Carapace width-weight relationship and condition factor of
_Austruca annulipes_ in mangroves of Penang Island

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Abstract. Carapace width-weight relationship and relative condition factor (_Kn_) of _Austruca annulipes_ were estimated from 2086 individuals comprising 1503 males and 583 females. Crabs were sampled from mangroves of Teluk Tempoyak and Pulau Betong during the study period of March 2017 to February 2018. Monthly sampling of crabs was conducted using hand catch method (catch per unit effort (CPUE)) with captured crabs counted as number of crabs/15 min/4 m². Data recorded was analysed in four categories; sex, dry and wet months, five size classes and sampling site. The carapace width-weight relationship of male and female crabs was significantly positive for the four categories with overall samples indicating positive allometric growth, except for males in the size class of 1.70 – 1.99 cm, and females in the size class of 0.80 – 1.09 cm that were characterized by negative allometric growth. The values of mean relative condition factor (_Kn_) of _A. annulipes_ was higher than 1 indicating that mangrove in Penang Island provide favourable habitat condition for the growth of _A. annulipes_.

1. Introduction

Fiddler crabs of family Ocypodidae, subfamily Ucinae are widely distributed throughout the tropics and subtropics of the world [1]. Eleven genera totalling 105 species are known at present, represented by 47 species found along the coast of the Indo-Pacific, 36 species in the Eastern Pacific, 21 species in the Western Atlantic and 1 species in the Eastern Atlantic [2]. Fiddler crabs generally inhabit intertidal areas with muddy or sandy open flats of protected shores, river banks, salt marshes, and mangrove mud with some species living close to the seawater while others can be found upstream as far as the upper intertidal limits of mangroves [3]. The most distinguishing characteristics of this crab is the presence of one enlarged claw in males that can make up more than half of the crab body weight.

Fiddler crabs are considered as important species in mangroves as their bioturbation activities in mangrove soil contribute significant roles in maintaining mangrove ecosystem functions [4]. Fiddler crabs also play an important role in food chains as they are the primary consumer of the mangrove food web, in which they facilitate the breakdown of mangrove detritus and bacteria thus making it available for consumers in mangroves [5]. Changes to the population structure of fiddler crab may result in changes occurring at the species level thus affecting ecosystem processes in mangrove ecosystems [6]. Therefore, assessing fiddler crab life history traits are vital in implementing an ecosystem-based management approach in mangroves.

The objective of the present study was to provide baseline data on carapace width-weight relationship and relative condition factor for fiddler crab, _Austruca annulipes_ sampled from the two mangrove areas: Teluk Tempoyak and Pulau Betong. Findings from this study is expected to
contribute to the development of a comprehensive baseline data of non-commercial however ecologically impactful benthic crustaceans in this region.

2. Materials and methods

2.1. Sampling strategy

This study was conducted in two mangrove forests: Teluk Tempoyak (TT) (N 05° 15.930’, E 100 11.546’), and Pulau Betong (PB) (N 05° 18.432’, E 100 11.663’) (Figure 1). Monthly sampling was conducted from March 2017 until February 2018 covering the dry months (June until November 2017) and wet months (March 2017 until May 2017, December 2017 until February 2018). The sampling activity was carried out during lowest tide of neap tide to ensure enough time was allocated to sample the area with equivalent effort distribution during the twelve consecutive months of sampling period.

Fiddler crabs were captured using the hand catch (catch-per-unit-effort (CPUE)) method modified from [7] and [8]. A total of six 2 x 2 meter quadrats were marked with thin plastic rope and anchored to wooden stakes buried in the mangrove sediments, with each quadrat spaced 5 meters apart. Individuals were trained for crab capture two months prior to sampling, and the same individual sampled the quadrats for the twelve months in the entirety of the sampling period to reduce bias on effort, and for the samplers to understand the behaviour of fiddler crabs inhabiting the quadrats that was sampled. Five minutes recovery time were given for fiddler crab to settle down and the catcher to identify the burrow and another 15 minutes for the catcher to catch the crab wandering on the sediment and excavate the burrow that have the crab. The captured crabs were placed in labelled plastic bags secured with cable ties and stored in a cooler containing ice to slow down crab movement, prevent fighting among crabs and loss of limbs during transportation to the laboratory. Crabs with complete appendages and in the intermoult or complete stages were used in this analysis. All samples were weighed, and carapace width were measured to the nearest 0.1 g and 0.1 cm, respectively using digital calliper. The identification process of the fiddler crab is based on [1] and [3].

Figure 1. Location of sampling site in Penang Island (Pulau Betong is in the Southwestern coast of Penang Island while Teluk Tempoyak is in South eastern coast of Penang Island.
2.2 Statistical analysis

The carapace width-weight relationship was calculated using $W = aL^b$ [9]. The values of constant $a$ and $b$ were estimated using the least-square method applied to the log transformed data as $\log W = \log a + b \log L$ [10], where $W$ (g) is total weight, $L$ (cm) is the total carapace width (from side to side between the tips of the antero-lateral angles, the widest part of the carapace), $a$ is the intercept value and $b$ is the regression coefficient (slope). The growth pattern i.e. positive allometry ($b > 3$), isometry ($b = 3$) and negative allometry ($b < 3$) was tested using Pauly’s equation [10].

$$t = \frac{\text{sd ln } L \cdot |b - 3| \cdot \sqrt{n - 2}}{\text{sd ln } W \cdot \sqrt{1 - r^2}}$$

(1)

Where $\text{sd ln } L$ and $\text{sd ln } W$ are the standard deviations of the ln Width and Weight. The value of $b$ is significantly different from the cubic law if the $t$ calculated is greater than the $t$ in the $t$ distribution table for $n - 2$ degrees of freedom.

The relative condition factor ($Kn$) was calculated through the following formula, $Kn = W/ aL^b$, [11], as cited by [9], where $W$ is the total weight (g), $a$ and $b$ are the intercept and slope obtained from width-weight equation.

Independent samples t-test was used to compare $b$ values and $Kn$ of crabs between the dry and wet months factor, the gender factor and sampling site while one-way ANOVA was used to compare the $b$ value and $Kn$ of crab between five size classes. The statistical analyses were performed using SPSS software v20.

3. Results

3.1 Carapace width-weight relationship and condition factor of male and female Austruca annulipes

A total of 2086 individuals of $A$. annulipes with 1503 males and 583 females were collected at mangroves of Teluk Tempoyak and Pulau Betong during the study period from March 2017 to February 2018. The range of average carapace width collected during the study for males ranged from 0.59 cm to 1.83 cm with range of average weight ranging from 0.05 g to 2.57 g. The ranged of averaged carapace width collected during the study for females ranged from 0.59 cm to 1.58 cm with ranged of averaged weight ranging from 0.05 g to 1.44 g. The $r^2$ value shows that there was a strong relationship between carapace width and weight of the male and female crab. (Table 1, Figure 2). There is a significant difference of the $b$ value of male and female from the cubic law ($p<0.05$) when tested with Pauly’s equation [10] (1). The result concluded that male and female $A$. annulipes collected during the study period experienced positive allometric growth.

| Group   | n    | $a$    | $b$    | 95% C. L of $b$          | $r^2$ |
|---------|------|--------|--------|--------------------------|------|
| Male    | 1503 | 0.330  | 3.343  | 3.324 - 3.361             | 0.940 |
| Female  | 583  | 0.248  | 3.115  | 3.072 - 3.151             | 0.867 |
Figure 2. Carapace width-weight relationship of a) male and b) female *Austruca annulipes*.

Relative condition factor calculated for male and female *A. annulipes* were not different (Table 2; \( p>0.05 \)).

**Table 2.** Relative condition factor (\( K_n \)) of male and female *Austruca annulipes*.

| Group  | n   | Min - Max | Mean  | Variance | t       | p     |
|--------|-----|-----------|-------|----------|---------|-------|
| Male   | 1503| 0.45 - 2.10 | 1.011 | 0.022    | -0.273  | 0.393 |
| Female | 583 | 0.40 - 1.90 | 1.013 | 0.026    |         |       |

3.2 Carapace width-weight relationship and condition factor of male and female *A. annulipes* caught during dry and wet months

Table 3 shows the carapace width-weight relationship of male and female *A. annulipes* during dry and wet months. The ranged of averaged carapace width collected during dry months ranged from 0.592 cm to 1.825 cm with ranged of averaged weight ranged from 0.05 g to 2.54 g. The ranged of averaged
carapace width collected during wet months ranging from 0.592 cm to 1.824 cm with ranged of averaged weight ranging from 0.06 g to 2.57 g. The $r^2$ value shows that there was a strong relationship between carapace width and weight of the male and female crab during dry and wet months (Table 3, Figure 3). Significant differences were detected for the $b$ value calculated for male and female during dry and wet months from the cubic law ($p<0.05$) when tested with equation (1). This shows that male and female *A. annulipes* collected during dry and wet month’s experienced positive allometric growth.

**Table 3.** Carapace width-weight relationship of male and female *Austruca annulipes* between dry and wet months. $a =$ intercept of regression line, $b =$ slope of regression line, C. L. = Confidence Level, $r^2 =$ regression coefficient

| Sex  | Group | $n$ | $a$  | $b$  | 95% C. L of $b$ | $r^2$ |
|------|-------|----|-----|-----|----------------|------|
| Male | Dry   | 650| 0.325| 3.333| 3.304 - 3.362 | 0.936|
|      | Wet   | 853| 0.336| 3.339| 3.315 - 3.362 | 0.944|
| Female | Dry | 272| 0.249| 3.083| 3.021 - 3.146 | 0.860|
|      | Wet   | 311| 0.245| 3.148| 3.093 - 3.192 | 0.878|

**Figure 3.** Carapace width-weight relationship of male and female *Austruca annulipes* between dry and wet months.

No variation was observed in the mean relative condition factor calculated between dry and wet months for male *A. annulipes* (Table 4; $p>0.05$). No significant difference in relative condition factor was observed between wet and dry months for female *A. annulipes* (Table 4; $p>0.05$).
### Table 4. Relative condition factor (Kn) of *Austruca annulipes* during dry and wet months.

| Sex  | Group | n    | Min - Max | Mean  | Variance | t   | p   |
|------|-------|------|-----------|-------|----------|-----|-----|
| Male | Dry   | 650  | 0.48 - 2.43 | 1.098 | 0.029    | 0.057 | 0.955 |
|      | Wet   | 853  | 0.57 - 2.48 | 1.098 | 0.029    |       |      |
| Female | Dry | 272  | 0.32 - 1.64 | 0.806 | 0.025 | -2.521 | 0.222 |
|       | Wet  | 311  | 0.45 - 1.18 | 0.807 | 0.015 |       |      |

3.3 *Carapace width-weight relationship and condition factor of male and female A. annulipes according to the crab carapace width group*

For males, the lightest body weight (0.08 g) was recorded in group 0.50 – 0.79 cm carapace width and the heaviest body weight (2.57 g) was recorded in group 1.70 – 1.99 cm carapace width. For females, the lightest body weight (0.05 g) was recorded in group 0.50 – 0.79 cm carapace width and the heaviest body weight (1.44 g) was recorded in group 1.40 – 1.69 cm carapace width. The r² values between five groups were significantly positive between carapace width and weight of the crab (Table 5, Figure 4). There were significant differences detected for the b value calculated for male and female across the five size classes from the cubic law (p<0.05) when tested with equation (1). The results concluded that *A. annulipes* in the size classes of 1.70 – 1.99 cm (male) and 0.80 - 1.09 cm (female) experienced negative allometric growth while other size classes experienced positive allometric growth.

### Table 5. Carapace width-weight relationship of male and female *Austruca annulipes* between five size classes. a = intercept of regression line, b = slope of regression line, C. L. = Confidence Level, r² = regression coefficient

| Sex  | Group (cm) | n | a    | b    | 95% C. L. of b | r²  |
|------|------------|---|------|------|----------------|-----|
| Male | 0.50 - 0.79 | 21 |       |      |                |     |
|      | 0.80 - 1.09 | 223| 0.321 | 3.547 | 3.450 - 3.645  | 0.721 |
|      | 1.10 - 1.39 | 736| 0.33  | 3.365 | 2.717 - 2.797  | 0.726 |
|      | 1.40 - 1.69 | 463| 0.326 | 3.376 | 3.328 - 3.425  | 0.649 |
|      | 1.70 - 1.99 | 60 | 0.507 | 2.574 | 2.371 - 2.777  | 0.146 |
| Female | 0.50 - 0.79 | 6  |       |      |                |     |
|       | 0.80 - 1.09 | 193| 0.251 | 2.757 | 2.655 - 2.858  | 0.588 |
|       | 1.10 - 1.39 | 347| 2.238 | 3.253 | 2.690 - 2.823  | 0.659 |
|       | 1.40 - 1.69 | 37 | 0.206 | 3.725 | 3.398 - 4.051  | 0.302 |
|       | 1.70 - 1.99 |    |       |      |                |     |

*blank area-carapace width-weight relationship was not done as the n < 30.*
Figure 4. Carapace width-weight relationship of male and female *A. annulipes* in five size classes.
No differences were observed in the mean relative condition factor calculated among five size classes for male and female *A. annulipes* (Table 6). Statistical analysis revealed no significant difference among five size classes for male and female *A. annulipes* (*p* > 0.05) (Table 6).

### Table 6. Relative condition factor (Kn) of *Austruca annulipes* between five size classes.

| Sex | Group (cm) | n  | Min - Max | Mean | Variance | p   |
|-----|------------|----|-----------|------|----------|-----|
| Male| 0.50 - 0.79| 21 | 0.814 - 1.236 | 1.005 | 0.011    | 0.961 |
|     | 0.80 - 1.09| 223| 0.589 - 2.187 | 1.017 | 0.039    |      |
|     | 1.10 - 1.39| 736| 0.447 - 1.671 | 1.010 | 0.019    |      |
|     | 1.40 - 1.69| 463| 0.534 - 1.299 | 1.008 | 0.015    |      |
|     | 1.70 - 1.99| 60 | 0.605 - 1.219 | 1.007 | 0.014    | _    |
| Female| 0.50 - 0.79| 6  | 0.599 - 1.618 | 1.043 | 0.110    | 0.973 |
|      | 0.80 - 1.09| 193| 0.485 - 1.866 | 1.013 | 0.026    |      |
|      | 1.10 - 1.39| 347| 0.407 - 1.804 | 1.012 | 0.023    |      |
|      | 1.40 - 1.69| 37 | 0.696 - 1.502 | 1.015 | 0.032    |      |

*No individual caught for female in the size class of 1.70 – 1.99 cm, thus no statistical analysis run.*

3.4 *Carapace width-weight relationship and condition factor of male and female A. annulipes according to sampling site*

The range of average carapace width collected at TT for male ranged from 0.71 – 1.83 cm with the range of average weight ranging from 0.08 – 2.37 g, while for females with 0.59 – 1.58 cm for carapace width and weighed between 0.06 – 1.44 g. The range of average carapace width collected at PB for male ranged from 0.59 - 1.62 cm with range of average weight ranging from 0.08 – 1.37 g, while for females with 0.69 – 1.49 cm for carapace width and weighed between 0.08 – 1.24 g. The r² value shows that there was a strong relationship between carapace width and weight of the male and female crab in the two sampling sites (Table 7, Figure 5). There are significant differences detected for the b value of males and females from the cubic law (*p*<0.05) when tested with equation (1). The results concluded that all *A. annulipes* males and females at PB experienced positive allometric growth, while females collected at TT experienced negative allometric growth.

### Table 7. Carapace width-weight relationship of male and female *Austruca annulipes* between sampling sites. a = intercept of regression line, b = slope of regression line, C. L. = Confidence Level, R² = regression coefficient

| Sex | Group | n  | a        | b        | 95% C. L of b | r²   |
|-----|-------|----|----------|----------|--------------|------|
| Male| TT    | 536| 0.315    | 3.482    | 3.454 - 3.511| 0.947|
|     | PB    | 967| 0.337    | 3.242    | 3.216 - 3.268| 0.916|
| Female| TT   | 280| 0.261    | 2.931    | 2.880 - 2.982| 0.871|
|      | PB    | 303| 0.243    | 3.168    | 3.174 - 3.309| 0.796|
Figure 5. Carapace width-weight relationship of male and female A. annulipes between sampling sites.

In TT, higher mean relative condition factor in both male and female compare to PB was observed (Table 8). Significant differences in \( Kn \) values were recorded among different sampling sites (Table 8, \( p<0.05 \)).

Table 8. Relative condition factor (Kn) of Austruca annulipes between sampling sites.

| Sex   | Group | n   | Min - Max | Mean  | Variance | t      | P    |
|-------|-------|-----|-----------|-------|----------|--------|------|
| Male  | TT    | 536 | 0.48 - 2.43 | 1.106 | 0.023    | 2.125  | 0.017|
|       | PB    | 967 | 0.57 - 2.48 | 1.086 | 0.021    |        |      |
| Female| TT    | 280 | 0.32 - 1.64 | 0.854 | 0.024    | 3.442  | <0.001|
|       | PB    | 303 | 0.45 - 1.18 | 0.811 | 0.021    |        |      |
4. Discussion

4.1 Carapace width-weight relationship

The carapace width-weight relationship and relative condition factor were estimated for Austruca annulipes according to four categories; male and female, during dry and wet months, between five carapace width size classes and between two sampling sites.

Generally, in this study, the growth of male and female crabs in the four categories were allometric i.e. size (growth) not proportional to weight. Only the b value for male in the size class of 1.70 – 1.99 cm and female in the size class of 0.80 – 1.09 cm were significantly less than 3, indicating negative allometric growth whereas all the b values for males and females in other categories were in positive allometric growth. Allometric growth pattern are common in crustaceans [12] and intertidal crabs [13] as allometric growth pattern is one of the adaptation factor in coping from the fluctuations in benthic habitat conditions [14]. A negative allometric growth pattern was observed by [15] for Uca tangeri in a tributary of Cross River, Nigeria. The differences in the relative growth of fiddler crab reported for different places may influenced by the habitat condition for example the productivity level [16], vegetation cover [17] and physicochemical parameter of the mangrove area [18].

Males of A. annulipes recorded higher b value in all four categories compared with females indicating that the growth of male crabs in terms of weight was faster than that of female crabs. The predicted trend in many brachyuran crabs is that males are typically larger and heavier than females [19–21]. This maybe the result of different role in reproductive effort between male and female. Size of male fiddler crab play an important role in mating process. Female’s fiddler crabs prefer bigger size male that can wave more rapidly than other as bigger size male will provide bigger burrow size for incubation process and male that can wave rapidly present a more fit individual compare to the slow waver [22].

No variation was observed for the b value calculated during dry and wet months between male and female A. annulipes. The differences in the b value do not depend on a single factor e.g. dry and wet months, it is the combination of multiple factor i.e. differences in the condition of the population sample [9], sampling procedure i.e. frequency and size classes of sample collected [23] and different environmental characteristics of the study area [24].

4.2 Relative condition factor

The mean relative condition factor (Kn) values for four categories of males and females A. annulipes; male and female, during dry and wet months, between five size classes and between sampling sizes were larger than one, indicating the condition of the mangroves of Penang Island is still conducive to support the population growth of A. annulipes in the area.

There were no significant differences for Kn values between male and female A. annulipes, male and female compared between dry and wet months and male and female between five size classes. It was noted that higher Kn value was observed in male and female caught at TT compare to sample caught at PB. Generally, the relative condition factor of a species in a population depends on combination of various biotic and abiotic factors especially in the fluctuating mangrove environment. Biological body processes such as gonad maturation process and environmental condition of the habitat e.g. fluctuation in salinity regime, and food availability can influence the metabolic rate of a species that eventually will influence the relative well-being of the crab living in the area.

5. Conclusion

Overall, crabs sampled indicated positive allometric growth, except for males in the size class of 1.70 – 1.99 cm and females in the size class of 0.80 – 1.09 cm that experienced negative allometric growth. The relative condition factor values show that mangrove in this study provided support for the growth of A. annulipes. The information obtained from this study will be useful for future comparison between benthic crustaceans in mangrove environment.
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