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COMPARISON ON NATURAL DIETS DIETARY COMPOSITION AND FOREGUT FULLNESS BETWEEN SEXES OF CRENATE SWIMMING CRAB, *Thalamita crenata* (RÜPPELL, 1830) FROM SETIU WETLANDS, TERENGGANU COASTAL WATERS, MALAYSIA

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Abstract: This study describes the natural diets of the crenate swimming crab, *Thalamita crenata* through observation on parameters for dietary composition between different sexes. A total of 30 pairs of *T. crenata* males and females were sampled from Setiu Wetlands, Terengganu, Malaysia. A significant difference ($\rho < 0.001$) was observed between body weight and the sex of *T. crenata*. Foregut fullness analysis revealed that males have a higher percentage of index score 4 than females (36.66% and 26.67%, respectively). A total of 12 different dietary items were identified in both sexes of *T. crenata*. Fish (male: 18.8%; female: 16.7%) and bivalve (male: 14.6%; female: 16.7%) were recorded as the most abundant in foregut content of both sexes of *T. crenata*. Gut content analysis reveals that *T. crenata* is a generalistic predator, cannibalistic and omnivorous as its diet is mainly composed of fishes, bivalves, slow-moving crustaceans and plants like seagrass and thus indicates their main food source. Overall, males possessed higher mean frequency of BW compared to females with 78.47 ± 17.66 g and 55.86 ± 14.48 g, respectively. No significant difference of food preferences was noted between the different genders and between the size of the crab (BW) with the mean fullness and dietary composition of *T. crenata.* This finding helps in understanding the dietary composition of different sexes of *T. crenata* and thus can be a reference focusing on this species population dynamics and ecology study mainly for management purposes and artificial diet development for the near future.

Keywords: Body weight, crenate swimming crab, dietary composition, foregut fullness, *Thalamita crenata*.

Introduction

Crenate swimming crab, *Thalamita crenata* also known as rocky spiny crab (Songrak *et al*., 2009) is commonly found in mangrove creeks (Muhd-Farouk *et al*., 2017) and shallow waters of the Indo-Pacific region (Cannicci *et al*., 1996). These crabs inhabit the rocky and muddy intertidal platform in front of the *Sonneratia*-fringe and swim in the swamps during their activity period (Vezzosi *et al*., 1995; Songrak *et al*., 2009; Muhd-Farouk *et al*., 2017). Such behaviour was also observed in mud crab, genus *Scylla* (Hill, 1979; Ikhwanuddin *et al.,* 2010; 2011; Amin-Safwan *et al.,* 2016) and other swimming crabs of the Indo-Pacific region (Cannicci *et al*., 1996). *T. crenata* can be found in South Africa, Madagascar, the Red Sea, the Persian Gulf, India, China, Indonesia, Malaysia, Singapore, Korea, Japan, Australia, Tuamotu, Tonga, Hawaii and French Polynesia (Wee & Ng, 1995). This species is fished mainly in the Southeast and East Asian countries and are frequently caught by trawlers, traps, seines and nets. Collapsible traps are also widely used by fisherman for collecting mud crab, especially in Malaysia (FAO, 2001). Although *T. crenata*

is one of the most common and widespread swimming crab species, little research has been done on this species or others within the genus (Vezzosi *et al*., 1995), mainly due to lower market value as it is small in size compared to the other commercial swimming crabs (Muhd-Farouk *et al*., 2017). However, due to its flesh quality and more abundant compared to mud crab (Muhd-Farouk *et al*., 2017), this species is favoured by the local community as a source of protein for their daily meals. As for their landing, there is no data recorded previously, thus proven that no in-depth study has been done on this species.

T. crenata can be classified as carnivorous and a predator. Its diet is mainly composed of bivalves and slow-moving crustaceans (Cannicci *et al*., 1996). Nonetheless, it also appears to be omnivorous as algae, seagrasses and other plant materials found in their stomachs (Cannicci *et al*., 1996). Moreover, cannibalism is common as the larger crabs feed on the young smaller crabs. Though *T. crenata* is known to be a predator, omnivorous and eats almost everything, the diet can still be influenced by the habitat that they are living in, gender (sexes), maturity stage, seasons and their activity period (Sigana, 2002; Hajisamae *et al*., 2015). Songrak *et al*. (2009) claimed that *T. crenata* activity period between sexes were different, where males favoured burrowing while females preferred swimming to search for their prey and both sexes were basically most active during the day (Chen *et al*., 2005).

The present study on natural diets of *T. crenata* focused on dietary composition and foregut fullness. The data obtained can be helpful in understanding the feeding habits between sexes and also for fisheries management of *T. crenata*. The information on the foregut fullness and dietary composition relationship is important to understand the feeding habit and nutritional requirement between male and female *T. crenata*. Up to now, only a handful studies have been available that have focused on *T. crenata* , which were carried out by Cannicci *et al.* (1996) and Mckillup and Mckillup (1996) have investigated on *T. crenata* natural diets and feeding habits, while, Songrak *et al.* (2009) focused on fishery biology of *T. crenata*. Susanto and Irnawati (2014) and Muhd-Farouk *et al.* (2017) studied on size at maturity and length-weight and width-weight relationship, while Kannupandi *et al*. (1997) focused on water parameter (salinity) on larvae and Sigana (2002) conducted a study on breeding cycle of *T. crenata*. This species is common in the Malaysian coastal waters, but still there is scarce information, thus further investigations are needed on natural diets of *T. crenata*. Knowledge of natural diet in animal species is generally essential to study to know their nutritional requirements, their interactions with other organisms and their culture potential (Williams, 1981), besides for evaluation purposes and functioning of the ecosystems (Krebs, 1989). The knowledge gained can support the expansion in terms of production and economy for this species in the near future. Therefore, the investigation on natural diet on *T. crenata* is critical to understand the behaviour and food preference between sexes of *T. crenata*, which is important to develop successful aquaculture and farming techniques for this species (Ikhwanuddin *et al*., 2009). Besides, the knowledge on the foregut fullness and the dietary items found can be used as pioneer research towards in-depth understanding on this particular species. Therefore, the objectives of this study were to determine the natural diets of *T. crenata* through dietary composition and foregut fullness and to compare the body weight and foregut fullness among different sexes of *T. crenata* from Setiu Wetlands, Terengganu Coastal Waters, Malaysia.

Materials and Methods

Crab samples and sampling technique

T. crenata samples were from Setiu Wetlands, Terengganu, Malaysia and obtained at two sampling stations**:** Sampling Station 1 (S1) and Sampling Station 2 (S2) (Figure 1), from April until June 2017 and the frequency for sampling

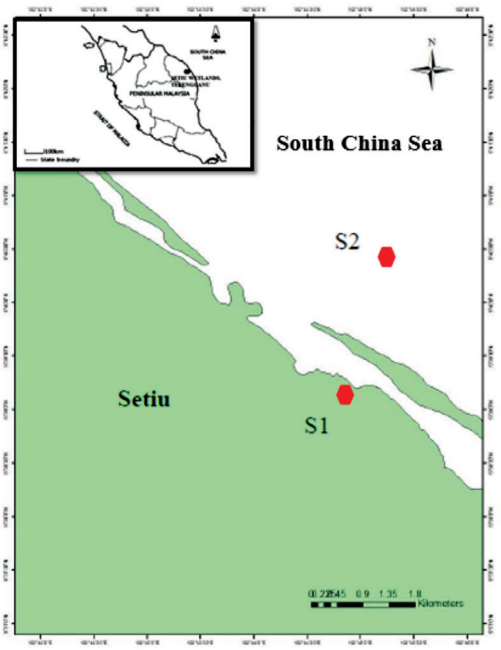

Figure 1: The sampling stations at Setiu Wetlands, Terengganu, Malaysia (S1 = Sampling Station 1 (Latitude: 5.69º; Longitude: 102.72º) and S2 = Sampling Station 2 (Latitude: 5.65º; Longitude: 102.75º)

was two days every week (Friday and Saturday). Setiu Wetlands is located along the coast facing the South China Sea in the state of Terengganu. It is located 60 km north of Kuala Terengganu. Setiu Wetlands is one of the most important wetlands in Malaysia as it has mangrove areas and salt marsh (Sigana, 2002) that are rich in biodiversity.

A total of 30 males and 30 females of the crab species *T. crenata* were sampled to identify and differentiate the dietary items in the foregut (Figure 2) using the crab collapsible traps. Crab collapsible trap is a traditional mud crab trap that is simple but a very effective equipment which is used to trap mud crabs (Poomikong *et al.,* 2005). No bait was used during sampling to avoid bias in gut content analysis. Thirty collapsible traps were used during the biosampling of *T. crenata*. The collapsible traps were deployed in the evening between 1600-1800 hours and left

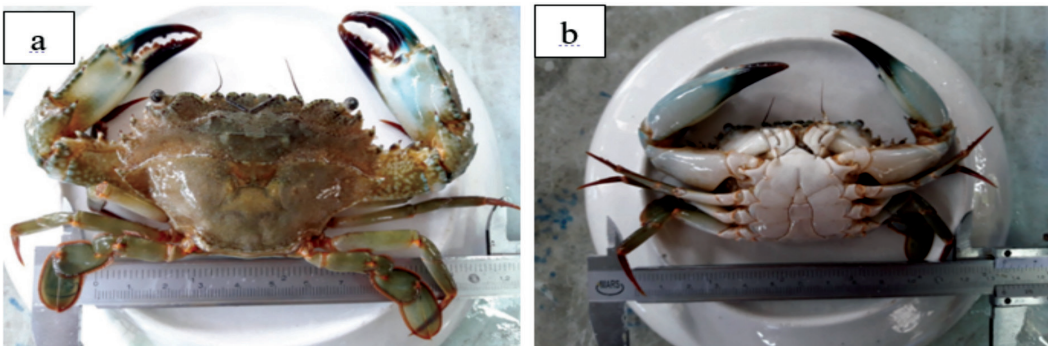

Figure 2: The dorsal (left) and ventral (right) view of *T. crenata* which was sampled from Setiu Wetlands, Terengganu, Malaysia

overnight and collected early the next morning (0800-0900 hours).

The crabs captured in the collapsible traps were then immediately transferred and frozen in an ice-chest (less than 1 hour) for physical measurement. The crab body weights (BW) and carapace width (CW) were measured using an electronic balance (Shimadzu, Japan, 0.001 g) and digital Vernier calliper (0.01 cm), respectively, according to the sexes of the crabs. The sex can be differentiated by observing the abdominal flap that is also known as an apron (Widigdo *et al.,* 2017). Male crab has a triangular like shape of an apron (narrower), while female crab possesses a broader shape (Figure 3).

Foregut Fullness

The carapace of the crab was directly opened to remove foregut for analysis of the foregut fullness and dietary composition. The foregut was handled in the most delicate way as the foregut is fragile and easily damaged. The fullness of the foregut was observed and recorded using the index of 1 to 4 (1 = 0-25% foregut fullness, 2 = 25-50% foregut fullness, 3 = 50-75% foregut fullness and 4 = 75-100% of foregut fullness) (Ikhwanuddin *et al.*, 2014) (Figure 4). After the fullness index is completely identified, each foregut was fixed in formalin, in 50 ml conical centrifuge tube (Falcon™) for seven days, followed by soaking in freshwater overnight and stored in 70% ethanol (Kunsook *et al*., 2014; Hajisamae *et al*., 2015) before proceeding with subsequent analysis.

Dietary Analysis

Individual foregut specimen was cut open in a petri dish using surgical ocular scissors and observed under a dissecting microscope to identify the dietary item (Ikhwanuddin *et al.,*

Figure 3: The figure (a) shows the apron of male, while figure (b) shows the apron of female *T. crenata*, (c) berried female crabs sampled from Setiu Wetlands, Terengganu, Malaysia

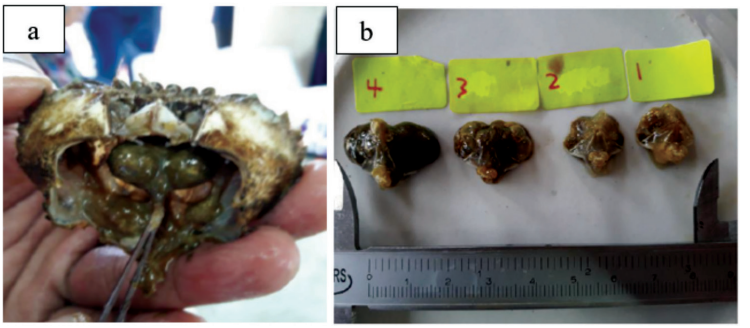

Figure 4: (a) The carapace of the crab was directly opened up to remove the foregut for the analysis, (b) The fullness of the foregut index of 1 to 4 (1 = 0-25% foregut fullness, 2 = 25-50% foregut fullness, 3 = 50-75% foregut fullness and 4 = 75-100% of foregut fullness)

2009). The dietary items were recorded and identified to the lowest possible taxanomic level. Various dietary items found in the foregut were allocated according to the different categories, such as sea star, oyster, fish, crab, bivalve, gastropod, seagrass and marine debris (De Lestang *et al*., 2000). The dietary item that cannot be differentiated was classified into the unidentified dietary item (Nesakumari & Thirunavukkarasu, 2014). The list of dietary compositions was formed and differentiated between that of the female and male. The number of occurrences for each dietary category found in the foregut were recorded for calculation of relative composition by volume of food (De Lestang *et al.,* 2000; Porter & De Lestang, 2002).

Data Treatment

The data were analysed for volumetric contribution, which is the percentage contribution to the volume of all dietary items present in each of the non-empty stomachs (Hajisamae *et al*., 2015). The percentage volumetric contribution of each dietary category to the total volume of the diet (%V) of each *T. crenata* was expressed using the point method, which considered the stomach fullness (Hyslop, 1980; De Lestang *et al*., 2000). The practical method to analyse the amount of each food item in each gut as referred to that of Hajisamae *et al*. (2015) and methods modified from Platell and Potter (2001) i.e. by evenly spreading the contents from each gut into the counting chamber and examining under a dissecting microscope. The area occupied by each food item in the chamber was converted into percentage of each food item.

Trophic attributes are referred to the indices that describe the status and expression of the importance of each prey item in the diets of fish species (Hyslop, 1980). The indices using in the present study as referred to Hajisamae *et al.* (2015) included: Vacuity Index (VI) - the number of empty stomachs as a percentage of the total number of stomachs examined; average number of food items refers to the average number of food item found in each stomach; and diet breadth (B_i) which is calculated using Levin's standardized index (Krebs, 1989). Below is the formula used to calculate the index:

$$B_i = [\frac{1}{n-1}] [(\frac{1}{\sum_{i,j=1}^{n} P^2 ij}) -1]$$

Where, Bi = Levin's standardised index for predator I; P_{ij} the proportion of the diet of predator I that is made up of prey j; n is the number of prey categories (Hajisamae *et al.,* 2015)

Diet overlap was calculated using the simplified Morisita index or Morisita-Horn index (Horn, 1966). Classification and definition of the rate of overlap were referred to Langton (1982) and Hajisamae *et al.* (2015), where low overlap is 0.00-0.29, moderate overlap is 0.30-0.59 and high overlap is 0.60-1.00, biologically significant. The formula for the Morisita-Horn index is as below:

$$C_{\mathrm{H}} = \frac{2(\sum Pij\ Pik)}{\sum P^2 jj + \sum P^2 ik}$$

Where, C_{H} is the Morisita-Horn index of overlap between species i and k, P_{ij} referred to the proportion of food i of the total food used by species j, P_{ik} is the proportion of food i of the total food used by species k and n the total number of food items (Hajisamae *et al.*, 2015).

Statistical Analysis

Analysis of variance (ANOVA) was used to test whether stomach fullness varied significantly amongst sizes and sexes and the relationship of dietary item and foregut fullness was analysed by using Non-parametric Independent-Samples Mann-Whitney U Test. The analysis of volumetric contribution, trophic attributes and diet overlap were done. Data were presented as mean, mean ± standard deviation and percentage (%). This statistical analysis was done using application of Social Science (SPSS) software (version 22.0 for Windows; SPSS Inc., Armonk, NY: IBM Corp.).

Results

Food and Dominant Food Items

There were 24 out of 30 female crabs and 26 out of 30 male crabs which had the foregut fullness index of 2, 3 and 4. The foregut fullness index of 1, in range of 0-25% of fullness was not further analysed as it was considered having an empty stomach (Ikhwanuddin *et al*., 2009), while the foregut fullness index of 2, 3 and 4 were further observed for the dietary composition analysis. There were 12 different dietary categories found in the foregut of the crab specimens from both females and males. The number of frequencies of each type of dietary item found in the foregut of crab was recorded to calculate the relative composition in the diets of crabs. The dietary composition analysis revealed that fish and bivalve were the most preferred food items both for female and male crabs as these dietary item categories were most dominant in the foregut of the crab samples with the same contribution of 16.7% of both fish and bivalve were found in female foregut, while 18.8% of fish and 14.6% of bivalve were found in the foregut of male *T. crenata* in the present study. Details of diet composition for males and females of *T. crenata* are presented in Table 1.

Dietary Attributes

From 30 samples of male crabs examined, 26 of them contained food (SF; number of stomach with food) with vacuity index (VI), average stomach fullness (FL), average number of food items (AF), total number of food items (TLF) and diet breadth (B_i) of 13.33, 2.83 ± 1.12, 2.83, 12 and 0.38, respectively. For female crabs, SF, VI, FL, AF, TLF and B_i were 24, 20, 2.63 ± 1.09, 2.63, 12 and 0.49, respectively. Results of dietary attributes for male and female crabs collected were analysed and shown in Table 2.

Foregut Fullness with Body Weight (BW) Relation Analysis

The foregut content analysis showed that 20.00% of female (100% in berried stage) and 16.67% of male were in foregut fullness index of 1, ranging from 0-25% foregut fullness. 23.33% of female (57.14% in berried stage) and 20.0% of male with the foregut fullness index of 2 which was ranged from 25-50% foregut fullness. 30.00% of female and 26.67% of male with the foregut fullness index of 3 which was ranged from 50-75% foregut fullness and 26.67% of female and 36.66% of male crabs were recorded with foregut fullness index of 4 which was ranged from 75-100% foregut fullness. Berried females

Table 1: Relative composition by volume of food from foregut content of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia (60 crabs; 30 males and 30 females)

Sex	SS	OY	FH	CP	CH	PR	BV	GS	SG	MD	UI	OT
Female	4.8	0.0	16.7	11.8	2.4	2.4	16.7	14.3	7.1	7.1	14.3	2.4
Male	0.0	6.2	18.8	10.4	2.1	4.2	14.6	10.4	6.3	10.4	8.3	8.3

Abbreviations: SS, sea star; OY, oyster; FH, fish; CP, crab pincer; CH, crab hepatopancreas; PR, propagule; BV, bivalve; GS, gastropod; SG, seagrass; MD, marine debris; UI, unidentified; OT, others.

Table 2: Trophic attributes of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia

	No. of samples	CW ± SD	BW ± SD	FL ± SD	TLF	AF	SF	VI	B_i
Female	30	6.07 ± 0.60	55.86 ± 14.48	2.63 ± 1.09	12	2.63	24	20	0.49
Male	30	6.78 ± 0.62	78.47 ± 17.66	2.83 ± 1.12	12	2.83	26	13.33	0.38

were recorded only in index 1 and 2. Table 3 showed the foregut fullness range according to sexes of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia in the present study.

From the total of 60 samples observed, 30 specimens of female and male of *T. crenata* were collected for the foregut content analysis. It was observed that the highest range of body weight was 110-130 g, where this range has the highest mean fullness of 4 for male, while the lowest mean fullness of 1 for female (in berried stage) (Figure 5). Overall, the males possessed higher mean frequency of BW compared to the females with 78.47 ± 17.66 g and 55.86 ± 14.48 g, respectively. Results from the present study also indicated the presence of 10 berried female (carrying eggs), representing 33.33% of the total number of female crabs. A significant difference ($\rho < 0.001$) was observed between body weight and the sexes of *T. crenata* (Table 4). The test for Independent samples showed that the mean BW for the male crabs was higher than that of the female crabs. The Test for Non-parametric

Table 3: Foregut fullness range according to sexes of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia

Foregut Fullness	Female	Male
1 (0-25%)	20.00% (100% berried female)	16.67%
2 (25-50%)	23.33% (57.14% berried female)	20.00%
3 (50-75%)	30.00%	26.67%
4 (75-100%)	26.67%	36.66%

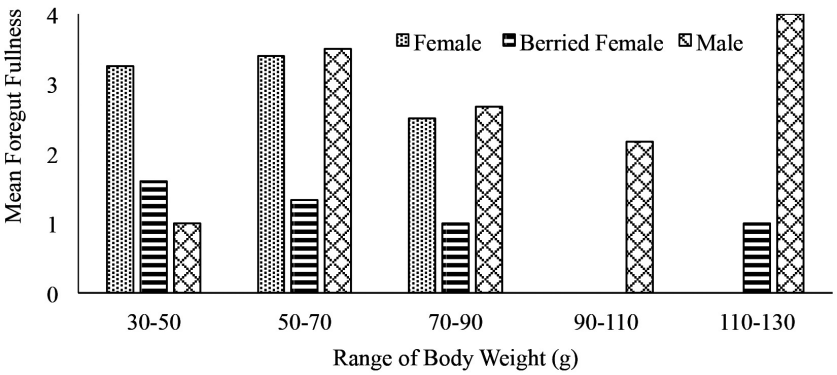

Figure 5: Mean foregut fullness index of *T. crenata* with different body weight range sampled from Setiu Wetlands, Terengganu, Malaysia (n=60)

Table 4: Result of ANOVA test between body weight with sexes, fullness and sexes and fullness of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Gendercode	.294	1	.294	27.912	.000
Fullness	.007	3	.002	.234	.872
gendercode * fullness	.025	3	.008	.777	.512
Error	.548	52	.011		
Total	.908	59			

a. R Squared = .397 (Adjusted R Squared = .316)

in Independent-Samples Mann-Whitney U Test showed there was no significant difference between the foregut fullness index of both female and male crabs ($\rho > 0.05$).

Dietary Overlap

Out of total 60 crabs examined, only six of them (10%) have value > 6.0, considered to be biologically significant overlap of food resources utilized by *T. crenata* (Table 5). The remaining were low overlap (0.00-0.29) with 53.33% and moderate overlap (0.30-0.59) with 36.67%. As for different sexes, male and female crabs, out of 30 crabs examined, only three of them had value > 6.0, indicating significant overlap of diets.

Discussion

Comparison of T. crenata Dietary Composition

The results of the present study showed the dietary comparison of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia, consisting of varieties of sessile and slow-moving invertebrates, including bivalves such as oyster, gastropods, sea star and crabs (proven by pincers and hepatopancreas found in their gut) fishes, propagules, seagrass, marine debris and others materials such as rocks, sand and wood. This dietary composition is almost similar to the dietary composition reported by Cannicci *et al.* (1996) in mangrove swamps of Kenya, which pointed out that *T. crenata* is a scavenger and a generalistic predator which consumes largely small invertebrates such as bivalves, gastropods, foraminifera, fish and polychaete. The diet of *T. crenata* is also quite similar to the mud crab, *Scylla serrata* (Hill, 1979), blue swimming crab, *Portunus pelagicus* (Ikhwanuddin *et al*., 2009; 2014; Hajisamae *et al*., 2015) and alien blue swimming crab, *Portunus segnis* (Safaie, 2016), where it feeds largely on small invertebrates. Besides, previous studies on food and feeding of mud crab, genus *Scylla* by Hill (1976), Prasad *et al.* (1984), Joel and Sanjeevaraj (1986) and Prasad and Neelakantan (1988) reported that they feed largely on mollusc, crustaceans and fish which are quite similar to the feeding habits of *T. crenata* found in the present study.

The locations inhabited by *T. crenata* do influence the food preferences of this species, as supported by Hajisamae *et al.* (2015) on *P. pelagicus*. As *T. crenata* inhabits extreme seaward fringe of mangrove swamps, it prefers intertidal platform in front of the *Sonneratia* fringe (Muhd-Farouk *et al*., 2017) and sometimes shelters itself in the small pool during low tide, so their food compositions comprise organisms that inhabit those areas. According to Cannicci *et al*. (1996), polychaetes are commonly found in the diets of *T. crenata* and other mud crabs' species as they inhabit muddy area, however, they are easily digested and hardly seen and identified under microscope. The mollusc species such as bivalves, oysters and gastropods are mostly found in the foregut of the *T. crenata*, but the gastropods are less likely to be found compared to other mollusc species – postulated that they are easily digested compared to the others, besides being covered by mud and hard to be recognized. The bivalves were identified based on the fragment of shell which remained in the foregut and were found crushed by the teeth of the crab (Nesakumari & Thirunavukkarusu, 2014). Sea stars are also shown to be in the diets of *T. crenata*. This is expected as these crabs also inhabit estuarine which has higher salinity compared to the mangrove area where it is near to the sea (Alongi & Sasekumar, 1992). It is observed that crabs have long, slim

Table 5: Percentage number of samples referred to Morisita-Horn indices for dietary overlap analysis of *T. crenata* sampled from Setiu Wetlands, Terengganu, Malaysia

	No. of samples	0.00-0.29	0.30-0.59	>0.6
All	60	53.33%	36.67%	10%
Female	30	56.67%	33.33%	10%
Male	30	50.00%	40.00%	10%

and sharp toothed chelae with a relatively high proportion of fast contracting muscles that are well adapted for the rapid snapping movements for capturing fast moving organism such as fish (Joel & Sanjeevaraj, 1986). This explained the finding of the fish bones in the diets of crabs in the present study.

Dietary Composition in Relation to Sex

Results showed that fish and bivalve were the most preferred by both female and male of *T. crenata* in the present study. Although fish and bivalves remained as the most preferred diets, there was a slight difference of food preference shown between female and male of *T. crenata,* whereby the most preferred dietary items for female were fish and bivalve, both with the percentage of 16.7%, followed by gastropods (14.3%) and crab pincer (11.8%), while for male crabs, the most preferred was fish (18.8%), followed by bivalve (14.6%), crab pincer (10.4%), gastropod (10.4%) and marine debris (10.4%). The present study showed that the males have higher foregut fullness of index 4 (36.66%) as compared to the females of which the highest was at foregut fullness of 3 (30.0%) which is different from the findings of a previous study by Ikhwanuddin *et al*. (2014) on *P. pelagicus*. The foregut fullness index 4 was recorded mainly from the females in that previous study and the mean foregut fullness index of female *P. pelagicus* was also greater than those of male *P. pelagicus*. However, the foregut fullness index was not affected by the sex of *P. pelagicus* (Ikhwanuddin *et al.,* 2014).

The trend in the present study showed that the male crabs consumed more food as compared to the female crabs. The result in the foregut fullness of the *T. crenata* between sexes in the present study was different from a previous study by Cannicci *et al.* (1996), where they reported that female BW was usually larger than the male crab as the female crab was more active in hunting for its prey. This might be due to the male crabs staying often in the burrows and had slower metabolism since they did not move around as much as the females to hunt for their prey. Besides, the larger male crabs had a greater opportunity to capture larger and prey of different types. The larger body size of the crab might have led to cannibalism during food limitation where larger crabs would usually feed on young smaller crabs (De Lestang *et al*., 2000). The present study also showed that crab hepatopancreas and crab pincer were mostly found in the larger crab. Crab hepatopancreas was mostly found in female *T. crenata* (CW > 6.00 cm, BW > 56 g), whereas the crab pincer was mostly been found in male *T. crenata* (CW > 6.67 cm, BW > 69 g).

Table 1 shows the differences between the male and female of *T. crenata,* in terms of types and quantity of food consumed and this is supported by previous finding by Safaie (2016) on *P. segnis*. The food that was consumed by the male and female did not give much difference in percentage of dietary categories in the crabs sampled. Results in the present study were quite like those of the previous studies by Ikhwanuddin *et al.* (2009; 2014) and Josileen (2011) on *P. pelagicus*, which reported that there was no difference in the quantity of the food consumed by different sexes of *P. pelagicus*. The identification of the food items in the foregut will contribute to the feeding formulation of *T. crenata* for aquaculture activity. *T. crenata* has a high commercial value in some countries such as Taiwan, China and Japan, but not in Malaysia. In the future, *T. crenata* commercial values may continue to increase, thus, the best technique in aquaculture activity could be plotted based on the findings of the present study. For example, previous studies by Ikhwanuddin *et al.* (2009; 2014) on *P. pelagicus* have been referred to for formulating the food pellets, which have high commercial value in Malaysia.

Foregut Fullness in Relation to Body Weight

Williams (1981) reported that diet composition changed a bit with the size of the crab although within broad taxonomic groups, where prey species change with the crab size. However, Edgar (1990) discovered an absence of size-related change in the diets of crab. The trend

in the previous study by Williams (1981) was similar with the present study, where the larger crabs have the highest fullness. As shown in Figure 5, the males of *T. crenata* which have the highest BW were in the range of 110-130 g and having the highest mean of the foregut fullness of 4 compared to other weight, while females have the lowest mean fullness of 1 at the range of BW of 110-130 g. This might be due to the influence of female maturity stage where from our observation, 33.33% of female crabs collected were at the last maturity stage (berried stage - carrying eggs), where they consumed less food, as reported by Hajisamae *et al.* (2015) and Safaie (2016) on *P. pelagicus* and *P. segnis*, respectively.

Cannicci *et al.* (1996) reported that female BW was usually larger than the male crab as the female crab was more active in hunting for its prey, while male crab preferred burrowing to hunt their prey. However, the present study recorded a different trend as the female has a lower foregut fullness and BW as compared to the male. This trend was likely related to the female maturation stages, where during the last stage of female maturity, portunid crabs commonly focused their energy for ovarian development and their survival (Amin-Safwan *et al*., in press), which sometimes involve moulting process. Moulting requires a lot of energy which is for the better use of the reproductive output for egg production purposes (Sigana, 2002). This theory explained that mature female crabs did not grow as large or moult as frequently due to its reproductive energy requirement. On the other hand, male crabs did not face problem with their maturity stage as they only use their energy for the somatic growth. Hence, the larger the male BW was, the higher their mean foregut fullness would be (Nesakumari & Thirunavukkarusu, 2014).

Conclusion

Males *T. crenata* crabs have the highest mean fullness of foreguts and a higher range of BW compared to the female crabs. The presence of the crab pincer and hepatopancreas in the foregut showed that *T. crenata* is cannibalistic. The dietary composition analysis revealed that slow-moving crustaceans such as sea star, bivalves and gastropods were preferred by *T. crenata*. In addition, this present study showed that *T. crenata* was primarily an omnivore with preference for marine animals whilst also feeding on plant items like sea grass. Fish and bivalve were recorded as the most preferred items by both female and male crabs as these dietary items were the most dominant in the foregut of the crab samples. Overall, this study has proven that the size of the crab (BW) has no significant difference with the mean fullness and dietary composition of the crab species. Generally, the study also showed that larger male crabs of *T. crenata* had the ability to capture more prey and consumed a variety of food items. The last maturity stage also influenced the feeding habits, as berried females only in fullness of 1 and 2, but not in the male crabs. For recommendations, increasing number of samples for future research is highly recommended, besides focusing on tidal rhythms and sampling periods (pre-monsoon, monsoon, post-monsoon, daylight or night catch) for better research outcomes. Therefore, this present study can help the formulation of food pellet that are suitable for *T. crenata* to be used in aquaculture activity in the near future.

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