



Journal of
**Fisheries and
Aquatic Science**

ISSN 1816-4927



Academic
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Biological Features of Sentinel Crab *Podophthalmus vigil* (Fabricus, 1798) in Terengganu Coastal Water, Malaysia

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ABSTRACT

Biological features of size at maturity, fecundity of berried female, size distribution, relationship of Carapace Width (CW) and Body Weight (BW) and sex ratio of sentinel crab, *Podophthalmus vigil* from Terengganu coastal water, Malaysia of South China Sea were studied. Sexual maturity (CW₅₀) was achieved at 11.51 cm for male and 9.53 cm for female. The mean fecundity was 312613.50±89835.08 eggs. Size distribution of male and female was slightly different with males have size range from 8.0 to 18.9 cm CW, while females ranged between 7.0 to 11.4 cm CW. The mean CW and BW of *P. vigil* males were significantly greater than that of females. The CW-BW relationship for males *P. vigil* was attained as $BW = 46.892e^{0.0719CW}$ ($R^2 = 0.1155$) and for females was estimated as $BW = 6.3117e^{0.2665CW}$ ($R^2 = 0.5523$). Finally, the sexual ratio of *P. vigil* for male to female was 1: 0.65. The data obtained from this study can be used as the baseline data for future study on *P. vigil* fishery and aquaculture management in Malaysia coastal water especially and within the Indo-pacific region generally.

Key words: Biological features, sentinel crab, *Podophthalmus vigil*

INTRODUCTION

Podophthalmus vigil is commonly known as the sentinel crab or formerly known as long-eyed swimming crab (Varadharajan *et al.*, 2012). The main characteristic of this crab is the present of two long eyes, reaching to or extended beyond edge of its carapace. The carapace is slightly broader than long; where the anterior margin much broader than posterior margin. The color of its carapace is green while chelipeds (first pair of leg) and the other part of the legs are violet to maroon in adult specimens. *Podophthalmus vigil* is a native marine species and is widely distributed in the Indo-Pacific region including Malaysian shore (Jones *et al.*, 2000; Mohammed and Coppard, 2008). Being known to live on sandy to muddy substrate in offshore water of tropical, subtropical and temperate regions, this crab is occasionally caught by trawlers but rarely in large numbers (Carpenter and Niem, 1998).

Size at sexual maturity, fecundity, size distribution, Carapace Width (CW) and Body Weight (BW) relationship and sex ratio are among the important aspects of biological features of crab fishery. This information is often required to manage crab fisheries on a sustainable basis. Sexual maturity is defined as the ability to successful mate and results in the extrusion of fertilized egg (Robertson and Kruger, 1994). Fecundity or reproductive potential can be defined as the number of ova shed during particular spawning season (Pillay, 1964) or the number of eggs produced in a single batch of spawning (Potter *et al.*, 1983). The later one is also known as “batch fecundity”.

Size distribution is important to ensure the size range of crab at a particular location. However, the pattern of size distribution fluctuates based on several determining factors such as growth rate, food availability and habitat loss. The relationship between body mass and length is a useful tool in ecological research, enabling easy and fast estimation of either CW or BW when only one parameter is available (Miyasaka *et al.*, 2007). This relationship is also often used to calculate the standing stock biomass, condition indices and used in the analysis of ontogenetic changes and several aspects of crustacean population dynamics. The study on sex ratio (male:female) of crabs will represent which sexes is relatively more abundant compare to the opposite sex at one particular area. Several estimations can be drawn from the sex ratio between male and female in which if they are varied strongly with season, one may preferred different habitats (characteristic of salinity and temperature differential distributions) and tend to form sex-aggregation (Xiao and Kumar, 2004).

The common portunid swimming crabs encountered from Malaysia coastal water are mud crabs, *Scylla* sp. and blue swimming crabs *Portunus* sp. *Podophthalmus vigil* is considered as one of the occasionally caught portunid swimming crab species. Personal observation shows that *P. vigil* is the by catch of blue swimmer crab, *P. pelagicus* from Malaysia coastal water. But recently, it was observed that *P. vigil* has been landed abundantly, becoming an addition to the crab fishery from Terengganu coastal water, Malaysia. Despite of its high potential to be commercialized, there is no study being done on *P. vigil* in Malaysia. This crab is also poorly described and studied from the Indo-Pacific region except studies by Subramanian (2001) from Tamil Nadu, India and Sather (1966) from Hawaii, USA. Literature reviews shows that the fishery landing of this crabs is not recorded in the Malaysia Annual Fisheries Reports (DoFM., 2013). Therefore the main objectives of this study were to determine the biological features in terms of size at maturity for both males and females, female fecundity, size distribution, relationship between CW and BW and sex ratio of *P. vigil* sampled from the Terengganu coastal water, Malaysia of South China Sea.

MATERIALS AND METHODS

Crab samples: All crab samples were collected weekly during August 2009 to November 2009 from Perhentian island and Redang island at 5°55'N, 102°43'E of South China Sea, Terengganu coastal water, Malaysia. A total of 223 individuals of *P. vigil* were randomly sampled throughout the whole study period. Specimens were sexed and the appropriate morphometric characters were measured and weighed.

Crab morphometrics and sexes: Crab size was measured as CW, which is the distance between tips of the ninth antero-lateral spines of the carapace (Fig. 1). The CW was measured to the nearest 0.1 cm using standard vernier calliper. The BW of the crabs was measured to the nearest 0.1 g using a digital electronic balance. All crabs were grouped in 0.5 cm size class intervals. The relationship between the CW and BW were determined by plotting linear regression morphometric graph. Crabs were sexed and sex ratio results were analyzed.

Size at maturity: Female crabs that had undergone pubertal (or maturity) moult with the accompanying widening and darkening of the abdomen were classified as matured females (Ikhwanuddin, 2007; Ikhwanuddin *et al.*, 2009, 2010, 2011). All other females were recorded as immature. Male maturity could not be determined from external characteristics. The male crab samples were dissected and examined in the laboratory. A section of the Anterior Vas Deferens



Fig. 1: Dorsal view of sentinel crab, *P. vigil* and the measurement for CW as indicated by the white double-ended arrow (distance between tips of the ninth antero-lateral spines of the carapace)

(AVD) of male crab was teased out in a drop of water on a glass slide and examined under a stereozoom microscope (Nikon AZ100M) for the presence of spermatophores containing sperm (Ikhwanuddin *et al.*, 2011; Robertson and Kruger, 1994). The presence of spermatophores indicates that the specimen can be classified as matured male. Carapace width at sexual maturity (CW_{50}) can be defined as the CW at which 50% of all individuals are sexually mature. Thus, CW_{50} could be estimated from the percentage (%) of mature males or females in their range size categories using logistic curve fitted with least square method by the following equation:

$$P_{cw} = 1/(1+e^{-a(cw-b)})$$

where, P_{cw} is the proportion of CW, a is the slope of the logistic curve and b is the CW at 0.5 proportion.

Fecundity of female crabs: A total of 10 berried females were obtained throughout the sampling period. The CW and BW of berried crabs were recorded. They were then killed and the fresh eggs were stripped off from the broad abdomen of the crab pleopod. The weight of freshly stripped egg mass was recorded and washed with fresh water before preserving in modified Gilson's fluid (Simpson, 1951). The immersed egg mass were shaken vigorously and left for 24 h. After 24 h, repeated shaking was done to help separate the eggs from eggs tissue and allow better penetration of the preservative into the egg mass (Bagenal, 1978). After three months the preserved egg mass were washed with water before counting (Bagenal, 1978). Eggs were counted using volumetric sub sampling (Bagenal, 1978). The cleaned eggs were poured into a 250 mL tall measuring cylinder in which they soon settled down. The total volume of eggs was noted. One milliliter of eggs volume was then removed and poured again into a 100 mL tall measuring cylinder containing 99 mL volume of water to make the volume mixture of eggs and water to be 100 mL. One milliliter of the mixture was drawn out using a 3 mm diameter feeding tube attached to 10 mL syringe for counting. Each time during sucking, the mixtures were stirred using glass rod to reduce the counting bias. The fecundity was taken as the mean of five counts.

RESULTS

Size at maturity: Out of 135 male samples, only 73 male crabs were matured (Table 1). The largest immature male encountered was 9.74 cm CW and the smallest matured male was 10.06 cm CW (Table 1). The mean size of mature male crabs was 11.81 ± 1.52 cm CW (Table 1). Crab size range was calculated for each 0.5 cm CW interval. The sampled male crabs were most frequently found in size range 11.5-11.9 cm CW (Fig. 2). Size at maturity for male crabs occurred at 11.51 cm CW with equation $P_{cw\ male} = 1/(1+e^{-0.90(cw-11.51)})$ (Fig. 3).

A total of 88 female crabs of *P. vigil* of various sizes were randomly sampled. Out of that, only 48 crabs showed matured abdomen. The largest immature female encountered was 10.67 cm CW

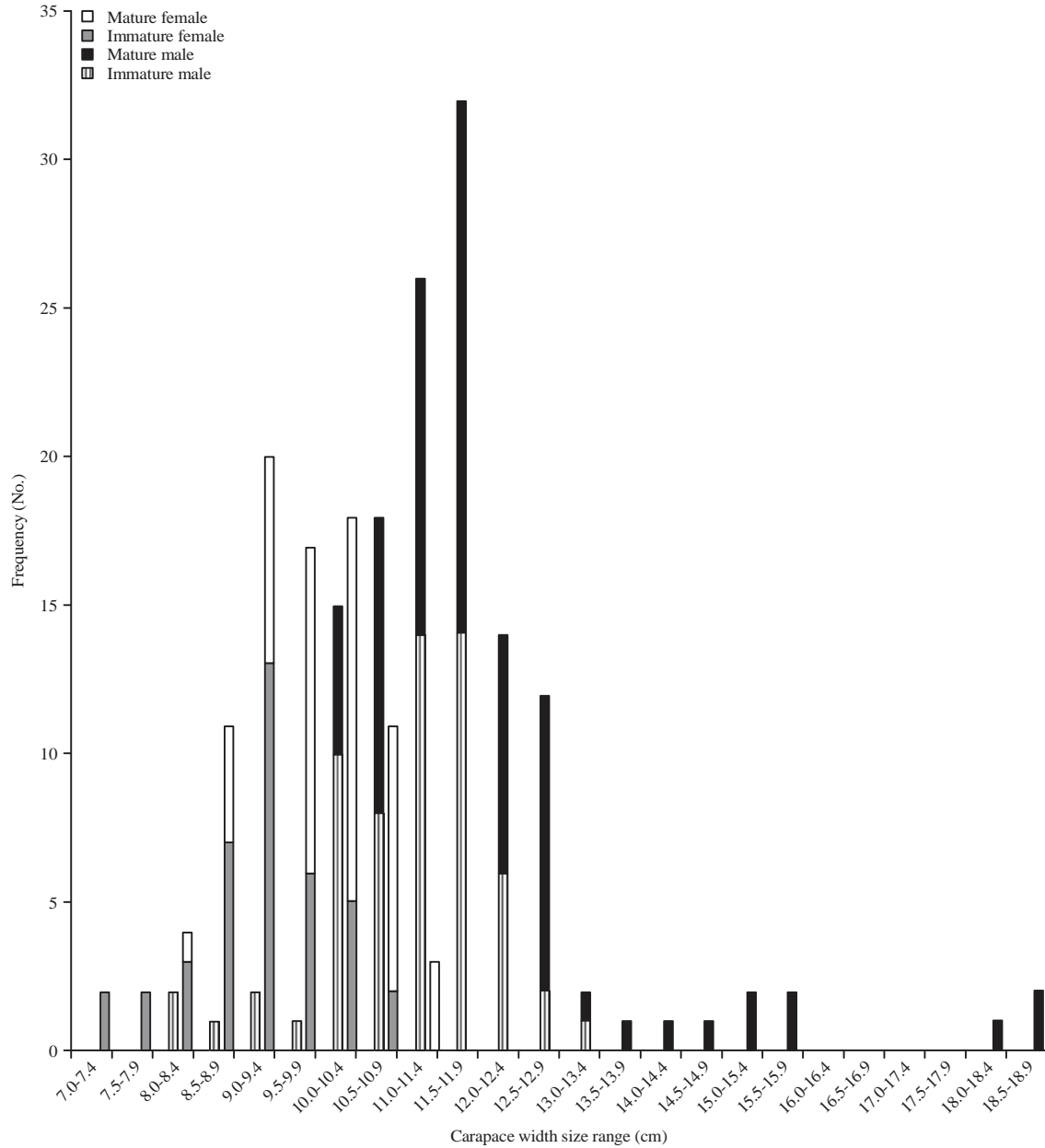


Fig. 2: Frequency of mature and immature *P. vigil* at each carapace width class (size class = 0.5 cm)

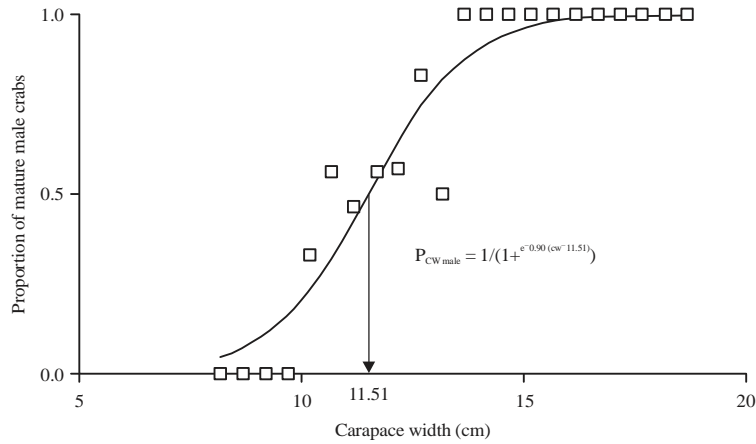


Fig. 3: Logistic curve of mature male *P. vigil*. The size at maturity (CW_{50}) was 11.51 cm, with a logistic equation of $P_{CW\ male} = 1/(1+e^{-0.90(cw-11.51)})$

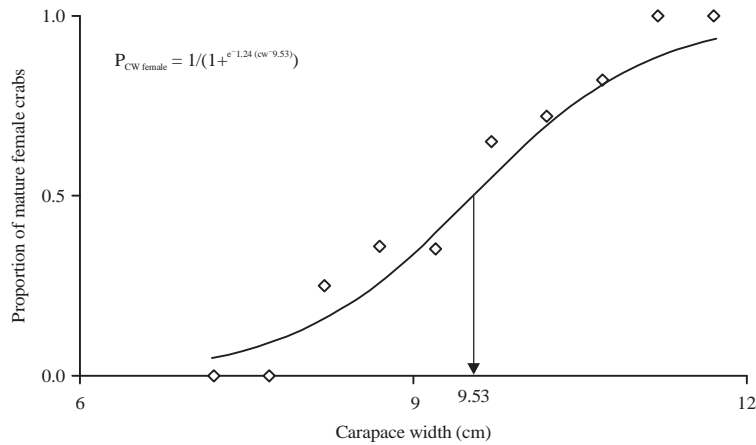


Fig. 4: Logistic curve of mature female *P. vigil*. The size at maturity (CW_{50}) was 9.53 cm, with a logistic equation of $P_{CW\ female} = 1/(1+e^{-1.24(cw-9.53)})$

Table 1: Mean CW size at maturity in male and female crabs of *P. vigil*

Parameters	Male CW (cm)		Female CW (cm)	
	Mature	Immature	Mature	Immature
Mean	11.81	8.95	9.70	9.46
Max.	18.89	9.74	11.25	10.67
Min.	10.06	8.04	7.17	7.08
SD	1.52	0.70	0.89	0.77
No.	73.00	62.00	48.00	40.00

and the smallest mature female was 7.17 cm CW (Table 1). The mean size of mature female crab was 9.70 ± 0.89 cm CW (Table 1). Crab size range was tabulated for each 0.5 cm interval. Approximately 55% of female crabs were found in the size range between 9.0-10.4 cm CW (Fig. 2). CW_{50} of female crabs was 9.53 cm with equation $P_{CW\ female} = 1/(1+e^{-1.24(cw-9.53)})$ (Fig. 4).

Fecundity: Out of 88 female crabs sampled, only 10 female crabs were berried. The CW of the berried females ranged from 9.40-10.70 cm. The minimum fecundity was found in crab having

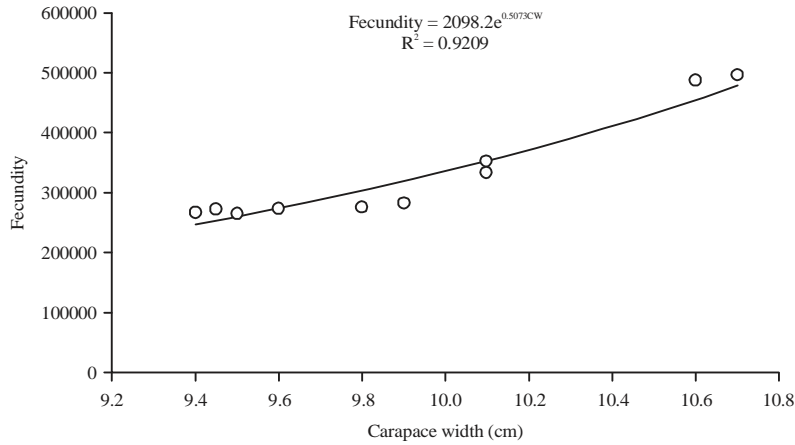


Fig. 5: Relationship between fecundity (egg numbers per female) and carapace width of *P. vigil* berried females

Table 2: Mean, maximum, minimum and standard deviation of carapace width and body weight in *P. vigil* female and male crabs sampled

Parameters	Male		Female	
	CW (cm)	BW (g)	CW (cm)	BW (g)
Mean	11.68	113.94	9.59	84.96
Max.	18.89	200.00	11.25	148.60
Min.	8.04	13.20	7.08	39.00
SD	1.62	30.69	0.84	24.57
No. (%)	135 (60.54%)	88 (39.46%)		

9.5 cm CW with 265,000 eggs, while the maximum fecundity was found in crab of 10.7 cm CW with 495, 900 eggs (Fig. 5). The mean fecundity was 312613.50 ± 89835.08 eggs with mean CW of 9.92 ± 0.46 cm. Fecundity (egg numbers per female) was positively correlated with female CW size with fecundity = $2098.2e^{0.50730CW}$ and $R^2 = 0.9209$ (Fig. 5).

Size distribution: The dominant size ranges for male and female *P. vigil* were 11.5-11.9 cm CW (23.70% of the male crabs sampled) and 9.0-9.4 cm CW (22.73% of the female crabs sampled) (Fig. 2). Male crabs’ shows broader size range from 8.0-18.9 cm CW, while female crabs had slightly narrower size range from 7.0-11.4 cm CW (Fig. 2).

Carapace Width (CW) and Body Weight (BW) relationship: The study shows that *P. vigil* males were significantly bigger and heavier than female crabs (Table 2). The mean CW and BW of *P. vigil* males were 11.68 ± 1.62 cm and 113.94 ± 30.69 g, respectively, while mean CW and BW of females were 9.59 ± 0.84 cm and 84.96 ± 24.57 g, respectively (Table 2). The CW-BW relationship for males *P. vigil* was attained as $BW = 46.892e^{0.0719CW}$ ($R^2 = 0.1155$) and for females was estimated as $BW = 6.3117e^{0.2665CW}$ ($R^2 = 0.5523$) (Fig. 6-7).

Sex ratio: A significant variation in sex ratio of male and female crabs was detected where male crabs are relatively more abundant than the female *P. vigil*. The sex ratio (male:female) was 1: 0.65, where male crabs contributed 60.54% while females contributed 39.46% (Table 2).

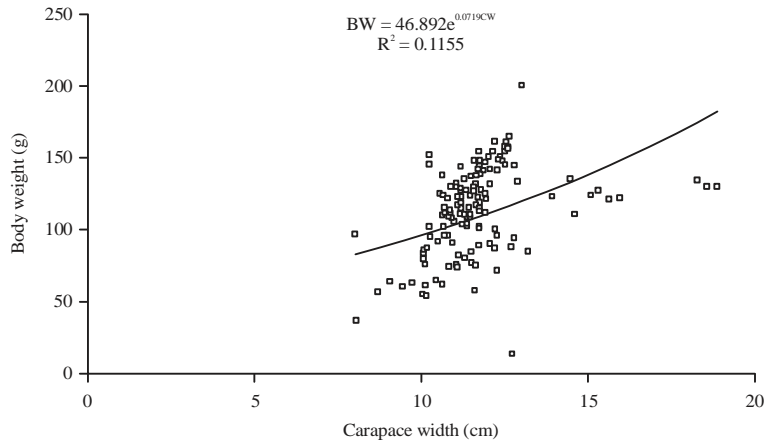


Fig. 6: Morphometric relationship between body weight and carapace width of male *P. vigil*

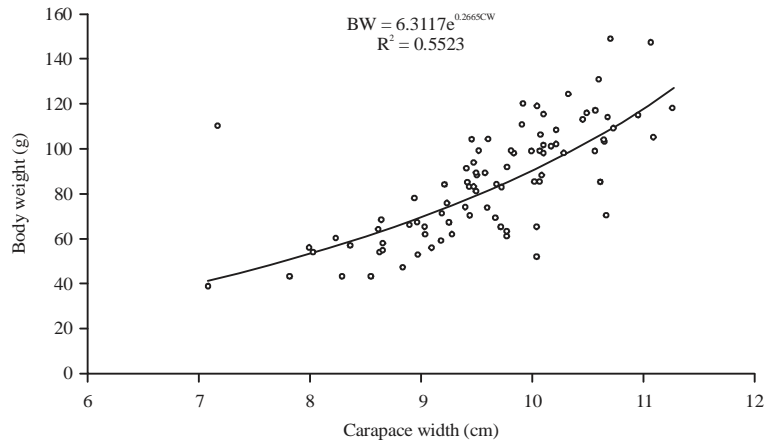


Fig. 7: Morphometric relationship between body weight and carapace width of female *P. vigil*

DISCUSSION

Literature review shows that there is no study been reported on sexual maturity of *P. vigil*. But there are a few studies on sexual maturity of other portunid crabs, mostly on blue swimming crabs, *Portunus* sp. and mud crabs, *Scylla* sp. (Batoy *et al.*, 1987; De Lestang *et al.*, 2003; Ikhwanuddin *et al.*, 2010, 2011; Kumar *et al.*, 2003; Lee and Hsu, 2003; Ogawa *et al.*, 2011; Potter *et al.*, 1983; Rasheed and Mustaqim, 2010; Robertson and Kruger, 1994; Sumpton *et al.*, 1989, 1994). Due to the lack of study on size at maturity in *P. vigil*, it is impossible to compare the results of size at maturity from the present study with other studies. This study shows that *P. vigil* females mature at a slightly smaller size than males (CW_{50} of males = 11.51 cm, CW_{50} of females = 9.53 cm). This is similar with results obtained by Sumpton *et al.* (1989) on *P. sanguinolentus* where the females mature at a smaller size than the males in Queensland, Australia. Comparatively, other studies on size at maturity for both *Portunus* sp. and *Scylla* sp., show that females mature at a larger size compare to male crabs (De Lestang *et al.*, 2003; Ikhwanuddin *et al.*, 2010, 2011; Rasheed and Mustaqim, 2010; Robertson and Kruger, 1994). It is postulated that crab's size at maturity probably varies due to geographical differences

(Ikhwanuddin *et al.*, 2009; Robertson and Kruger, 1994). This is clearly shown by Robertson and Kruger (1994), where there was a large difference in the minimum size of mature *S. serrata* females from Australia (minimum size = 13.8 cm CW) and South Africa (minimum size = 10.4 cm CW) although both populations occur at similar latitudes. These differences in size at maturity among the population of the same species of crab may also be attributed to variation in moult increment and in number of moults (Rasheed and Mustaqim, 2010).

The number of eggs produced per ovulation in the present study is very large and varies with crab size. Although, there is no comparable data on the female fecundity of *P. vigil*, the trend observed in the present study where larger crabs produce more eggs than smaller ones, as suggested by Warner (1977) was observed in other portunid females as well (Batoy *et al.*, 1987; De Lestang *et al.*, 2003; Hamasaki *et al.*, 2006; Potter *et al.*, 1983). This trend was strongly supported by Kumar *et al.* (2003), where, *P. pelagicus* female's fecundity increased 83.9% with an increase of CW from 10.5-12.5 cm. The present study scope does not determine the crab fecundity from more than one batch of crab eggs within a spawning period. Most of the previous fecundity estimation in portunid crabs have based on the number of eggs borne by females at only one particular time (Kumar *et al.*, 2003; Lee and Hsu, 2003; Mann *et al.*, 1999; Potter *et al.*, 1983). However, it is known that crustaceans are multiple spawners where larger crabs can produce two or more batches of eggs within a spawning period (De Lestang *et al.*, 2003). This is because the larger crabs (older crabs) have a far longer intermolt period between copulation and egg extrusion than smaller crabs (younger crabs), thus giving them greater amount of time to accumulate extra energy reserves required to produce eggs. This relationship between fecundity and body size is also expected in *P. vigil*.

The study shows that males were significantly larger in size (CW ranged from 8.0-18.9 cm) compared to the size of females (CW ranged from 7.0-11.4 cm). The smaller female crabs size may attribute to females may have reduced somatic growth compared to males because they concentrate on their energetic budget for gonad development (Litulo, 2005). Study by Xiao and Kumar (2004) also shows that male crabs grow faster hence moult more frequently than females, thus yielding a more broadly size of male rather than smaller size range in females.

In studying spiny crab species, such as *P. vigil* which has long ninth antero-lateral spines of the carapace, difficulties during the measurement of the species may arise due to extremities of the crab carapace spines that can easily snapped or injuries caused by the crab during measurement process. Therefore, it is convenient to be able to convert into CW when only the 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 *P. vigil* and the amount of time required to record CW in the study of these species. CW and BW are the most frequently used dimensions in the study of crustaceans and CW-BW relationship can be used for many purposes, calculating the standing stock biomass, condition indices and analysis of ontogenetic and aspects of fish or crustacean population dynamics. BW to CW ratio becomes smaller in females than males in the present study probably due to the large claws of the latter. The study also show that the rate of increase in male BW is more than in female which shows that male *P. vigil* are heavier than the females.

The present study clearly shows that male crabs are relatively more abundant than the females where the sex ratio (male:female) of *P. vigil* sampled are 1:0.65. The unequal sex ratio possibly because male and female prefer different habitats (different salinity or temperature preference between sexes, as observed in blue crab, *Callinectes sapidus* (Sumer *et al.*, 2013) and/or tends to form sex-aggregations (DeGoursey and Auster, 1992). The reductions of female crabs can be due

to the spawning season period during sampling where female crabs tend to migrate to sandy banks for egg extrusion (Sumpton *et al.*, 1994). Knuckey (1996) supports this result where the percentage of female drop rapidly compares to male *S. serrata* because of the spawning migration. Changes in feeding behavior can also reduce the attractiveness of commercial pots to female crabs during the spawning period (Xiao and Kumar, 2004). According to Czerniejewski and Wawrzyniak (2006), the dominance of males in the population is due to their much greater mobility. This suggest that the male's ability to move faster gives them better opportunities to catch food and in consequence, to achieve a higher rate of growth and a better condition. This could be the reason why the percentage of the male crabs is more than female crabs for the study site.

This study on the biological features of *P. vigil* can be used as baseline data for further study and useful in management and exploitation of *P. vigil* natural resources for both fishery and aquaculture management in Malaysia coastal water and within the Indo-pacific region.

ACKNOWLEDGMENT

We would like to thank the Institute of Tropical Aquaculture, Universiti Malaysia Terengganu for their support and financial assistance. This study was supported in part by the Malaysia's Ministry of Higher Education under Niche Research Grant Scheme (NRGS) (Vot. No. 53131).

REFERENCES

- Bagenal, T.B., 1978. Method for Assessment of Fish Production in Fresh Waters. Blackwell Scientific Publications, London, ISBN: 9780632001255, Pages: 365.
- Batoy, C.B., J.F. Sarmago and B.C. Pilapil, 1987. Breeding season, sexual maturity and fecundity of the blue crab, *Portunus pelagicus* (L.) in selected coastal waters in leyte and vicinity, Philippines. *Ann. Trop. Res.*, 9: 157-177.
- Carpenter, K.E. and V.H. Niem, 1998. The Living Marine Resources of the Western Central Pacific: Cephalopods, Crustaceans, Holothurians and Sharks. Food and Agriculture Organization of the United Nations, Rome, Italy, ISBN-13: 9789251040522, Pages: 716.
- Czerniejewski, P. and W. Wawrzyniak, 2006. Body weight, condition and carapace width and length in the Chinese mitten crab (*Eriocheir sinensis* H. Milne-Edwards, 1853) collected from the Szczecin Lagoon (NW Poland) in spring and autumn 2001. *Oceanologia*, 48: 275-285.
- De Lestang, S., N.G. Hall and I.C. Potter, 2003. Reproductive biology of the blue swimmer crab (*Portunus pelagicus*, Decapoda: Portunidae) in five bodies of water on the west coast of Australia. *Fish. Bull.*, 101: 745-757.
- DeGoursey, R.E. and P.J. Auster, 1992. A mating aggregation of the spider crab (*Libinia emarginata*). *J. Northwest Atlantic Fish. Sci.*, 13: 77-82.
- DoFM., 2013. Annual fisheries statistic 2013. Department of Fisheries Malaysia, Penang, Malaysia.
- Hamasaki, K., K. Fukunaga and S. Kitada, 2006. Batch fecundity of the swimming crab *Portunus trituberculatus* (Brachyura: Portunidae). *Aquaculture*, 253: 359-365.
- Ikhwanuddin, M., 2007. The biology, fishery and the development of seed production technology of blue swimming crab, *Portunus pelagicus* (Linnaeus, 1766). Ph.D. Thesis, Faculty of Resource Science and Technology, University Malaysia Sarawak, Malaysia.
- Ikhwanuddin, M., G. Azmie, H.M. Juariah, M.Z. Zakaria and M.A. Ambak, 2011. Biological information and population features of mud crab, genus *Scylla* from mangrove areas of Sarawak, Malaysia. *Fish. Res.*, 108: 299-306.

- Ikhwanuddin, M., M.L. Shabdin and A.B. Abol-Munafi, 2009. Size at maturity of blue swimming crab (*Portunus pelagicus*) found in Sarawak coastal water. *J. Sustain. Sci. Manage.*, 4: 56-65.
- Ikhwanuddin, M., Z. Bachok, W.W.Y.M. Faizal, G. Azmie and A.B. Abol-Munafi, 2010. Size of maturity of mud crab *Scylla olivacea* (Herbst, 1796) from mangrove areas of Terengganu coastal waters. *J. Sustain. Sci. Manage.*, 5: 134-147.
- Jones, D.S., M.A. Hewitt and A. Sampey, 2000. A checklist of the cirripedia of the South China Sea. *Raffles Bull. Zool.*, 48: 233-307.
- Knuckey, I.A., 1996. Maturity in male mud crabs, *Scylla serrata* and the use of mating scars as a functional indicator. *J. Crustacean Biol.*, 16: 487-495.
- Kumar, M.S., Y. Xiao, S. Venema and G. Hooper, 2003. Reproductive cycle of the blue swimmer crab, *Portunus pelagicus*, off Southern Australia. *J. Mar. Biol. Assoc. UK.*, 83: 983-994.
- Lee, H.H. and C.C. Hsu, 2003. Population biology of the swimming crab *Portunus sanguinolentus* in the Waters off Northern Taiwan. *J. Crust. Biol.*, 23: 691-699.
- Litulo, C., 2005. Population structure and reproductive biology of the fiddler crab *Uca inversa* (Hoffman, 1874) (Brachyura: Ocypodidae). *Acta Oecologica*, 27: 135-141.
- Mann, D., T. Asakawa and M. Pizzutto, 1999. Development of a Hatchery System for Larvae of the Mud Crab *Scylla serrata* at the Bribie Island Aquaculture Research Centre. In: *Mud Crab Aquaculture and Biology*, Keenan, C.P. and A. Blackshaw (Eds.). Watson Ferguson and Co., Brisbane, Australia, pp: 153-158.
- Miyasaka, H., M. Genkai-Kato, Y. Goda and K. Omori, 2007. Length-weight relationships of two varunid crab species, *Helice tridens* and *Chasmagnathus convexus*, in Japan. *Limnology*, 8: 81-83.
- Mohammed, S.W.C. and S.E. Coppard, 2008. Ecology and distribution of soft-sediment benthic communities off Viti Levu (Fiji). *Mar. Ecol. Prog. Ser.*, 371: 91-107.
- Ogawa, C.Y., K. Hamasaki, S. Dan and S. Kitada, 2011. Fishery biology of mud crabs *Scylla* spp. at Iriomote Island, Japan: Species composition, catch, growth and size at sexual maturity. *Fish. Sci.*, 77: 915-927.
- Pillay, T.R., 1964. An aid to identification of the Mysid cat fishes of Bangladesh. *Bangladesh J. Zool.*, 2: 1-12.
- Potter, I.C., P.J. Chrystal and N.R. Loneragan, 1983. The biology of the blue manna crab *Portunus pelagicus* in an Australian estuary. *Mar. Biol.*, 78: 75-85.
- Rasheed, S. and J. Mustaqim, 2010. Size at sexual maturity, breeding season and fecundity of three-spot swimming crab *Portunus sanguinolentus* (Herbst, 1783) (Decapoda, Brachyura, Portunidae) occurring in the coastal waters of Karachi, Pakistan. *Fish. Res.*, 103: 56-62.
- Robertson, W.D. and A. Kruger, 1994. Size at maturity, mating and spawning in the Portunid crab *Scylla serrata* (Forsk.) in Natal, South Africa. *Estuarine Coastal Shelf Sci.*, 39: 185-200.
- Sather, B.T., 1966. Observations on the molt cycle and growth of the crab, *Podophthalmus vigil* (Fabricius) 1) (Decapoda, Portunidae). *Crustaceana*, 11: 185-197.
- Simpson, A.C., 1951. The fecundity of the plaice. *Fish. Invest. Ser.*, 17: 1-27.
- Subramanian, V.T., 2001. On the exploitation of portunid crab *Podophthalmus vigil* (Weber) along the Chennai coast in Tamil Nadu. *Indian J. Fish.*, 48: 431-434.
- Sumer, C., I. Teksam, H. Karatas, T. Beyhan and C.M. Aydin, 2013. Growth and reproduction biology of the blue crab, *Callinectes sapidus* Rathbun, 1896, in the Beymelek Lagoon (Southwestern Coast of Turkey). *Turk. J. Fish. Aquat. Sci.*, 13: 675-684.

- Sumpton, W.D., G.S. Smith and M.A. Potter, 1989. Notes on the biology of the portunid crab, *Portunus sanguinolentus* (Herbst), in subtropical Queensland waters. *Aust. J. Mar. Freshwater Res.*, 40: 711-717.
- Sumpton, W.D., M.A. Potter and G.S. Smith, 1994. Reproduction and growth of the commercial sand crab, *Portunus pelagicus* (L.) in Moreton Bay, Queensland. *Asian Fish. Sci.*, 7: 103-113.
- Varadharajan, D., P. Soundarapandian and N. Pushparajan, 2012. New record of a long eyed swimming crab *Podophthalmus vigil* Fabricius, 1798 from Pondicherry Coast, South East Coast of India. *Int. J. Pharmaceut. Biol. Arch.*, 3: 1244-1246.
- Warner, G.F., 1977. *The Biology of Crabs*. Elek Science, London, UK., ISBN-13: 9780236400874, Pages: 202.
- Xiao, Y. and M. Kumar, 2004. Sex ratio and probability of sexual maturity of females at size, of the blue swimmer crab, *Portunus pelagicus* Linnaeus, off Southern Australia. *Fish. Res.*, 68: 271-282.