FLOWER MORPHOLOGY AND HERBIVORY PALATABILITY OF THE EXOTIC *HIBISCUS ROSA-SINESIS* AND THE NATIVE *HIBISCUS TILIACEUS* ON AN ELEVATION GRADIENT IN MO'OREA, FRENCH POLYNESIA

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Abstract. Certain plants are known to grown along a gradient of environmental conditions. *H. tiliaceus,* a native hibiscus species in Mo'orea, and *H. rosa-sinesis*, an exotic species, are such plants, both growing from the coast up to mountainous elevations. The differences in morphology and herbivory palatability were examined in this study, using the brown land crab *C. carnifex* as the model organism. Morphological trends were examined by measuring hibiscus dimensions in coastal and mountainous hibiscus. A hierarchy of hibiscus palatability was established between both species of hibiscus and their leaves to reveal trends in palatability. In addition, a hibiscus origin preference test was conducted with coastal and mountainous hibiscus to study environmental influences on herbivory palatability. Results showed that mountainous hibiscus had larger dimensions than coastal hibiscus, a hierarchy of hibiscus palatability did exist with flowers being preferred over leaves, and mountainous hibiscus was preferred over coastal hibiscus in *C. carnifex.* These results suggest environmental stressors influencing hibiscus growth on a gradient, and nutrient or chemical composition of hibiscus influencing herbivory palatability.

Key words: Hibiscus tiliaceus; Hibiscus rosa-sinesis; *Plant morphology;* Cardisoma carnifex; *Herbivory; Food preference; Elevation gradient; Mo'orea; French Polynesia*

INTRODUCTION

While some plants can only survive under specific environmental conditions, there are some plants that can survive along a gradient of environmental conditions (Bohnert, Nelson, and Jenson 1995**)**. The various environmental conditions that plants are subject to when grown along a gradient can play a role in influencing the properties of the plant. Specifically, elevation gradients have been known to affect plant morphology and herbivory palatability (Bell 2006).

Studies on plant morphology have shown that plant leaf size and flower size tends to decrease with elevation (Morecroft 1992, Herrera 2005). One study conducted in the Montane Rain Forest in Southern Mexico showed that leaf area significantly decreased with increasing elevation (Velázquez-Rosas 2002). Another study conducted in China showed that bamboo leaf size decreased significantly with increased elevation (Guo 2018). This trend is due to higher altitudes having increased environmental stressors, such as lower temperatures and higher solar radiation (Morecroft 1992).

Other studies have also shown that plants at higher elevations tend to have higher nutrient contents. A study in the alpine region of Europe showed leaf nitrogen levels in 150 plant species were shown to increase with increased elevations (Korner 1989). Another study conducted on the alpine lady's mantle plant showed that both nitrogen and phosphorous levels in leaves of the plant increased with increasing altitude (Morecroft 1992). Nitrogen is an essential element to herbivores because they need nitrogen to produce amino acids, proteins, and DNA (Matson Jr. 1980). Likewise, phosphorous is also an essential element to herbivores because it is needed for ATP to drive cellular function (Cease 2016).

Herbivores such as crabs have chemoreceptors that aid them in identifying the most nutrient rich food to consume (Wolcott 1992). In Mo'orea, the French Polynesia, it was observed that the brown terrestrial crab *Cardisoma carnifex* often formed clusters of burrows under coastal vegetation, notably under the hibiscus trees (personal observation). *C. carnifex* is an herbivore known to eat many plants, but particularly hibiscus (Hartnoll 1988). Thus, *C. carnifex* was chosen to conduct an herbivory palatability test in coastal versus mountainous *H. tiliaceus and H. rosa-sinesis.* In addition, the hierarchy of food preference in native versus exotic hibiscus was established.

Since patterns of herbivory and morphology tend to differ in native versus exotic plants (Morrison 2011), two members of the Malvaceae family, *Hibiscus tiliaceus* and *Hibiscus rosa-sinesis,* were selected to make a comparison. These two species of hibiscus grow from the edge of the coast all the way to 800m mountain elevations on the island of Mo'orea, French Polynesia (Petard 1986). *H. tiliaceus,* characterized by heart shaped leaves and yellow flowers with a burgundy center, are native to Mo'orea (Elevitch and Thomson 2004). On the other hand, *H. rosa-sinesis,* characterized by almond shaped leaves with spikey edges and flower colors ranging from pink, red, orange, and white, are exotic to Mo'orea (Florence 2004).

In this paper, I compare differences in flower morphology, leaf morphology, and herbivory palatability of *Hibiscus tiliaceus* and *Hibiscus rosa-sinesis* in *C. carnifex* along an elevation gradient. Specifically, I address the following questions: 1) What morphological differences exist between coastal and mountainous *H. tiliaceus* and *H. rosa-sinesis*? 2) What is the hierarchy of hibiscus palatability in native vs. exotic hibiscus in the brown land crab, *Cardisoma carnifex?* 3) Do coastal and mountain influences affect hibiscus palatability of *C. carnifex?*

I hypothesize that in both species of hibiscus, leaves and flowers would be smaller at higher elevation due to increased environmental stressors. I also hypothesize that *C. carnifex* will prefer exotic *H. rosa-sinesis* over the native *H. tiliaceus* based on past literature (Morrison 2011), and mountainous hibiscus will be preferred over coastal hibiscus due to increased nutrient content at higher elevations.

METHODS

Study site

This study was conducted on the island of Mo'orea in French Polynesia (GPS location: -17.541482, -149.827843). Four study sites were used for this study: two coastal, low elevation sites and two mountainous, high elevation sites. Coastal, low elevation sites included the coast along the UC Gump Research Station (-17.490502, -149.826348) and Piha'ena Beach (-17.485497, -149.831304). Mountainous, high elevation sites included the Agricultural School, Lycée Agricole Opunohu (-17.532948, -149.834226), and Belvedere watch point and hiking trails (-17.540358, -149.826856). I collected the leaves and flowers of *H. tiliaceus* and *H. rosa-sinesis* at each study site, except for at the Agricultural School where only *H. rosa-sinesis* was present (Figure 1).

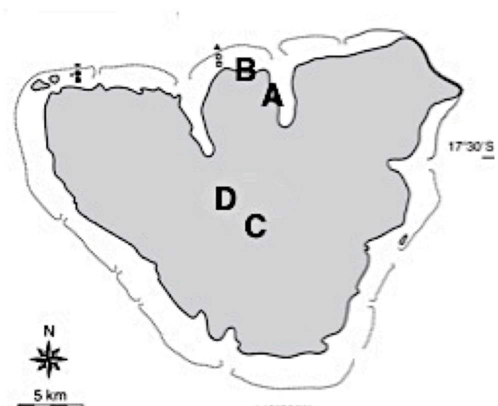

FIG. 1. Sites sampled in this study. Gump Research Station is indicted by "A," Piha'ena Beach by "B," Belvedere by "C," and the Agricultural School by "D"

Hibiscus morphology

At each of the four study site sites, twenty leaves and twenty flowers of *H. tiliaceus* and *H. rosa-sinesis* were selected for morphological analysis. For each site, 12 trees of each species were assigned a unique number from 1-12 based on the order they were encountered. Then, a random number generator was used to randomly select 5 trees of each species to sample, for a total of 10 trees at each site. For the 10 trees sampled at each site, the 4 largest leaves and the 4 largest flowers within 1.5 meters tall were hand picked off the tree for sampling. For each flower and leaf that was picked, I used measuring tape to record the maximum leaf width and length, as well as the maximum petal width and length.

There were two exceptions to this methodology that occurred while conducting this study. First, at the Agricultural school, where only *H-rosa-sinesis* was found, 10 leaves and 10 flowers were collected following the method above, but no *H. tiliaceus* was collected. Therefore, 20 *H. tiliaceus* leaves and flowers were collected from Belvedere to compensate. Second, at Belvedere, it was discovered that *H. tiliaceus* flowers were difficult to locate on trees, and even if a few were located, they were grown at unreachable heights. Therefore, freshly fallen *H. tiliaceus* flowers were picked up from the ground of the hiking trail (n=50) and the 20 largest were selected for the morphology study.

I used this data to test my hypothesis to see if coastal, low elevation hibiscus have larger petal and leaf dimensions than mountainous, high elevation hibiscus.

Hierarchy of Hibiscus Herbivory Palatability Test

A second component of my study aimed to establish a hierarchy of palatability between *H. tiliaceus* flowers, *H. tiliaceus* leaves, *H. rosa-sinesis* flowers, and *H. rosa-sinesis* leaves in the brown land crab, *C. carnifex.* First, 10 land crabs were captured at the burrows adjacent to the UC Gump Station by setting up a pitfall trap with a 7.5 L bucket dug into the ground that was baited with hibiscus. After 10 crabs were captured, each individual crab was placed in a 7.5 L flowerpot as a chamber for the duration of the study. A strainer was used as a lid to allow for oxygen flow and a piece of aluminum foil was used to loosely cover the lid to provide shelter. In addition, rock & coral sediment was placed at the bottom of the chamber to mimic the crab's natural habitat by the shore, and petri dishes filled with water were placed in the chamber.

To conduct the herbivory palatability experiment, the four factors (*H. tiliaceus* flowers, *H. tiliaceus* leaves, *H. rosa-sinesis* flowers, and *H. rosa-sinesis* leaves) were paired against each other in 6 unique ways, and through the course of 6 days, each pairing was offered to each of the crabs (Table 1). Each day, the pairing being tested would be collected at the hibiscus trees along the coast adjacent to the UC Gump Research Station. Only leaves and flowers free of disease and insect herbivory were collected. The plants were then taken back to the lab and wiped clean of any debris. Exactly 1.00 gram of each flower and/or leaf being tested that day was measured on an analytical balance, for a total of 2 grams of food per crab per day. Only the petals of the flowers were used to keep everything uniform. This was done 10 times to create 10 portions of food to feed to each of the crabs.

TABLE. 1. The 6 unique pairings tested over the course of 6 days.

Day	Pairing tested
1	*H. rosa* flower & *H. tiliaceus* flower
2	*H. rosa* leaf vs. *H. tiliaceus* leaf
3	*H. rosa* flower vs. *H. tiliaceus* leaf
4	*H. rosa* leaf vs. *H. tiliaceus* flower
5	*H. rosa* flower vs. *H. rosa* leaf
6	*H. tiliaceus* flower vs. *H. tiliaceus* leaf

Each feeding period began at 12pm on a given day and ended at 6pm. At 12pm, after the plant pairing had been weighed and portioned, they were placed equidistant from the crab (~20cm each way). At 6pm daily, the leftover flower/leaf parts were removed from the chamber and weighed on the analytical balance. The leftover mass was then subtracted from the original mass of 1.00 gram to determine the amount of each plant that the crab consumed (response variable). This 6 day experiment was repeated 3 times.

Hibiscus origin preference test

The final component of my study aimed to determine if hibiscus grown at different elevations and environments have an effect on palatability. In this case, the leaves and flowers of *H. tiliaceus* and *H. rosa-sinesis* were collected along the coast near the UC Gump Research Station as the low elevation study site. Leaves and flowers were also collected at the Belvedere hiking trail to represent the high elevation study site. Thirty leaves and thirty flowers of each species were gathered at each site and this was repeated after day 6 of the experiment. Care was taken to choose leaves free of disease and herbivory and about the same size/age. The flowers and leaves were stored in the refrigerator at 4°C until they were presented to the crabs and after 6 days, they were discarded and a fresh batch was collected.

Each day, the pairing to be tested (Table 2) was wiped clean of debris and then 1.00 gram of each coastal and mountainous plant was weighed on the analytical balance. Only the petals of the flowers were used to keep everything uniform. To distinguish between coastal and mountainous plants, a small piece of duct tape measuring .5 cm x .5 cm was placed on each plant, then a permanent marker was used to label the plant "C" for coastal and "M" for mountainous. This was repeated 10 times daily to create 10 portions of food for the 10 crabs.

TABLE. 2. The different mountain vs. coastal pairings tested over the 12 days.

Days	Pairing tested
1-3	*H. tiliaceus* flower: mountain vs. coastal
4-6	*H. rosa* flower: mountain vs. coastal
7-9	*H. tiliaceus* leaf: mountain vs. coastal
10-12	*H. rosa* leaf: mountain vs. coastal

The crabs were fed the pairing of the day daily at 12pm and given 6 hours to eat. At 6pm, the leftover plant matter was removed, the duct tape identification tag was carefully removed, and the remaining plant material was measured again on the analytical balance. This ending mass was then subtracted from the original mass of 1.00 gram to determine the amount of each plant the crab consumed.

Statistical Analyses

All statistical tests were performed using Microsoft Excel. All student's t-tests and ANOVA tests were performed with an alpha value of 0.05. All student's t-tests assume normal distribution, homogeneity of variance, simple random sample, the data follows a continuous or ordinal scale, and that a fairly large sample size is used (Seltman 2018). ANOVA assumes normal distribution, equal variance, and independent errors (Seltman 2018).

Hibiscus Morphology

Student's t-test were used to compare the average petal lengths, average petal widths, average leaf lengths, and average leaf widths of both species of hibiscus. Box plots showing averages with whiskers showing standard deviation were also created.

Hierarchy of Hibiscus Herbivory Palatability Test

Box plots showing the average consumption with whiskers showing standard deviation of consumption of each plant part in a pairing were created to visually depict the differences in consumption between plant parts.

Hibiscus Origin Preference Test

A two way repeated measured ANOVA was used to compare average consumption of mountain vs. coastal plant plants of each individual plant part across the 3 trials. Box plots showing average consumption with whiskers showing standard deviation were also generated.

RESULTS

Hibiscus Morphology

The average petals and leaf dimensions of *H. tiliaceus* and *H. rosa-sinesis* were both larger at higher, mountainous elevations than lower, coastal elevations.

In *H. tiliaceus* from coastal conditions, the dimensions were on average smaller than their mountainous counter parts. The leaf width ranged from 13.4 cm to 22.2cm with an average of 17.29 cm (± 2.25 SD), the leaf length ranged from 12.0 cm to 20.0 cm with an average of 15.4 cm (± 1.87 SD), the petal width ranged from 5.0 cm to 9.0 cm with an average of 6.87 cm (± 1.02 SD), and the petal length ranged from 6.20 cm to 10.2 cm with an average of 8.27 cm (±1.15 SD) (Figure 2).

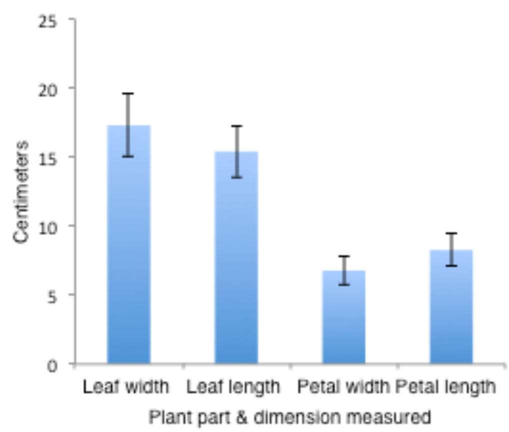

FIG. 2. Coastal *H. tiliaceus* average dimensions. Bars show average dimension in centimeters and error bars show standard deviation.

In *H. tiliaceus* from mountainous conditions, the dimensions were on average larger than their coastal counter parts. The leaf width ranged from 25.2 cm to 34.8 cm with an average of 29.4 cm (± 2.98 SD), leaf length ranged from 19.2 cm to 26.1 cm with an average of 22.1 cm (± 2.27 SD), petal width ranged from 6.2cm to 9.9 cm with an average of 7.9 cm (± 0.93 SD), and petal length ranged from 7.6 cm to 10.8 cm with an average of 9.17 cm (± 0.94 SD) (Figure 3).

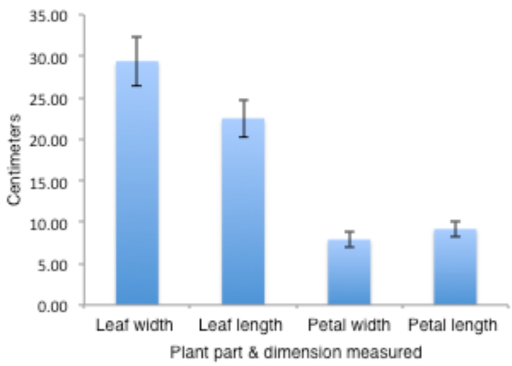

FIG. 3. Mountainous *H. tiliaceus* average dimensions. Bars show average dimension in centimeters and error bars show standard deviation.

In *H. rosa-sinesis* from coastal conditions the dimensions were on average smaller than their mountainous counter parts. The leaf width ranged from 3.6 cm to 6.8 cm with an average of 4.64 cm (± 0.85 SD), leaf length ranged from 5.00 cm to 10.40cm with an average of 8.18 cm (± 1.23 SD), petal width ranged from 3.40 cm to 5.80 cm with an average of 4.66 cm (± 0.61 SD), and petal length ranged from 6.4cm to 8.4 cm with an average of 7.31 cm (± 0.52 SD) (Figure 4).

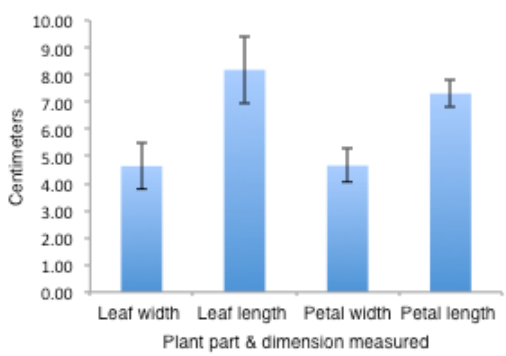

FIG. 4. Coastal *H. rosa-sinesis* average dimensions. Bars show average dimension in centimeters and error bars show standard deviation.

In *H. rosa-sinesis* from mountainous conditions, the dimensions were on average larger than their coastal counter parts. The leaf width ranged from 8.1 cm to 16.8 cm with an average of 11.78 cm (± 2.39 SD), leaf length ranged from 12.6 cm to 19.8 cm with an average of 16.42 cm (± 1.96 SD), petal width ranged from 4.8 cm to 7.0 cm with an average of 5.79 cm (± 0.70 SD), and petal length ranged from 7.0 cm to 8.8 cm with an average of 7.92 cm (± 0.49 SD) (Figure 5).

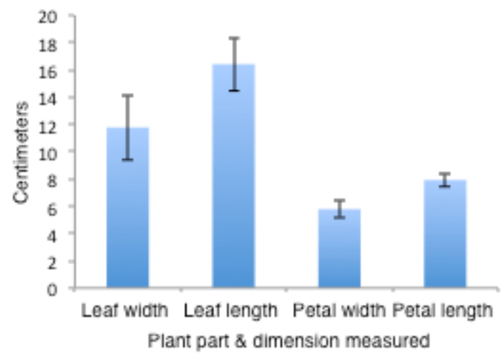

FIG. 5. Mountainous *H. rosa-sinesis* average dimensions. Bars show average dimension in centimeters and error bars show standard deviation.

Student's t-tests were used to compare the means of the dimensions of hibiscus parts from coastal vs. mountainous origins. For *H. tiliaceus*, the average petal length ($p< 0.05$), petal width ($p< 0.001$), leaf length ($p< 0.001$), and leaf width ($p< 0.001$) were all found to be significantly different for coastal versus mountainous origins (Table 3).

TABLE 3. Student's t-test result for coastal and mountainous *H. tiliaceus* plant part dimensions.

Plant part & dimension	t-statistic	p-value
Petal length	2.7057	0.01014811
Petal width	3.6195	0.000857488
Leaf length	10.8136	3.71526E-13
Leaf width	14.5101	4.4314E-17

For *H. rosa-sinesis*, the average petal length ($p< 0.001$), petal width ($p < 0.001$), leaf length ($p< 0.001$), and leaf width ($p< 0.001$) were also all found to be significantly different for coastal versus mountainous origins.

TABLE 4. Student's t-test result for coastal and mountainous *H. rosa-sinesis* plant part dimensions.

Plant part & dimension	t-statistic	p-value
Petal length	3.8398	0.000452792
Petal width	5.4584	3.14826E-06
Leaf length	15.9198	2.12521E-18
Leaf width	12.5826	4.00704E-15

Hierarchy of Hibiscus Herbivory Palatability Test

H. rosa-sinesis flowers were preferred the most in the hierarchy test, being consumed on average more than all three other plant plants (Table 5). *H. tiliaceus* flowers were the next most preferred, being consumed on average more than both of the leaf species, but not *H. rosa-sinesis* flowers. *H. tiliaceus* leaves were the third most preferred, being consumed on average more than *H. rosa-sinesis* leaves, but not *H. rosa-sinesis* flowers and *H. tiliaceus* flowers. Finally, the least preferred plant part was *H. rosa-sinesis* leaves. They were on average consumed less than all 3 other plant parts when paired with them.

TABLE 5. The pairings tested and more consumed individual of the pair.

Pairing	More consumed
H. rosa-sinesis flower & *H. tiliaceus* flower	*H. rosa.* flower
H. rosa-sinesis flower & *H. tiliaceus* leaf	*H. rosa.* flower
H. rosa-sinesis flower & *H. rosa.* leaf	*H. rosa.* flower
H. tiliaceus flower & *H. rosa-sinesis* leaf	*H. tiliaceus* flower
H. tiliaceus flower & *H. tiliaceus* leaf	*H. tiliaceus* flower
H. tiliaceus leaf & *H. rosa-sinesis* leaf	*H. tiliaceus* leaf

In the *H. rosa-sinesis* flower & *H. tiliaceus* flower pairing, *H. rosa-sinesis* flower had an average consumption of 0.67 g (± 0.09 SD) compared to *H. tiliaceus* with an average consumption of 0.32 g (± 0.14 SD). In the *H. rosa-sinesis* flower & *H. tiliaceus* leaf pairing, *H. rosa-sinesis* flower had an average consumption of 0.59 g (± 0.15 SD) compared to *H. tiliaceus* leaves with an average consumption of 0.27 g (± 0.13 SD). In the *H. rosa-sinesis* flower & *H. rosa-sinesis* leaf pairing, *H. rosa-sinesis* flower had an average consumption of 0.58 g (± 0.10 SD) while *H. rosa-sinesis* leaves had an average consumption of 0.26 g (± 0.13 SD). In the *H. tiliaceus* flower & *H. rosa-sinesis* leaf pairing, *H. tiliaceus* flowers had an average consumption of 0.58 (± 0.13 SD) compared to *H. rosa-sinesis* leaves with an average consumption of 0.20 g (± 0.13 SD). In the *H. tiliaceus* flower & *H. tiliaceus* leaf pairing, *H. tiliaceus* had an average consumption of 0.58 g (± 0.10 SD) compared to *H. tiliaceus* leaves with an average consumption of 0.27 g (± 0.13 SD). In the *H. tiliaceus* leaf & *H. rosa-sinesis* leaf pairing, *H. tiliaceus* leaves had an average consumption of 0.53 g (± 0.11 SD) compared to *H. rosa-sinesis* leaves with an average consumption of 0.20 g (± 0.09 SD) (Figure 6).

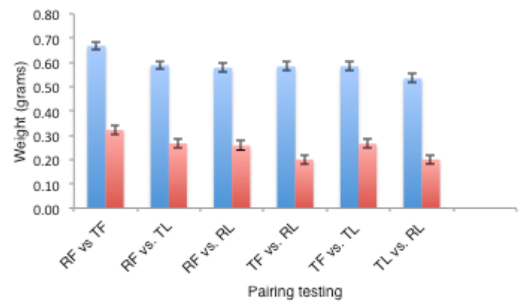

FIG. 6. Average consumption of the 6 pairings across all crabs in 3 repeated trials. RF= *H. rosa-sinesis* flower, TF= *H. tiliaceus* flower, RL= *H. rosa-sinesis* leaf, TL= *H. tiliaceus* leaf. Bars show average amount consumed in grams and error bars show standard deviation.

Hibiscus Origin Preference Test

On average, the crabs preferred hibiscus from the mountain rather than the coast, consuming 50.98% more of the mountainous hibiscus parts than coastal hibiscus parts (Figure 7).

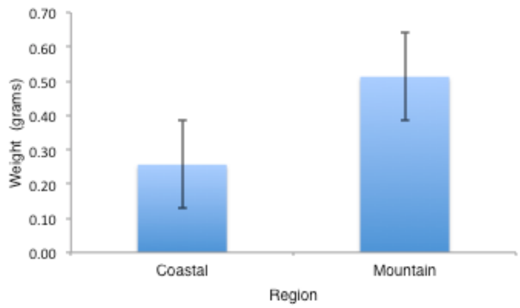

FIG. 7. The average consumption of coastal versus mountainous hibiscus parts consumed across all 10 crabs in 3 repeated trials. Bars show average amount consumed in grams and error bars show standard deviation.

For *H. tiliaceus* petals, the average consumption of mountainous petals was 0.45 g (± 0.09 SD), compared to the average consumption of coastal petals, which was 0.34g (± 0.08 SD) (Figure 8).

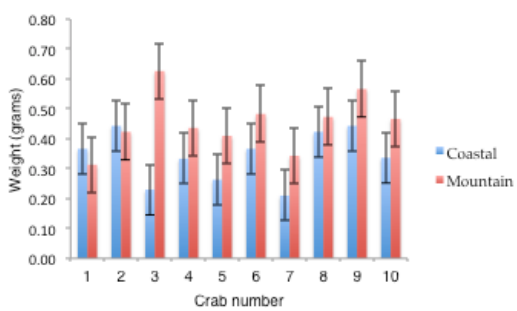

FIG. 8. The average consumption of *H. tiliaceus* petals of the 10 crabs in 3 trials. Bars show average amount consumed in grams and error bars show standard deviation.

For *H. tiliaceus* leaves, the average consumption of mountainous leaves was 0.54 g (± 0.06 SD), compared to the average consumption of coastal leaves, which was 0.25 g (± 0.05 SD) (Figure 9).

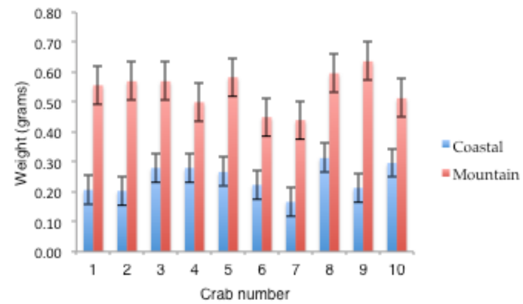

FIG. 9. The average consumption of *H. tiliaceus* leaves of the 10 crabs in 3 trials. Bars show average amount consumed in grams and error bars show standard deviation.

For *H. rosa-sinesis* petals the average consumption of mountainous petals was 0.51 g (± 0.11 SD), compared to the average consumption of coastal petals, which was 0.25g (± 0.07 SD) (Figure 10).

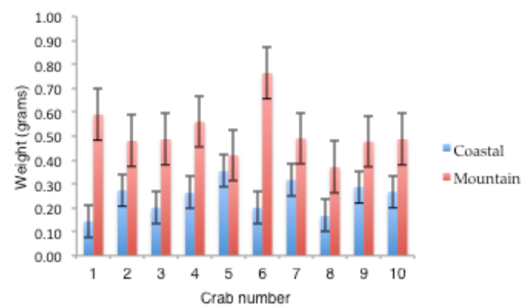

FIG. 10. The average consumption of *H. rosa-sinesis* petals of the 10 crabs in 3 trials. Bars show average amount consumed in grams and error bars show standard deviation.

For *H. rosa-sinesis* leaves the average consumption of mountainous petals was 0.54 g (± 0.07 SD), compared to the average consumption of coastal leaves, which was 0.19g (± 0.08 SD) (Figure 11).

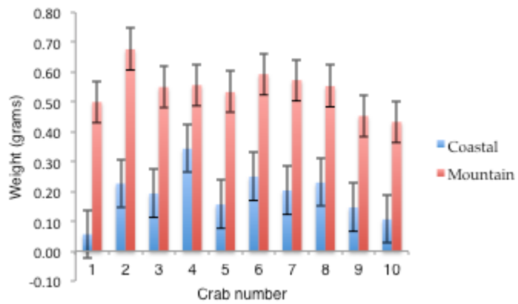

FIG. 11. The average consumption of *H. rosa-sinesis* leaves of the 10 crabs in 3 trials. Bars show average amount consumed in grams and error bars show standard deviation.

A two way repeated measures ANOVA was used to compare the means of the hibiscus parts from coastal versus mountainous origins. The consumption of leaves and flowers of *H. rosa-sinesis* were both found to be statistically significant ($p < 0.05$). For *H. tiliaceus*, only the consumption of leaves was significant ($p<0.05$), while the difference in flower consumption in coastal versus mountainous parts were insignificant ($p > 0.05$) (Table 6).

TABLE 6. The F and p-values from a two way repeated measure ANOVA test.

Plant part	F value	p-value
H. tiliaceus flower	1.475	0.3484
H. rosa-sinesis flower	26.07	0.03628
H. tiliaceus leaf	156.8	0.006319
H. rosa-sinesis leaf	344.8	0.002888

DISCUSSION

Hibiscus Morphology

My results show that for both species of hibiscus, the mountainous type has greater leaf width, leaf length, petal width, and petal length. This result conflicts past studies (Velazques-Rosas 2002, Guo 2018) that show that plant size generally decreases with increasing altitude. However, several other factors besides altitude could be influencing plant size in this scenario.

It is possible that coastal environments in Mo'orea have increased environmental stressors, due to salinity influence in the soil, increased insolation in plant parts, and decreased canopy cover. Salinity is known to negatively impact plant metabolism by restricting stomata functioning and photosynthetic rates, and consequently, plant growth rate will decrease (DeLaune 1987). In Mo'orea, *H. tiliaceus* can grow right at the coastline where its roots are submerged in saltwater, whereas *H. rosa-sinesis* could be found as close as 3 meters away from saltwater (Elevtich & Thomson 2006), therefore, salinity could be playing a role in influencing the hibiscus dimensions observed. The coastal trees of *H. tiliaceus* and *H. rosa-sinesis* are also generally more insolated than mountainous trees, and it has been shown that with increasing insolation, plant size tends to decrease because the plants do not need as large of a surface area to capture sunlight compared to plants with low insolation (Ackerly et. al, 2002). Additionally, partial canopy cover is known to positively influence plant growth rates (Maloney 2007), and *H. tiliaceus* and *H. rosa-sinesis* trees grow with little to no canopy cover along the coastline of Mo'orea (personal observation**).**

Hierarchy of Hibiscus Herbivory Palatability

My results show that *H. rosa-sinesis* flowers were consistently the most preferred amongst crabs, being more consumed when paired with *H. rosa-sinesis* leaves, *H. tiliaceus* flowers, and *H. tiliaceus* leaves. The second most preferred plant part was *H. tiliaceus* flowers, being more consumed when paired with *H. rosa-sinesis* leaves and *H. tiliaceus* leaves, but not *H. rosa-sinesis* flowers. The third most preferred hibiscus part was *H. tiliaceus* leaves, being more consumed with paired with *H. rosa-sinesis* leaves but not *H. rosa-sinesis* flowers or *H. tiliaceus* flowers. The least most preferred hibiscus part was *H. rosa-sinesis* leaves, being least consumed when paired with all three other hibiscus parts.

These results show that crabs prefer hibiscus flowers to hibiscus leaves in both species of *H. tiliaceus* and *H. rosa-sinesis.* This could be due to several factors, including flowers being more visually attractive since *H. rosa-sinesis* flowers range from red, pink, orange, and white while *H. tiliaceus* flowers are bright yellow while on trees and a dull orange shade once they fall from the trees (Florence 2004, Elevitch and Thomson 2004). Another reason could be nutrient content, as previous studies analyzing hibiscus nutrient distribution have shown that the flowers of the plant tend to be more nutritious than the leaves due to higher nutrients required in reproductive parts of the flower (Trivellini, 2011, de Lima et. al, 2015) Another reason could be toughness of the plant. The flowers of both species are easier to break apart and chew than the leaves (Choong 1996), so this could be evidence for the optimal foraging theory, which says that when foraging for food, animals will choose what requires the least energy expenditure and the most energy payoff (Pyke 1984). In this case, *H. rosa-sinesis* leaves, being more difficult to break apart and chew, would be more energetically costly for the crabs to eat than *H. tiliaceus* leaves.

Previous studies have shown that generalist herbivores will prefer exotic plants to native plants due to exotic plants not evolving chemical defense mechanisms like native plants have against herbivores (Morrison 2011). My results show that this is was true for the flowers of both species, with *H. rosa-sinesis* flowers being preferred over *H. tiliaceus* flowers, but the opposite was true for the leaves. *C. carnifex* preferred the native *H. tiliaceus* leaves over the exotic *H. rosa-sinesis* leaves. This could be because that *H. rosa-sinesis* leaves already contain a greater amount of secondary metabolites than *H. tiliaceus* leaves before being introduced to Mo'orea, making the *H. rosa-sinesis* leaves less palatable (Cox 2008). Although it is likely that *C. carnifex* did not drive the evolution of secondary metabolites in hibiscus due to them predating on the leaves after they have fallen from the plant, it is likely that other herbivores have caused the hibiscus to evolve secondary metabolites against generalist herbivores (Cox 2008) and that *C. carnifex*'s herbivory patterns are affected by these metabolites.

Hibiscus Origin Preference Test

The results of this test show that overall, ~51% more mountainous hibiscus parts were consumed than coastal hibiscus parts in total across all trials, demonstrating that the crabs have a strong preference for mountainous hibiscus parts. Consistently throughout the pairings, the mountainous hibiscus part was consumed more, and the difference between average consumption between coastal and mountainous hibiscus parts were found to be statistically significant in all plant parts except *H. tiliaceus* petals.

The reason for this preference could be due to mountainous plants containing less secondary metabolites since there tend to be less herbivores at higher elevations, and therefore less secondary metabolites need to be created by higher elevation plants as defense mechanisms (Descombes et. al 2016). Previous studies have shown an inverse relationship between herbivory palatability and medicinal activity due to secondary metabolites (Cox 2008), and my findings support this correlation, since *C. carnifex* preferred higher elevation plants that contain less secondary metabolites.

The fact that *H. tiliaceus* petals showed no statistically significance difference in consumption between mountainous and coastal parts could suggest that the composition of the flowers are similar, thus not inducing a significant preference in *C. carnifex.*

Conclusion & Future Directions

Overall, this study revealed some interesting patterns in flower morphology, leaf morphology, and herbivory palatability in *C. carnifex.* Petal and leaf dimensions for *H. tiliaceus* and *H. rosa-sinesis were* significantly larger for mountainous than coastal species. *H. rosa-sinesis* flowers were the most palatable to *C. carnifex,* followed by *H. tilaceus* flowers, then *H. tiliaceus* leaves, and lastly *H. rosa-sinesis* leaves. *C. carnifex* consistently preferred hibiscus parts from the mountains rather than from the coast in both species of hibiscus, with the exception of *H. tiliaceus* petals in which the difference in consumption was not statistically significant. These findings could be further explored in the following ways: The flower morphology study can be expanded upon by testing a wider range of locations throughout Mo'orea, such as Temae Beach and where coastal *H. tiliaceus* is present, and Maharepa where coastal *H. rosa-sinesis* is present. The herbivory palatability test could be expanded upon by including more plants that land crabs are known to eat, and possibly including *Thespia Populnea*, another flower of the Malvacae family that was noted to grow along the coast of the UC Gump Research Station near *H. tiliaceus* and *H. rosa-sinesis* trees. The hibiscus origin preference test can also be expanded upon by testing for soil nutrient content where hibiscus grow at high and low elevations and seeing if soil nutrient content at different elevations is correlated with difference in herbivory palatability.

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