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Population dynamics of mantis shrimp, *Harpiosquilla harpax* in the coastal waters of Pantai Remis, Perak, Peninsular Malaysia

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Abstract

This study estimated the length-weight relationship, sex ratio and population parameters of mantis shrimp, *Harpiosquilla harpax* from the coastal waters of Pantai Remis, Perak, Malaysia between February 2012 and October 2012. Total length and weight of 804 specimens of *H. harpax* were measured and the sex ratio was 1: 0.83 (M: F). Males of *H. harpax* were dominant over the females throughout the study period. The value of relative growth coefficient (b) for *H. harpax* was 2.698 for males and 2.884 for females. For the length-weight relationship, the species exhibited negative allometric growth for males, females and combined sexes. The L_∞ and K of *H. harpax* was 18.38 cm and 1.10 yr^{-1} for males; and 21.53 cm and 0.75 yr^{-1} for females. The growth performance index (φ') was calculated as 2.57 for males and 2.54 for females. Total mortality (Z), natural mortality and fishing mortality was found to be 4.084 yr^{-1}, 2.247 yr^{-1} and 1.837 yr^{-1} for males; whereas 3.259 yr^{-1}, 1.674 yr^{-1}, 1.585 yr^{-1} for females, respectively. The recruitment pattern of the species was continuous throughout the year for males and females. The exploitation level (E) of *H. harpax* was estimated at 0.449 for males and 0.486 for females. It is revealed that the stock of *H. harpax* was very close to optimum level of exploitation (E = 0.50) in the coastal waters of Pantai Remis, Perak, Malaysia.

Keywords: *Harpiosquilla harpax*, Condition factor, Sex ratio, Recruitment, Exploitation

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Introduction

The mantis shrimp *H. harpax* is locally known as 'udang lipan' in Peninuslar Malaysia and one of the popular food in Malaysia. It occurs very widely in the Indo-West Pacific ranging from Red Sea, Gulf of Oman, Madagascar, South Africa, Sri Lanka, Pakistan, India, Thailand, Singapore, Malaysia and Indonesia. To this date, the status of this shrimp is still undefined as it is assumed as trash fish (Wild Fisheries Research Program, 2009). However, the main uses of this shrimp for food is for local dishes like 'mee udang lipan' and 'mee rebus udang lipan' in Pantai Remis, Malaysia.

Population dynamics of stomatopod has been studied in other countries such as in Mekong Delta of South Vietnam by Dinh *et al*. (2010), in Kuala Tungkal of Jambi Province Sumatera Island, Indonesia by Wardiatno and Mashar (2011), and in Madras of India by James and Thirumilu (1993). Many researches have been completed on the behaviour of mantis shrimp (Manfrin and Piccinetti, 1970), population genetics of stomatopod (Barber *et al*., 2002) and relationship between body length, processed meat length and seasonal changes in net processed-meat of *Oratosquilla oratoria* (Kodama *et al*., 2006). However, study regarding population biology of stomatopods in Malaysia is still lacking. Therefore, the present study was undertaken on the population dynamics to know the stock status of *H. harpax* in the coastal waters of the Pantai Remis, Perak, Peninsular Malaysia

Materials and methods

Study area and sampling

The present study was conducted in the coastal waters of Pantai Remis, (4° 26' 41.9202" N, 100° 37' 2.4564" E), Perak, Peninsular Malaysia (Fig. 1). This mantis shrimp is usually caught by a trawl net and random sampling was implemented monthly between February 2012 and October 2012. The samples were preserved in a freezer until ready to be analyzed. In the laboratory, total length of 804 individuals was measured using a digital calliper to the nearest 0.1 mm and total weight was taken by an electronic balance of 0.001 g accuracy.

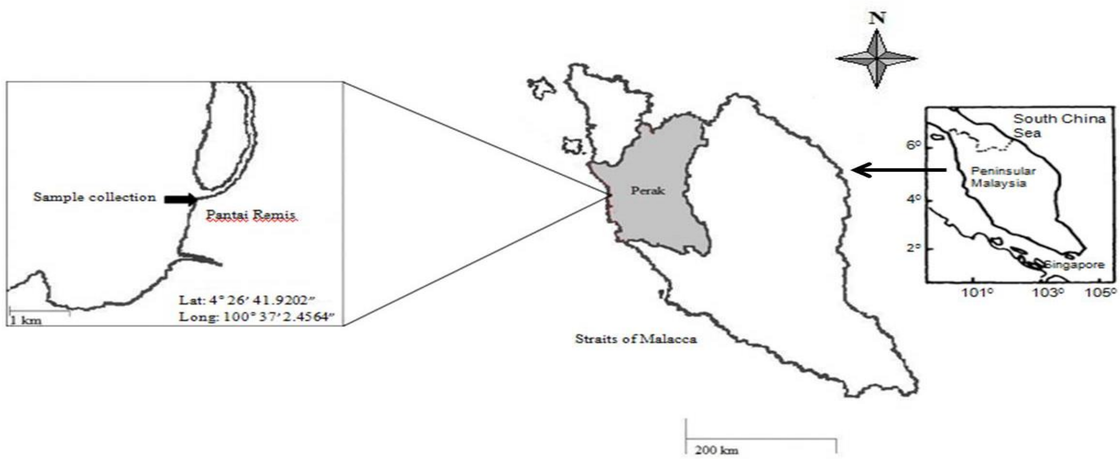

Figure 1: Geographical location of the sampling sites in coastal waters of Pantai Remis (4° 26' 41.9202" N, 100° 37' 2.4564" E), Perak, Peninsular Malaysia.

Data analysis

To establish the length-weight relationship, $W=aL^b$ was used where W is the weight (g), L is the total length (cm), 'a' is the intercept (condition factor) and 'b' is the slope (relative growth coefficient). In addition, 95% confidence limits of the parameters a and b and the statistical significance level of r^2 were estimated.

Total length frequencies data of *H. harpax* was grouped by 1 cm interval. The data were then analysed using the FiSAT (FAO ICLARM Fish Stock Assessment Tools) software, explained in details by Gayanilo Jr. *et al*. (1996). Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth function (VBGF) were estimated using ELEFAN-1 routine (Pauly and David, 1981) in the FiSAT software. K scan routine was conducted to estimate reliable value of K. The L_∞ and K were used to calculate the growth performance index (φ') (Pauly and Munro, 1984) of the species *H. harpax* using below equation:

$$\varphi' = 2 \log10 L_\infty + \log10 K$$

Total mortality (Z) was calculated using Jones and van Zalinge Plot (Jones and van Zalinge, 1981) and natural mortality was estimated by Pauly's empirical formula (Pauly, 1980):

$$\text{Log}_{10}M = -0.0066 – 0.279 \text{Log}_{10}L_\infty + 0.6543.\text{Log}_{10} K + 0.4634 \text{Log}_{10} T$$

Where M is the natural mortality, L_∞ is the asymptotic length; K is the growth coefficient of the VBGF, and T is the mean annual water temperature (^{0}C) of habitat.

Fishing mortality (F) was estimated using the relationship as F=Z-M; where Z is the total mortality, F is the fishing mortality and M is the natural mortality.

The exploitation level (E) was obtained by the formula of Gulland (Gulland, 1971) as E=F/Z. The recruitment pattern was determined by projecting the available length frequency data backwards on the length axis as described in FiSAT. Normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

Results

Length-weight relationships

Length weight relationships were calculated for males and females separately. The regression between total length (TL) and total body weight (TW) for both males and females of *H. harpax* showed negative allometric relationship (Fig. 2). The exponential length-weight equation was $W=0.0225TL^{2.6978}$ (r^2= 0.7148, $p<0.05$) for males and $W= 0.0142TL^{2.8837}$ (R^2=0.8988, $p<0.05$) for females. The computed growth coefficient (b) was 2.6978 for males and 2.8837 for females. The *b* values ranged from 2.538 to 2.858 for males and from 2.784 to 2.984 for females at 95% confidence limit (Table 1).

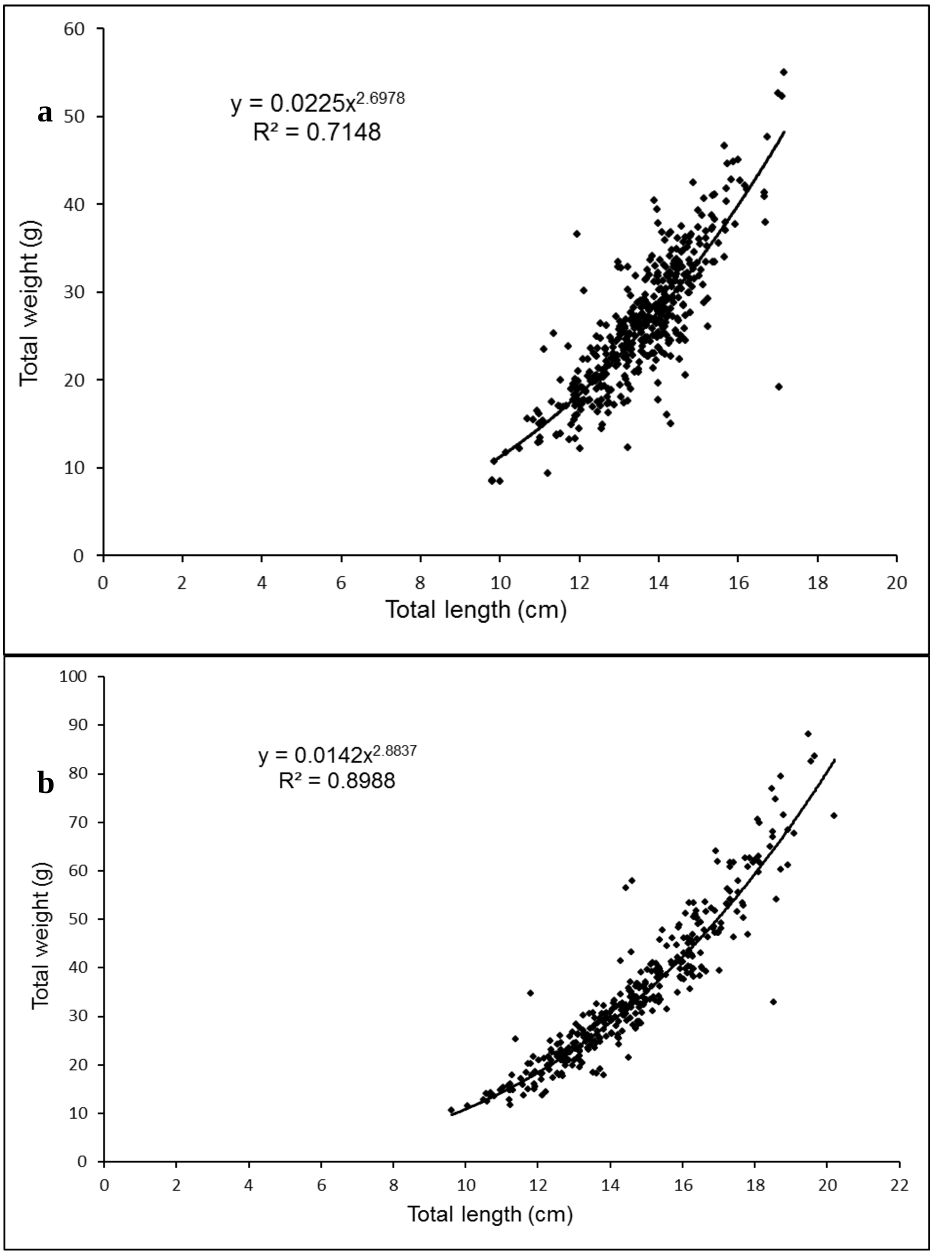

Figure 2: Length weight relationship for males (a) and females (b) of *H. harpax* in the coastal waters of Pantai Remis during February - October, 2012.

Table 1: Length weight relationship parameters of *H. harpax* in the coastal waters of Pantai Remis, Perak during the study period from February to October 2012.

Sex	N	a	b	95% CI of b	r^2	Growth type
M	439	0.023	2.698	2.538 – 2.858	0.715 (p<0.05)	Allometric (-)
F	365	0.014	2.884	2.784 – 2.984	0.899 (p< 0.05)	Allometric (-)
B	804	0.015	2.852	2.767 – 2.983	0.841 (p<0.05)	Allometric (-)

Condition factor and sex ratio

Based on the graph above, the relative condition factor was calculated monthly for both male and female of *H.harpax*. The highest value of condition factor (CF) for males of *H. harpax* was 1.021 in September and for females was 1.025 in May, while the lowest value for males was 1.002 in March and for females was 1.01 in December (Fig. 3). A total number of 804 specimens were examined with 365 females and 439 males of *H. harpax*. The overall sex ratio for the study period was found to be 1: 0.83 (M: F). Males were predominant throughout this study except in February, June and October (Fig. 4). Chi square test revealed that the total number of males was significantly higher than females in the samples of *H. harpax* throughout the sampling period (χ^2= 30.98, df = 8, p<0.05).

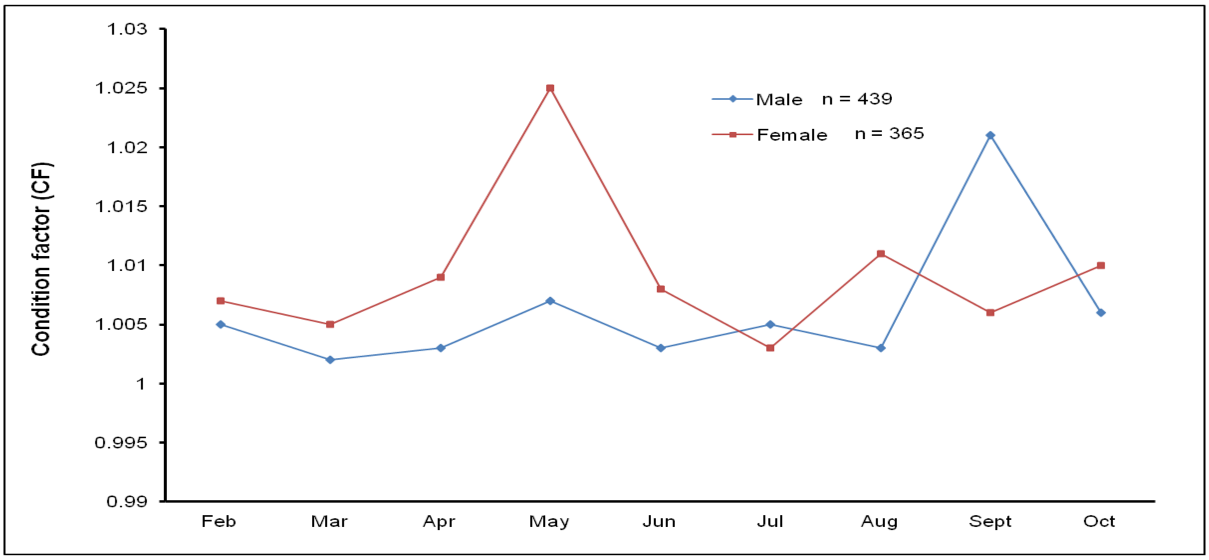

Figure 3: Condition factors of *H. harpax* from coastal waters of Pantai Remis, Peninsular Malaysia waters during February – October, 2012.

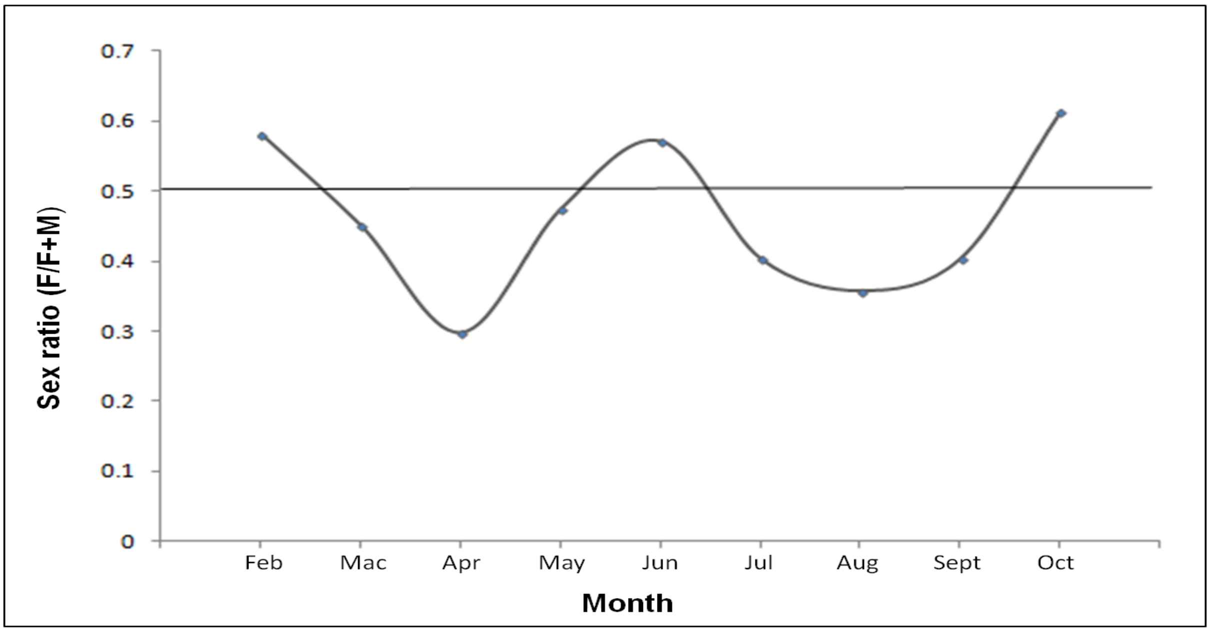

Figure 4: Temporal variations of sex ratio of *H. harpax* in the coastal waters of Pantai Remis, Perak. The dotted line indicates a ratio of 1:1 (Males : Females).

Exploitation and recruitment

The best value of von Bertalanffy growth function (VBGF), asymptotic length (L_∞) and growth coefficient (K) obtained using the ELEFAN-I was 18.38 cm and 1.10 yr^{-1} for males, and 21.53 cm and 0.75 yr^{-1} for females (Fig. 5). The optimized growth curves with the best value of VBGF are shown on the restructured length distribution for males and females (Fig. 6). The observed maximum length was 17.50 cm and the predicted maximum length was 18.43 cm for males, while for female these values were 20.50 cm and 21.43 cm, respectively (Fig. 7). The range of confidence interval at 95% was 17.35 to 19.50 cm for males, and 19.70 to 23.16 cm for females (Table 2). The growth performance index (φ') was found to be 2.57 for males and 2.541 for females. The values of total mortality (Z) and natural mortality (M) were calculated using Jones and van Zalinge Plot (Fig. 8). The value of total mortality (Z) for males was 4.084 yr^{-1} and it was 3.259 yr^{-1} for females. The natural mortality (M) for males was 2.247 yr^{-1} and it was 1.674 yr^{-1} for females. The fishing mortality rate (F) was obtained by subtracting the total mortality (Z) with the natural mortality (M). It was estimated that the value of fishing mortality rate was 1.837 y^{-1} for males and 1.585 y^{-1} for females (Table 2). From these figures, an exploitation rate (E) was calculated at 0.449 and 0.486 for males and females, respectively.

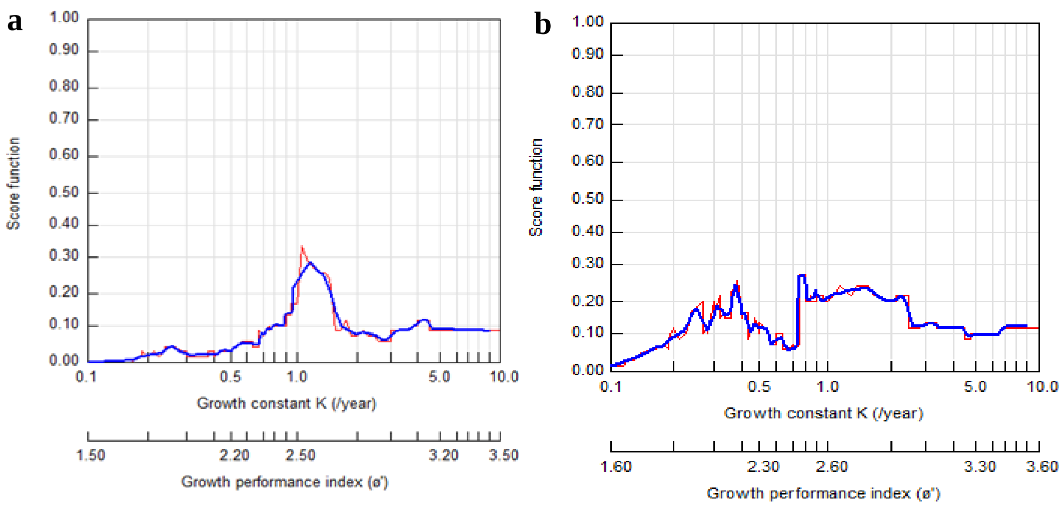

Figure 5: K-scan routine for best value of von Bertalanffy growth function (VBGF), asymptotic length (L∞) and growth coefficient (K) of males (a) and females (b) of *H. harpax* using ELEFAN-I.

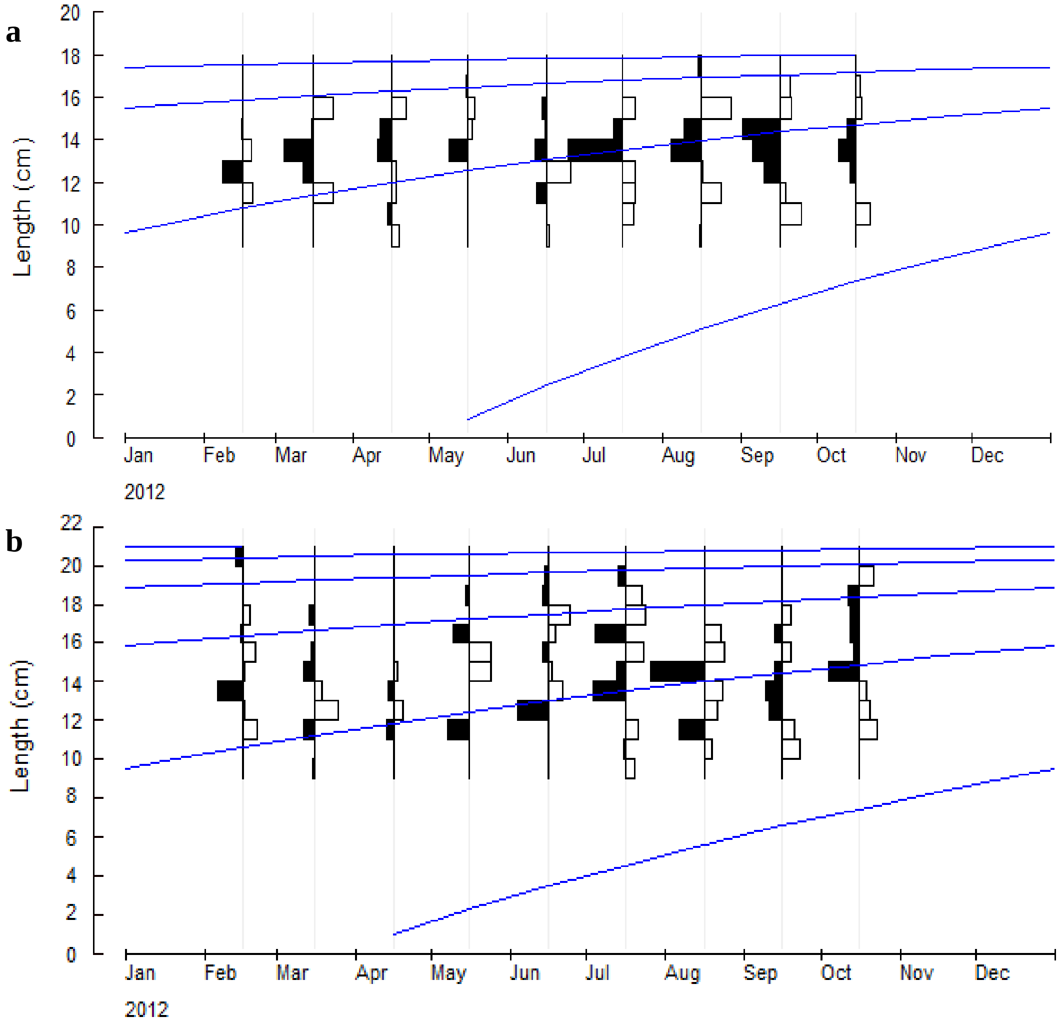

Figure 6: von Bertalanffy growth curves of *H. harpax* for males (a) and females (b) superimposed on the restructured length-frequency histograms

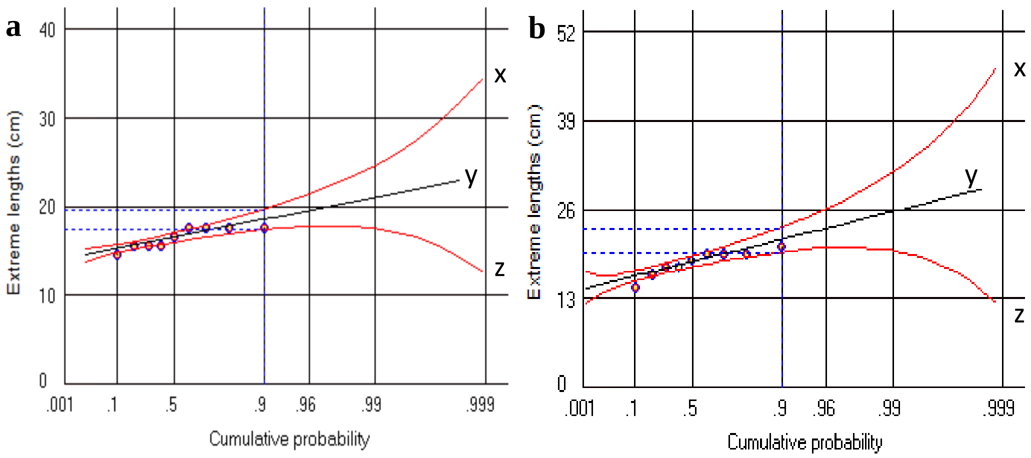

Figure 7: Predicted maximum length for males (a) and females (b) of *H. harpax* based on extreme value theory (Formacian *et al*., 1991). The predicted maximum length value and the 95% confidence interval are obtained from the intersection of overall maximum length with the line y and x, z, respectively.

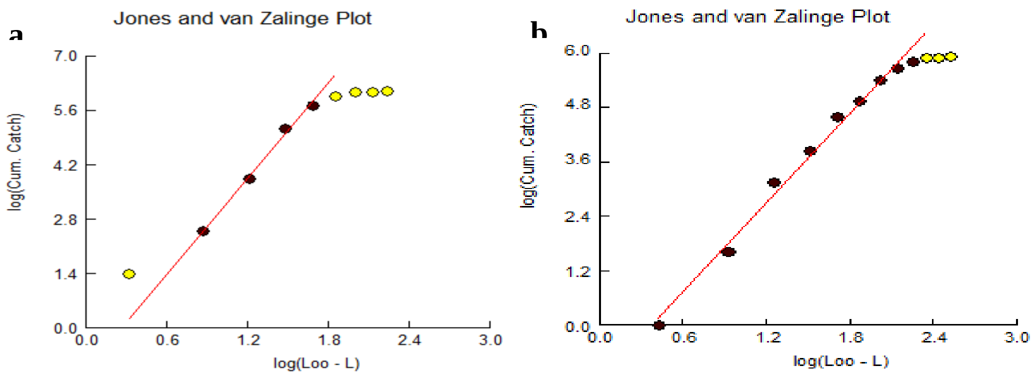

Figure 8: Jones and van Zalinge Plot for males (a) and females (b) of *H. harpax* in the coastal waters of Pantai Remis, Perak.

Table 2: Estimated population parameters of *Harpiosquilla harpax* in the coastal water of Pantai Remis, Perak.

Population parameters	Male	Female
Asymptotic length (L∞)	18.38 cm	21.53 cm
Growth coefficient (K)	1.10 yr^{-1}	0.75 yr^{-1}
Growth performance index (φ')	2.57	2.541
Total mortality (Z)	4.084 yr^{-1}	3.259 yr^{-1}
Fishing mortality (F)	1.837 yr^{-1}	1.585 yr^{-1}
Natural mortality (M)	2.247 yr^{-1}	1.674 yr^{-1}
Exploitation level (E)	0.449	0.486
95% confidence interval	17.35-19.50 cm	19.70 – 23.16 cm

The recruitment patterns of *H. harpax* were continuous for both males and females throughout the year (Fig. 9). The recruitment varied from 0.84 to 15.96% for males and 0.72 to 18.71% for females throughout the study. The highest recruitment for males was in May with 15.95% while the lowest was in November at 0.84%. For females, the highest recruitment was in March with 18.71%, while the lowest was in November at 0.72%.

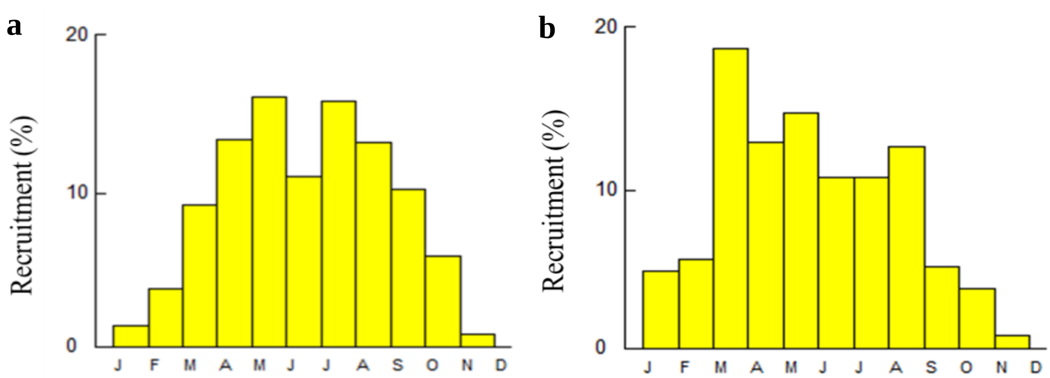

Figure 9: Recruitment patterns of males (a) and females (b) of *H. harpax* in the coastal area of Pantai Remis, Perak.

Discussion

The estimated value of ‘b’ for *H. harpax* was 2.698 for males, 2.884 for females and 2.852 for combined sexes, respectively. Based on the results of the analysis of length-weight relationship, we observed that the growth patterns of *H. harpax,* for both males and females were negative allometric, as the value of regression coefficient (b) was significantly ($p<0.05$) below 3. The estimated value of ‘b’ for both sexes of *H. harpax* was 2.852 and it lied between the values mentioned by Carlander (1977) and Ecoutin *et al*. (2005), which are significantly lower from isometric value 3 at 5% level. This species undergo negative allometric growth which could be caused by the competition of mantis shrimp populations among themselves as well as the competition among mantis shrimp with fish or other crustacean species. During the study period at the study site, there was abundance of other fish and crustaceans were found to inhabit the same area as the *H. harpax*. Regression analysis on the log-transformed data showed a strong relationship between both sexes of *H. harpax* (r^2 = 0.841) ($p<0.05$). It is reported (Mili *et al*., 2011) that Squilla mantis in the Gulf of Gabes (Tunisia), has strong relationship in both sexes as the regression coefficient (r^2) for males, females and combined sexes were above 0.96, which was very close to $r^2 = 1$.

When compared to the value ‘b’ of *H. raphidea* (b = 2.73 for males and b = 2.743 for females) from mud flats in Kuala Tungkal, not much difference was observed between *H. harpax* and *H. raphidea* (Wardiatno and Mashar, 2011). In another study, Mili *et al*. (2011) found the value ‘b’ for males and females, and both sexes of Squilla mantis to be 3.2097, 3.0644 and 3.1375, respectively indicating a positive allometic growth as the value ‘b’ was more than 3. The variations in b values between populations might be due to the differences in geographical locations and environmental conditions (Maynou, 2005).

The relative condition factor (CF) of *H. harpax* was the highest and peaked at 1.021 in September for males and 1.025 for females in May. This CF is also one of the ways to find the spawning season of aquatic organism if only the length and weight measurement were taken instead of the weight of mature gonad of females. The highest peak of CF for females *H. harpax* was in May and suddenly dropped in June (Fig. 3). Thus, it can be concluded that the peak spawning season for *H. harpax* was in May-June. This result is almost similar with Kodama *et al*. (2006) who reported that the peak spawning period of *Oratosquilla oratoria* was in March-June in the Tokyo Bay.

An appropriate number of males and females mantis shrimps can be mated during artificial spawning which can be known through calculating sex ratio. Throughout this study, the sex ratio for *H. harpax* was found to be 1: 0.83 (M: F). Comparing with the studies implemented by Wardiatno and Mashar (2010), the sex ratio of *H. raphidea* from Indonesia was 1:1.46 (males: females) giving a female-biased ratio while the sex ratio of *H. harpax* is giving a male-biased with ratio of 1:0.83. While in squilla mantis, males were dominated over females in five months throughout the year, especially in May to August (Mili *et al*., 2011). The higher ratio of males against females for both *H. harpax* and *Squilla mantis* might be due to the females staying in burrows to incubate their eggs (Mili *et al*., 2011).

The asymptotic length (L_∞) and growth co-efficient (K) of *H. harpax* reported by Dinh et al. (2010) from Mekong Delta was 21.0 cm and 0.89 yr^{-1}, while L_∞ and K values of *S. mantis* from Ebro Delta was 20.0 cm and 1.60 yr^{-1} for males and 20.0 cm and 1.30 yr^{-1} for females (Abello and Martin, 1993). The highest value of L_∞ (21.53 cm) for females *H. harpax* was observed in the present study. The highest value of K (1.60 yr^{-1}) was also observed in Ebro Delta waters (Abello and Martin, 1993) for *S. mantis* and the lowest was found in female of *H. harpax*. The value of L_∞ and K estimated growth performance index (φ') for the present study were varied between 2.37 and 2.57 (Table 3).

Table 3: Growth parameters (L_∞ and K) and computed growth parameter index (φ') of mantis shrimp from different countries

Location	Species	L_∞ (cm)	K (yr^{-1})	(φ')	Source
Malaysia	*H. harpax*	18.38 (M) 21.53 (F)	1.10 0.75	2.57 2.54	Present study
Malaysia	*Miyakea nepa*	16.28 (M) 17.73 (F)	1.10 0.75	2.47 2.37	Present study
Vietnam	*H. harpax*	21.0 (B)	0.89	2.59	Dinh *et al*. (2010)
Ebro Delta	*S. mantis*	20.0 (M) 20.0 (F)	1.6 1.3	2.81 2.72	Albello and Martin (1993)

In mantis shrimp population that have been exploited, mortality is a combination of natural and fishing mortality (Yusli and Ali, 2011). In the present study at Pantai Remis, the total mortality for *H. harpax* were found to be higher for males and females than the *H. harpax* in littoral marine waters of the Mekong Delta, South of Viet Nam, where total mortality (Z), natural mortality (M), fishing mortality rate (F) and the exploitation rate (E) were 3.23, 1.80, 1.43 and 0.44, respectively (Dinh et al., 2010). Similar results were observed in *H. raphidea* where the total mortality (Z), natural mortality (M), fishing mortality rate and the exploitation rate (E) were 0.820, 0.473, 0.342 and 0.42, respectively (Yusli and Ali, 2011). The rate of exploitation in the present study was 0.449 for males and 0.486 for females. The exploitation rate of *H. harpax* for both males and females in the coastal waters of Pantai Remis was higher than both studies in Vietnam and Indonesia. It can be concluded that the exploitation level for the studied *H. harpax* has been below the optimum exploitation rate of E= 0.50 according to Gulland (1971) and Pauly (1984). Therefore, fishermen still have the opportunity to capture the mantis shrimp in coastal waters of Pantai Remis, but it must be confirmed by the stock assessment study to ensure that the mantis shrimp is not be overexploited.

Conclusions

The relative growth pattern was negative allometric for both males and females of *H. harpax*. The peak spawning season was observed in May-July although some matured gonad was found in other months which indicated as multi-spanner behaviour of this species. The population of males were predominant over females in the investigated area. The rate of exploitation for *H. harpax* was slightly below the optimum level of Exploitation (E=0.50) and thus precautions or stock assessment regarding this species in the coastal waters of Pantai Remis, must be taken so that the species might not undergo over exploitation.

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