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WIDTH-WEIGHT AND LENGTH-WEIGHT RELATIONSHIPS OF THE TRI-SPINE HORSESHOE CRAB, *Tachypleus tridentatus* (LEACH 1819) FROM TWO POPULATIONS IN SABAH, MALAYSIA: IMPLICATIONS FOR POPULATION MANAGEMENT

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Abstract: A morphometry study of 259 individuals of Tri-spine horseshoe crab *Tachypleus tridentatus* was carried out from April to October 2014 in two populations in Sabah, Malaysia, one in Tanjung Limau and another in Inderasabah. Two methods were used, i.e. visual search and gill netting. Both sites showed a higher number of males with 1.01:1 OSR (χ^2=0.005, df=1, P>0.05) in Tanjung Limau, and 2.42:1 OSR (χ^2=19.55, df=1, P<0.05) in Inderasabah. *T. tridentatus* collected from Tanjung Limau are larger than the population from Inderasabah. The prosomal width (PW) frequency for males ranged from 30-31 cm and 26-27 cm whereas for females ranged from 38-39 cm and 30-31 cm in Tanjung Limau and Inderasabah respectively. The prosomal width-weight relationship were $W=0.0028\ PW^{3.9273}$ and $W=0.0125\ PW^{3.5245}$, while the total length-weight relationship are $W=0.0152\ TL^{2.8465}$ and $W=0.0202\ TL^{2.7536}$ for Tanjung Limau and Inderasabah respectively. Two-way ANCOVA revealed a significant difference among PW-weight relationship in males and females in these two locations (F=4.74, df=1, P<0.05). It confirms that both populations demonstrate allometric growth (b≠3) with a higher increment of PW-weight as compared to TL-weight, which agrees with previous studies that reported similar traits. The differences in these morphometric parameters in both populations of *T. tridentatus* in this study suggest that they may derive from two discrete populations. The findings of this study are useful to estimate the size of adults and spawning individuals of *T. tridentatus* for better management of the population of this unique animal.

Keywords: Horseshoe crab, *Tachypleus tridentatus*, width-weight relationship, length-weight relationship, Sabah, Malaysia.

Introduction

The Tri-spine horseshoe crab, *Tachypleus tridentatus* (Leach, 1819) is among the three Asian horseshoe crab species that belongs to sub-family Tachypleinae. *Tachypleus tridentatus* distributes within 12° N to 31° N and 90° E to 125° E geographical areas (Sekiguchi & Shuster, 2009). Recent fossil discovered in Manitoba, Canada, resembles the extant horseshoe crabs proved that the horseshoe crab has lived at least 445 million years ago with very little morphological changes from their ancestor (Mattei & Bekeey, 2008; Rudkin *et al.,* 2008). All the three Asian species (tri-spine horseshoe crab *Tachypleus tridentatus*, coastal horseshoe crab *Tachypleus gigas* and mangrove horseshoe crab *Carcinoscorpius rotundicauda*) were reported to exist in the waters along the coast of Malaysia (Zaleha *et al.,* 2008; Srijaya *et al.,* 2010; Ismail *et al.,* 2011; Ismail *et al.,* 2012; Chatterji & Pati, 2014; Robert *et al.,* 2014). Even though the Asian horseshoe crab does not have multiple utilization like *Limulus polyphemus* that commercially harvested in the production of LAL endotoxins detection kit and as commercial bait to catch eel and conch in United States (US), but still the public is unconscious of the biological and ecological importance of these horseshoe crabs (Tan *et al.,* 2012).

The length/width-weight relationships are important tools in fishery management, for example in estimating the average weight at a given length/width of particular species (Lawson *et al.,* 2013). Such relationships provide a mathematical relationship between the two variables and yield information on the general well-being, variation in growth with sex, size at maturity, gonad development and breeding season of a particular animal species (Karnik & Chakraborty, 2001; Chatterji & Pati, 2014; Mohanty *et al.,* 2014; Susanto & Irnawati, 2014). According to Vijayakumar *et al*. (2000), the study of relationship between the body parameter will provide important information in a comparative growth of various body parameters which is essential to define the growth of a particular species. Allometric study and relationship between the length/width-weight has been widely conducted in various marine organisms such as fish (Zakaria *et al.,* 2000; Abowei *et al.,* 2009; Mohanty *et al.,* 2014), crustaceans (Sukumaran & Neelakantan, 1997; Atar & Seçer, 2002; Thirunavukkarasu & Shanmugam, 2011; Gopalakrishnan *et al.,* 2014; Susanto & Irnawati, 2014), mollusc (Karnik & Chakraborty, 2001), and including the horseshoe crab (Vijayakumar *et al.,* 2000; Chiu & Morton, 2001; Srijaya *et al.,* 2010; Ismail *et al.,* 2012; Sahu & Dey, 2013; Chatterji & Pati, 2014). Therefore, this study attempts to determine such relationship in a population of horseshoe crab in Malaysia, particularly in Sabah.

Despite the importance of such information, there is very little existing information on the horseshoe crab allometric and length/width-weight relationships study in Malaysia. One was carried out on *T. gigas* in Peninsular Malaysia (Ismail *et al.,* 2012) and on *T. tridentatus* in Papar, Sabah (Chatterji & Pati, 2014). Thus, this study aims to determine these morphometric relationships among the local horseshoe crab, *T. tridentatus* collected from two different locations in Sabah, Malaysia, and add some baseline data on morphometric study in order to understand the growth and morphological aspects of this species.

Methodology

Study Sites

This study was conducted in two locations in the east coast of Sabah, namely, Tanjung Limau (N 06°44.562' E 117°23.528') and Inderasabah (N 04°18.043' E 118°14.378') located in Sandakan and Tawau divisions respectively (Figure 1). Surrounded by two different seas namely Sulu Sea in Tanjung Limau and Celebes Sea in Inderasabah, both locations were selected based on the abundant and availability of the horseshoe crab, *T. tridentatus* as reported by locals. Samples were collected during sampling in April till October 2014.

Sampling Technique

Two different methods were used in this study. (I) visual search - used in Tanjung Limau, and (II) gill-netting - used in Inderasabah. In this study, sampling was carried out opportunistically according to the weather condition and availability of help from the locals on sites.

Visual Search

The search for horseshoe crab, *T. tridentatus* was conducted for four consecutive days during daytime of the highest spring tide (two hours of searching; starting an hour before and ended an hour after the highest tide) coincided on the full moon phases. The beach was patrolled from a small boat that steered along the beach line covering 8,000 m stretch × 5 m width towards the high tides line. The presence of spawning *T. tridentatus* were spotted based on the formation of spawning foam (stream of fine air bubbles) that released from the permeable sediments as the female horseshoe crab started to dig. All spotted horseshoe crabs were recorded and gently handpicked out from water to be sexed based on the presence of modified claws on the first and second pair appendages of walking legs, recorded for morphometric measurement and weighed before released into the water.

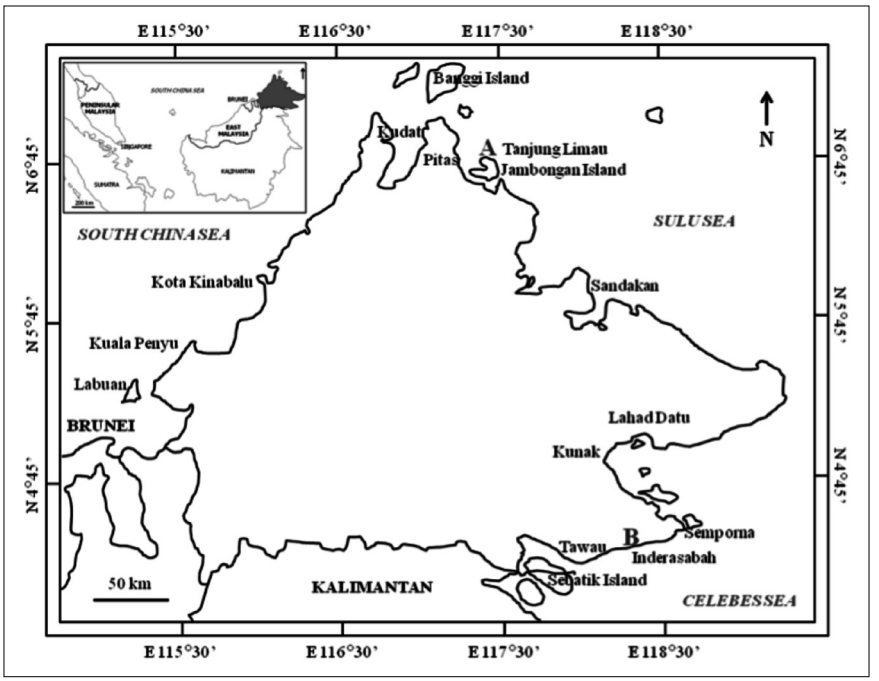

Figure 1: Schematic map showing the study sites i.e. (A) Tanjung Limau, and (B) Inderasabah. Inlet shows map of Malaysia

Gill Netting

The gill nets (Figure 2) were used into the sea down to a depth of 10 m, approximately 1-3 km offshore. The net (mesh size 11.4 cm; 1.0 m height × 400 m length; a type of net commonly used by fishermen to catch crabs in the study area) were used with at least 24 hours soaking time. After 24 hours, the net was hauled and all tangled horseshoe crabs were removed from the net, sexed, measured and weighed before released to the sea at capture point.

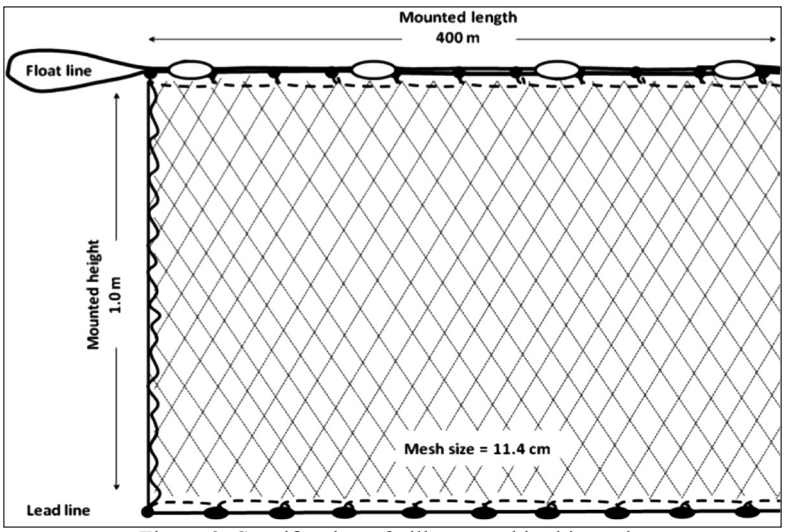

Figure 2: Specification of gill net used in this study

Morphometric Parameter Measurements

Collected horseshoe crabs were measured to the nearest 0.1 cm using a measuring tape for their prosomal width (PW), the widest part of the prosoma; carapace length (CL), the length from the tip of prosoma to the anus; telson length (TEL), the length from anus to the tip of tail; total length (TL), the length from the tip of prosoma to the end of telson; and intraocular distance (IO), the distance between two compound eyes (Figure 3). The horseshoe crabs were also weighed for their body weight (BW) by using digital balance (model DJC31G-30). The measurements and weight were only taken for fine specimens only, whereas injured individuals were immediately released upon capture.

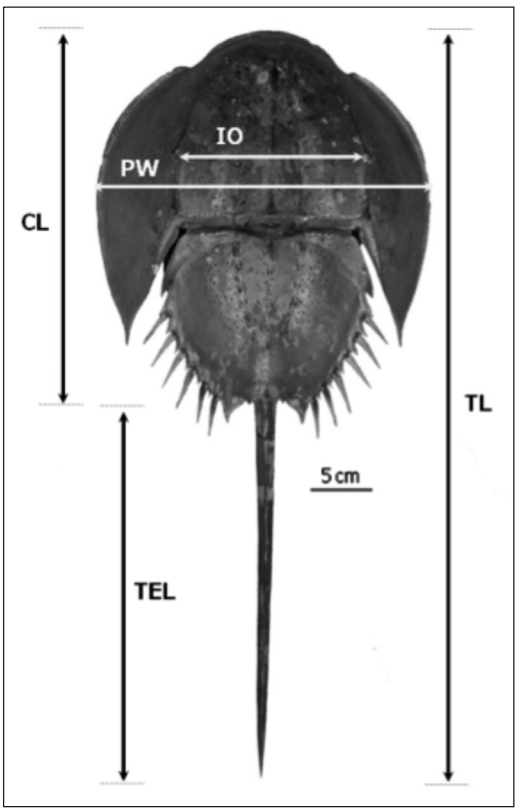

Figure 3: The measurement (in centimetre) of morphological parameters for horseshoe crabs. (PW) prosomal width, (CL) carapace length, (TEL) telson length, (TL) total length, and (IO) intraocular distance

Statistical Analysis

Data obtained for all measurements were pooled according to the sex of specimens and study sites. The width-weight and length-weight relationships were determined separately for males and females and between study sites by least squares method using the logarithmic forms of the exponential equation $W=“aL^b”$, where W=weight (g), L=length (cm) or width (cm), ‘a’ is the intercept of the regression curve and ‘b’ the regression coefficient (Le Cren, 1951). The observed values of length/width and weight were transformed into logarithmic values and the regression equation of Log W = a + b Log L was calculated, and straight line was fitted to the scatter plot using Microsoft Office Excel version 2007. The ANCOVA (Analysis of Covariance) test was carried out using SPSS Statistics software version 17.0 to determine differences in the regression of log width/length and log weight in both locations, and between male and female populations of the horseshoe crab.

Results

A total of 308 individuals of horseshoe crab, *T. tridentatus* were collected. A significantly higher number was collected in Tanjung Limau of 195 (male, n=98; female, n=97) whereas only 113 (male, n=80; female, n=33) in Inderasabah (χ^2=12.37, df=1, P<0.05). From these total collection, the overall operational sex ratio (OSR) values for both areas were calculated. OSR in Tanjung Limau was in even balance with 1.01:1 (male: female; χ^2=0.0051, df=1, P>0.05). Whereas in Inderasabah, the OSR was male-biased with 2.42:1 (χ^2=19.55, df=1, P<0.05).

From the total individuals collected, 41 (male, n=18; female n=23) individuals from Tanjung Limau and eight (male, n=7; female, n=1) from Inderasabah were excluded from the analysis due to incomplete morphometric data (i.e. badly injured individuals, broken telson and deformation of morphological parameter). The exclusion of these individuals made up a total of 259 individuals with complete

Table 1: The mean±SD of morphometric parameters measured from Tanjung Limau and Inderasabah (N=259)

Morphometric Parameters (cm)	Tanjung Limau		Inderasabah	
	Male (n=80)	Female (n=74)	Male (n=73)	Female (n=32)
Prosomal width	30.9±1.9	37.0±2.4	25.3±1.6	30.7±2.5
Carapace length	29.9±2.2	38.0±2.8	24.9±1.8	31.6±2.3
Telson length	33.8±4.5	41.6±5.9	28.0±3.6	34.3±3.5
Total length	64.0±5.7	79.5±7.3	53.0±4.8	65.9±5.4
Intraocular distance	16.1±1.0	21.2±1.9	13.6±0.9	17.5±1.3

data used for morphometric analysis in this study as shown in Table 1. The individuals collected from Tanjung Limau showed higher measurements in all body parameters measured than the population collected in Inderasabah.

The prosomal width (PW) and body weight (BW) of *T. tridentatus* varies with sexes with females being larger and heavier than males. In Tanjung Limau, PW_{male} are 25.0-35.0 cm and PW_{female} are 31.0-42.0 cm, with BW_{male} of 1080-3010 g and BW_{female} of 2435-6820 g. In Inderasabah, the PWs are 20.0-28.7 cm and 24.2-35.5 cm, whereas the BWs are 615-1555 g and 1395-3685 g for both male and female, respectively.

Prosomal Width (PW) Measurement

The PW frequency distribution for both sexes is shown in Figure 4. The highest PW ranged from 30.0-31.0 cm (male, n=32, 40%) and 38.0-39.0 cm (female, n=23, 31%) in Tanjung Limau (Figure 4a). The measurements ranged from 26.0-27.0 cm (male, n=30, 41%) and 30.0-31.0 cm (female, n=10, 31%) in Inderasabah (Figure 4b). The population of *T. tridentatus* in Inderasabah are in smaller size as compared to the population in Tanjung Limau.

The PW values of spawning population in Tanjung Limau were normally distributed. 87.5% (n=70) males measuring ranged from 28.0-34.0 cm, 3.8% (n=3) smaller than 28.0 cm, and only 8.8% (n=8) were larger than 34.0 cm. For the females, 73.0% (n=54) ranged from 36.0-41.0 cm, 24.4% (n=18) were smaller than 36.0 cm and only 2.7% (n=2) were larger than 41.0 cm (Figure 5a).

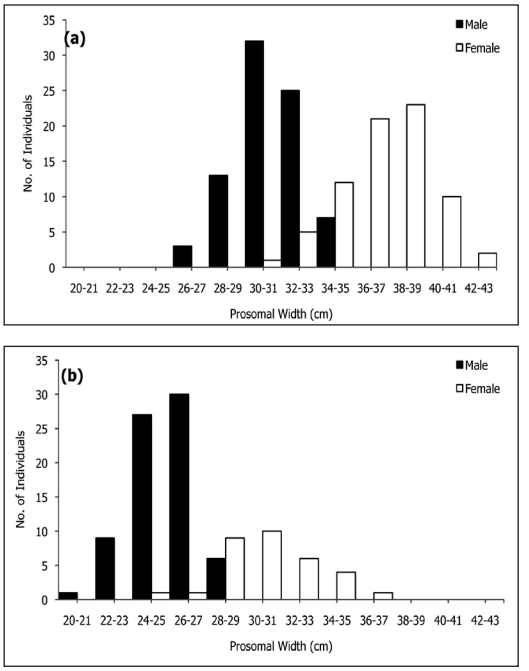

Figure 4: Range of prosomal width-frequency distribution of male and female horseshoe crabs collected in (a) Tanjung Limau, and (b) Inderasabah, Sabah, Malaysia

The PW values recorded in Inderasabah were 90.4% (n=66) males measuring ranged from 21.0-27.0 cm, 1.4% (n=1) smaller than 21.0 cm, and only 8.2% (n=6) were larger than 27.0 cm. For the females, 78.1% (n=25) ranged from 28.0-33.0 cm, 6.3% (n=2) were smaller than 28.0 cm and only 15.3% (n=5) were larger than 33.0 cm (Figure 5b). It is clearly seen that smaller PW in females were usually redundant with the measurement of moderate or large males.

Prosomal Width (PW)/Total Length (TL)-Weight Relationships

The PW-weight and TL-weight relationships for the total catch (male and female combined) are shown in Figures 5a-d for Tanjung Limau and Figures 6a-d for Inderasabah. In general, the PW/TL-weight relationship of horseshoe crab from both study sites does obey the cube law with the value of 'b' varied from 2.76 to 3.93 indicates allometry growth. The PW-weight relationship has stronger correlation (r=0.94) in both sites as compared to TL-weight relationship (r=0.88 in Tanjung Limau and r=0.87 in Indersabah). Two-way ANCOVA analysis has revealed that there is significant difference of PW-weight relationship (F=4.74, df=1, P<0.05) between male and female in both sites. Such difference is not seen for TL-weight relationship (F=0.68, df=1, P>0.05) suggesting similar rates of increment among sex in both populations.

The PW-weight and TL-weight relationships of *T. tridentatus* according to sex in Tanjung Limau and Inderasabah are shown in Figures 7-10. The values of 'b' in PW-weight in Tanjung Limau i.e. 2.14 (male) and 2.87 (female); and Inderasabah 2.57 (male) and 2.24 (female). These 'b' values seem even lower in TL-weight relationship with only 1.47 and 1.21 in males, whilst 1.43 and 2.23 in females in Tanjung Limau and Inderasabah respectively (Figs. 9 and 10).

The correlation of coefficient (r) value of PW-weight relationship is higher in male and female for both sites as compared to TL-weight relationship. Strong relationships was observed in the male PW-weight in Inderasabah (r=0.91, Figure 10a) and female PW-weight in Inderasabah (r=0.90, Figure 8b). The lowest PW-weight relationship is shown in male horseshoe crab in Tanjung Limau with r=0.73 (Figure 7a).

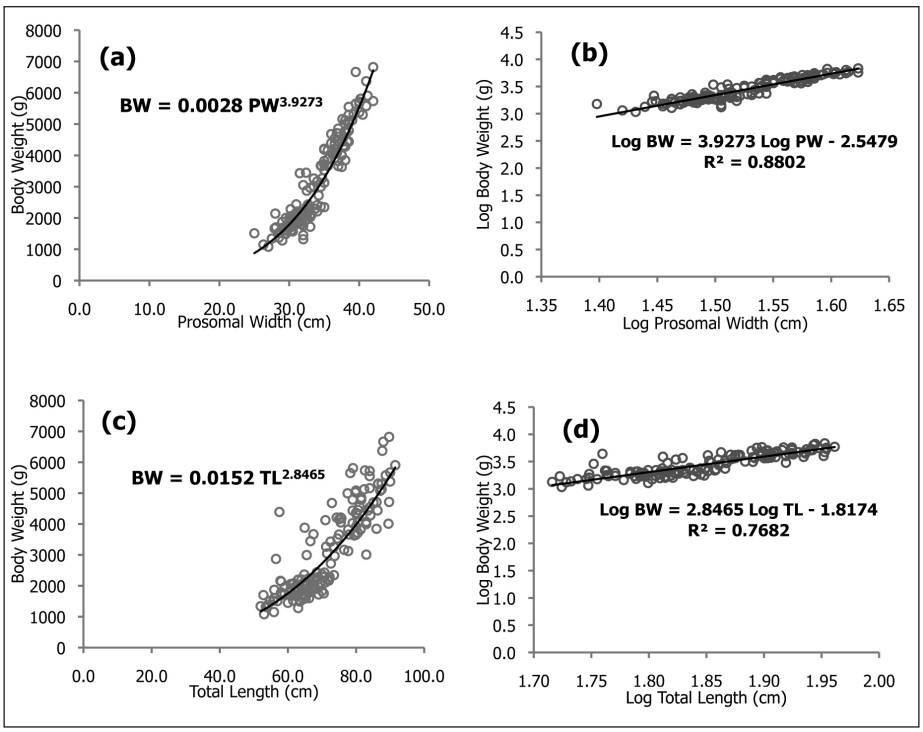

Figure 5: The PW-weight and TL-weight relationships of *T. tridentatus* in Tanjung Limau (n=154). The curve in (a) and (c) represents the observed PW/TL-weight while (b) and (d) represents the regression linear of log PW/TL against weight

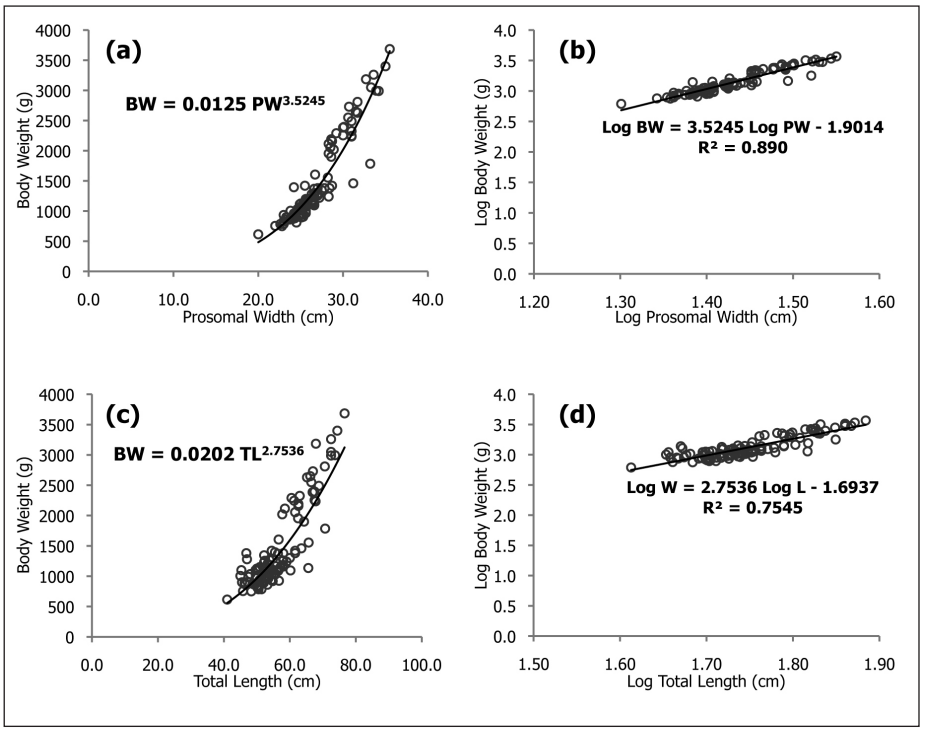

Figure 6: The PW-weight and TL-weight relationships of *T. tridentatus* in Inderasabah (n=105). The curve in (a) and (c) represents the observed PW/TL-weight while (b) and (d) represents the regression linear of log PW/TL against weight

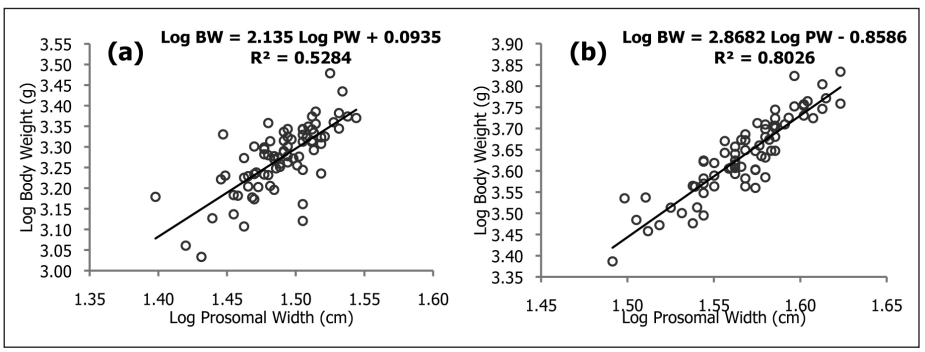

Figure 7: The log prosomal width-weight relationship of *T. tridentatus* in Tanjung Limau, (a) male, n=80, and (b) female, n=74

The *r* values in TL-weight relationship are somewhat lower than the PW-weight relationship. The highest *r* value in TL-weight relationship was shown in female in Inderasabah (r=0.78) followed by male (r=0.70) and female (r=0.65) in Tanjung Limau, whereas the lowest is male from Inderasabah (r=0.60). One-way ANCOVA revealed that both PW-weight and TL-weight in male and female *T. tridentatus* were significantly different in Tanjung Limau (PW-weight: F=71.20, df=1, P<0.001 and TL-weight: F=119.88, df=1, P<0.001), and Inderasabah (PW-weight: F=91.15, df=1, P<0.001 and TL-weight: F=96.95, df=1, P<0.001).

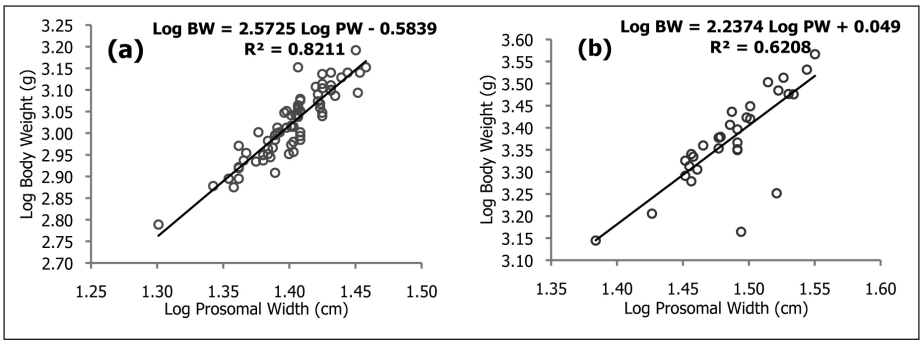

Figure 8: The log prosomal width-weight relationship of *T. tridentatus* in Inderasabah, (a) male, n=73, and (b) female, n=32

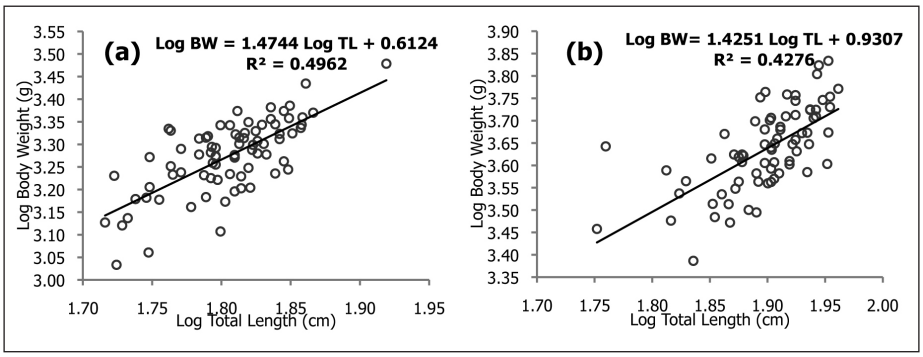

Figure 9: The log length-weight relationship of *T. tridentatus* collected in Tanjung Limau, (a) male, n=80, and (b) female, n=74

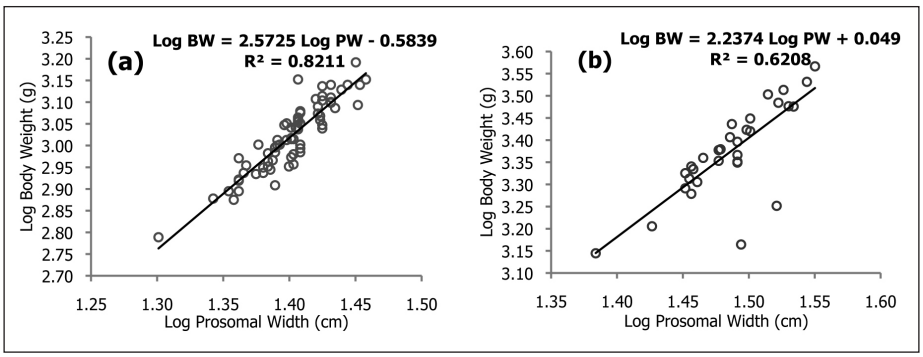

Figure 10: The log length-weight relationship of *T. tridentatus* collected in Inderasabah, (a) male, n=73, and (b) female, n=32

Discussion

In this study, horseshoe crabs collected by using visual search at shallow waters Tanjung Limau represent the spawning population which come to nest close to the shore. Whereas, no spawning area was found in Inderasabah, leading us to deploy another catch method, i.e. gill netting which targets animals at deep water down to 10 m depth. At this depth, the horseshoe crabs might be foraging individuals and specifically not in a spawning mode.

An OSR of male to female of 1.01:1 in Tanjung Limau indicates a monogamous behaviour of a spawning population, with no tandem or unpaired females nor satellite males, which is common for *T. tridentatus* as reported in Japan (Botton *et al.,* 1996) and all Asian horseshoe crabs (Mattei *et al.,* 2010). This is not surprising since the method to catch targets the shorelines, where only nesting pairs are available. In fact, all spotted *T. tridentatus* in Tanjung Limau were in amplexed pair, which the male clings onto the female's ophistosoma spine using their modified claws (Brockmann, 1990). The American species *L. polyphemus* show high spawning density demonstrating polygamous behaviour with 2 to 6 male per female OSR (Cohen & Brockmann, 1983) or even higher up to 15 males as reported by Loveland and Botton (1992).

It is reported that the unpaired males of *L. polyphemus* often return to the beach during spawning season (Cohen & Brockmann, 1983; Suggs *et al.,* 2002). However, this incident was not common in the Asian horseshoe crabs (Mattei *et al.,* 2010). Surprisingly, one unpaired male was seen swimming rapidly along the high tide line during sampling in June in Tanjung Limau, which happened to be a spawning season. Instead of searching for mate, this unpaired male might come ashore to forage, or it may accidentally be detached from the female during their way ashore to nest as evidenced by a bad injury on the right clasper which is used to cling onto the female during spawning.

There was a higher number of male than female horseshoe crabs collected at deep waters in Inderasabah. Similar findings were reported elsewhere that male individuals usually outnumbered the females (Cohen & Brockmann, 1983; Walls *et al.,* 2002; Carmichael *et al.,* 2003; Smith *et al.,* 2006; Tan *et al.,* 2012). In Malaysia, female-biased harvesting by fisherman, especially the gravid females to be sold and served as a delicacy, or exported to fulfil high demands from locals and neighbouring country contributes to this male-skewed phenomenon (Christianus & Saad, 2009).

The sex ratio of the horseshoe crab population in Inderasabah recorded higher number of male as compared to female by 2.42:1 (71%:29%). This ratio is similar to OSR of *L. polyphemus* offshore trawl survey of 63%:37% as reported by Hata and Berkson (2003) and 69%:31% by Smith *et al.* (2006). The males even far outnumber the females of another horseshoe crab species, *T. gigas* collected by gill nets in the east coast of Peninsular Malaysia with 93% male to only 7% female (Faridah *et al.,* 2015). This indicates that male biased OSR is normal in the horseshoe crab foraging population, but demonstrates a monogamous behaviour with an OSR of 1:1 when it comes to spawning.

Prosomal Width (PW) Measurement

Horseshoe crab population in Tanjung Limau is larger in size to Inderasabah, with female PW wider than male in both study sites. Sexual size dimorphism is one of the characteristics for the horseshoe crab species (Chatterji *et al.,* 1994; Botton *et al.,* 1996; Chiu & Morton, 2001; Suggs *et al.,* 2002; Sekiguchi & Shuster, 2009). This is partly due to the female reaching maturity at least with one additional instar stage from the male except *C. rotundicauda* which reach maturity after 13th moult in both sexes (Sekiguchi *et al.,* 1988).

The smallest PW recorded among the spawning pairs in Tanjung Limau was 25.0 cm for male and 31.0 cm for female. These indicate the smallest size of sexual maturity of the horseshoe crab population in Sabah, which agrees perfectly with the report by Sekiguchi *et al.* (1988), reared *T. tridentatus* matured at PW of 24.42±1.87 cm and 27.84±1.67 cm for male and female respectively. This confirms that individual with lower PW may be considered as juvenile for the population in Tanjung Limau. In addition to population collected in Inderasabah, the smallest PW recorded was 20.0 cm for male and 24.0 cm for female, representing foraging individuals that make

the whole population. To reach the size, these horseshoe crab moults at least 15 or 16 times in the fourteenth year (Sekiguchi *et al.*, 1988).

According to description of Sekiguchi *et al.* (1988), the smallest spawning male and female in Tanjung Limau are at least in the 16th and 17th instar stage. In Inderasabah, the smallest collected *T. tridentatus* were at least in 15th and 16th instar stages respectively. Thus, confirming that all the horseshoe crabs collected in both study sites were adult population with different instar stages.

A study on 16 morphological characteristics including PW on *L. polyphemus* from seven locations ranging from Cape Cod Bay down to Gulf of Mexico by Riska (1981) revealed that there was a different in both size and shape among the horseshoe crabs within the studied localities. For example, the size of adults *L. polyphemus* were larger in Cape Cod, but decrease in size as going down to the south in Gulf of Mexico. Pierce *et al.* (2000) found that the larger size of *L. polyphemus* in Delaware Bay were genetically different from the smaller size in Chesapeake Bay, suggesting two discrete populations. Similar traits were recorded for *T. tridentatus* populations in this study, where the Tanjung Limau (north) adult population were bigger in size as compared to the south population in Inderasabah, suggesting discrete populations as concluded for *L. polyphemus*.

Width-weight and Length-weight Relationships

PW shows a higher increment compared to TL. PW increases about four times higher than BW (b=3.93) whereas TL increases about three times (b=2.85) in Tanjung Limau. The difference between the increment of PW (b=3.52) and TL (b=2.75) is smaller in Inderasabah. Vijayakumar *et al.* (2000) reported higher increment of PW of *T. gigas* collected from India with b=5.24 as compared to TL with b=2.46. This indicates a better increment of PW of *T. gigas* in their population but better TL increment of *T. tridentatus* in horseshoe crab in Sabah.

For log-transformed data, the value of 'b' usually lies between 2.5 to 4.0 and 3 is the ideal value of 'b' (isometric), deviation from 3 indicates allometric (Zakaria *et al.,* 2000; Atar & Seçer, 2003). The log-transformed data for PW-weight and TL-weight relationships for both male and female horseshoe crabs from Tanjung Limau and Inderasabah showed a negative allometry with the value of 'b' < 3 indicates that the increment of body weight more slowly than the PW and TL. According to Chatterji and Pati (2014), marine organisms showed an isometric growth in all their body parts in a stable environment. Therefore the value of 'b' recorded in the present study which is not equivalent to 3 confirms an allometric growth in these populations. Ismail *et al.* (2012) also recorded an allometric growth for *T. gigas* from Pahang on the east coast of Peninsular Malaysia in their study, except for female collected from Cherating, Pahang which shows an isometric growth (b=3.02).

The TL-weight relationship showed a higher increment in female than male, i.e. 2.29 vs 1.21 in Inderasabah while somehow the increment of TL-weight in Tanjung Limau showed similar rates of increment with 'b' value 1.43 (female) and 1.48 (male). Contradict with previous studies by Chatterji and Pati (2014) for *T. tridentatus* from Papar, Sabah with 10.90 and 2.89 in female and male respectively. According to Atar and Seçer (2003), the shape and the fatness of the species (as reflected in the PW, TL and weight) often affect the value of 'b', but they were various factors including reproductive activities that might be responsible for the differences. On the other hand, Mohanty *et al.* (2014) mentioned that combinations of psychological status together with gonad weight also caused a higher weight gain especially during breeding season. These two statements might explain the high weight increment reported by Chatterji and Pati (2014) as their data were based on spawning pairs that migrates onshore to nest.

Lower 'b' value in males compared to females for horseshoe crab population in

Malaysia was reported in a few studies. Tan *et al.* (2012) recorded 2.56 and 2.84 for *T. gigas* from Balok, Pahang, and Ismail *et al.* (2012) recorded 0.73 and 1.68 for Chendor, and 1.85 and 2.07 for Cherating, also in Pahang. These findings support our study that the TL increment in female was higher than the male. Nevertheless, none of these studies reported 'b' value is equivalent to 3, which is also in agreement with our findings. Thus, confirming the growth in both male and female horseshoe crab is allometric.

Collection of the female horseshoe crab is preferable as compared to male. The results of this study indicate that at Inderasabah, the horseshoe crabs population leaning towards male as compared to that of Tanjung Limau. An uncontrolled collection of female individuals may shift the horseshoe crab population towards male-dominated population that could hamper the management plan. This activity also brings negative conservation implication for horseshoe crabs in general.

Conclusion

Tachypleus tridentatus in Sabah shows the negative allometric growth (b<3) in PW/TL-weight relationships for both male and female populations, which means the increment of PW/TL was faster than the body weight. These two discrete populations of *T. tridentatus* in Sabah is male-skewed in the open sea (as represented by Inderasabah population), but demonstrates monogamous behaviour (OSR 1:1) for spawning population in Tanjung Limau. The findings from this study can be used to estimate the size of an adult and spawning individuals of *T. tridentatus* for better management of the population of this unique animal.

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