Sains Malaysiana 44(3)(2015): 379–386

Length-Weight Relationships of *Acetes* spp. Sampled Along the West Coast of Peninsular Malaysia

(Hubungan Panjang-Berat *Acetes* spp. yang Disampel Sepanjang Pantai Barat Semenanjung Malaysia)

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ABSTRACT

The present study describes the length-weight relationships (LWRs) of four Acetes *species (*Acetes indicus, A. serrulatus, A. japonicus *and* A. sibogae*) which were sampled from offshore trawling and inshore catches along the west coast of Peninsular Malaysia. Morphometric measurements (total length, TL and wet weight, WW) were obtained from the samples and LWRs were estimated. All LWRs were significant (*$p<0.05$*) for the four species, with the coefficient of determination,* $R^2>0.659$*. The estimated* b *values for LWR were 2.432-3.403. The* R^2 *value was >0.84 when the data was analysed according to inshore and offshore samples. Male and female* A. indicus *and* A. serrulatus *demonstrated negative allometric growth whilst male* A. japonicus *and* A. sibogae *showed isometric growth type. Positive allometric growth was depicted by a combined group of male and female* A. sibogae. *This study has contributed to the knowledge of the offshore and inshore distribution patterns of different populations of* Acetes *spp. in the Straits of Malacca. It also presents a comparison of the LWRs between offshore and inshore catches of* A. indicus *and* A. serrulatus, *with the inshore catches of* A. japonicus *and* A. sibogae, *which have not been previously reported. The findings of this study would contribute to the conservation and management of this commercially important fisheries resource.*

Keywords: Acetes*; inshore catches; length-weight relationship; Malaysia; offshore trawling*

ABSTRAK

Kajian ini menerangkan hubungan panjang-berat (LWRs) empat spesies Acetes *(*Acetes indicus, A. serrulatus, A. japonicas *dan* A. sibogae*) yang telah disampel daripada tangkapan pukat tunda di luar pesisir dan tangkapan pantai di sepanjang pantai barat Semenanjung Malaysia. Ukuran morfometrik (jumlah panjang, TL dan berat basah badan, WW) telah diperoleh daripada sampel dan LWRs telah dianggarkan. Semua LWRs menunjukkan perbezaan yang signifikan (*$p<0.05$*) bagi keempat-empat spesies tesebut, dengan pekali penentuan,* $R^2>0.659$*. Anggaran nilai* b *bagi LWR ialah 2.432-3.403. Nilai* R^2 *adalah >0.84 apabila data dianalisis mengikut sampel pantai dan luar pesisir. Jantan dan betina* A. indicus *dan* A. serrulatus *menunjukkan pertumbuhan alometrik negatif manakala jantan* A. japonicas *dan* A. sibogae *menunjukkan pertumbuhan jenis isometrik. Pertumbuhan alometrik positif digambarkan oleh kumpulan gabungan jantan dan betina* A. sibogae. *Kajian ini telah menyumbang kepada pengetahuan corak taburan populasi* Acetes *spp. yang berbeza di luar pesisir dan pantai di Selat Melaka. Ia juga menunjukkan perbandingan antara LWRs tangkapan pesisir luar dan pantai* A. indicus *dan* A. serrulatus *dengan tangkapan pantai* A. japonicas *dan* A. sibogae *yang belum dilaporkan sebelum ini. Hasil kajian ini akan menyumbang kepada pemuliharaan dan pengurusan sumber perikanan komersial yang penting ini.*

Kata kunci: Acetes*; hubungan panjang-berat; Malaysia; perikanan pukat tunda luar pesisir; tangkapan pantai*

INTRODUCTION

Sergestid shrimps of the genus *Acetes* (Decapoda, Sergestidae) are small planktonic shrimps (10-40 mm in total length), locally known as '*Udang Geragau*' or '*Udang Baring*' (Omori 1978, 1975). They are among the most commonly exploited zooplankton species (Holthuis 1980) and provide a major source of protein to coastal human populations (Omori 1978). Currently, 14 species are recognized and distributed throughout the world (Longhurst 1970; Omori 1975; Xiao & Greenwood 1993). In Malaysia, *Acetes* shrimps occur widely in the west coast of Peninsular Malaysia (Fernandez-Leborans et al. 2009; Longhurst 1970; Omori 1975; Pathansali 1966) and constitute about 62% or more of the total shrimp landings in 2010 (DOF 2010).

Previous studies on *Acetes* focused mainly on the distribution, morphology, reproductive biology and morphometry studies (Amin et al. 2010, 2009a, 2009b; Arshad et al. 2008, 2007) based on inshore catches using traditional fishing gears. However, the majority of *Acetes* landings are from offshore trawling activities (DOF 2010), but the length and weight relationship data of this genus remains scarce. Length-weight relationships (LWRs) are crucial in fishery management for the estimation of weight or biomass from length data, calculation of the indices of condition (Anderson & Neumann 1996; Jobling 2002;

Le Cren 1951) and for life-history and morphological comparisons between populations of the same species or comparisons between species (Petrakis & Stergiou 1995; Stergiou & Politou 1995). The objective of the present study was to provide reference data on the length-weight relationships of the major offshore and inshore *Acetes* shrimp species sampled along the west coast of Peninsular Malaysia. Data from this study is expected to facilitate the conservation and management of *Acetes* shrimps which have been heavily exploited as a fisheries resource.

Materials and Methods

Sample collection and identification

Acetes specimens were sampled from inshore catches using push-nets and trawling activities at sea more than 5 nautical miles (nm) offshore along the west coast of Peninsular Malaysia (Figure 1), from August 2007 to October 2008. The Global Positioning System (GPS) was used to mark the geographical position of each sampling location (Table 2). Samples were fixed and preserved immediately in 95% ethanol (Merck, Germany) upon collection as described by Lai et al. (2010) and Wong (2013). Fixation and preservation in ethanol was carried out to prevent degradation of DNA by enzymes upon death of the specimens as the latter would be used for DNA analyses in subsequent studies (Bucklin 2009; Wong 2013). The species and sexes of *Acetes* spp. were identified under a dissecting microscope (Leica ZOOM 2000™ , Model No. Z45V, Germany) according to the key characters described by Omori (1975) and Wong (2013) (Table 1).

Length-weight measurements and analyses

Total lengths (TL) and wet weights (WW) of all samples were measured within three days from the date of collection (Wong 2013). This was to reduce the effect of potential weight reduction from dehydration and possible distortion of samples due to long-term storage in ethyl alcohol (Andriguetto & Haimovici 1988; Black & Dodson 2003; Bucklin 2009; Díaz-Viloria et al. 2005; DiStefano et al. 1994; Vergara-Solana et al. 2014).TL was measured along the dorsal surface from the anterior tip of the rostrum to the posterior end of the telson and measured to the nearest

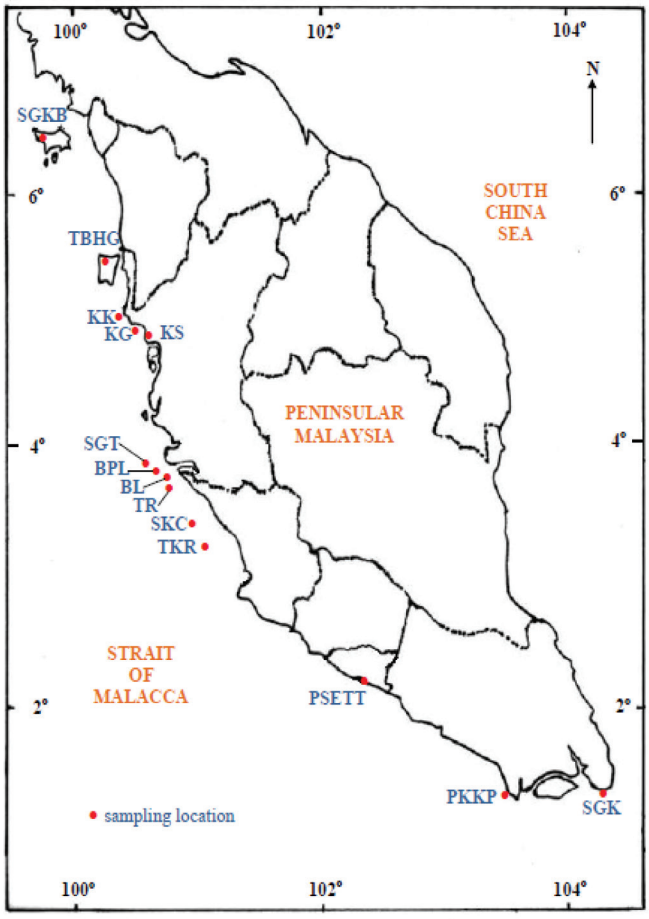

FIGURE 1. Map of Peninsular Malaysia showing the 14 locations (•) where *Acetes* were sampled for this study. The sampling locations are – SGKB: Sungai Kubang Badak; TBHG: Teluk Bahang; KK: Kuala Kurau; KG: Kuala Gula; KS: Kuala Sepetang; SGT: Sungai Tiang; BPL: Bagan Pasir Laut; BL: Bagan Lipas; TR: Teluk Rhu; SKC: Sekinchan; TKR: Tanjong Karang; PSETT: Portuguese Settlement; PKKP: Pulau Kukup; SGK: Sungai Kubang Badak

0.01 mm using a digital calliper. For WW determination, shrimps were blotted dry on paper towels and weighed to the nearest 0.1 mg using an Adventurer™ analytical balance (OHaus, USA).

LWR was established by $W = aL^b$ (Pauly 1984), where W is the wet weight (WW) and L is the total length (TL). The parameters *a* (equation intercept) and *b* (regression coefficient, slope) were estimated by least squares linear regression on log-log transformed data: log$WW = \log a + b\log TL$. The 95% confidence interval (CI) values of parameters *a* and *b* were calculated. The null hypothesis of isometric growth, H_0:*b* = 3 was tested by Student's *t*-test (Sokal & Rohlf 1987).

Results and Discussion

A total of 1112 specimens of *Acetes*, sampled from the west coast of Peninsular Malaysia, were analysed. The specimens were differentiated according to their species and sexes based on the morphological characters described by Omori (1975) and Wong (2013). An overview of the key characters used for species identification as well as sex differentiation is presented in Table 1. Sample sizes (N) obtained were 53 *Acetes sibogae*, 74 *A. japonicus*, 381 *A. serrulatus* and 604 *A. indicus*. The length-weight relationships are summarized in Tables 3 and 4 according to species and between inshore and offshore samples, respectively. The LWRs estimated in this study were significant at $p < 0.05$, with a coefficient of determination of $R^2 \geq 0.659$ for the four *Acetes* species (Table 3). When the LWRs were estimated for inshore and offshore samples of *A. indicus* and *A. serrulatus*, R^2 was >0.84 (Table 4).

The numerical value of *b* is used in LWRs as an indicator of growth type (*i.e.* to determine whether deviation from isometric growth has occurred). It normally falls between 2.5 and 3.5, and is often close to 3 (Binohlan & Pauly 2000; Pauly 1984). When *b* = 3, the body of the organism increases in all dimensions in the same proportion as it grows (Jobling 2002). The value of *b* is >3 when the organism becomes fatter and <3 when it becomes slimmer as it increases in body length. LWR is also used to assess the condition or 'well-being' of individual organisms (Jobling 2002). In the present study, the overall estimated *b* values of LWR were between 2.285 to 3.403 (Tables 3 & 4). This is similar to earlier studies of LWR of *Acetes* spp. in the coastal waters of Malaysia (Amani et al. 2011; Amin et al. 2009b, 2009c, 2008; Arshad et al. 2012, 2008, 2007), Bombay (Deshmukh 2002), Western Australia (Ikeda & Raymont 1989), Guangdong, China (Lei 1988), Inland Sea of Japan (Uye 1982) and Bangladesh (Zafar et al. 1998a,

TABLE 1. Morphological characters, based on Omori (1975) and Wong (2013), that were used for (a) differentiating the sexes and (b) identification of the four *Acetes* species sampled from the west coast of Peninsular Malaysia

(a)

	Sex	
Morphological characters	Male	Female
Petasma	Present	Absent
One pair of protruberances (genital coxae) between the third pair of pereiopods and first pair of pleopods	Present	Absent
Lower antennular flagellum	Present, with 1 or 2 clasping spines	Present, without clasping spines

(b)

Morphological characters	Species			
	Acetes indicus	*Acetes serrulatus*	*Acetes japonicus*	*Acetes sibogae*
Male				
Petasma	Without pars astringens	Without pars astringens	Without pars astringens	Pars astringens present with one large hook at the outer margin
Lower antennular flagellum	One clasping spine, no triangular projections	Two clasping spines, presence of triangular projections	Two clasping spines, no triangular projections	One clasping spine, no triangular projections
Female				
Third thoracic sternite (basis of the third pair of pereiopods)	Basis has sharp projections	No projections at basis	No projections at basis	Basis has blunt projections

TABLE 2. Sampling locations of *Acetes* spp. collected along the west coast of Peninsular Malaysia

Species	Sampling Location (Abbreviation)	Latitude	Longitude	Sampling Methods
Acetes indicus	Kuala Kurau (KK)	5°0'11.41"N	100°25'22.47"E	In-shore
	Kuala Gula (KG)	4°55'0.35"N	100°27'39.54"E	In-shore
	Sungai Tiang (SGT)	3°55'9.28"N	100°36'15.02"E	Off-shore
	Bagan Pasir Laut (BPL)	3°49'11.80"N	100°41'4.16"E	Off-shore
	Bagan Lipas (BL)	3°45'48.83"N	100°44'18.62"E	Off-shore
	Teluk Rhu (TR)	3°42'47.86"N	100°45'11.12"E	Off-shore
	Sekinchan (SKC)	3°26'42.08"N	100°54'39.76"E	Off-shore
	Tanjong Karang (TKR)	3°19'48.37"N	101° 2'20.32"E	Off-shore
	Portuguese Settlement (PSETT)	2°10'57.14"N	102°15'57.91"E	In-shore
	Pulau Kukup (PKKP)	1°19'5.39"N	103°26'37.77"E	In-shore
	Sungai Kapal (SGK)	1°20'51.04"N	104°13'12.94"E	In-shore
Acetes serrulatus	Sungai Tiang (SGT)	3°55'9.28"N	100°36'15.02"E	Off-shore
	Bagan Pasir Laut (BPL)	3°49'11.80"N	100°41'4.16"E	Off-shore
	Bagan Lipas (BL)	3°45'48.83"N	100°44'18.62"E	Off-shore
	Teluk Rhu (TR)	3°42'47.86"N	100°45'11.12"E	Off-shore
	Sekinchan (SKC)	3°26'42.08"N	100°54'39.76"E	Off-shore
	Tanjong Karang (TKR)	3°19'48.37"N	101°2'20.32"E	Off-shore
	Pulau Kukup (PKKP)	1°19'5.39"N	103°26'37.77"E	In-shore
	Sungai Kapal (SGK)	1°20'51.04"N	104°13'12.94"E	In-shore
Acetes japonicus	Kuala Kurau (KK)	5° 0'11.41"N	100°25'22.47"E	In-shore
	Kuala Gula (KG)	4°49'47.77"N	100°27'1.33"E	In-shore
	Teluk Bahang (TBHG)	5°27'36.91"N	100°12'44.51"E	In-shore
Acetes sibogae	Sungai Kubang Badak (SGKB)	6°23'58.75"N	99°43'32.21"E	In-shore

TABLE 3. Descriptive statistics and estimated parameters of the length-weight relationships of the four *Acetes* species collected along the west coast of Peninsular Malaysia

Species	N	Sex	TL Range (mm)	WW Range (mg)	*a*	95 % CI of *a*	*b* (S.E.)	95 % CI of *b*	Growth	R^2
Acetes indicus	340	F	16.71 – 38.94	18.00 – 287.30	0.008	0.006 – 0.011	2.778 (0.045)	2.688 – 2.867	A– (4.933)	0.917 ***
	264	M	15.07 – 29.52	14.90 – 110.40	0.010	0.007 – 0.014	2.694 (0.053)	2.589 – 2.799	A– (5.773)	0.907***
	604	B	15.07 – 38.94	14.90 – 287.30	0.007	0.006 – 0.008	2.829 (0.029)	2.773 – 2.886	A– (5.896)	0.941 ***
Acetes serrulatus	194	F	15.28 – 26.55	14.20 – 70.00	0.013	0.007 – 0.023	2.637 (0.104)	2.431 – 2.843	A– (3.490)	0.769 ***
	187	M	14.21 – 25.87	12.10 – 49.90	0.010	0.006 – 0.016	2.699 (0.084)	2.533 – 2.865	A– (3.583)	0.847 ***
	381	B	14.21 – 26.55	12.10 – 70.00	0.009	0.006 – 0.013	2.749 (0.064)	2.623 – 2.875	A– (3.921)	0.829 ***
Acetes japonicus	49	F	15.25 – 22.00	11.60 – 33.00	0.017	0.006 – 0.050	2.432 (0.179)	2.072 – 2.791	A– (3.173)	0.798 ***
	25	M	14.25 – 18.59	8.50 – 20.60	0.002	0.0001 – 0.031	3.153 (0.473)	2.175 – 4.132	I (0.323)	0.659 ***
	74	B	14.25 – 22.00	8.50 – 33.30	0.005	0.002 – 0.010	2.883 (0.139)	2.606 – 3.160	I (0.842)	0.856 ***
Acetes sibogae	10	F	19.29 – 23.04	22.40 – 40.00	0.001	0.000 – 0.009	3.393 (0.315)	2.667 – 4.119	I (1.247)	0.936 ***
	43	M	18.17 – 21.93	17.00 – 33.10	0.002	0.001 – 0.005	3.191 (0.162)	2.864 – 3.519	I (1.179)	0.904 ***
	53	B	18.17 – 23.04	17.00 – 40.00	0.001	0.000 – 0.002	3.403 (0.130)	3.143 – 3.664	A+ (3.100)	0.931 ***

N = number of individuals; Sex: F = female, M = male, B = total females and males; TL = total length (mm); WW = wet weight (mg); Regression parameter: *a* = intercept, *b* = slope; CI = confidence interval; S.E. = standard error of the slope *b*; Growth: A = allometric, I = isometric, + = positive, – = negative; R^2: coefficient of determination; significance level: *P<0.01< P< 0.05, **P< 0.01< P< 0.05, ***P< 0.001

1998b, 1997), in which *b* values for the genus *Acetes* ranged from 2.155 to 3.472.

Acetes indicus and *A. serrulatus*, in general, demonstrated negative allometric growth for males and females and in overall pooled data of both sexes (Tables 3 & 4). As for *A. japonicus* and *A. sibogae*, the males showed an isometric growth type. Differences in growth patterns were, however, observed between males and females of *A. japonicus* whereas the pooled data of both sexes for *A. sibogae* showed positive allometric growth as compared with isometric growth in the case of individual sexes (Table 3). Values of $b < 2.5$ or $b > 3.5$ are often derived from

TABLE 4. Descriptive statistics and estimated parameters of the length-weight relationships for the inshore and offshore samples of *A. indicus* and *A. serrulatus* collected along the west coast of Peninsular Malaysia

Species		N	Sex	TL Range (mm)	WW Range (mg)	*a*	95 % CI of *a*	*b* (S.E.)	95 % CI of *b*	Growth	R^2
Acetes indicus	in-shore	241	F	16.71 – 29.20	18.00 – 93.00	0.006	0.004 – 0.009	2.911 (0.072)	2.770 – 3.052	I (1.236)	0.874 ***
		197	M	15.07 – 23.26	14.90 – 52.20	0.007	0.004 – 0.011	2.836 (0.086)	2.666 – 3.005	I (1.907)	0.848 ***
		438	B	15.07 – 29.20	14.90 – 93.00	0.005	0.004 – 0.007	2.940 (0.041)	2.858 – 3.021	I (1.463)	0.921 ***
	off-shore	99	F	17.38 – 38.94	26.40 – 287.30	0.008	0.004 – 0.015	2.803 (0.104)	2.597 – 3.009	I (1.894)	0.882 ***
		67	M	15.32 – 29.52	15.00 – 110.40	0.009	0.005 – 0.015	2.733 (0.090)	2.554 – 2.912	A– (2.967)	0.935
		166	B	15.32 – 38.94	15.00 – 287.30	0.006	0.004 – 0.009	2.867 (0.057)	2.755 – 2.979	A– (2.333)	0.940 ***
Acetes serrulatus	in-shore	39	F	18.81 – 26.55	18.90 – 60.20	0.001	0.0001–0.003	3.335 (0.176)	2.978 – 3.693	I (1.903)	0.906 ***
		30	M	19.52 – 25.87	26.90 – 49.60	0.031	0.001 – 0.100	2.285 (0.181)	1.914 – 2.655	A– (3.950)	0.851 ***
		69	B	18.81 – 26.55	18.90 – 60.20	0.006	0.002 – 0.014	2.806 (0.125)	2.556 – 3.056	I (1.552)	0.882 ***
	off-shore	155	F	15.28 – 24.07	14.20 – 70.00	0.002	0.001 – 0.003	3.326 (0.106)	3.116 – 3.536	A+ (3.075)	0.865 ***
		157	M	14.21 – 22.21	12.10 – 49.90	0.003	0.002 – 0.005	3.157 (0.094)	2.972 – 3.342	I (1.670)	0.880 ***
		312	B	14.21 – 24.07	12.10 – 70.00	0.002	0.001 – 0.003	3.305 (0.066)	3.175 – 3.435	A+ (4.621)	0.889 ***

N = number of individuals; Sex: F = female, M = male, B = total females and males; TL = total length (mm); WW = wet weight (mg); Regression parameter: *a* = intercept, *b* = slope; CI = confidence interval; S.E. = standard error of the slope *b*; Growth: A = allometric, I = isometric, + = positive, – = negative; R^2: coefficient of determination; significance level: $*P<0.01<P<0.05$, $**P<0.01<P<0.05$, $***P< 0.001$

aquatic samples with narrow size ranges (Froese 2006; Froese & Pauly 2011; Jobling 2002). It is hypothesized that these *b* values in female *Acetes* shrimps could also signify individuals that have spawned their eggs and are thus longer in relation to their weight ($b < 2.5$) or ovigerous females with mature, unfertilized eggs that are heavier relative to their lengths ($b > 3.5$) (Amin et al. 2009b; Froese 2006). Furthermore, the availability of food resources and favourable environmental conditions at a particular location might play an important role in determining the allometric growth type in male and female *Acetes* shrimps (Wong 2013).

Male and female *A. japonicus* and *A. sibogae* showed isometric growth among inshore catches (Table 3). Since the samples of two species were not found among offshore trawling catches, LWRs were compared only for inshore and offshore samples of *A. indicus* and *A. serrulatus* (Table 4). With the exception of *A. indicus* females showing isometric growth for inshore and offshore groups, the overall growth type of the inshore groups differed from that of the offshore groups for both species. Differences in LWR between the inshore and offshore groups of both species (Table 4) could be due to the presence of at least two cohorts representing two annual generations at different life stages, i.e. spawning and pre-spawning *Acetes* aggregations (Omori 1975; Wong 2013). This is because *Acetes* species have spawning peaks twice a year which follow the monsoon seasons (Amin et al. 2009b, 2009c; Oh & Jeong 2003) and undergo seasonal migration between shallow inshore and deeper offshore waters at different life stages (Chiou et al. 2000; Omori 1978, 1975).

It is speculated that negative allometric growth shown by offshore male *A. indicus* and inshore male *A. serrulatus* could be due to individuals which had become spent and were dying following spawning peaks (Omori 1978, 1975; Wong 2013). In addition, isometric and positive allometric growth might indicate sufficient food resources in the neritic zones and the horizontal migration of mature males and gravid females from open waters to favourable inshore regions for spawning (Table 4) (Omori 1975; Wong 2013). Swarms of adult *Acetes* in the open sea represent ephemeral stocks that are vulnerable to predation, environmental fluctuations as well as scarcity of food resources as compared with inshore regions. Surface water currents and wind blowing towards land stimulate *Acetes* shrimps to swarm to shallow inshore waters. Spawning peaks may follow this migration pattern in tropical waters and hence larvae and juveniles are able to grow out in these resource-rich waters and avoid the offshore open seas (Omori 1978, 1975; Wong 2013).

Variations in *a* and *b* differ with the size range of the samples (Froese & Pauly 2011). The use of LWR should therefore be strictly limited to the size ranges applied when estimating regression parameters (Dulčić & Kraljević 1996; Froese & Pauly 2011; Gonçalves et al. 1997; Morey et al. 2003; Muto et al. 2000; Petrakis & Stergiou 1995). The LWRs estimated in this study would contribute additional data to the available LWRs of *Acetes* spp. in other geographical areas or new data and serve as a reference for future comparisons with other available data.

Conclusion

This study presents reference data on the length-weight relationships of the major *Acetes* species sampled from the west coast of Peninsular Malaysia. It provides the first basic information on LWRs for *A. indicus* and *A. serrulatus* from the offshore waters of the Straits of Malacca. Isometric and positive allometric growth trends in offshore and inshore catches of *A. indicus* and *A. serrulatus* as well as inshore *A. japonicus* and *A. sibogae* denote that these waters could still provide an optimal environment for the growth of these shrimps. The LWR parameters could be used for future studies on the growth and population dynamics of the major *Acetes* spp. exploited in this region. The findings of this study have contributed to the formulation of ecological as well as intergradation studies for the conservation and management of this commercially important fisheries resource.

Acknowledgements

This study was supported by a UTAR Postgraduate Research Fund (6202/W01).

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Received: 15 November 2013
Accepted: 22 September 2014