SPECIES DIVERSITY, CARAPACE WIDTH-BODY WEIGHT RELATIONSHIP, SIZE DISTRIBUTION AND SEX RATIO OF MUD CRAB, GENUS *Scylla* FROM SETIU WETLANDS OF TERENGGANU COASTAL WATERS, MALAYSIA

IKHWANUDDIN, M.*[1], BACHOK, Z.[2], HILMI, M. G.[3], AZMIE, G.[1] AND ZAKARIA, M. Z.[3]

[1]*Institute of Tropical Aquaculture, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu,* [2]*Institute of Oceanography, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu and* [3]*Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu, 21030 Kuala Terengganu*

**Corresponding author: ikhwanuddin@umt.edu.my*

Abstract: The study was aimed to determine the species diversity, carapace width (CW)-body weight (BW) relationship, size distribution and sex ratio of mud crab, genus *scylla* from Setiu Wetlands of Terengganu coastal waters, Malaysia. A total of 1,000 crabs of various sizes (6 – 15 cm CW), sex and species were randomly collected during the monsoon season. The study showed that the mud crab species composition was dominated by *Scylla olivacea* (65.0%), followed by *Scylla paramamosain* (21.8%) and *Scylla tranquebarica* (13.2%). The male crabs were significantly bigger and heavier than females for all the mud crab species sampled. The rate of increase in body weight of *S. olivacea* was more than the other two mud crab species of *S. paramamosain* and *S. tranquebarica*. The dominant size range with respect to carapace width for all the mud crabs sampled was between 9.0cm and 9.9cm. The male crabs are relatively more abundant than the females for all the mud crab species sampled (1:0.82).

KEYWORDS: Species diversity, carapace width-body weight relationship, size distribution, sex ratio, mud crab, *Scylla* spp.

Introduction

The mud crab, genus *Scylla,* is common throughout the Indo-Pacific region on the mud flats of the littoral, parts of the supralittoral and the intertidal zones (Keenan *et al*., 1998). Mud crabs rarely occur in sandy and rocky areas and are distributed over a wide range of salinity from 2 ppt to oceanic waters, from the coast to the interior brackish water (Giasuddin and Fokhrul, 1992). Mud crabs are also commonly associated with mangrove swamps and nearby inter-tidal and sub-tidal muddy habitats (Keenan, 1999).

In spite of the increasing interest in mud crab farming in Malaysia, information on biological and fisheries information of the mud crab is still unsatisfactory except for reports on mud crab biology and fishery by Ikhwanuddin (2001) and on mud crab culture operation by Chang and Ikhwanuddin (1999), Ikhwanuddin and Oakley (1999), and Ikhwanuddin and Oakley (1998). The information on biology and fishery can be generated from capture fishery. This information included species diversity, the carapace width-body weight relationship, size distribution and sex ratio. Literature review showed that there is no study on capture fishery of mud crabs from the coastal waters of Peninsular Malaysia. The information is important to understand the behavior and characteristic of mud crab and that could be useful in the management of exploitation on mud crab resources. The objective of the present study was to determine the species diversity, the carapace width-body weight relationship, size distributions and sex ratio of mud crab species from Terengganu coastal waters of Peninsular Malaysia.

Materials and methods

The study was conducted at Setiu Wetlands' coastal waters of Terengganu, Malaysia of South China Sea (Figure 1) during the monsoon season from November 2008 till February 2009. Setiu Wetlands is situated in the northeast of Terengganu, at Kampung Penarik (5^0 40' N; 102^0 46' E) about 300 meters from the shoreline, parallel to the beach and reaching a narrow river mouth at Kuala Setiu Baharu.

Crab samples were provided by the local fisherman from Setiu Wetlands. A total of 1,000 crabs were randomly measured for crab size and identified to species and sex. The crab samples were used to determine the species diversity, the carapace width-body weight relationship, size distribution and sex ratio.

The recent study by Keenan *et al*. (1998) was used to identify the different species of mud crab, genus *Scylla* (Table 1). Crab size was measured as the external carapace width, which was the distance between the tips of 9^{th} antero-lateral spines of the carapace (Figure 2). The carapace width was measured to the nearest 0.1 cm by vernier callipers. Crab weight was measured to the nearest gram by using a digital electronic balance of 0.1 gm sensitivity. Crabs were separated into male and female based on the shape of the abdomen (Figure 3). The female crab had a wider and globular abdomen. In younger females, the abdomens were invariably triangular. The male crab had a narrow and straight abdomen. The relationship between the carapace width-body weight was determined by linear regression. All samples were counted and categorized based on size, measured with 0.9 cm size range to determine the size distribution. The number of female and male crabs were recorded to determine the mud crab sex ratio. The relationship between carapace width and body weight in males and females was also determined through regression analysis. Data were presented as mean and Microsoft excel was used for plotting the graphs.

Results

Species diversity

The result from the study showed that the species composition of mud crab was dominated by *S. olivacea* with 65.0% of the total crabs sampled, of which 33.0% were males and 32.0% were females (Table 2). *S. paramamosin* were also common with 21.8% of the total crabs sampled, where males (13.1%) were more abundant than females (8.7%) (Table 2). *S. tranquebarica* was uncommon with only 13.2% of the total crabs sampled, of which 8.8% were males and 4.4% were females (Table 2).

The carapace width (CW)-body weight (BW) relationship

The study showed that *S. olivacea* males were significantly ($P<0.001$) heavier than females (Table 3). The mean CW and BW of *S. olivacea* males were 9.42cm ± 1.28 (range: 6.22-14.3cm; n = 330) and 153.97g ± 100.98 (range: 33.30-762.00g; n = 330.00) (Table 3). For females of *S. olivacea*, the mean CW and BW are 8.90cm ± 1.13 (range: 6.71-12.71cm; n = 320.00) and 111.16g ± 47.90 (range: 40.00-301.00g; n = 320.00) (Table 3). The CW-BW relationship for males and females *S. olivacea* was estimated as follows $BW = 3.9137e^{0.3741CW}$ ($R^2 = 0.8263$; n = 330) and $BW = 5.0028e^{0.3385CW}$ ($R^2 = 0.798$; n = 320) respectively (Figure 4 and Figure 5). The overall CW-BW relationship of *S. olivacea* was estimated as follows $BW = 4.0857e^{0.3656CW}$ ($R^2 = 0.8206$; n = 650) (Figure 6). Linear regression of relationship between CW and BW of *S. olivacea* was estimated as follows Log BW = 3.4167 Log CW – 1.2076 ($R^2 = 0.8259$; n = 650) (Figure 7).

For the *S. paramamosain*, males were also significantly ($P<0.001$) heavier than females (Table 4). The mean CW and BW of *S. paramamosain* males were 9.34cm ± 1.45 (range: 6.30-14.00cm; n = 131.00) and 148.80 ± 96.99g (range: 37.50-731.00g; n=131.00) (Table 4). For the

S. paramamosain females, the mean CW and BW were 9.43cm ± 1.06 (range: 6.80-12.30cm; n = 87.00) and 135.27g ± 48.09 (range: 55.00-313.00g; n = 87.00) (Table 4). The CW-BW relationship for males and females *S. paramamosain* was estimated as follows as $BW = 5.2449e^{0.3425CW}$ ($R^2 = 0.8876$; n = 131) and $BW = 10.341e^{0.2666CW}$ ($R^2 = 0.7275$; n = 87) respectively (Figure 8; Figure 9). The overall CW-BW relationship of *S. paramamosain* was estimated as follows $BW = 6.3001e^{0.2814CW}$ ($R^2 = 0.8385$; n = 218) (Figure 10). Linear regression relationship between CW and BW of *S. paramamosain* was estimated as follows Log BW = 2.8413 Log CW - 0.6483 ($R^2 = 0.7655$; n = 218) (Figure 11).

The study also showed that the *S. tranquebarica* males were significantly ($P<0.001$) bigger and heavier than females and similar results were found with *S. olivacea* and *S. paramamosain* (Table 5). The mean CW and BW of *S. tranquebarica* females were 9.47cm ± 1.63 (range: 6.30-13.45cm; n = 88.00) and 153.20g ± 1044.74 (range: 37.50-550.00g; n = 88.00) (Table 5). For the *S. tranquebarica* males, the mean CW and BW were 9.39cm ± 1.05 (range: 6.80-12.02cm; n = 44.00) and 139.36g ± 46.68 (range: 80-301g; n = 44.00) (Table 5). The CW-BW relationship for males and females *S. tranquebarica* was estimated as follows as $BW = 4.9193e^{0.3445CW}$ ($R^2 = 0.9211$; n = 88) and $BW = 17.067e^{0.2184CW}$ ($R^2 = 0.5574$; n = 44) respectively (Figure 12; Figure 13). The overall CW-BW relationship of *S. tranquebarica* was estimated as follows $BW = 6.1677e^{0.3226CW}$ ($R^2 = 0.8564$; n = 132) (Figure 14). Linear regression relationship between CW and BW of *S. olivacea* was estimated as follows Log BW = 3.0073 Log CW – 0.8038 ($R^2 = 0.8452$; n = 132) (Figure 15).

Size distribution

The results from the crabs sampled showed that the dominant size range for male *S. olivacea* was between 9.0cm and 9.9cm, with 35.2% size frequency. The uncommon size range for male was between 14.0cm and 14.9cm (Table 6) with 0.6% size frequency. The dominant size range for female *S. olivacea* was between 8.0cm and 8.9cm, with 34.4% size frequency. The uncommon size range for female *S. olivacea* occurs at two different size range classes which were between 11.0cm and 11.9cm, and 12.0cm and 12.9cm, with 1.9% size frequency (Table 6). From the overall 650 individuals of *S. olivacea* sampled, the dominant size range for *S. olivacea* was between 9.0cm and 9.9cm with 33.2% and size class between 14.0cm and 14.9cm were the uncommonly size range sampled with 0.3 % size frequency (Table 6).

The results from the crabs sampled showed that the dominant size range for male *S. paramamosain* was between 9.0cm and 9.9cm, with 28.2% size frequency while the uncommon size range was between 14.0cm and 14.9cm, with 0.8% size frequency (Table 7). The dominant size range for females was also between 9.0cm and 9.9cm, with 44.8% size frequency. The uncommon size range for female *S. paramamosain* occurs at two different size range classes which were between 6.0cm and 6.9cm, and 12.0cm and 12.9cm, with 1.9% size frequency (Table 7). From the overall 218 individuals of *S. paramamosain* sampled, the dominant size range for *S. paramamosain* was between 9.0cm and 9.9cm with 34.9% size frequency and the uncommon size range for *S. paramamosain* was between 14.0cm and 14.9cm with 0.5 % size frequency (Table 7).

The results from the crabs sampled showed that the dominant size range for male *S. tranquebarica* was between 10.0cm and 10.9cm, with 27.3% size frequency, and the uncommon size range was between 12.0cm and 12.9cm, with 3.4% size frequency (Table 8 and Figure 20). The uncommon size range for female *S. tranquebarica* was between 11.0cm and 11.9cm with 2.3% size frequency. From the overall 132 individuals of *S. tranquebarica* sampled, the dominant size range for *S. tranquebarica* was between 9.0cm and 9.9cm, with 34.1%, and the uncommon size range was between 13.0cm and 13.9cm, with 3.0% size frequency (Table 8).

Sex ratio

The study showed that the sex ratio (male: female) of the mud crab species sampled from the Setiu Wetlands was 1: 0.97 for *S. olivacea*, 1: 0.66 for *S. paramamosain* and 1: 0.5 for *S. tranquebarica* (Table 9). The result clearly showed that male crabs were relatively more abundant than the females for all the mud crab species.

Discussion

Results from this study show that *S. olivacea* is the most abundant species (65%), followed by *S. paramamosain* (21.8%) and *S. tranquebarica* (13.2%). These results confirm the observation made by Keenan *et al*. (1998) that the distribution of *S. olivacea* and *S. tranquebarica* are associated with each other where it occurs. Both *S. olivacea* and *S. tranquebarica* are commonly found from the South China Sea and also in specific location around the Indo-Pacific (Keenan *et al*., 1998). *S. paramamosain* was recorded as the second common *Scylla* species from this site. This does not follow Keenan, Davie and Mann's hypothesis, where *S. paramamosain* is abundant species of *Scylla* where it occurs (Keenan *et al*., 1998). The species has been positively identified from the continental coast of the South China Sea which included the coast of Southeastern China (Ma *et al*., 2006), coastal waters of Mekong, Vietnam (Macintosh *et al*.,2002; Overton and Macintosh, 2002) and coastal waters of Sarawak, Malaysia (Ikhwanuddin, 2001). *S. paramamosain* were also identified from coastal waters other than the continental coast of the South China Sea such as south into the Java Sea (Keenan *et al*., 1998), Andaman Sea in Ranong Province, Thailand (Tongdee, 2001) and from Sulu Sea, in the Marudu Bay, Sabah, Malaysia (Ikhwanuddin, 2001).

No *S. serrata* species were recorded from this study, even though it is reported as being widespread (Keenan *et al*., 1998). Ikhwanuddin (2001) also reported the absence of this species from Sarawak coastal waters. Both evidence from present study and from Ikhwanuddin (2001) showed that *S. serrata* is not normally found on the continental coast of the South China Sea. Other than the South China Sea, this species have been positively identified from a wide range of location in the Indo-pacific, where it occurs naturally from South Africa to Tahiti, north to Okinawa, and south to Port Hacking in Australia and the Bay of Islands, New Zealand (Keenan *et al*., 1998).

The present study showed that male crabs were relatively more abundant than female crabs (Table 9) for all crab species sampled. This can be explained by the offshore spawning migration by the female crabs during the monsoon season. This migration attribute to the reduction of the female crabs during the spawning season as been pointed out by Hill (1992) and Ikhwanuddin (2001). The spawning migration also occurs in the Northern Territory, Australia, where the percentage of female crabs drops rapidly compared to male *S. serrata* during the wet season (Knuckey *et al*., 1995). Present study also showed that the male *S. paramamosain* was approximately 50.0% higher in number than the female *S. paramamosain*. Same pattern can be seen for *S. tranquebarica,* with a sex ratio 1: 0.66. This result suggests that females of both *S. paramamosain* and *S. tranquebarica* migrate offshore for spawning. This pattern is similar with the result from telemetry study by Ikhwanuddin (2001) which showed that, *S. tranquebarica* do migrate offshore during spawning season, in the same manner as *S. serrata* but not for *S. olivacea*. Results from the present study suggest that both *S. paramamosain* and *S. tranquebarica* show free-ranging movement as compared to *S. olivacea* which is an intertidal species and shows restricted movement.

In studying the spiny crab species, such as the mud crab, measuring the carapace width (CW) of crabs is often somewhat difficult, and during attempts to measure them, either the extremities of the crab can be broken or the investigator can be injured by the crab. It is therefore convenient to be able to convert into CW when only the body weight (BW) is known or CW-BW regression may be extensively used to estimate CW from BW because of the difficulties in handling spiny crabs such as the mud crab and the amount of time required to record CW in the study of these species. These relationships are often used to calculate the standing stock biomass, condition indices, and used in the analysis of ontogenetic changes and several other aspects of fish or crustacean population dynamics. The body weight to carapace width ratio is smaller in females than males in all the mud crab species due to the large claws of the latter. The study also shows that the rate of increase in BW of *S. olivacea* is more than other species, suggesting that *S. olivacea* are heavier than other mud crab species.

In Malaysia, mangrove forests cover an area of approximately 5, 86,000 ha, of which about 57% in the state of Sabah, 26% in the state of Sarawak and 17% in Peninsular Malaysia. The mangrove forests are situated along sheltered coastlines and estuaries of large rivers. Mud crab fisheries in Malaysia are confined to the estuaries and coastal areas, which support mangrove swamp development. The local coastal fishers of Malaysia used to exploit the mud crab for their own consumption. Heavy exploitation of immature crabs may affect the sustainable yield. It is suggested that one consideration to be put up in the future is that crab fishing should be prohibited during spawning peak season of certain mud crab size for specific *Scylla* species of which can affect the sustainable wild stock.

Distribution for both sexes of *S. olivacea* from Setiu Wetlands (Table 7) showed that approximately 45.0% of the crabs sampled during present study were immature. The crab capture fishery in Malaysia is expected to continue to grow in the future for several reasons. Firstly, there is an increasing demand for the commodity. Secondly, the capture fishery resource supports the culture of this species, where the wild capture fishery is still the only source of supply of juvenile crabs for the aquaculture sector. And lastly, knowledge and experience in crab culture techniques are improving. However, there has to be more careful planning and some guidelines for the conservation of crab fishery expansion to ensure sustainability of the fishery resource. In Thailand for example, berried crabs are prohibited from being caught between October and December (Poovachiranon, 1992). In Queensland, Australia, fishing of females and undersized males of CW less than 15.0 cm are prohibited under the regulation (Cowan, 1991). Whereas in New South Wales, Australia, regulations only allow the sale of all mud crabs that are 8.6 cm CW and over (Cowan, 1991).

Conclusion

The results show that the distribution of *S. olivacea* and *S. tranquebarica* are associated with each other from study site, where *S. olivacea* was the most abundant mud crab species caught at 65% of the total mud crab samples measured. *S.paramamosain* was positively identified from the study site of South China Sea whereas no *S. serrata* were recorded. The male crabs were relatively more abundant than the females for all the mud crabs species sampled from the study site during the monsoon season. The immature *S. olivacea* caught were relatively higher than the mature crabs. The rate of increase in *S. olivacea* body weight was more compared to other mud crab species, which shows that *S. olivacea* were heavier and bigger than the other two mud crab species of *S. paramamosain* and *S. tranquebarica*. The biological and fishery information which included species diversity, carapace width-body weight relationship, size distribution and sex ratio gathered from the present study is useful in management and exploitation of mud crab resources in Terengganu coastal waters particularly and in Malaysia generally.

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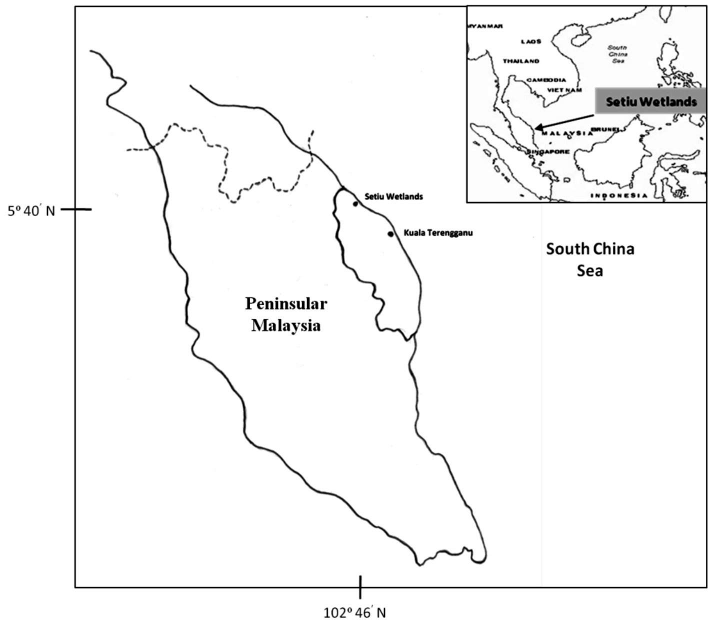

Figure 1: Maps of Setiu Wetlands of Terengganu coastal waters, Malaysia.

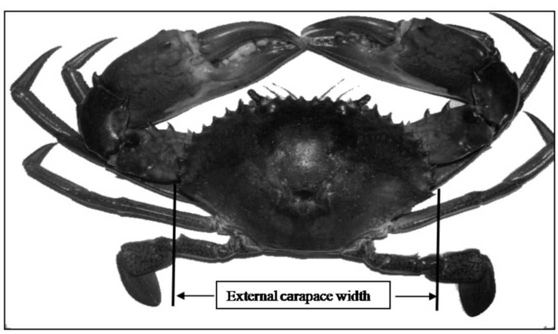

Figure 2: Measurement of the external carapace width to determine the crab size.

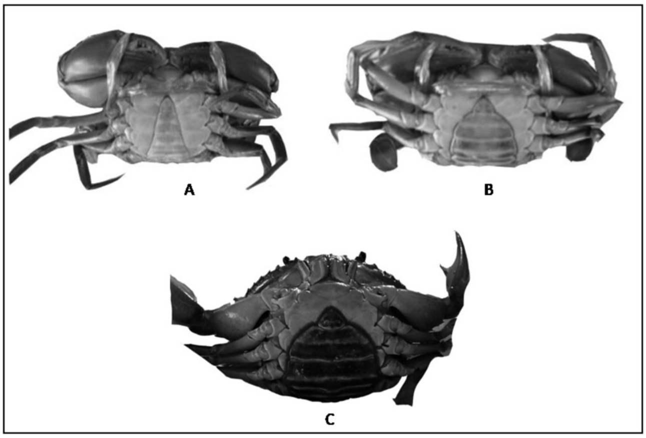

Figure 3: **A.** Male of *S. olivacea;* **B.** Immature female of *S. olivacea;* **C.** Mature female of *S. olivacea*.

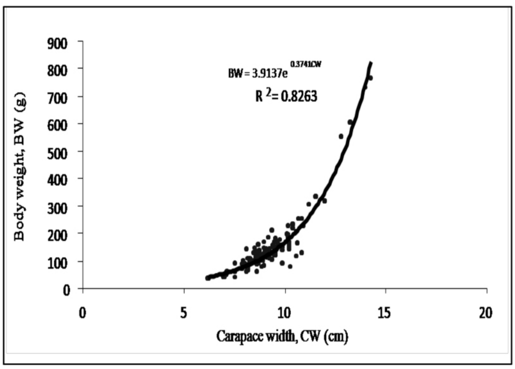

Figure 4: Relationship between body weight (BW) and carapace width (CW) of *S. olivacea* male.

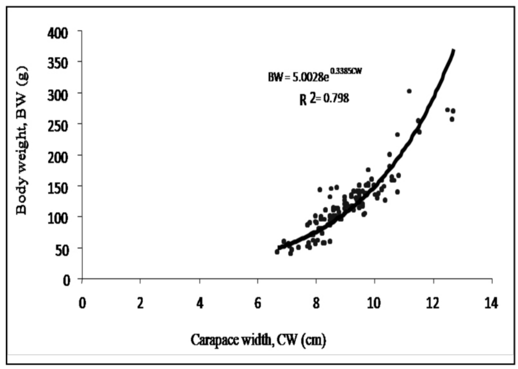

Figure 5: Relationship between body weight (BW) and carapace width (CW) of *S. olivacea* female.

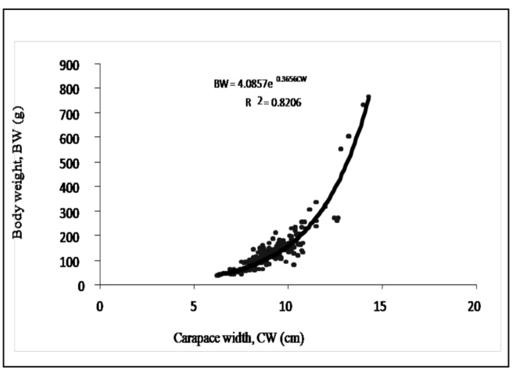

Figure 6: Relationship between body weight (BW) and carapace width (CW) of *S. olivacea*.

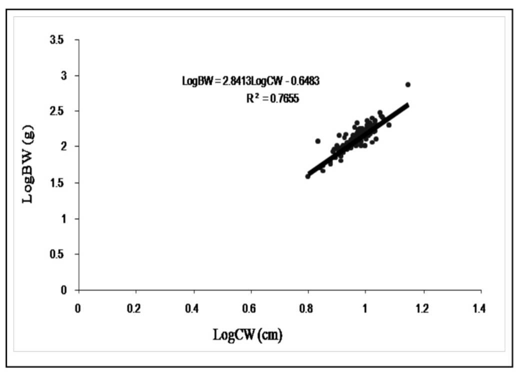

Figure 7: Linear regression of relationship between body weight (BW) and carapace width (CW) of *S. olivacea*.

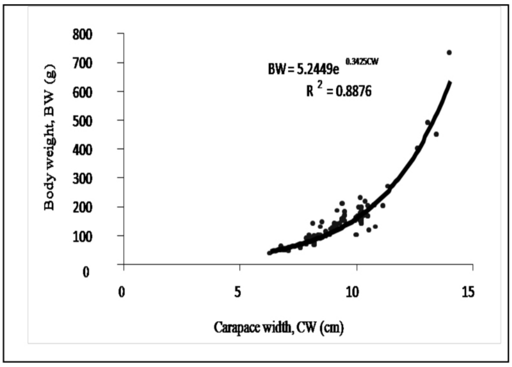

Figure 8: Relationship between body weight (BW) and carapace width (CW) of *S. paramamosain* male.

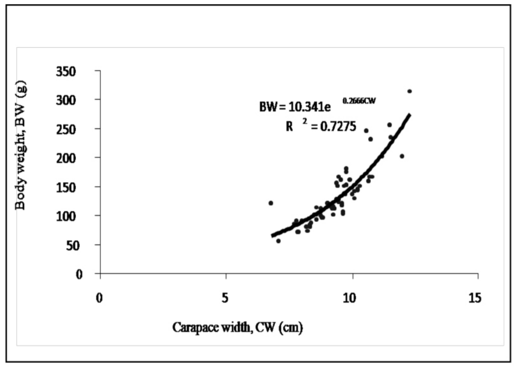

Figure 9: Relationship between body weight (BW) and carapace width (CW) of *S. paramamosain* female.

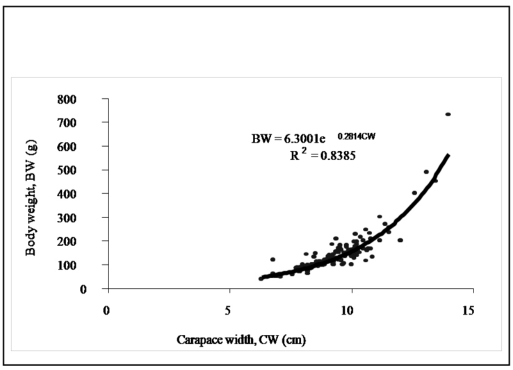

Figure 10: Relationship between body weight (BW) and carapace width (CW) of *S. paramamosain*.

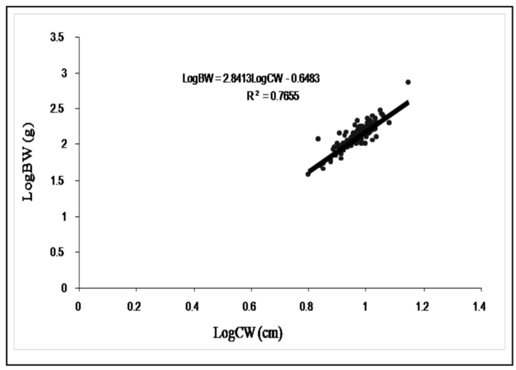

Figure 11: Linear regression of relationship between body weight (BW) and carapace width (CW) of *S. paramamosain*.

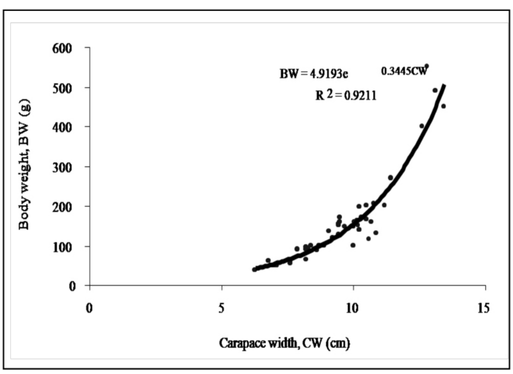

Figure 12: Relationship between body weight (BW) and carapace width (CW) of *S. tranquebarica* male.

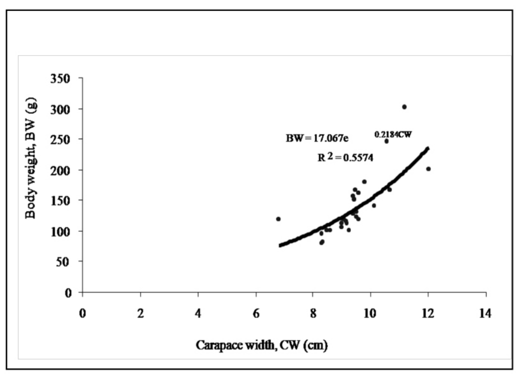

Figure 13: Relationship between body weight (BW) and carapace width (CW) of *S. tranquebarica* female.

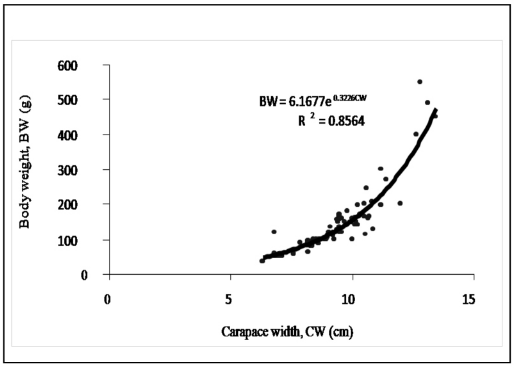

Figure 14: Relationship between body weight (BW) and carapace width (CW) of *S. tranquebarica*.

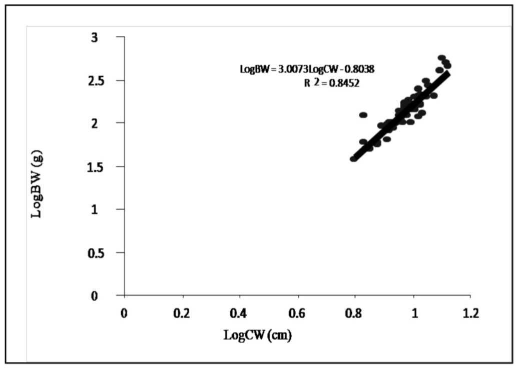

Figure 15: Linear regression of relationship between body weight (BW) and carapace width (CW) of *S. tranquebarica*.

Table 1: Characters useful in determining species identity of adult mud crab, genus *Scylla* (Keenan *et al*., 1998).

Species	Frontal lobe spines		Cheliped	
	Shape	Height	Carpus spines	Propodus spines
S. serrata	Blunted point	High	Both obvious	Obvious
S. tranquebarica	Blunted	Moderate	Both obvious	Obvious
S. paramamosain	Triangular	Moderately high	Inner absent, outer reduced	Obvious
S. olivacea	Rounded	Low	Inner absent, outer reduced	Reduced

Table 2: Species distribution of mud crabs sampled from Setiu Wetlands, Terengganu.

Species	Total (no)		Total (%)		
	Male	Female	Male	Female	Both sexes
S. olivacea	330	320	33%	32%	65%
S. paramamosain	131	87	131%	8.7%	21.8%
S. tranquebarica	88	44	8.8%	4.4%	13.2%
Total	1000				100

Table 3: Relationship between body weight (BW) and carapace width (CW) of *S. olivacea* sampled from Setiu Wetlands, Terengganu.

	Female		Male	
	CW (cm)	BW (g)	CW (cm)	BW (g)
Mean	8.9	111.16 [a]	9.42	153.97 [a]
Max	12.71	301.00	14.30	762.00
Min	6.71	40.00	6.22	33.30
sd	1.13	47.90	1.28	100.98
n	320.00		330.00	

[a] *Body weight (BW) of males are significantly (P<0.01) heavier than females.*

Table 4: Relationship between body weight (BW) and carapace width (CW) of *S. paramamosain* sampled from Setiu Wetlands, Terengganu.

	Female		Male	
	CW (cm)	BW (g)	CW (cm)	BW (g)
Mean	9.43	135.27 [a]	9.34	148.80 [a]
Max	12.30	313.00	14.00	731.00
Min	6.80	55.00	6.30	37.50
sd	1.06	48.09	1.45	96.99
n	87.00		131.00	

[a] *Body weight (BW) of males are significantly (P<0.01) heavier than females.*

Table 5: Relationship between body weight (BW) and carapace width (CW) of *S. tranquebarica* sampled from Setiu Wetlands, Terengganu.

	Female		Male	
	CW (cm)	BW (g)	CW (cm)	BW (g)
Mean	9.39	139.36 [a]	9.47	153.20 [a]
Max	12.02	301.00	13.45	550.00
Min	6.80	80.00	6.30	37.50
sd	1.05	46.68	1.63	104.74
n	44.00		88.00	

[a] *Body weight (BW) of males are significantly (P<0.01) heavier than females.*

Table 6: Size frequency distribution for mud crab, *S. olivacea* sampled from Setiu Wetlands, Terengganu.

Size range	Frequency (no of crabs)		Frequency (%)		
	Male	Female	Male	Female	Both sexes
6-6.9	6	8	1.8	2.5	2.2
7-7.9	26	56	7.9	17.5	12.6
8-8.9	84	110	25.5	34.4	29.8
9-9.9	116	98	35.2	30.6	32.9
10-10.9	76	36	23.0	11.3	17.2
11-11.9	8	6	2.4	1.9	2.2
12-12.9	8	6	2.4	1.9	2.2
13-13.9	4	0	1.2	0.0	0.6
14-14.9	2	0	0.6	0.0	0.3
Total	330	320	100.0	100.0	100.0

Table 7: Size frequency distribution for mud crab, *S. paramamosain* sampled from Setiu Wetlands, Terengganu.

Size range	Frequency (no of crabs)		Frequency (%)		
	Male	Female	Male	Female	Both sexes
6-6.9	6	2	4.6	2.3	3.7
7-7.9	14	5	10.7	5.7	8.7
8-8.9	30	19	22.9	21.8	22.5
9-9.9	37	39	28.2	44.8	34.9
10-10.9	33	16	25.2	18.4	22.5
11-11.9	4	4	3.1	4.6	3.7
12-12.9	2	2	1.5	2.3	1.8
13-13.9	4	0	3.1	0.0	1.8
14-14.9	1	0	0.8	0.0	0.5
Total	131	87	100.0	100.0	100.0

Table 8: Size frequency distribution for mud crab, *S. tranquebarica* sampled from Setiu Wetlands, Terengganu.

Size range	Frequency		% Frequency		
	male	female	male	female	both sexes
6-6.9	6	2	6.8	4.5	6.1
7-7.9	10	0	11.4	0.0	7.6
8-8.9	17	8	19.3	18.2	18.9
9-9.9	20	25	22.7	56.8	34.1
10-10.9	24	6	27.3	13.6	22.7
11-11.9	4	1	4.5	2.3	3.8
12-12.9	3	2	3.4	4.5	3.8
13-13.9	4	0	4.5	0.0	3.0
Total	88	44	100.0	100.0	100.0

Table 9: Sex ratio of mud crab, genus *Scylla* sampled from Setiu Wetlands, Terengganu.

Mud crab species	*S. olivacea*	*S. paramamosain*	*S. tranquebarica*
No. of male crabs sampled	330	131	88
No. of female crabs sampled	320	87	44
Sex ratio (male:female)	1:0.97	1:0.66	1:0.50