Malays. Appl. Biol. (2018) 47(6): 69–75

ESTIMATION OF SIZE AT SEXUAL MATURITY OF BLUE CRAB, *Portunus pelagicus* IN PENINSULAR MALAYSIA

NORLIYANA ASEMARI, NUR ATIKAH MATDAH, SIMON KUMAR DAS* and YOSNI BAKAR

School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
**E-mail: simon@ukm.edu.my*

Accepted 10 July 2018, Published online 31 December 2018

ABSTRACT

The size at the onset of maturity of the blue crab (*Portunus pelagicus*) is an important reference for decision making in fisheries management. The size at 50% sexual maturity (SOM_{50}) was investigated for crabs from the opposite coasts (east and west) of peninsular Malaysia. A total of 1554 and 1546 crabs from Kuala Kedah (west) and Mersing (east), respectively were utilized. Four common models were used for estimating SOM50. The SOM50 estimated for females (113-118 mm) were higher than males (105-110 mm). Crabs from Kuala Kedah attained maturity at bigger size than crabs from Mersing. The Akaike information criterion corrected for small sample indicated that the models were comparable but Lysack's model appeared the best for female crabs from Kuala Kedah. The use of gonadosomatic index (GSI) to estimate size at maturity for this species is not precise.

Key words: Gonadosomatic index, blue crab, size at maturity, management

INTRODUCTION

Experience world-wide has demonstrated that where unrestricted use of marine fisheries resources is allowed, there is little incentive for individuals harvesting the resource to conserve stocks. The resulting competition among and between user groups often leads to reduced biological and economic productivity. Left unmanaged, the increase in fishing effort that results from competition is reflected in lower individual catches of smaller and less valuable specimens and reduced financial returns in the commercial fishing sector (Smith & Addison, 2003). For instance, a high proportion of mud crabs, caught in Matang were estimated to be immature (Kosuge, 2001). Similarly, the size of the mature blue crab females and average fecundity has been reported to decrease in the Gulf of Thailand (Kunsoo *et al*., 2014).

The portunid crabs are found in nearshore marine and estuarine waters throughout the Indo-West Pacific. The principal management tool to ensure sustainability in the commercial crab fisheries is maintaining minimum landing size (MLS) well above the size at the onset of sexual maturity (SOM) of crabs to ensure adequate egg protection for crab stocks. Fisheries biologists prefer to conceive SOM as the average size at which 50% of the individuals are mature (SOM_{50}). In developed fishery industry, additional regulations include seasonal closures, ban on landing of soft-shelled and ovigerous crabs, mandatory escape gap in pots or by a one-sex harvesting strategy (Hamid *et al.,* 2016).

Currently, there is no restriction on crab harvest in Malaysia and the implementation of effective management will necessarily depend on scientific information as well as on willingness and cooperation of the crab fishers. SOM of crabs varies among species, and within species depending on geographical locations which may reflect differences in genetic composition and environment such as density and water temperature. The waters of the west coast of Peninsular Malaysia is exposed to the Andaman Sea and the Indian Ocean while the east coast is opened to the South China Sea and the Pacific Ocean. Although we expect the environment to be comparatively similar, nonetheless they may be subtle differences between the coasts that may affect the crab populations. The study aims to provide the information on SOM_{50} of crabs in the waters of the west and east coasts of Peninsular Malaysia.

* To whom correspondence should be addressed.

MATERIALS AND METHODS

Sampling regimes

Samples were obtained from Kuala Kedah (6°5'60"N, 100°17'60"E) in the west coast and Mersing (2°25'52"N, 103°50'50"E) in the east coast of Peninsular Malaysia. Approximately 100 *Portunus pelagicus* were collected monthly from each sampling location landing ports for a year to give a total of 1554 (1002 males, 552 females) and 1546 (866 males, 680 females) crabs from Kuala Kedah and Mersing, respectively.

Measurements

The carapace width (CW) for each crab which is the distance between tips of the two lateral spines of the carapace was measured to the nearest 1 mm using a digital vernier caliper. The weight of the gonad was obtained to the nearest gram (g) and used to determine the gonadosomatic index [GSI, GSI = (Gonad weight/Body weight)*100] (Simon *et al*., 2009, 2012). The ovary was scored to one of four stages of maturity and the males into three stages based on the macroscopic appearance of the gonad as outlined by Zhu *et al.* (2011).

Size at sexual maturity

The GSI was tested as a reproductive flag to estimate SOM_{50}. In addition SOM_{50} was also estimated per 10 mm size-class by fitting four non-linear models shown below:

1. Lysack's model (1980)

$$P_L = \frac{G}{1+e^{-d(CW50-CW)}}$$

2. Bakhayokho's model (1983)

$$P_L = \frac{1}{1+e^{a+bCW}} \text{ where CW50} = \text{-a/b}$$

3. Gompertz's model (1825)

$$P_L = e^{-e^{-\theta(CW-CW50)}}$$

4. White's model (2002)

$$P_L = \frac{1}{1+e^{\left[-\ln(19)\frac{CW-CW50}{CW95-CW50}\right]}}$$

In all the above models, P_L is the proportion mature at carapace width *CW*. *CW50* or the size at which 50% of crabs are mature and *d*, *a*, *b*, θ and *CW95* are parameters to be estimated. *d* is the rate at which maturity is attained; *a, b* and θ are parameters that define the shape and position of the fitted curve. To determine the best model for expressing SOM_{50} (or denoted *CW50* in the above models), the Akaike information criterion (*AICc*) corrected for small number of observations was used,

$$AICc = n\ln(\hat{\sigma}^2) + 2K + \frac{2K(K+1)}{n-K-1}$$

where *n* = number of observations, *K* = number of parameters and σ^2 = estimate of residual variance.

RESULTS

The size ranges for males were 81-165 mm and 84-155 mm for Kuala Kedah and Mersing respectively while for females were 93-165 mm for Kuala Kedah and 76-166 mm Mersing.

Male gonads were small and negligible in terms of weight and could not be accurately used to obtain the GSI values. The GSI for female crabs of Kuala Kedah and Mersing, respectively were shown in Figure 1. Estimated SOM_{50} for Kuala Kedah was 120 mm and for Mersing was 110 mm. Even though estimates of SOM_{50} could be ascertained using GSI, the approach highlights the potential problem of where to establish the border line at which the crabs were considered as mature. The GSI values equal to or greater than a specific percentage of the maximum GSI for the crabs must be known when using this approach. Hamid *et al.,* (2016) reported that GSI > 3 can be regarded as mature in Sulawesi while GSI > 4 can be classified as mature for crabs in Australia.

The SOM_{50} estimated by the four models showed that both male and female crabs from Mersing tended to attain sexual maturity at smaller sizes than the crabs from Kuala Kedah. The SOM_{50} for Mersing males were 100.08 – 105.34 mm while Mersing females were 110.52 – 113.79 mm (Figure 2). Crabs from Kuala Kedah attained SOM_{50} at 107.69 mm – 110.89 and 116.43 – 118.35 for males and females, respectively (Figure 3). Among the male crabs, the lowest SOM_{50} was obtained from Gompertz (1825) model for both Mersing (100.08 mm) and Kuala Kedah (107.69 mm) samples. The other three models (Lysack, Bakhayokho and White) showed relatively identical values of SOM_{50} (105.3mm and 110.8 mm). Similar trends were observed for females.

For the maturation rate i.e. the rate at which crabs attained maturity, (*d* of Lysack's), was 0.13 mm^{-1} (Mersing) and 0.2 mm^{-1} (Kuala Kedah) for males and 0.22 mm^{-1} (Mersing) and 0.37 mm^{-1}(Kuala Kedah) for females. Smaller values of maturation rate

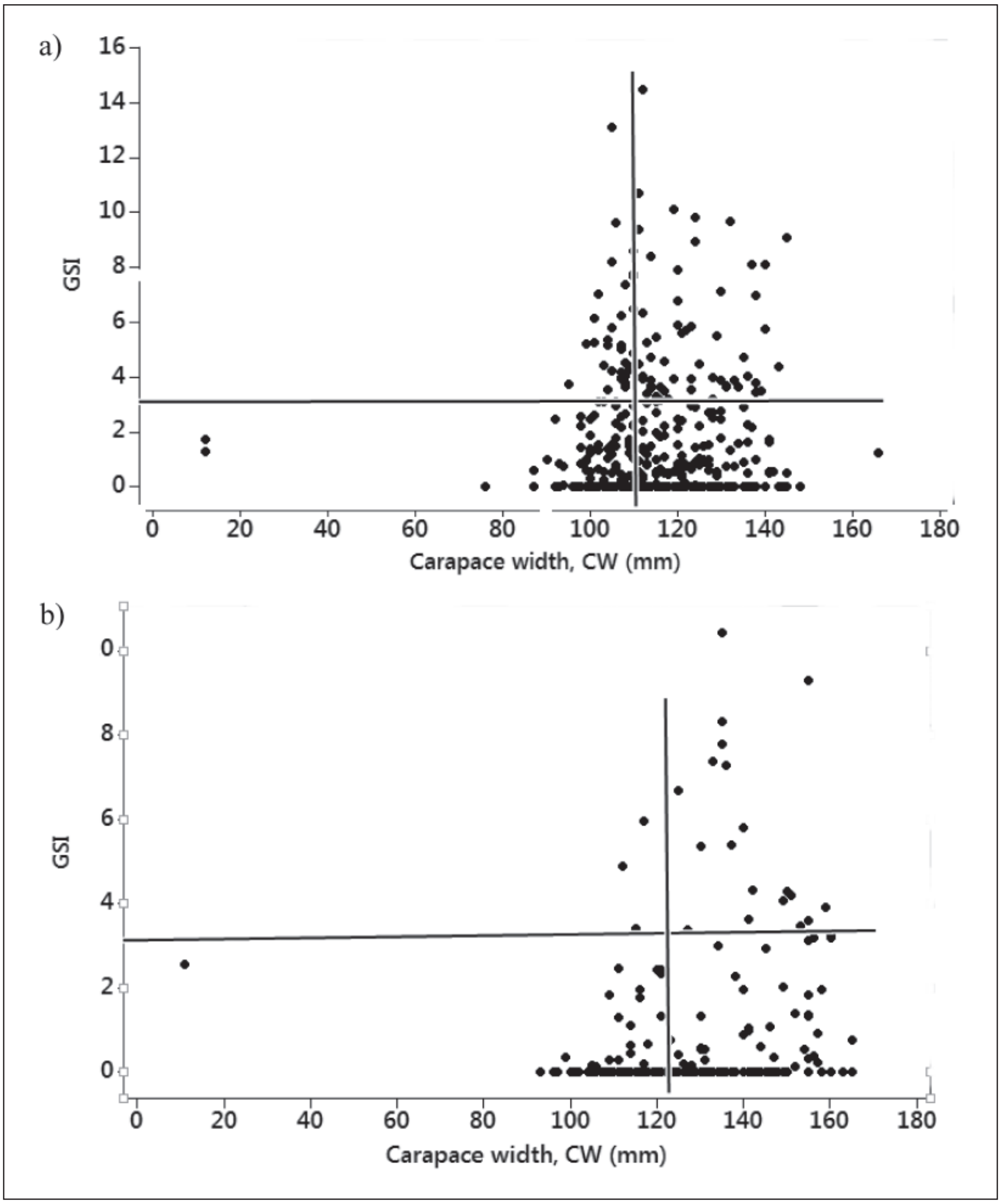

Fig. 1. Plots of female gonadosomatic index (GSI) against carapace width (CW) for a) Mersing and b) Kuala Kedah. Horizontal lines denote mature individuals (GSI>3) and vertical lines represent CW at which 50% of individuals attain maturity.

(θ) were obtained from Gompertz (1825) model. Males again showed smaller values (0.08 mm^{-1} for Mersing and 0.15 mm^{-1} for Kuala Kedah) than females (0.15 mm^{-1} for Mersing and 0.29 mm^{-1} for Kuala Kedah).

The four models are comparatively similar in terms of *AICc* values for Mersing samples. However, Lysack's model with the smallest *AICc* (-60.3) could be accepted as the best for female crabs from Kuala Kedah (-60.3) while Lysack's, Bakhayokho's and White's models were comparable for male crabs (Table 1).

DISCUSSION

SOM have been determined for crabs inhabiting temperate or subtropical waters but scarcely reported in tropical waters. The length at which *P. pelagicus* reaches sexual maturity varies depending on growth rate, which is a direct function of temperature (Fisher, 1999). For example the SOM_{50} for both males and females in Western Australia is 97 mm, while in the Philippines SOM_{50} is 106 mm (Kangas, 2000; De Lestang *et al*., 2003). The corresponding size in Sulawesi is 119 cm for males and 108 cm for

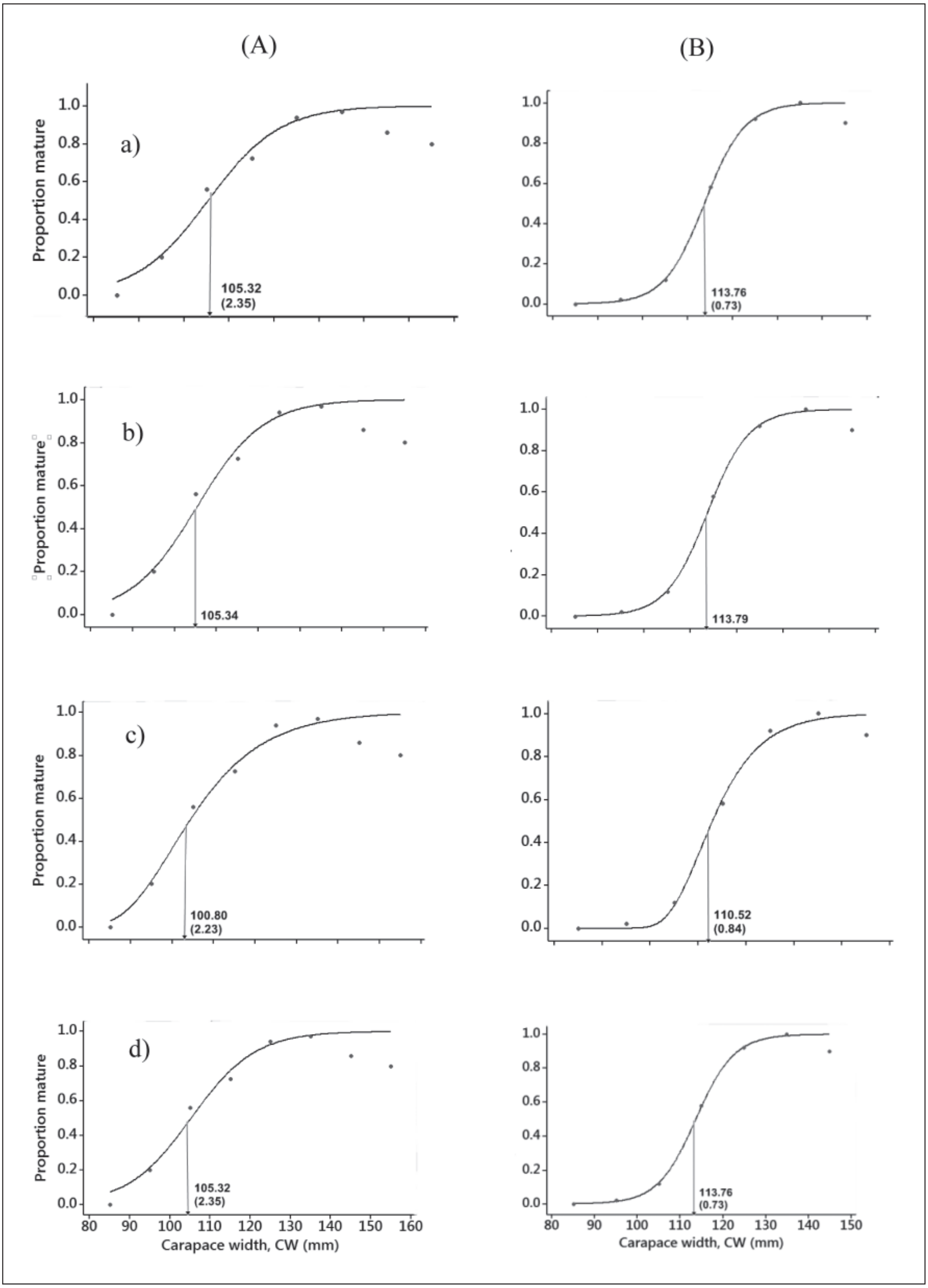

Fig. 2. The maturity curves for male (A) and female (B) crabs from Mersing based on Lysack (a), Bakhayokho (b), Gompertz (c) and White (d) models. Arrows and numbers denote CW_{50}'s and their standard errors.

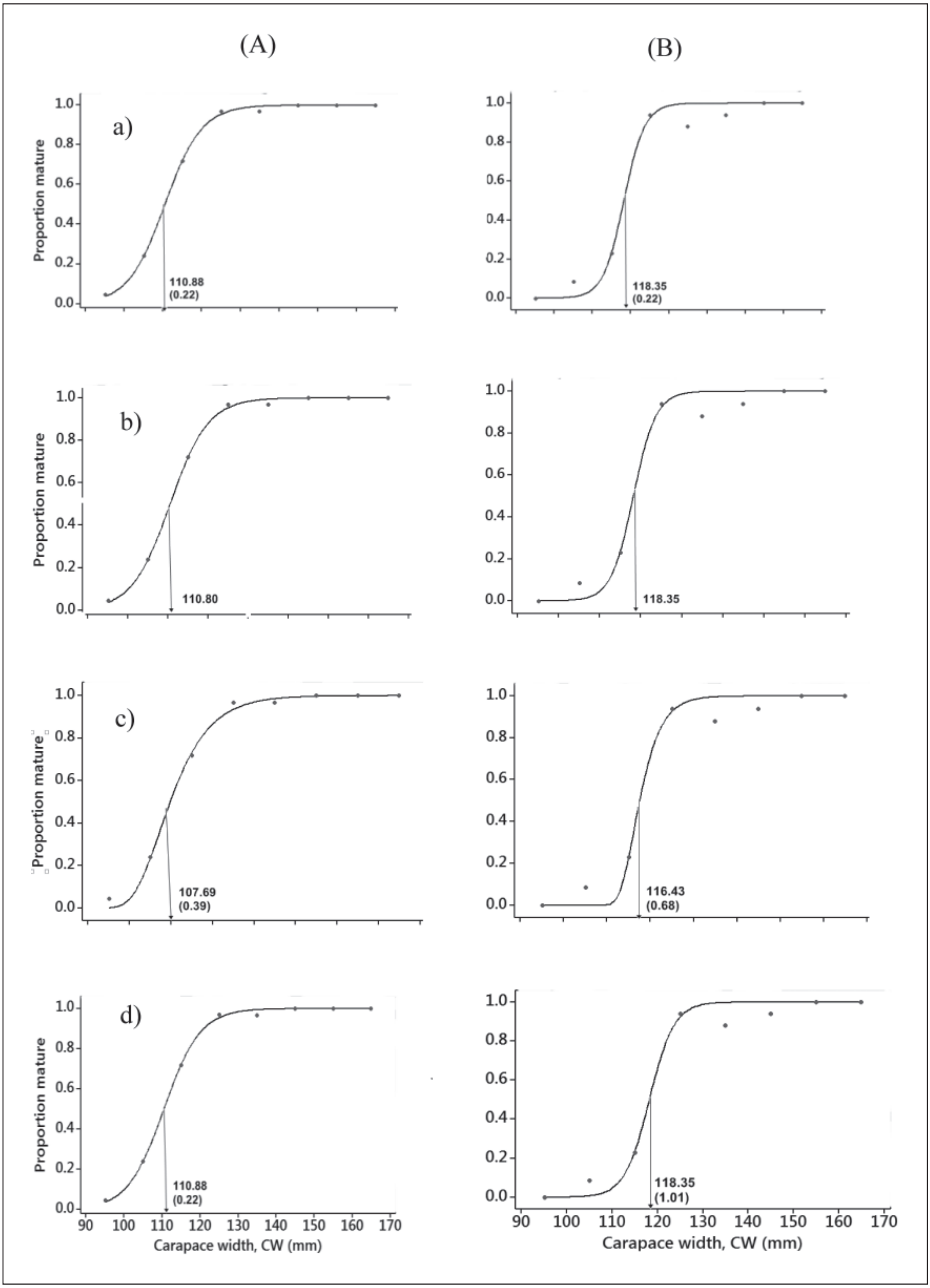

Fig. 3. The maturity curves for male (A) and female (B) crabs from Kuala Kedah based on Lysack (a), Bakhayokho (b), Gompertz (c) and White (d) models. Arrows and numbers denote CW_{50}'s and their standard errors.

Table 1. Size at maturity (L_{50}), 95% confidence interval C.I.) and the corrected Akaike Information Criterion (AICc) for each model by population and sex

Population	Sex	Model	L_{50} (mm)	95% C.I. of L_{50}	AICc
Mersing	Male	Lysack	105.32	99.46, 111.34	-25.933
		Bakhayokho	105.34	–	-25.933
		Gompertz	100.08	94.26, 105.11	-27.529
		White	105.32	99.46, 111.34	-25.934
	Female	Lysack	113.77	111.73, 115.51	-31.823
		Bakhayokho	113.79	–	-31.822
		Gompertz	110.52	108.21, 112.95	-30.894
		White	113.77	111.73, 115.51	-31.823
Kuala Kedah	Male	Lysack	110.88	109.92, 110.98	-60.318
		Bakhayokho	110.89	–	-60.318
		Gompertz	107.69	106.35, 108.32	-49.750
		White	110.88	109.92, 110.97	-60.318
	Female	Lysack	118.35	117.92, 118.97	-60.318
		Bakhayokho	118.34	–	-34.558
		Gompertz	116.43	115.33, 118.24	-34.328
		White	118.35	116.89, 120.58	-34.558

females (La Sara *et al*., 2016), Turkey at 115-120 mm (Tureli & Yesilyurt, 2017) and India at 80-90 mm (Soundarapandian *et al*., 2013). On a smaller geographic scale, SOM_{50} in this study is higher than that obtained by Ikhwanuddin *et al.* (2009) who reported SOM_{50} of 85 mm for male and 95 mm for female crabs of Sarawak waters. Differences in the reported values are most likely due to differences in the methodology of determining SOM_{50} (Zhu *et al.,* 2011), geography and the degree of exploitation of the resources (Kunsoo *et al*., 2014). A more serious potential error in the estimation is caused by biased sampling of crabs (Smith & Addison, 2003). Often samples do not represent crabs of all sizes, rather samples comprising of large crabs caught by traps or bought from fishermen. In this study, although catches obtained using active fishing methods, such as seine-netting have been shown to represent a far better the size composition of the population (Smith *et al*., 2004), yet the proportion of mature crabs in the samples was relatively high at 60% thus exposing the bias of obtaining samples from fishers who inadvertently caught larger crabs. Consequently, for any size class, the proportion of mature females were overestimated, so shifting the maturity curve fitted to the proportions of mature crabs in each size class to the left, hence yielding an underestimate of the SOM_{50}.

Zhu *et al.* (2011) recognizes the large differences in the estimated SOM_{50} using different methods where the author reported the AIC values tended to indicate the best model for estimating the size at sexual maturity of bigeye tuna using non-linear regression was Lysack's model. The models used for crabs in this study performed relatively well but Lysack's model was the best fit model for female crabs from Kuala Kedah. Other approaches such as logistic regression relating maturity and carapace width have been applied for crabs elsewhere (Ikhwanuddin *et al.,* 2009).

The minimum landing site (MLS) was discussed by Ungfors (2007) on the edible crab *Cancer pagurus*. Based on this study, It is recommended that the MLS for *P. pelagicus* in Peninsula Malaysia be set at CW_{75} or the equivalent of about 125 mm to allow for sustainable crab resources.

CONCLUSION

The SOM_{50} for Kuala Kedah were higher than Mersing for both male and female crabs. Male crabs had lower SOM_{50} than female crabs. Based on the non-linear models SOM_{50} for males ranged from 110.08 mm to 110.89 mm and from 110.52 mm to 118.35 mm for females. It is recommended that the minimum landing size (MLS) for crabs in Malaysian waters be set at 75% maturity which corresponds to roughly 125 mm CW.

ACKNOWLEDGEMENTS

We would like to thank the anonymous reviewers for their thoughtful comments and efforts towards improving our manuscript. We also would like to thank Institute of Climate Change, Universiti Kebangsaan Malaysia for the financial support through the research grant GUP-2017-023.

REFERENCES

Bakhayokho, M. 1983. *Biology of the cuttlefish Sepia officianalis hierradda of the Senegal coast FAO Technical Paper.* Amsterdam: FAO, Fisheries Technical Paper. pp. 263.

De Lestang, S., Hall, N.G. & Potter, I.C. 2003. Reproductive biology of the blue swimmer crab (*Portunus pelagicus*) in five bodies of water on the west coast of Australia. *Fisheries Bulletin,* **101**: 745-757.

De Lestang, S., Hall, N.G. & Potter, I.C. 2003. Reproductive biology of the blue swimmer crab (*Portunus pelagicus*) in five bodies of water on the west coast of Australia. *Fisheries Bulletin*, **101**: 745-757.

Gompertz, B. 1825. On the nature of the function expressive of the law of human mortality. *Philosophical Transaction of the Royal Society of London*, **115**: 513-585.

Hamid, A., Djamar, T.F., Etty Rianai & Wardiato, Y. 2016. Reproductive biology of blue swimming crab (*Portunus pelagicus*) in Lasongko Bay Southeast Sulawesi-Indonesia. *ACCL Bioflux,* **9(5)**: 121-124.

Ikhwanuddin, M., Shabdin, M.L. & Abol-Munafi, A.B. 2009. Size at maturity of Blue Swimming Crab found in Sarawak Coastal Water. *Journal of Sustainability Science and Management,* **4(1)**: 55-65.

Kangas, M.I. 2000. Synopsis of the biology and exploitation of the blue swimmer crab, *Portunus pelagicus* Linnaeus, in Western Australia. *Fisheries Research Report,* **121**: 1-22.

Lysack, W. 1980. *Lake Winnepeg fish stock assessment program*. Canada: Manitoba Department Natural Resources. pp. 118.

Simon, K.D., Bakar, Y., Samat, A., Zaidi, C.C., Aziz, A. & Mazlan, A.G. 2009. Population growth, trophic level and some aspects of reproductive biology of two congeneric archer fishes (*Toxotes chatareus*, Hamilton 1822 and *Toxotes jaculatrix*, 1767) inhabiting Malaysian coastal waters. *Journal of Zhejiang University Science B*, **10(12)**: 902-911.

Simon, K.D., Mazlan, A.G., Bakar, Y., Samat, A., Zaidi, C.C., Arshad, A., Temple, S.E. & Nancy., J.B.P. 2012. Aspects of the reproductive biology of archer fishes *Toxotes chatareus*, (Hamilton 1822) and *Toxotes jaculatrix* (Pallas 1767). *Environmental Biology of Fishes*, **93(4)**: 491-503.

Smith, M.T. & Addison, J.T. 2003. Methods for stock assessment of crustacean fisheries. *Fisheries Research,* **65**: 231-256.

Soundarapandian, P., Varadharajan, D. & Boopathi, A. 2013. Reproductive biology of the commercially important portunid crab, *Portunus sanguinolentus* (Herbst). *Journal of Marine Science: Research & Development*, **3(2)**: 1-9.

Ungfors, A. 2007. Sexual maturation of edible crab (*Cancer pagurus*) in the Skagerrak and the Kattegat, based on reproductive and morphometric characters. *ICES Journal of Marine Science,* **64**: 318-327.

White, W.T., Hall, N.G. & Potter, I.C. 2002. Size and age compositions and reproductive biology of the nervous shark *Carcharhinus cautus* in a large subtropical embayment, including an analysis of growth during pre and postnatal life. *Marine Biology,* **141**: 1153-1164.

Zhu, G., Dai, X., Song, L. & Xu, L. 2011. Size at sexual maturity of bigeye tuna *Thunnus obesus* in the Tropical Waters: a Comparative Analysis. *Turkish Journal of Fisheries and Aquatic Sciences,* **11**: 151-158.