighed and shell measurements were taken. Manual caliper measurements of widest shell diameter, widest aperture diameter, and maximum height were logged with the crab ID. Cheliped size was also measured to estimate crab size. *Coenobita clypeatus* was placed in an examination container (3" x 5") on a damp paper towel. A ruler was placed diagonally across a corner of the container. The hermits backed into the corner and were photographed against the ruler to determine cheliped size with the least crab stress.

Shells were labeled A – Z then AA – ZZ and so on. Vacant shells are weighed and the same length, width and height measurements as *C. clypeatus* are taken. Internal volume was also measured by filling the shells with water and measuring that volume of water. Each shell was also assigned a weight, either no weight, 25%, 50%, or 75% more weight than the group of four's no weight shell. Poster putty were then attached to the shells to gain each weight interval and stored for trial use. These weight intervals were used to create the least amount of stress for the crabs while still testing their internal volume/weight ratio.

IV/W TRIALS

Solitary Trials

Two situations are tested to examine the IV/W ratio in *C. clypeatus*. The first is a solo trial ($t = 25$) where one hermit crab chosen randomly is presented with the three weight options and a non-weighted option in a trial container (5" x 8"). In this container, the hermits are provided with objects such as rocks, moss, and wood to simulate a natural habitat and reduce stress. Hermit crabs were removed from their shell using a natural behavior. Shells were rapped on by a thimble to encourage muscle relaxation to extract them without mortality. If this action is unsuccessful, then shells will be made unmovable by holding the crab down or surrounding the shell with heavy objects. This option will encourage a voluntary evacuation of the shell. Options of presented shells are chosen in relation to the hermit crabs approximate size and overall weight. Weight options include a weight similar to the original shell, 25%, 50% and 75% more weight

than the original shell. For one hour the crab was observed and any aggressiveness, investigations and switching behaviors including time and number of switches. With every switch that occurred, the label of the new shell was recorded to compare measurements with the old shell and to identify the crab. Original shells that were labeled with numbers were removed at the end of the trial to confirm the weight of the organism and measure the IV/W ratio to compare to the newly inhabited shell. The 25 solo *C. clypeatus* subjects were not also tested in the group trials.

Group Trials

Similar trials ($t = 15$) were run in a group setting. *C. clypeatus* ($n = 5$) were chosen at random with respect to similar cheliped size. Five shell options, three of which having the weight intervals and two having no weight added were presented in a trial container (5" x 8"). Again, containers were simulated to be a natural habitat. Crabs were not removed from their shells for these trials. The group was monitored for an hour, reporting any investigations, piggybacking, aggressive behavior, vacancy chains and shell switches. Any crab with a new shell identity was recorded. If old shells that were numbered remained they were collected for IV/W analysis and paired with the correct new crab identity. Solitary trials and group trials are performed to ensure success of shell switching in some level since isolated crabs tend to take longer to emerge than in group settings (Bartnmess-LeVassear and Freeberg, 2015).

POST TRIAL MEASUREMENTS

IV/W ratios for shells that were originally a shelter for a crab were determined using the water volume method. These shells were also weighed now that they were empty to calculate the weight of the organism. Additionally, crabs with new identities were weighed and the previously recorded shell weight was subtracted as another method of determining the organisms' weight.

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MATERIALS LIST

Analytical Balance (Minimum 0.01g or better)

Manual Caliper

Gastropod shell ID book

Sliding ruler

Aquarium (10 Gallon or more)

Plastic testing containers (11 x 6 x 3in)

Pen/Paper for recording

Poster putty in varying degrees of density

5 gallon bucket (crab collection)

Thimble

Under 2 mL graduated cylinder (Or other liquid measuring tool)