June 2018

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EAP Tropical Biology and Conservation Program,
Spring 2018
8 June 2018

**Abstract**
*Coenobita compressus*, more commonly known as the Ecuadorian hermit crab, can be found across the pacific coast of Costa Rica. If you go to a beach along this coast, you often see these crabs walking around in all directions without clear aim. In my study, I examined the reasons for these crabs' movement, and hypothesized that they were motivated by food, water, shells, and sun avoidance. I offered crabs shells and food and monitored their behavior before and after. If the hermit crabs' movement was motivated by their need to find food or shells, then they would no longer have a reason to move after I provided them with said food or shells, and their movement should slow or stop. I indeed found that this was the case, and that crabs were motivated to move by the desire for shells and food. I also noted the crabs' sun avoidance behaviors during this time. I then put crabs in water and recorded the time it took for them to leave it. I found that crabs hid from the sun by resting under rocks, and that they consistently tried to quickly escape the water. Therefore hermit crabs are also motivated to move by the desire to avoid water and the sun. Tests involving multiple food items revealed that some crabs switch between foods while others stay at one food, and that crabs have food preferences. Different foraging strategies and food preferences may also influence how a crab moves in regards to finding food.

## Razones por los movimientos de cangrejos ermitaños, *Coenobita compressus*

**Abstracto**
*Coenobita compressus*, más comúnmente conocida como el cangrejo ermitaño ecuatoriano, se puede encontrar a través de la costa pacífica de Costa Rica. Si uno va a una playa a lo largo de esta costa, a menudo va a ver estos cangrejos caminando en todas direcciones . En mi estudio, examiné las razones del movimiento de estos cangrejos y formulé la hipótesis de que estaban motivados por la comida, el agua, las conchas y la . Ofrecí conchas y comida a los cangrejos y grabé sus comportamientos antes y después. Si el movimiento de los cangrejos ermitaños estaba motivado por su necesidad de encontrar comida o conchas, entonces ya no tendrían una razón para moverse después de que les haya dado dichos alimentos o conchas, y su movimiento debería disminuir o detenerse. De hecho, descubrí que este era el caso y que los cangrejos estaban motivados para moverse por su necesidad de obtener conchas y comida. También noté los comportamientos de evitación de rayos solares de los cangrejos durante este tiempo. Luego puse los cangrejos en el agua y medí el tiempo que tardaron en dejarlo. Descubrí que los cangrejos se escondían del sol descansando debajo de las rocas y que constantemente trataban de escapar rápidamente del agua. Por lo tanto, los cangrejos ermitaños también están motivados para moverse por el deseo de evitar el agua y el sol.

Las pruebas que incluyeron varios alimentos revelaron que algunos cangrejos cambian de alimento mientras que otros se limitan a un alimento y que los cangrejos tienen preferencias alimenticias. Las diferentes estrategias de alimentación y las preferencias alimentarias también pueden influir en los patrones de como los cangrejos se desplazan en busca de comida.

**Introduction**

Most animals on the planet utilize their ability to move. By studying animal behavior, we can understand the reasons for their movement. For example, a lion crouched down moving through the grass we know is stalking its prey. We are also able to recognize a male monkey moving through trees following a female as mate guarding. However if you go to a beach on the pacific coast of Costa Rica, you will likely encounter hermit crabs, *Coenobita compressus,* moving around in all different directions. Unlike the other animals, it would not immediately be clear to you what the hermit crabs were doing. The most common behavior to see in the hermit crabs is just walking, however the goal or destination of the hermit crabs during this behavior is not self evident.

Hermit crabs are small compared to their habitat. Because of this, it is unlikely that necessities like food or shells would wash up to their exact location on the beach. Hermit crabs must continuously walk around and explore the vastness of their habitat to increase the likelihood that they will encounter the things they need.

The hermit crabs in this study, Coenobita *compressus,* are land dwelling hermit crabs that need water during mating, and to keep their gills moist (Gross, 1960). Like all other hermit crabs, shells are also a necessity for them. *Coenobita compressus* are different than the hermit crabs that live in the tidal pools and shallow ocean nearby, however they do compete somewhat for shells. Hermit crabs wear gastropod shells over their bodies for protection. Shells can be taken from dead gastropods that wash up on shore, or taken from other hermit crabs. Hermit crabs molt, and every time they do so they will require a bigger shell. Another necessity is food. Hermit crabs are omnivores and eat a variety of different foods. During my time with the hermit crabs I witnessed them eating fruit, seeds, sap, wood, leaf litter, cow bones, and fish.

Even though it appears that the hermit crabs are walking around with no goal, in actuality they must be motivated to move by something during this time. Because hermit crabs must move around to find the things they need, for the purpose of this study we can assume that hermit crabs actually do have reason in mind when walking around, and that this reason likely is to encounter these necessities. Moreover, once the hermit crabs receive what they need, their movement should slow or stop since their reason for movement was fulfilled. These assumptions allowed me to test and uncover the reason for the hermit crabs' unclear walking behavior, and answer the question: Why do hermit crabs move?

**Methods**

I spent approximately 23 hours on the beach of Islita in Cuajiniquil observing and experimenting with the hermit crabs. I was mainly there before high tide, or at the beginning of high tide during the morning and early afternoon. I conducted a series of

experiments that included food, shells, water, and sunlight, to test if these were reasons for movement within the hermit crabs.

**Experiment A/B: Shell/ food tests**

I observed the hermit crabs for 5 minutes and marked their position at each minute with small flags. While observing I noted the times the hermit crabs were walking and staying still. I also noted the hermit crabs' sun evasion behaviors such as hiding under rocks. After 5 minutes I introduced either food or shells to the crab. I did this by placing the food or shells about 30cm away from the hermit crab in the direction it was moving. I tried not to startle the hermit crabs by staying out of their line of sight; I remained angled behind the hermit crabs or behind rocks when placing the food and shells. If the crab decided to eat or switch shells I observed them for another 5 minutes. Afterwards I measured the distance between each flag to obtain the distance traveled.

**Experiment C: Left out food/ shell tests**

Experiment C was done to gauge the number of hermit crabs that were walking around looking for food or shells at a given time. I set out food and shells twice a day for 3 days for a total of 6 trials. The food and shells were placed separately in each trial. These trials were done in both rocky areas and areas near leaf litter. In each trial I recorded the number of hermit crabs that ate the food or touched the shells, and the number that passed by and ignored the food and shells over a span of 10 minutes. Ignoring in this case is passing within 15cm and not visiting the food or shells. 15cm was chosen because it is approximately the distance at which hermit crabs are known to be able to smell food (Burggren, 2009).

**Experiment D: Multiple food items test**

I placed different food items near each other and counted the number of hermit crabs at each food item every 2 minutes for 20 minutes. I counted the number of hermit crabs that moved between food items, the number that returned to the same food item, and the number that passed by but ignored the food items. The food items included mango, rotting banana, chicken, and in one test a mangrove seed. Mango, rotting banana, and chicken were chosen because hermit crabs have been shown to detect the smell of these foods (Burggren,2009). The mangrove seed happened to within the area I had placed the food during one trial, so I decided to include it in the study however I was unable to identify its species.

**Experiment E: Water tests**

I set out salt water in broken coconuts and bowl shaped shells. I observed each water bowl for 10 minutes and recorded the number of hermit crabs that visited the water and the number that ignored it. I also placed 10 hermit crabs inside the water and recorded how long it took them to exit the pool

## Results

### Experiment A: Shell tests

Of 20 individuals ,7 (35%) ignored the shells, 10 (50%)touched the shells, and three (15%) moved into shells. The three that moved into shells were observed for an additional 5 minutes. The distance traveled by each crab divided by the number of seconds each spent walking is taken as the speed of each crab. The speed before and after taking the shell can be seen in table 1. Two crabs decreased in speed after taking the shell, while one increased in speed.

**Table 1**
**The speed of an individual crab before and after adorning new shell**

| Crab | Speed before taking shell (cm/s) | Speed after taking shell (cm/s) |
|---|---|---|
| 1 | 1.5 | .67 |
| 2 | .44 | .04 |
| 3 | .72 | 1.1 |

### Experiment B: Food tests

Of 20 individuals 16 ate the banana. One individual ate three different food items at three different times during the observation, changing speeds between each food item. This created skewed speeds and therefore this individual was not included in the data. The speed of each hermit crab was again compared before and after eating. This can be seen in figure 1. The graph shows that the hermit crabs moved more slowly after eating. The orange line has a slope of 1, and represents what the distribution would look like if hermit crabs maintained a constant speed after eating. However 12 out of 15 (80%) of the individuals are under this line. Therefore the hermit crabs had faster speeds before eating. The black line is the trend line, which also lies under the orange line.

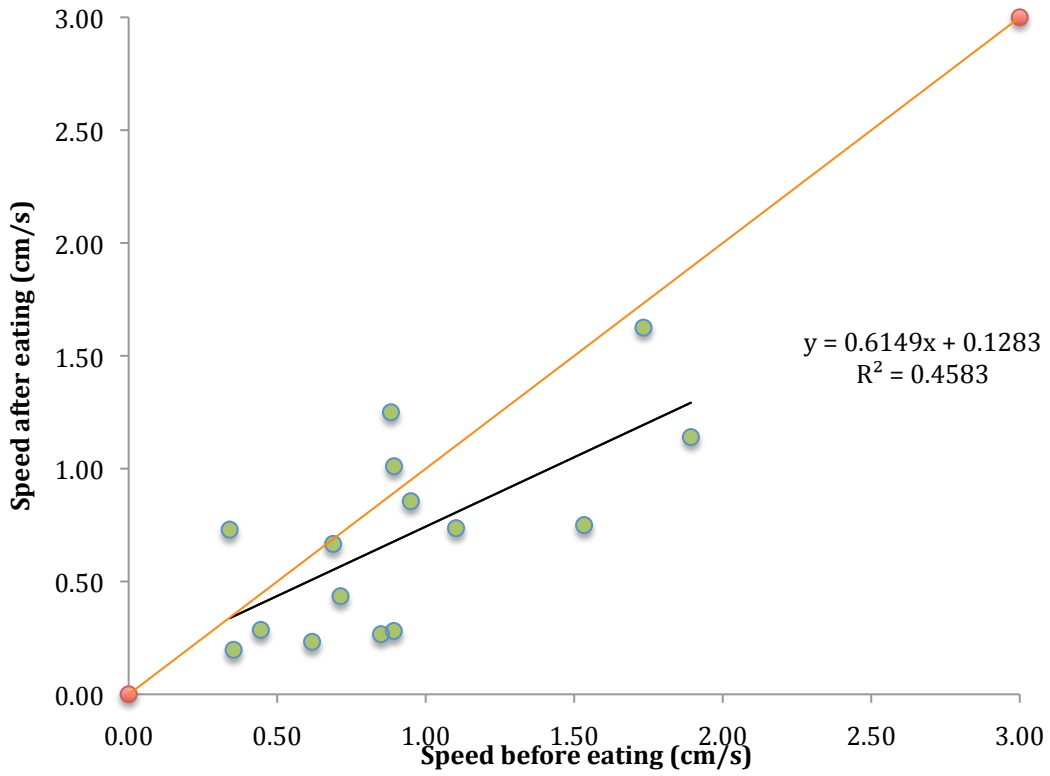



**Figure 1**
The speed of 15 individual crabs before eating and after eating. Black line represents the trend line of the data. The orange line represents a line with a slope of 1.

**Experiment A/B: Sun avoidance behavior**

Of 40 individuals in the food and shell tests, 34 crabs (85%) exhibited sun avoidance behavior, which included sitting under a rock or leaf or being in the shade when coming to a rest. This means that rather than stopping to rest in open exposed areas, they stopped in areas where they were protected from the sun. Of the hermit crabs that exhibited sun avoidance behavior, they did so an average of 86% of the time, with 14 individuals resting under a rock/ leaf/ shaded area during 100% of the time they rested. This data was taken during the food and shells tests, when weather was sunny with some clouds that brought shade for spans of a few minutes at a time.

**Experiment C: Left out food and shells**

In two trials, more crabs ignored the food than ate it. In three trials more crabs ate the food than ignored it, and in one trial the categories were equal. In half of the shell trials, more crabs ignored the shells than touched them. In two trials more crabs touched the shells, and in one trial, no crabs touched or ignored the shells. In all but one trial, there was a consistently higher number of crabs that both ignored and interacted with the banana than with the shells. This can be seen from Table 2.

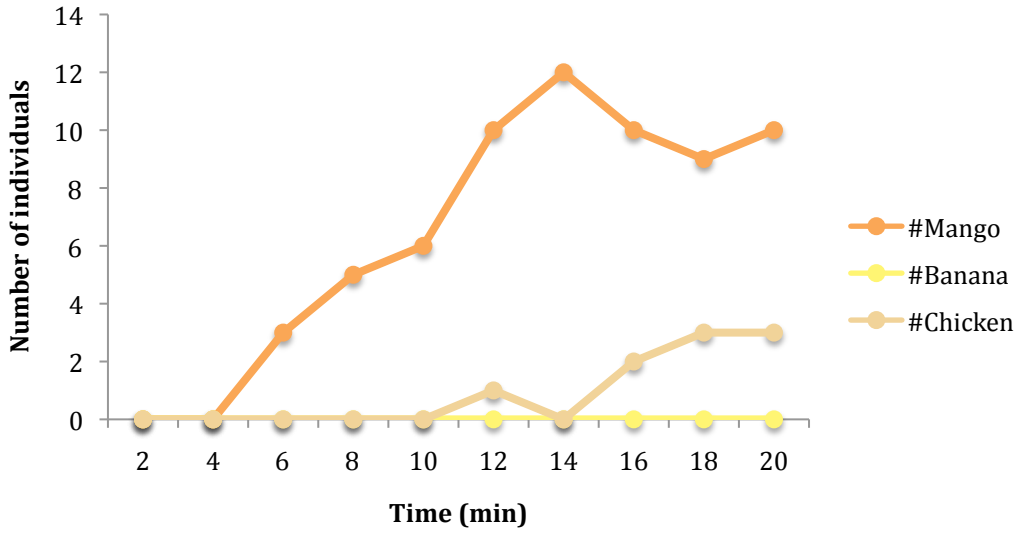
**Table 2**
**The number of crabs that interacted with/ ignored provided food and shells**

| Trial | Ate food | | Ignored food | Touched shell | | Ignored shell |
|---|---|---|---|---|---|---|
| 1 | 6 | < | 15 | 0 | < | 3 |
| 2 | 2 | < | 10 | 1 | < | 2 |
| 3 | 7 | > | 1 | 0 | < | 2 |
| 4 | 9 | > | 3 | 3 | > | 2 |
| 5 | 7 | > | 1 | 0 | = | 0 |
| 6 | 1 | = | 1 | 3 | > | 1 |

**Experiment D: Multiple food items test**

In trial one, the mango was the most popular food item (figure 2). The banana was not eaten at all, and the chicken was eaten sparingly across the 20 minute span of observation. There were three instances where hermit crabs switched between food items, moving from chicken to mango. There were 5 hermit crabs that only ate mango, and returned to the mango after finishing eating it earlier in the trial. There were 6 hermit crabs that moved by the food items but did not eat anything. In the second trial chicken was more popular than mango. Banana was still the least eaten food item. The mangrove seed received slightly less visitors than the mango. In this trial 8 hermit crabs switched between foods. 7 hermit crabs returned to the food item they had finished eating, and 3 hermit crabs ignored the food items.

Trial 1:



Trial 2:

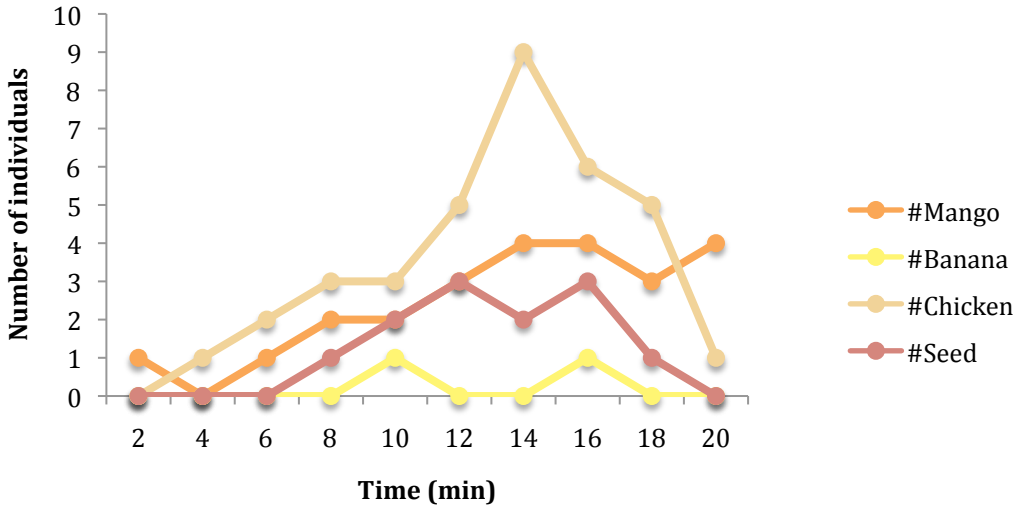



**Figure 2**
The number of crabs eating each food item at 2 minute intervals for 20 minutes.

**Experiment E: Water tests**

In Table 3 it can be seen that in all 6 trials only one hermit crab came to the water. In every trial, however there were multiple crabs that passed by the water but did not approach it. In Table 4, the fastest time taken by a crab to leave the water was 4 seconds, and the slowest time was 7 seconds.

**Table 3**
**Number of crabs that visited the water and ignored the water**

| Trial | Came to water | Ignored water |
|---|---|---|
| 1 | 0 | 5 |
| 2 | 0 | 3 |
| 3 | 1 | 9 |
| 4 | 0 | 5 |
| 5 | 0 | 4 |
| 6 | 0 | 4 |

**Table 4**
**Seconds taken for a crab to leave the water**

| Crab | Time taken to leave water (s) |
|---|---|
| 1 | 5 |
| 2 | 6 |
| 3 | 4 |
| 4 | 4 |
| 5 | 6 |
| 6 | 7 |
| 7 | 5 |
| 8 | 5 |
| 9 | 4 |
| 10 | 6 |

**Discussion**

In the shell tests, hermit crabs were found to be interested in shells 65% of the time. However, I observed one hermit crab that ignored the provided shell attack another hermit crab for its shell. This suggests that hermit crabs not interested in the provided shells could still be interested in other shells, or that that the presence of desire for shells fluctuates within an individual.

Out of the three hermit crabs that took the shells, one moved faster afterwards. However, this data point is somewhat misleading as the hermit crab was only walking for 24 seconds out of the 5 minutes. In this time it moved 27cm, compared to the 150cm it walked in 208 seconds before taking the shell. Considering this data, it can be concluded that this hermit crab also had a decrease in activity despite its speed increasing.

In the food tests the crabs ate the food 80% of the time. They also tended to decrease their speed after eating. This decrease in speed suggests that their reason for movement has been lessened or fulfilled by the food.

The decrease in speed after encountering food and shells in experiments A and B means that searching for food and shells is a reason for movement in the hermit crabs quite often, food more so than shells. Looking at hermit crab biology, this makes sense. Depending on their size, hermit crabs can molt between 1 and 4 times a year (Burggren, 2009). They often search for shells before they are about to molt, and will even look for smaller shells during this time because initially their body masses will shrink (Fotheringham, 2003). Afterwards as their bodies become bigger, hermit crabs must find bigger shells. This means that hermit crabs are looking for shells at multiple times during the year, making their search pretty common, which is reflected in the data. However hermit crabs must eat at least more commonly than a few times a year, which is why a higher number of hermit crabs ate the food than felt or moved into shells.

In experiment C, the food was visited more than the shells despite the tests being done at the same time. This may be due to the fact that crabs can smell the food and locate it by smell if they desire it. Hermit crabs looking for shells must identify them

amongst the crushed shells and rocks, making the task difficult. In some trials many hermit crabs passed up the food and in others the food was eaten more than it was ignored. Food preference, which is examined more in experiment D, may play a role in if a hermit crab decides to stop and eat or not.

In experiment D the hermit crabs were given multiple food choices. The banana, which I had used during all of the food tests, turned out to be their least favorite food. The hermit crabs preferred mango and chicken. Many hermit crabs were seen staying at a single food item and even returning to it after walking away. There were a few hermit crabs however, which were exploratory and moved between food items. One hermit crab left the mango to go circle around the banana but ended up moving back to eat the mango. Another hermit crab in the second trial moved between and ate all four food items. This suggests that hermit crabs have different preferences for food and possibly even different foraging strategies. Based on the data, some hermit crabs prefer to stick with one food that they find, and others will move on from a food item to find an inspect another. These individual differences in strategies dictate how often a hermit crab will move to find food. Therefore, another reason for a hermit crabs' movement is to fulfill their food preferences or act out their preferred foraging strategy.

Hermit crabs that have more exploratory foraging strategies and find new food items can help other hermit crabs find the food items. Hermit crabs have been known to be attracted to aggregations (Laidre, 2010). The presence of one hermit crab at a food item lets other hermit crabs know that there is something worth eating. Food items that are checked out by more exploratory individuals can eventually lead to the formation of groups, which then attract more individuals. Attraction to aggregations may have been a factor influencing what food items the hermit crabs decided to eat, however I did not examine this in my study.

The water experiments show that the hermit crabs don't like to be in the water, and are not attracted to it despite needing to keep their gills wet. Almost every hermit crab ignored the salt water I set out. Every hermit crab also quickly left the water after being dropped into it. This quick avoidance movement suggests that unless they need water for their gills or for mating, the hermit crabs will avoid pools of water. This makes sense as crabs can drown if they are in the water too long (Cameron, 2005). So water is a reason for movement, but more often for its avoidance.

The water tests also suggest that a reason for a hermit crab's movement can be to be in its preferred habitat type. If they are plopped into an aquatic environment they will move to find a more habitable space. Everyday as the tide rose on the beach, hermit crabs moved from rocks lower on the beach to rocks higher up. I also observed hermit crabs moving to the leaf litter. Crabs are known to inhabit many different areas such as the intertidal, sandy beaches, and inland regions with vegetation (Burggren, 2009), so this desire to be in a certain habitat can possibly drive their movement as well.

Similarly, avoidance of sunlight was revealed to be another reason for movement. The high percent of individuals (85%) that showed the behaviors, and how frequently they did so (86% of the time), suggests that this sun avoidance behavior is common, and could often be a reason for movement when a hermit crab is out and exposed the sun. Hermit crabs must expose themselves to the sun as they walk from place to place. However, if they are exposed even when resting, which can span for hours, their shell may become too hot. Sun avoidance behavior may have developed to prevent this

overheating of the shells, as to not damage the fragile body. During my observations, I noticed that most crabs that were not in the open where I was searching for them. They were hidden under rocks or leaf litter. They were difficult to find as they are able to burrow themselves in the sand under the rocks. Resting under rocks as they travel could be an extension of this hiding and burrowing behavior.

Overall the desire for food and shells, more commonly food, as well as the desire to find preferred food are all reasons for hermit crab movement. The different foraging strategies hermit crabs have influence hermit crab movement in regards to searching for food, as more exploratory foragers will move more. Avoidance of water and sunlight can also be considered reasons for movement in hermit crabs.

**Acknowledgments**

I would like to thank my host family for taking care of me during the time of my research, as well as the other students that resided with me in Cuajiniquil. I'd also like to thank the people that assisted me with my research, Minito, Steven, and Megan. Thank you to my advisors, Frank and Andres, as well as my peer reviewer Calla for giving me advice and guidance during my project.

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