SIZE OF MATURITY OF MUD CRAB *Scylla olivacea* (Herbst, 1796) FROM MANGROVE AREAS OF TERENGGANU COASTAL WATERS

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Abstract: This study was conducted to determine the size of maturity (CW_{50}) of mud crab, *Scylla olivacea* (Herbst, 1796) from Setiu Wetlands, the mangrove area of Terengganu coastal waters. A total of 400 crabs were randomly collected from August 2008 to February 2009 in order to determine the size at maturity (CW_{50}). Size at maturity (CW50) recorded in this study was 9.06 cm CW for female crab and 8.97 cm CW for male crab. To ensure appropriate exploitation of *S. olivacea* in future, the study proposes to adopt Legal Minimum Carapace Width at 8.97 cm CW for both *S. olivacea* males and females.

KEYWORDS: Size of maturity, Mud crab, *Scylla olivacea*

Introduction

Mud crabs, *Scylla* spp., also known as mangrove crabs, occur naturally in association with mangrove swamp and nearby intertidal and subtidal muddy habitats. The recent research by Keenan *et al*. (1995) in the South East Asia region presented convincing arguments for the recognition of three species in the mud crab, genus *Scylla*, *Scylla serrata, Scylla olivacea* and *Scylla tranquebarica* (Keenan *et al*., 1995; Keenan, 1996). Subsequent studies have also recognized an additional new species identified as *S. paramamosain* (Keenan *et al*., 1998; Keenan, 1999). This study also suggests that the historical data on mud crab, *Scylla* spp. need to be revised (Keenan *et al*., 1998).

S. serrata is the most widespread *Scylla* species, distributed throughout the Indo-Pacific from South Africa to Tahiti, north to Okinawa, and south to Port Hacking in Australia and the Bay of Island, New Zealand (Keenan *et al*., 1998). *S. tranquebarica* is commonly found from the South China Sea but also occurs at specific other locations around the Indo-Pacific and is often associated with *S. olivacea* (Keenan *et al*., 1998). *S. paramamosain* commonly found from the continental coast of the South China Sea, south into the Java Sea (Ng, 1998). *S. olivacea* is a moderately widespread species, frequently found in the South China Sea, but also occurs at various other locations across the Indo-west pacific and is often associated with *S. tranquebarica* (Keenan *et al*., 1998).

Reproductive biology in mud crab species has been investigated throughout the Indo-pacific region such as Malaysia (Ong, 1966; Ikhwanuddin, 2001), South Africa (Robertson and Kruger, 1994; Hill, 1975), Papua New Guinea (Quinn and Kojis, 1987), China (Li *et al*., 1999), Australia (Heasman *et al*., 1985) and India (Pillai and Nair, 1968). In spite of the increasing interest in mud crab farming, reproductive biology information of the mud crab is still unsatisfactory. Information on the biology of mud crab in Malaysia is meager, except study by Ikhwanuddin (2001) in Sematan, Sarawak coastal waters of South China Sea and reports on mud crab culture operation in Sarawak, Malaysia by Chang and Ikhwanuddin (1999), Ikhwanuddin and Oakley (1999), and Ikhwanuddin and Oakley (1998). This reproductive biology information is important to understand the behavior

and characteristic of mud crab and this is useful in the management of exploitation of mud crab resources for capture fishery and aquaculture. Sizes at sexual maturity, mating and spawning periods are important reproductive biological information for the management of any fishery (Robertson and Kruger, 1994). Studies have shown that the pressure from commercial or recreational fishing has lead to a reduction in size at sexual maturity in the spiny lobster (Polovina, 1989) and far greater for blue swimming crab, *Portunus pelagicus* in the west coast of Australia (de Lestang *et al*., 2003a & b). This basically shows that the size of sexual maturity can be an indicator for fishing pressure status, which is an important parameter for the management of the mud crab fishery. So the main objective of the present study was to determine the size of maturity of mud crab, *S. olivacea* from mangrove area of Terengganu coastal waters.

Materials and methods

All the mud crab, *S. olivacea* samples were collected from August 2008 to February 2009 in the Setiu Wetlands. Setiu Wetlands is the protected mangrove area of Terengganu. Setiu Wetlands is situated in the northeast of Terengganu at 05˚ 40' N and 102˚ 46' E (Figure 1). A total of 200 female crabs and 200 male crabs were used to determine its size of maturity with crab size between 6.0cm and 14.0cm carapace width.

Identification of the mud crab, *S. olivacea* was based on morphological characters described by Keenan *et al.* (1998) (Table 1). Size of the crabs was measured as the external carapace width, where the distance between the tips of 9th antero-lateral spines of the carapace were measured (Figure 2). Carapace width (CW) was measured to the nearest 0.1cm using vernier calipers. Body weight (BW) of the crabs was measured to the nearest 0.1gm sensitivity using digital electronic balance.

The male and female crabs were separated based on the shape of the abdomen. The female crab has a wider and globular abdomen whereas the male has a narrow and straight abdomen (Figure 3). Matured female crab crabs have a large round pigmented abdominal flap while the immature female crabs have small, pale abdominal flap (Calogeras & Knuckey, 1995) (Figure 3). Male crabs were dissected to determine its maturity. The male crabs were examined and classified based on their external appearance of vas deferentia. Matured male crabs have enlarged and white vas differentia

Data were presented as mean ± standard deviation. Appropriate measure of the size of maturity (CW_{50}) in both male and female crabs Size of maturity was determined when 50% of the crabs were sexually matured. CW_{50} was determined by using the linear regression at CW range that produced percentage of maturity at 50%.

Results

Only 100 crabs of all measured female *S. olivacea* had mature abdomen. Mature female crabs were most frequently found (21.5%) in sizes ranging between 8.0cm and 8.5cm CW (Table 2). The immature female were also most frequently found (31.0%) in sizes ranging between 8.0cm and 8.5cm CW. The largest immature female encountered was at size 10.6cm CW and the smallest mature female was at size 8.0cm CW. The mean value of size of maturity of female crab was at 9.8 ± 0.9cm (Table 3). Size of maturity in females based on mature abdomen was most frequently found (21.0%) in sizes ranging between 9.0cm and 9.5cm CW (Figure 5). Using the abdominal flap changes for female as an indicator of crab maturity, the percentage of mature female crabs was calculated for each 0.5 cm CW interval from CW range of 6.5 cm (the smallest size range of the

crab sampled) to CW range of 13.0 cm (the largest size range of the crabs sampled). Using the linear regression at the carapace width ranges that show percentage of maturity, CW_{50} occurred at 9.1 cm CW in the female crabs with $y = 13.9x + 14.6$ and $R^2 = 0.8$ (Figure 6 and Figure 7).

Out of 200 male crabs sampled, only 100 crabs of *S. olivacea* had matured. Male crab maturity was determined based on the presence of enlarged and white vas deferens. Male crabs were most frequently found (16.5%) in three different size range classes, which were between 8.0cm and 8.5 cm CW, 8.5cm and 9.0 cm CW and 9.5cm and 10.0cm CW (Table 4). The immature male *S. olivacea* were most frequently found (27.0%) in sizes ranging between 8.0cm and 8.5cm CW (Figure 8). The largest immature male encountered was 9.94cm CW and the smallest mature male was 8.00cm CW. The mean value of size of maturity of male crab was at 9.9 ± 0.93m (Table 5). Size of maturity in males based on the presence of enlarged and white vas deferens was most frequently found (29.0%) in sizes ranging between 9.5cm and 10.0cm CW (Figure 9).

Using the presence of vas deferens for male as an indicator of crab maturity, the percentage of mature male crabs was calculated for each 0.5cm CW interval from CW range of 6.0cm (the smallest size range of the crab sampled) to CW range of 13.5cm (the largest size range of the crab sampled). Linear regression analysis at the carapace width ranges that show percentage of maturity, CW_{50} occurred at 8.9 cm CW in the male crabs with $y = 20.9x – 22.1$ and $R^2 = 0.9$ (Figure 10 and Figure 11).

Discussion

Sexual maturity is defined as the ability to successful mate, resulting in the extrusion of fertilized egg (Robertson & Kruger, 1994). The pubertal moult stage in *Scylla* spp. is said to be a reliable indicator of the ability of female crab to mate (Robertson and Kruger, 1994). Studies have also shown that the females *Scylla* spp. moult again after the pubertal moult (Robertson & Kruger, 1994; Quinn & Kojis, 1987; Heasman, 1980; Ong, 1966). Detailed reproductive studies were not possible within the scope of the study for all the four species of *Scylla*, however it is suggested that some of these female population pass through at least two mature instars. Literature review shows that comparable data on the reproductive biology of *Scylla* spp. are very few. Table 6 shows a summary of available data on CW_{50} of *Scylla* spp. from other studies. From Table 6, it is apparent that, the CW_{50}-female for the two unidentified *Scylla* spp. is larger than *S. olivacea* in the present study. The result from the present study also shows that the *S. olivacea* male mature at a smaller size than female crabs, a similar result obtained by Robertson and Kruger (1994) for *Scylla* spp. (Table 6). The different size of maturity is also related to geography. Table 6 shows that the CW_{50}-female recorded in Papua New Guinea is smaller (10.5 cm CW; Quinn & Kojis, 1987) than in South Africa (12.3 cm CW; Robertson & Kruger, 1994). This difference in size could be related to the different criteria on which size at maturity was also based geographical differences. In Papua New Guinea, Quinn and Kojis (1987) used colour and size as an indicator of gonad maturity to determine CW_{50}-female. Whereas in South Africa, Robertson and Kruger (1994) used the attainment of the mature abdomen form, the same manner used in the present study to determined CW_{50}-female. Unfortunately CW_{50} is mostly unknown and comparisons between studies therefore have to be based on minimum size at maturity (Robertson & Kruger, 1994). The summary of available data on size at sexual maturity from various localities is presented in Table 7 for female *Scylla* spp. and in Table 8 for male *Scylla* spp.

The smallest mature female recorded in Malaysia was 9.9 cm CW by Ong (1966) for *Scylla* spp. as compared to *S. olivacea* in the present study, the size of the *Scylla* spp. is larger (Table 7). The smallest size at maturity based on the different criteria in Table 7, shows that *S. tranquebarica* is larger than *S. olivacea*. This indicates that size at maturity is different in various parts of the

world (Table 7). Poovachiranon (1992), and Quinn and Kojis (1987) suggested that the size at maturity for *Scylla* spp. is larger at higher latitudes as compared to at lower latitudes. Robertson and Kruger (1994), do not agree with Quinn and Kojis's hypothesis because the large difference in the minimum size at which females in Australia, 13.8 cm CW (28^0S), and in South Africa, 10.4 cm CW (29^0S), attain the mature abdomen form, despite almost similar latitudes at which they occur (Table 7). *S. serrata* are the most widespread *Scylla* spp. with *S. olivacea* and *S. tranquebarica* commonly found in the South-China Sea (Keenan *et al.,* 1998). This suggests that both *S. olivacea* and *S. tranquebarica* will show less difference in size at maturity from different localities as they are commonly found in the South-China Sea. There is insufficient data to determine the size at maturity of *S. paramamosain* and *S. tranquebarica* in the present study. Quinn and Kojis (1987) do suggest that *S. paramamosain* can undergo their maturity molt at a larger CW (12.0 cm) than *Scylla* spp. A study by Ikhwanuddin (2001) shows that the CW_{50} for *S. tranquebarica* is larger than both *S. olivacea* studied by Ikhwanuddin (2001) and as in the present study as shown in Table 6. From the study, it is suggested that size of maturity in *Scylla* spp. is larger than *S. tranquebarica* and *S. tranquebarica* is larger than *S. olivacea*.

Heavy exploitation of immature crab may affect the sustainable yield. In Thailand for example, berried crab are prohibited from being caught between October and December (Poovachiranon, 1992). In the near future, some guidelines for the conservation of the wild stock resource should therefore be considered. 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). It is suggested that one of the considerations to be put up in the future is crab fishing should be prohibited during spawning peak season of a certain mud crab size for specific *Scylla* species of which can effect the sustainable wild stock. This certain mud crab size is referred to as the Legal Minimum Carapace Width (LMCW). If LMCW is to be adopted in the present study site of the Terengganu coastal water, the proposed LMCW is 8.97 cm CW for both *S. olivacea* males and females, where the CW_{50} of *S. olivacea* from the present study is 8.97 cm CW for males and 9.06 cm CW for females.

Conclusion

From the study, the size at maturity for *S. olivacea* is 8.97 cm CW for male and 9.06 cm CW for female. If Legal Minimum Carapace Width (LMCW) is to be adopted in the present study site of the Terengganu coastal waters, aimed to ensure appropriate exploitation of the mud crab, the proposed LMCW is 8.97 cm CW for both *S. olivacea* males and females.

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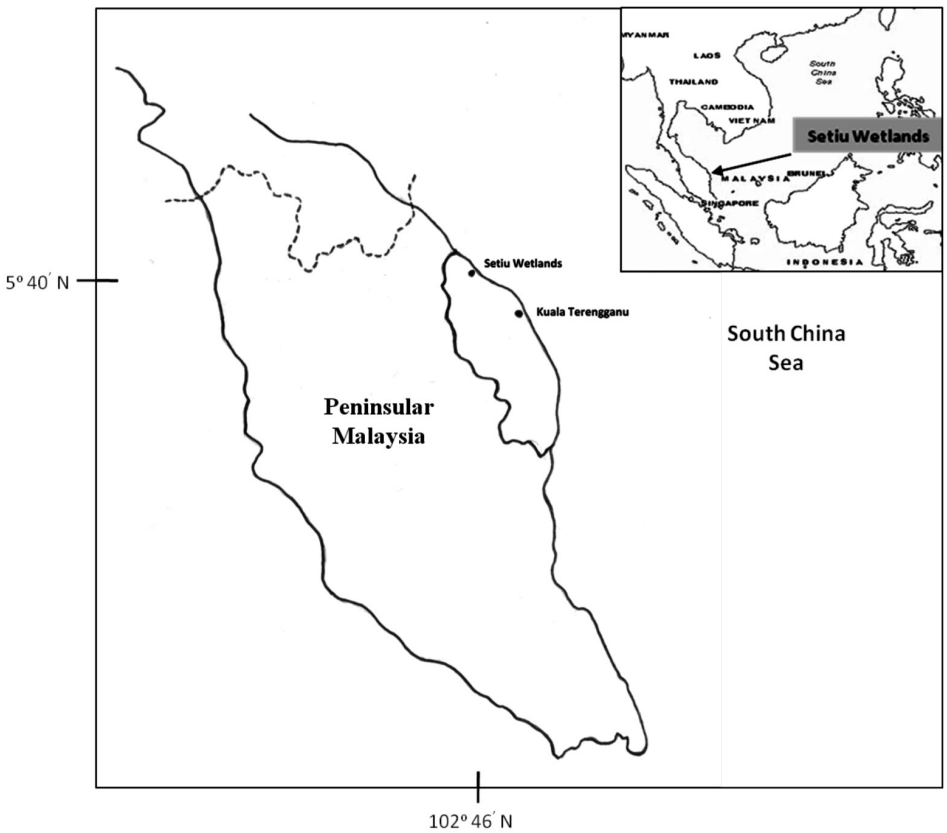

Figure 1: Maps of Setiu Wetlands, Terengganu coastal waters of the South China Sea

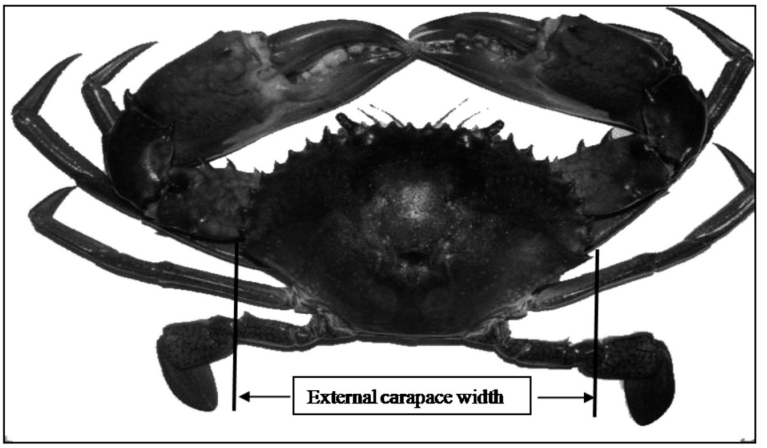

Figure 2: Measurement of the external carapace width to determine the crab size.

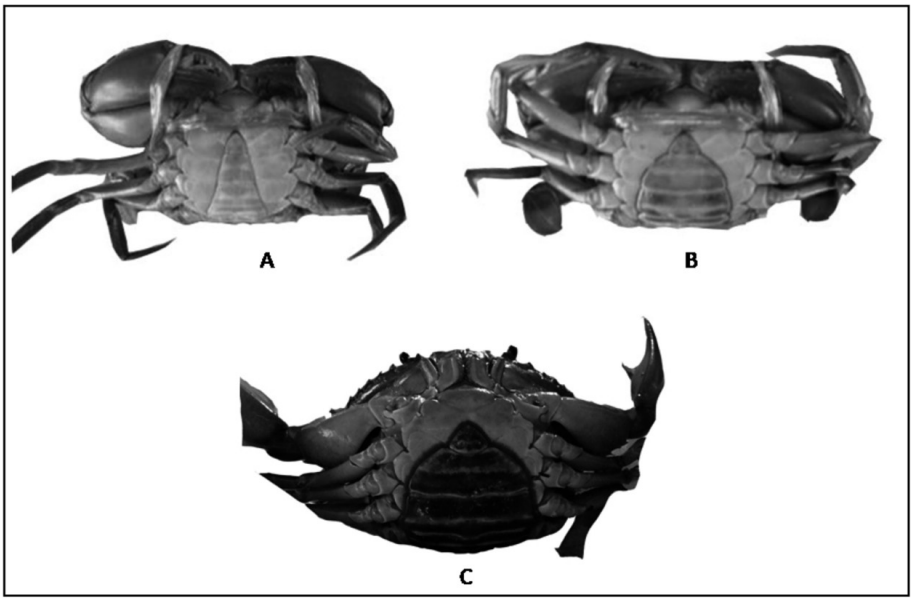

Figure 3: **A.** Male of *S. olivacea;* **B.** Immature female of *S. olivacea;* **C.** Mature female of *S. olivacea*.

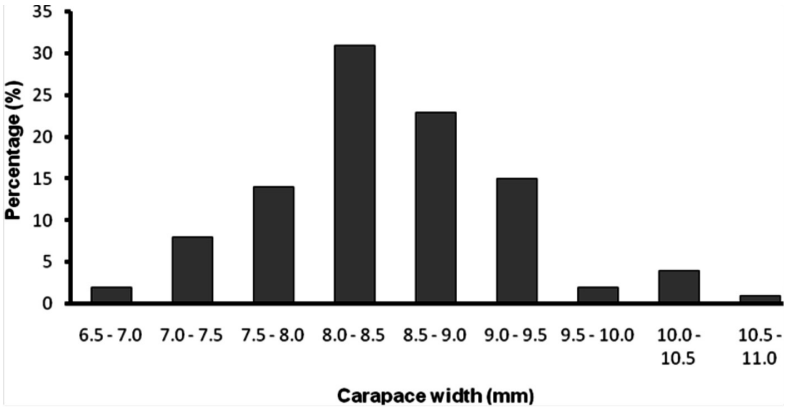

Figure 4: Length frequency of immature female crabs of *S. olivacea.*

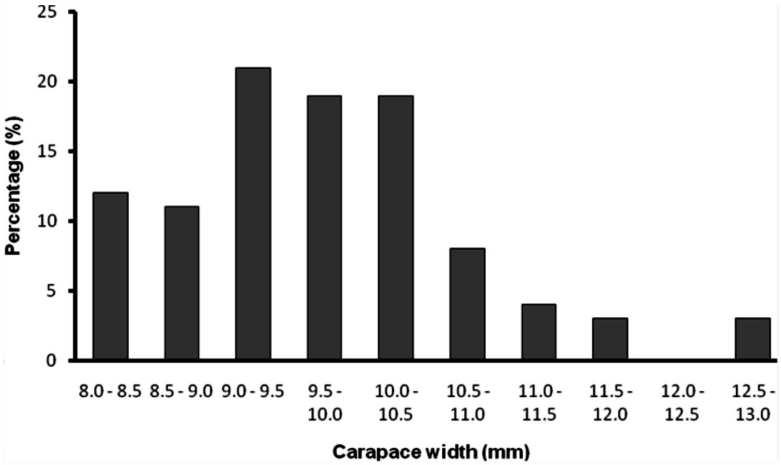

Figure 5: Length frequency of female crabs at maturity of *S. olivacea*.

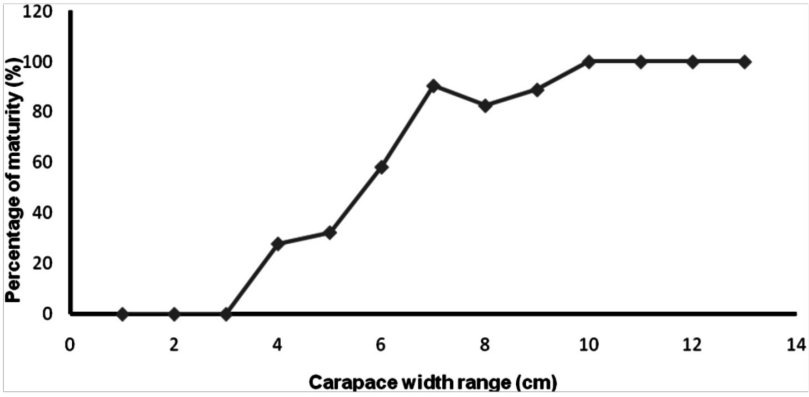

Figure 6: Female *Scylla olivacea* size at maturity.

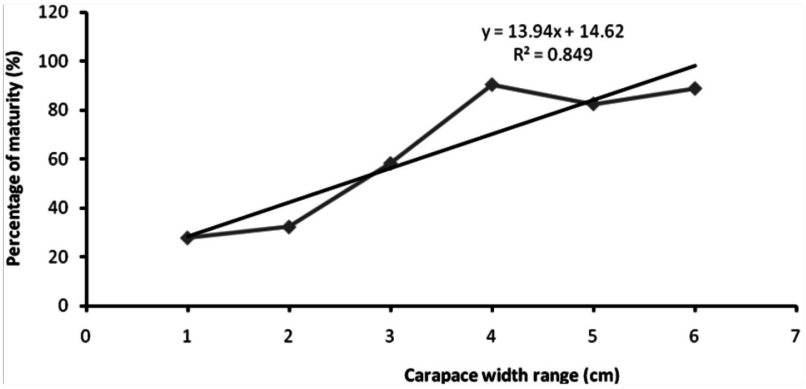

Figure 7: Linear regression of female *Scylla olivacea* size at maturity. Size at maturity (CW_{50}) for female *Scylla olivacea* was 9.06 cm CW.

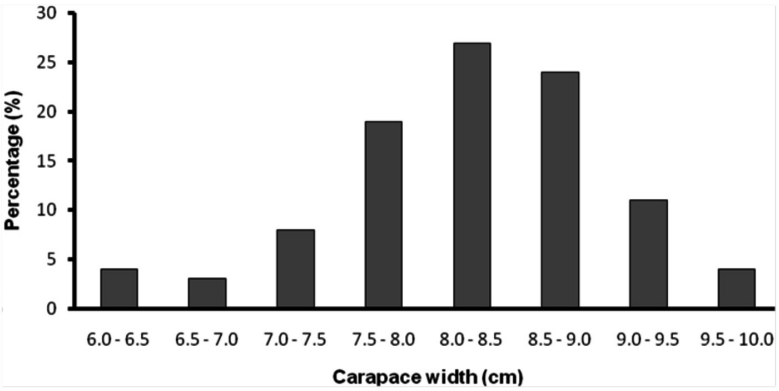

Figure 8: Length frequency of immature male *S. olivacea.*

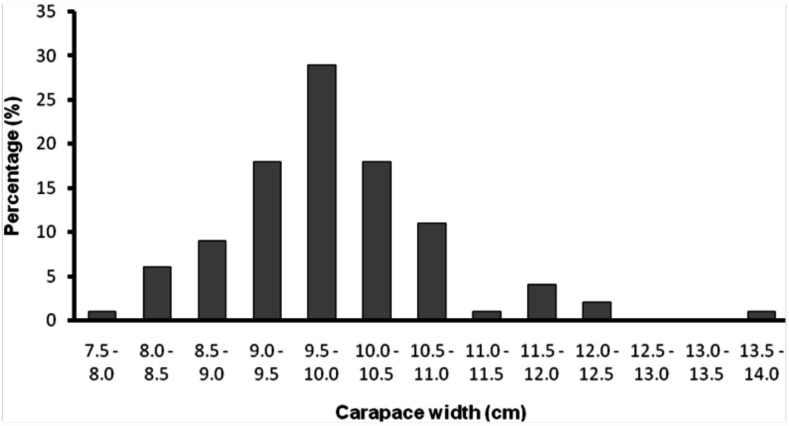

Figure 9: Length frequency of male crabs *S. olivacea* at maturity.

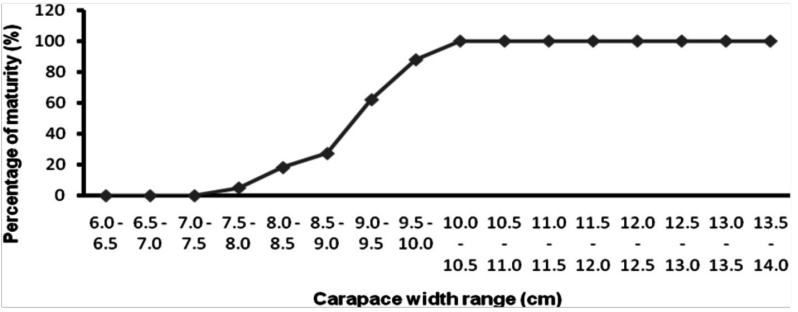

Figure 10: Male *S. olivacea* size at maturity.

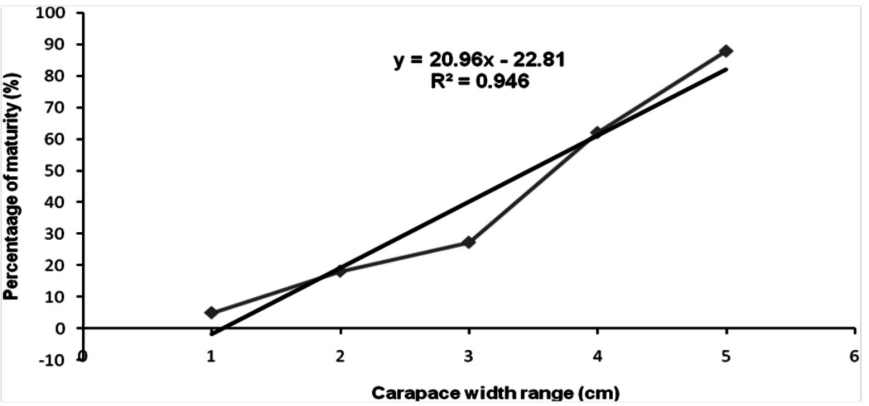

Figure 11: Linear regression of male *S. olivacea* size at maturity. Size at maturity (CW_{50}) for male *S. olivacea* was 8.97 cm CW.

Table 1: Morphological 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. olivacea	Rounded	Low	Inner absent, outer reduced	Reduced
S. tranquebarica	Blunted	Moderate	Both obvious	Obvious
S. paramamosain	Triangular	Moderately high	Inner absent, outer reduced	Obvious

Table 2: Size range of carapace width (cm) frequency number and frequency percentage of maturity of female *S. olivacea.*

Size range (cm)	6.5 - 7.0	70.0 - 75.0	7.5 - 8.0	8.0 - 8.5	8.5 - 9.0	9.0 - 9.5	9.5 - 10.0	10.0 - 10.5	10.5 - 11.0	11.0 - 11.5	11.5 - 12.0	12.0 - 12.5	12.5 - 13.0	Total
Freq.	2	8	14	43	34	36	21	23	9	4	3	0	3	200
%	1	4	7	21.5	17	18	10.5	11.5	4.5	2	1.5	0	1.5	100
Mat. freq.	0	0	0	12	11	21	19	19	8	4	3	0	3	
Mat. %	0	0	0	27.9	32.35	58.3	90.48	82.61	88.9	100	100	100	100	

Note: Freq. – Frequency; % - Frequency percentage; Mat. freq. –Maturity frequency; Mat. % - Maturity frequency percentage

Table 3: Size at maturity in female crabs (cm).

	Scylla olivacea	
	Mature abdomen	Immature abdomen
Mean	9.7913	8.4406
Max	12.71	10.59
Min	8	6.71
Sd	0.97	0.745
N	100	100
Total sample	200	

Table 4: Size range of carapace width (cm) frequency number and frequency percentage of maturity of male *S. olivacea.*

Size range (cm)	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	8.5-9.0	9.0-9.5	9.5-10.0	10.0-10.5	10.5-11.0	11.0-11.5	11.5-12.0	12.0-12.5
Freq.	4	3	8	20	33	33	29	33	18	11	1	4	2
%	2	1.5	4	10	16.5	16.5	14.5	16.5	9	5.5	0.5	2	1
Mat. freq.	0	0	0	1	6	9	18	29	18	11	1	4	2
Mat. %	0	0	0	5	18.2	27.3	62.1	87.9	100	100	100	100	100

Note: Freq. – Frequency; % - Frequency percentage; Mat. Freq – Maturity frequency; Mat. & - Maturity frequency percentage.

Table 5: Size at maturity in male crabs (cm).

	Scylla olivacea	
	Mature abdomen	Immature abdomen
Mean	9.91	8.22
Max	14.00	9.94
Min	8.00	6.21
Sd	0.93	0.78
N	100.00	100.00
Total sample	200.00	

Table 6: Size when 50% of crab at maturity (CW_{50}) in *Scylla* sp. from other studies.

Locality	Lat.	Species	CW_{50}-My (cm)		Source
			Female	Male	
Terengganu, Malaysia	5^0N	*S. olivacea*	9.06	8.97	Present study
Sarawak, Malaysia	1^0N	*S. olivacea*	8.6	-	Ikhwanuddin (2001)
Sarawak, Malaysia	1^0N	*S. tranquebarica*	9.2	-	Ikhwanuddin (2001)
Papua New Guinea	6^0S	*Scylla* spp.	10.5	-	Quinn & Kojis (1987)
South Africa	29^0S	*Scylla* spp.	12.3	9.2	Robertson & Kruger (1994)

Table 7: Size at maturity based on mature abdomen in female *Scylla* spp. from various localities.

Locality	Lat.	Species	Mature abdomen		Source
			n	CW range (cm)	
Terengganu, Malaysia	5^0N	*S. olivacea*	200	8.0-12.71	Present study
Sarawak, Malaysia	1^0N	*S. olivacea*	593	6.2-15.3	Ikhwanuddin (2001)
Sarawak, Malaysia	1^0N	*S. tranquebarica*	416	7.7-15.7	Ikhwanuddin (2001)
Penang, Malaysia	5^0N	*Scylla.* spp.	6	9.9-11.4	Ong (1966)
Thailand	12^0N	*Scylla.* spp.	-	8.94	Poovachiranon (1992)
India	13^0N	*Scylla.* spp.	-	9.0-11.0	Marichamy & Rajapackiam (1992)
Philippines	15^0N	*Scylla.* spp.	24	6.2-12.6	Lavina (1980)
Papua New Guinea	6^0S	*Scylla.* spp.	-	8.5-19.0	Quinn & Kojis (1987)
Australia	28^0S	*Scylla.* spp.	339	13.8-20.4	Heasman (1980)
South Africa	29^0S	*Scylla.* spp.	1,269	10.4-20.0	Robertson & Kruger (1994)

Table 8: Size at maturity based on sperm in AVD in male *Scylla* spp. from various localities.

Locality	Lat.	Species	Sperm in AVD		Source
			n	CW range (cm)	
Terengganu, Malaysia	5^0N	*S. olivacea*	200	8.0-14.00	Present study
Sarawak, Malaysia	1^0N	*S. olivacea*	153	?-11.5	Ikhwanuddin (2001)
Sarawak, Malaysia	1^0N	*S. tranquebarica*	98	?-13.9	Ikhwanuddin (2001)
Australia	28^0S	*Scylla.* spp.	48	10.8-18.7	Heasman (1980)
South Africa	29^0S	*Scylla.* spp.	93	8.3-15.6	Robertson & Kruger (1994)

AVD = Anterior vas deferen