Some population biology aspects of edible orange mud crab *Scylla olivacea* (Herbst, 1796) of Kotania Bay, western Seram District, Indonesia

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Abstract. Population biology aspects of the orange mud crab *Scylla olivacea* of Kotania Bay mangrove swamp, Western Seram District of Indonesia was investigated to derive information for its management. Sampling was carried out on a monthly basis during January to June 2016. The result showed that there was high correlation between carapace width and weight relationship (r = 0.9884) for both sexes. The large crabs have a carapace width greater than 10 cm, the weight of male is greater than that of female. The mud crabs of the carapace width size between 12-14 cm of both male and female accounted for the major catches while the smallest mud crab caught was 8.8 cm. The proportion of males to females sex ratio was not significantly different with a ratio of 1.14:1. The relative condition factor of this mud crab varied over time but not significantly different for both sexes.
Key Words: mud crab, population parameter, management, Maluku.

Introduction. Kotania Bay Waters of Western Seram District is a semi enclosed coastal area with high in marine resources productivity since surrounded by three main tropical ecosystems *i.e.* mangrove, coral reefs, and sea grass beds. Of these three ecosystems the mangrove ecosystem is the dominant one and consequently contributes immensely to its productivity. Some pelagic fishes (skipjack tuna, anchovy, mackerel), some molluscs (blood clam, mangrove oyster, terebralia), mud crab, echinoderms, and macro algae are all of economic and non economic value. These are an example of fish resources found in this area (Wouthuyzen & Sapulete 1994; DKP Kab. SBB 2014; Huliselan et al 2017).

Mud crabs of the genus *Scylla* are exploited both commercially and for subsistence by artisanal fishermen of the tropical Indo-Pacific regions including Terengganu, Malaysia (Mirera 2013), India (Sathiadhas & Najmudeen 2004), Western Seram (Tetelepta & Makatita 2012; Tetelepta et al 2017), and in Southeast Maluku (Fikri & Siahainenia 2017) of Indonesia. Market demand, monetary value, ease of capture, weak fisheries management and economic dependency on this product have led to over exploitation of this crustacean species (Le Vay 2001).

In Kotania Bay mud crabs of the genus *Scylla* commonly caught by local fishermen consist of three species i.e. *Scylla serrata*, *S. olivacea* and *S. paramamosain. S. serrata* is the dominant species followed by *S. olivacea.* This fishery has been conducted for more than 25 years and generates significant income to the local fishing community. The population of mud crabs is under threat and has continuously declined over years. The causes of this decline include the destruction and polluting of mud crab habitats, the over-exploitation and undersized catch of mud crab (Makatita 2012; Natan & Tetelepta 2013; Tetelepta & Makatita 2012; Tetelepta et al 2016).

Considering the importance of the mud crab fishery for local fishermen of Kotania Bay it is noteworthy that very little is known of its population biology or population structure. Less attention has been focussed on the ecological factors that may regulate the population structure of mud crabs. The capture of wild marketable size adults, if not well managed, may affect the stock recruitment. Thus, biological information on the population biology of commercial mud crab species is important for its future management and conservation purposes. This study will provide some important information on the size distribution, carapace width-weight relationship, sex ratio and condition factor of *S. olivacea* of Kotania Bay.

Material and Method. Mud crab samples were taken from the villages of Kotania, Wael and Masika Jaya, District of Western Seram (Figure 1). During spring tides all mud crabs caught by local fishermen were sampled and measured for external carapace width and body weight before being sold by fishermen. This study was conducted from January to June 2016 with two weeks interval sampling period. A total number of 284 individual mud crab were sampled and classified into male and female based on the morphology of the abdominal segment (Fisheries Fact Sheet 2013). Sex ratio was estimated per monthly sampling and for total observation. Chi-square test was used to determine if the proportion of males and females was significantly different from the 1:1 expected ratio with the probability level was set at 0.05 (Zar 1999; Fowler & Cohen 1990).

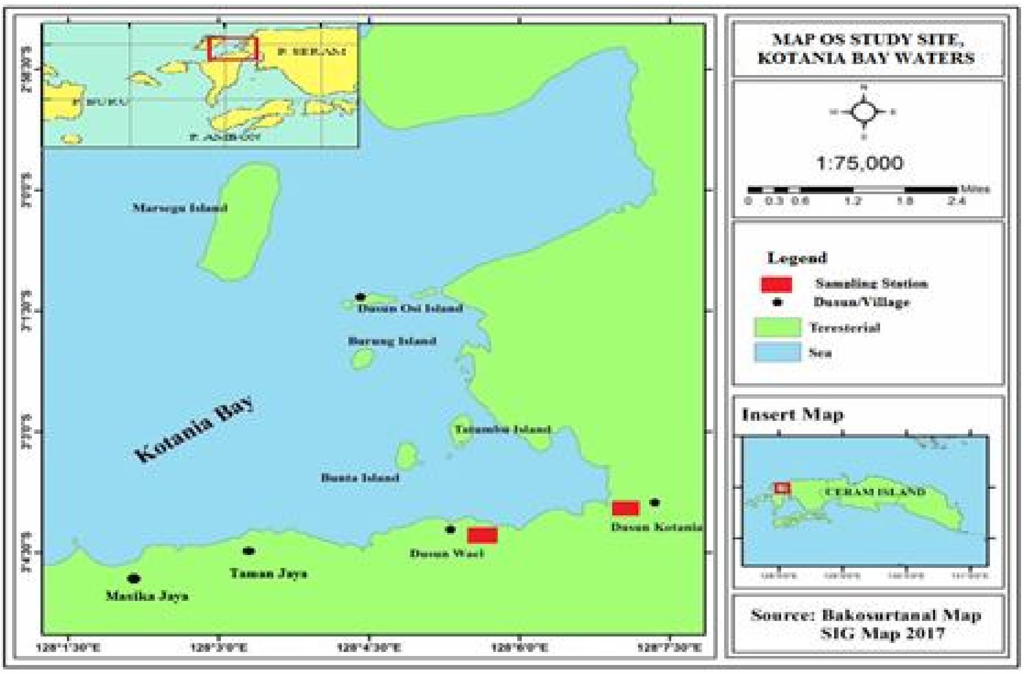

Figure 1. Map of Kotania Bay of Western Seram District showing the study site.

Carapace width-weight relationship of male and female mud crab was analysed using an analysis of variance (Zar 1999). The result will determine whether the analysis should be estimated separately by sex or whether both sexes should be combined. The carapace width relationship was subsequently calculated using the equation proposed by Sparre & Venema (1992) as follow:

$$W_{(i)} = qECW_{(i)}^{b}$$

where: $W_{(i)}$ = weight (g);
ECW = external carapace width (cm);
q and b = parameters.

The growth pattern of mud crab was determined based on *b* value whether it is isometric growth (b = 3) or allometric growth (b ≠ 3) using t-Student test based on Pauly (1984). The analysis was done in the computer software of Microsoft Excel Version 2010 with statistical difference were considered significant when p < 0.05. The test of regression coefficient between male and female mud crab was conducted through *t-test* according to Zar (1999) using the following formula:

$$t = \frac{b_1 - b_2}{S_{b_1 - b_2}}$$

where: b_1 = male regression coefficient;
b_2 = female regression coefficient;
S_{b1-b2} = pooled standard deviation.

Allometric and isometric growth pattern test of *b* coefficient was conducted following the formula suggested by Pauly (1984) as follows:

$$t = \left(\frac{sd\ x}{sd\ y}\right)\left(\frac{|b - 3|}{\sqrt{1 - R^2}}\right)\left(\sqrt{n - 2}\right)$$

where: t = student test;
sd x = standard deviation for carapace width;
sd y = standard deviation for weight;
b = regression coefficient;
R^2 = coefficient of determinant;
n = number of sample.

Sex ratio was estimated per sampling period according to Jirapunpipat (2008). A chi-square test was used to determine if the proportion of males and females were significantly different from 1:1, and the probability level was set at 0.05.

A factor being the condition of the mud crab was analysed based on relative condition factor (*Kn*) both for male and female and was estimated per sampling period. The formula for relative condition factor 'Kn' was calculated for each individual crab by dividing the observed weight by calculated weight. The mean Kn values were estimated for different sexes using the following formula (Bagenal & Tesch 1978; Froese 2006):

$$Kn = \frac{W}{W'}$$

where: K_n = relative condition;
W = weight observed;
W' = weight estimated.

Size frequency distribution was calculated based on percent class interval which was set to 1.00 cm carapace width for every period of observation. The result will then be plotted graphically and analysed descriptively according to Nicholas (1999).

Results and Discussion

Carapace width-weight relationship. The relationships between carapace width and weight for both sexes were significantly different (ANCOVA, $p < 0.05$). Small size male and female crabs with a carapace width below 10 cm have the same weight at the same carapace width size. However, in larger crabs with a carapace width greater than 10 cm, the weight of males is greater than that of females at the same carapace width size (Figure 2). This carapace width-weight relationship of this species has a strong relationship for both males and females with an R^2 value of 0.9962 and 0.9774, respectively. This relationship pattern was also found for the same species at Ranong Province, Thailand (Jirapunpipat 2008), Pichavaram mangrove, south-east India (Viswanathan et al 2016) and in Terengganu, Malaysia (Musa et al 2017).

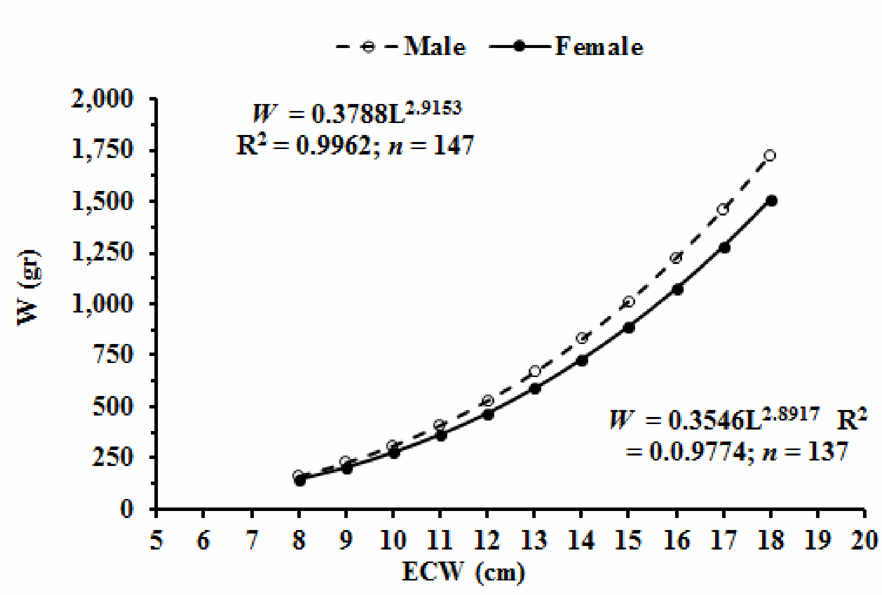

Figure 2. Carapace width-weight relationship of males and females of *Scylla olivacea*.

The *b* value for males and females were lower than 3 except for male mud crabs at May and June and for females at the June sampling period (Table 1). The *t* student test shows a negative allometric growth pattern ($p < 0.05$) both for males and females at all sampling periods. We found length increment was faster than weight increment except for male mud crabs in May and June, and female mud crabs in June ($p < 0.05$) demonstrating that length increment is faster than weight increment. Table 1 shows width-weight relationship, correlation coefficient (r) and coefficient of determination (R^2) for male and female mud crab. There is high correlation coefficient (*r*) between carapace width and weight both for males and females through-out the sampling period. A study by Waiho et al (2016) in Malaysian waters and another study by Viswanathan et al (2016) in Pichavaram mangrove of south-east India show negative allometric growth for females whilst positive allometric growth for males. A study by Musa et al (2017) shows a different growth pattern for different season. Female mud crabs have negative allometric growth during pre-monsoon (October) while males have positive allometric growth during pre-monsoon and negative allometric growth during post-monsoon (January). Site differences, season and food availability could contribute for these differences (Jirapunpipat 2008; Sentosa & Syam 2011; Musa et al 2017).

Table 1

Width-weight relationship of male (M) and female (F) mud crab *S. olivacea* per sampling period

Month	$W=aL^b$ *(M)*	*r*	R^2	$W=aL^b$ *(F)*	*r*	R^2
Jan.	$W=1.0078L^{2.6220}$	0.9971	0.9943	$W=0.3253L^{2.8401}$	0.9688	0.9386
Feb.	$W=0.8724L^{2.5835}$	0.9502	0.9029	$W=0.9418L^{2.6532}$	0.9993	0.9986
Mar.	$W=0.4283L^{2.8396}$	0.9974	0.9949	$W=0.2207L^{3.0970}$	0.9995	0.9990
Aprl.	$W=0.2880L^{2.9502}$	0.9992	0.9985	$W=0.2014L^{3.0821}$	0.9568	0.9155
May	$W=0.2781L^{3.0499}$	0.9968	0.9938	$W=0.3421L^{2.9687}$	0.9987	0.9975
Jun.	$W=0.2411L^{3.1228}$	0.9983	0.9967	$W=0.2378L^{3.1490}$	0.9984	0.9970

Size frequency distribution. The size distribution of male mud crabs ranged from 8.8 to 17.8 cm with the average size caught being 13.6 cm carapace width. For female crabs sizes ranged from 9.8 to 17.2 cm with an average size of 13.5 cm carapace width (Figures 3 and 4). The size distribution of both sexes was similar throughout the study period and the size most commonly caught between 12.0 and 14.0 (21.44%) whilst mean size caught was 13.5 cm for both males and females.

A study by Jirapunpipat (2008) at Klong Ngo mangrove swamp, Thailand, found size frequency distribution of this species ranged between 4.0 and 15.4 cm whilst Waiho et al (2016) at Malaysian waters found size distribution between 4.7 and 13.4 cm carapace width. Musa et al (2017) found size frequency distribution between 6.7 to 11.2 cm. Most of *S. olivacea* caught at Kotania Bay during sampling period were comprised of quite large size individuals compared to the same species found in Buswang, Philippines (Walton et al 2006); Klong Ngo, Thailand (Jirapunpipat 2008) and Malaysia (Waiho et al 2016; Musa et al 2017) and Eastern Gulf of Thailand (Koolkalya et al 2016).

Sex ratio. The total number of orange mud crab sampled throughout all sampling period were 147 males and 137 females. There is no difference in sex ratio (X^2 test: p: 0.05) for different sampling periods with an overall sex ratio of 1.14:1. Table 2 shows monthly sex ratio of orange mud crab from Kotania Bay.

Table 2

Monthly and total sex ratio of orange mud crab *S. olivacea* of Kotania Bay

Month	*Male*	*Female*	*M/F*	X^2
January	21	17	1.24:1	0.4211
February	24	16	1.50:1	1.6000
March	34	27	1.26:1	0.8033
April	20	23	0.87:1	0.2093
May	25	20	1.25:1	0.5556
June	27	29	0.93:1	0.0714
Total	151	132	1.14:1	1.2756

The sex ratio of orange mud crab could differ over time as found by Musa et al (2017) where in pre-monsoon the sex ratio was 1:1 whilst in post-monsoon the sex ratio change to 3:1 of males to females. Jirapunpipat (2008) found the overall sex ratio was 1.3:1. The seasonal trends in sex ratio may be linked with migration patterns; in particular, the offshore migration of mature females for spawning (Jirapunpipat 2008; Ogawa et al 2012).

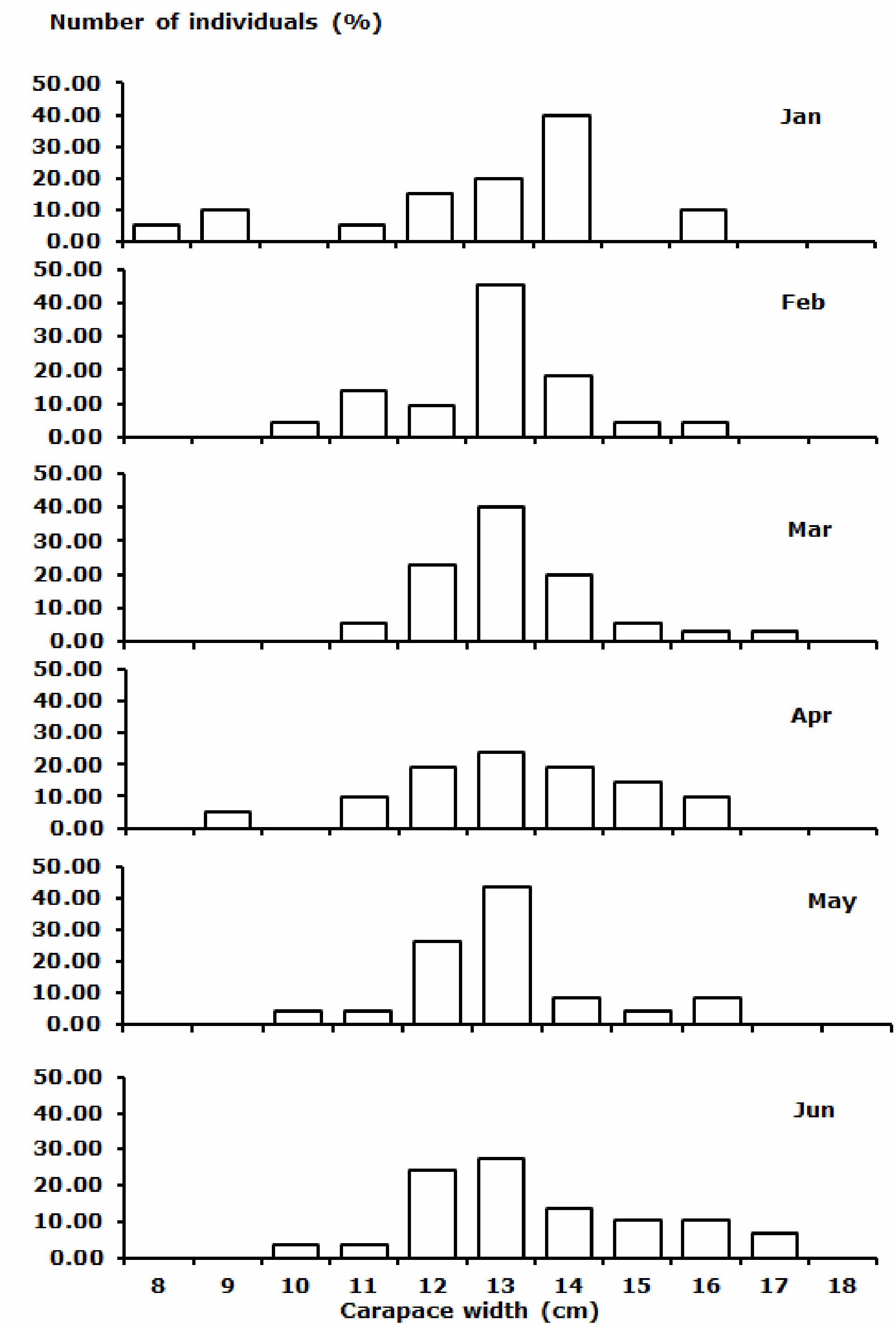

Figure 3. The percentage of size frequency of male *Scylla olivacea* caught from January to June 2016.

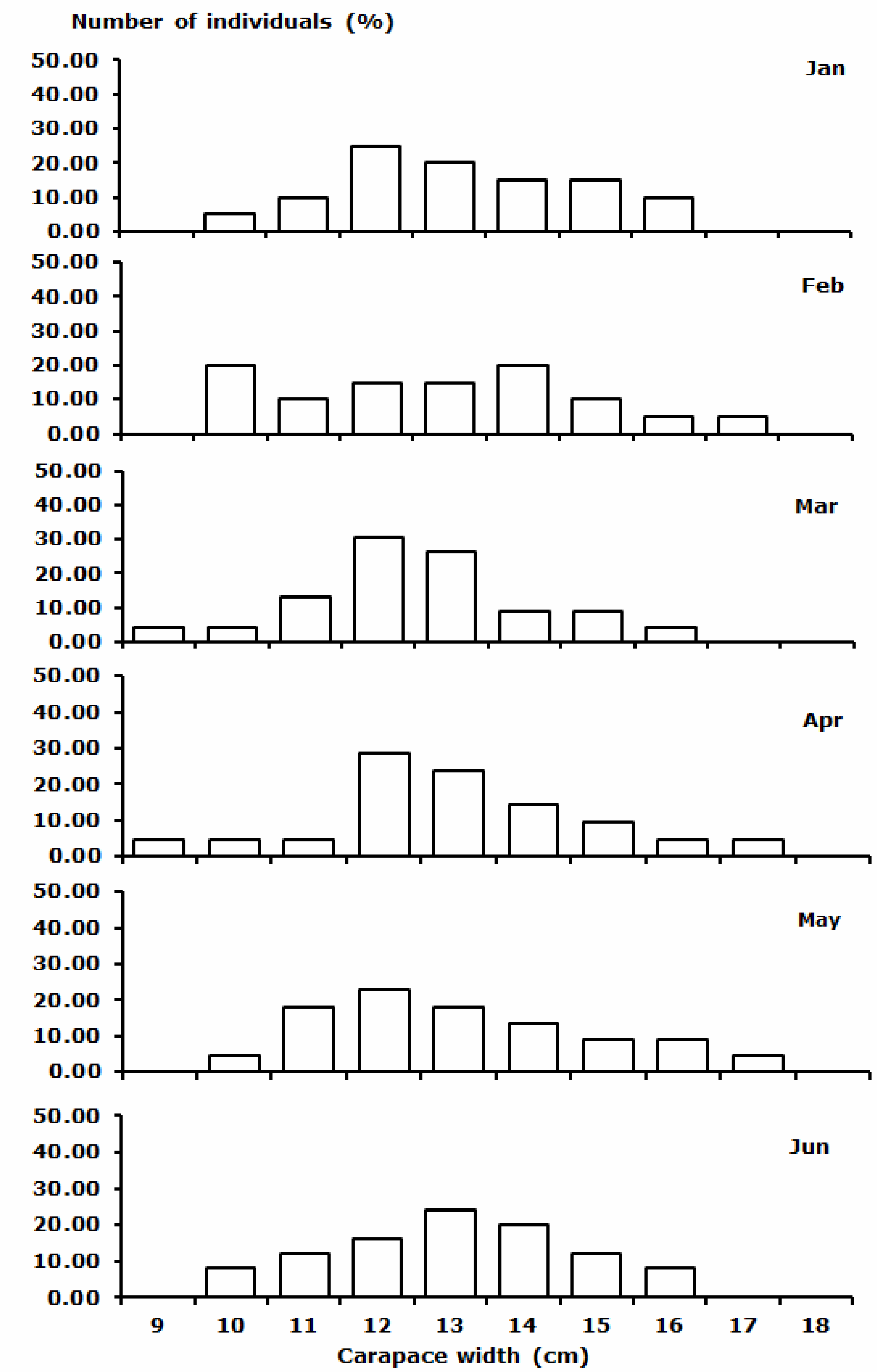

Figure 4. The percentage of size frequency of female *Scylla olivacea* caught from January to June 2016.

Condition factor. The relative condition factor of orange mud crab was evaluated for each sampling period and for both sexes (Figure 5). The condition factor for this species followed the same pattern by both males and females. A fluctuation in condition factor occurs over time and varied between 0.9993-1.0085 for males and between 0.9983-1.0082 for females but not significantly different between sexes ($t_{stati\ (-0.6332)} < t_{(\alpha 2):2.2281}$).

The study by Jirapunpipat (2008) on the same species found a variation of the relative condition factor over time with maximum values of 0.3904 in July for females and for males it was maxium at 0.1421 in September. Musa et al (2017) found variation in the condition factor between pre-monsoon and post-monsoon. In pre-monsoon and pos-monsoon *Kn* value for females mud crab ranged from 0.017 to 0.021 and 0.16 to 0.19 respectively, whilst male mud crabs ranged from 0.17 to 0.24 and from 0.16 to 0.25. Condition factor can be used as an indicator of individual fatness (Bagenal & Tesch 1978). Variation in *Kn* values can be affected by natural food abundance and reproductive condition of the animal (King 2007).

This present study shows *Kn* values of *S. olivacea* from this area was higher than what was found by Jirapunpipat (2008) from Klong Ngao mangrove swamp, Thailand and from Terengganu, Malaysia (Musa et al 2017). Carapace length size distribution from this study was also larger from those two studies, which could explain this difference.

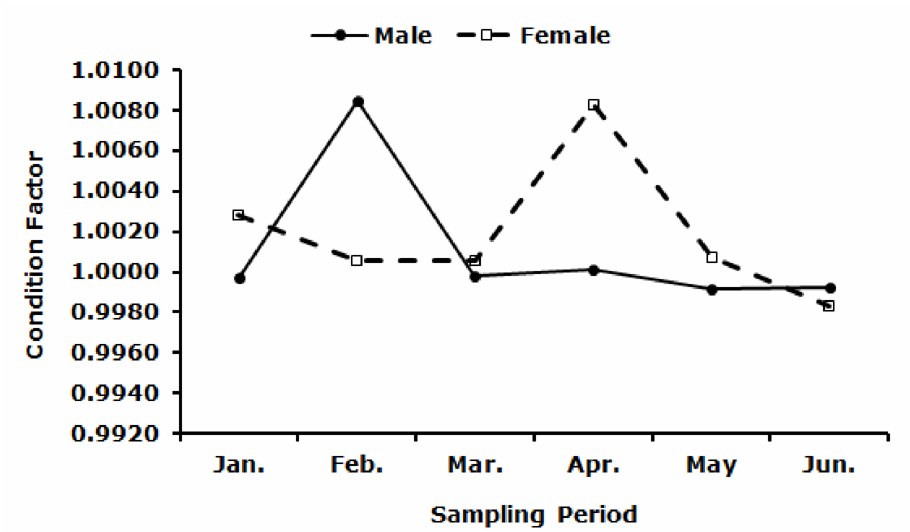

Figure 5. Monthly change of condition factor of male and female *Scylla olivacea*.

Conclusions. Carapace width-weight relationship of orange mud crab *S. olivacea* of Kotania Bay showed a high corelation (r = 0.9884) for both sexes with males having higher weight at carapace width over 10.0 cm. There was no difference between overall sex ratio of males and females and between sampling periods. The overall smallest orange mud crab caught was 8.8 cm carapace indicating first recruitment to the trap fishing started at this size whilst the carapace width size range between 8.8 and 17.6 cm. The size frequency distribution of *S. olivacea* shows that carapace width between 12-14 cm was the dominant size (60.60%) caught in this fishery. The relative condition factor varied between month but was not statistically different. These findings could facilitate the local agencies to impose the fishery regulation of mud crabs of Kotania Bay particularly of under-sized crabs for sustainable stock management of this fishery.

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