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Morphometric length-weight relationships of wild penaeid shrimps in Malindi-Ungwana Bay: Implications to aquaculture development in Kenya

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ABSTRACT

The present investigation describes the biology of penaeid shrimps and their fishery studies on morphometric length-weight relationships estimated during the two monsoon seasons from Malindi–Ungwana Bay in Kenya. A total of 1238 penaeid shrimps belonging to *Fenneropenaeus indicus*, *Penaeus monodon*, *Marsupenaeus japonicus*, *Metapenaeus monoceros*, *Penaeus canaliculatus* and *Penaeus semisulcatus* were collected from the two seasons with South East Monsoon (SEM) recording more diverse species than the North East Monsoon (NEM). The length-weight relationship analyses of most penaeid species exhibited positive allometric growth significantly different from 3.0 ($p < 0.05$) with strong relationship between lengths and weights of these species. The carapace length of the six penaeid shrimps at first maturity (L_{50}) suggested that their spawning starts at different sizes with *P. monodon* achieving the largest size ($L_{50} = 54.2$ mm CL) while *M. monoceros* at the smallest size ($L_{50} = 30.2$ mm CL). Large proportions of female *F. indicus*, *P. semisulcatus* and *M. monoceros* had gonad stages IV and V recorded during SEM than in NEM seasons. The abundance of *F. indicus* and *M. monoceros* with matured gonads in both seasons confirms the suitability of *F. indicus* and *M. monoceros* for sustainable shrimp culture production in Kenya.

Introduction

Lately, penaeid shrimps have been considered as one of the most valuable fishery resources in Malindi-Ungwana Bay in the north coast of Kenya. Nevertheless, wild stocks of penaeid shrimp have declined rapidly in recent years, largely as a result of fishing pressure and habitat loss in the mangrove and estuarine areas. Information on the early life of penaeid shrimps development in Malindi-Ungwana Bay is relatively inadequate. Few studies on shrimps have been presented by Kimani et al. (2011), Mkare et al. (2014) and Munga et al. (2013, 2014).

In fisheries biology, length versus weight and/ or length versus length relationships are important tools as they provide information on growth patterns and the general condition of the fish that can be used in population structure analysis (Guino-o II, 2012). However, some differences have been reported in these studies among the penaeid species, sexes, sites and seasons for both cultured and wild populations (Pérez-Castañeda and Defeo, 2002). There is little information on morphometric studies on the length-weight relationships of penaeid shrimps in Malindi-Ungwana Bay despite its great economic value in Kenya.

In 1984, a feasibility study by the Kenyan Government/ FAO/ UNDP has shown that the coastal region of Kenya has a high potential for crustacean farming (Rasowo and Radull, 1985). There are enough seeds in the wild, which are affordable to the potential farmers to be used to stock ponds (Wanjiru, 2009). However, for mariculture to take off commercially with substantial potentials, already demonstrated by trials in extensive shrimp culture at Ngomeni shrimp farm (Abila, 2010), information on the cost-benefit analysis involved in the extensive versus semi-intensive systems of production for shrimp culture in traditional brackish water tidal ponds needs to be addressed adequately. Since this is one of the prerequisites for developing effective management and conservation strategies (Mojekwu and Anumudu, 2015) needed when

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exploiting penaeid shrimps, feasible systems for shrimp culture can be developed from an ecological point of view to promote a sustainable production and trade in penaeid shrimp resources along the Kenyan coast (Gatune, 2012).

This study was therefore designed to evaluate morphometric length-weight relationships among the wild penaeid shrimps in Malindi-Ungwana Bay, and correlate these relationships with relative growth and condition factors of different penaeid species to render information about the sustainable design for the rearing strategies of shrimp mariculture.

Materials and Methods

Study area

Malindi-Ungwana Bay is located between Malindi (Latitudes: S 03° 10′ 00″ – S 02° 30′ 00″) and Ras Shaka, north of Kipini (Longitudes: E 40° 05′ 00″ – E 40° 30′ 00″) covering the Ungwana Bay along the Northern Coast of Kenya (Fig. 1). It is characterized by two major rivers, which discharge into the bay, with River Sabaki at its southern most limit, while River Tana is at its northern most limit. During the spring tides, Malindi-Ungwana Bay has average depths of 12 m and 18 m at 1.5 nautical miles and 6.0 nautical miles respectively, followed by a sharp depth increase of 100 m after 7.0 nautical miles but generally decreasing northwards (Mwatha, 2002).

The study had six sample stations, four of which were located within the estuaries (S1, S2, S3 and S4), while the other two sample stations (S5 and S6) were within the shallow waters. S1 is located around the River Sabaki (S 03° 09′ 28″, E 040° 08′ 02″); S2 is located at Ngomeni (S 02° 59′ 27″ – S 03° 00′ 04″, E 040° 09′ 54″ – E 040° 10′ 31″); S3 is located at Kurawa (S 02° 43′ 17″, E 040° 10′ 44″); and S4 is located at Mvundeni Kengeleni beach (S 02° 32′ 02″ – S 02° 32′ 03″, E 040° 30′ 17″ - E 040° 31′ 07″). The shallow water survey was stratified by depth and distance from shore, and the entire bay was divided into four depth zones using regular polygons. The total area of each zone was estimated in ArcGIS area calculator such as; <10 m depth (137.3 nm^2) represented Zone 1, 10–20 m

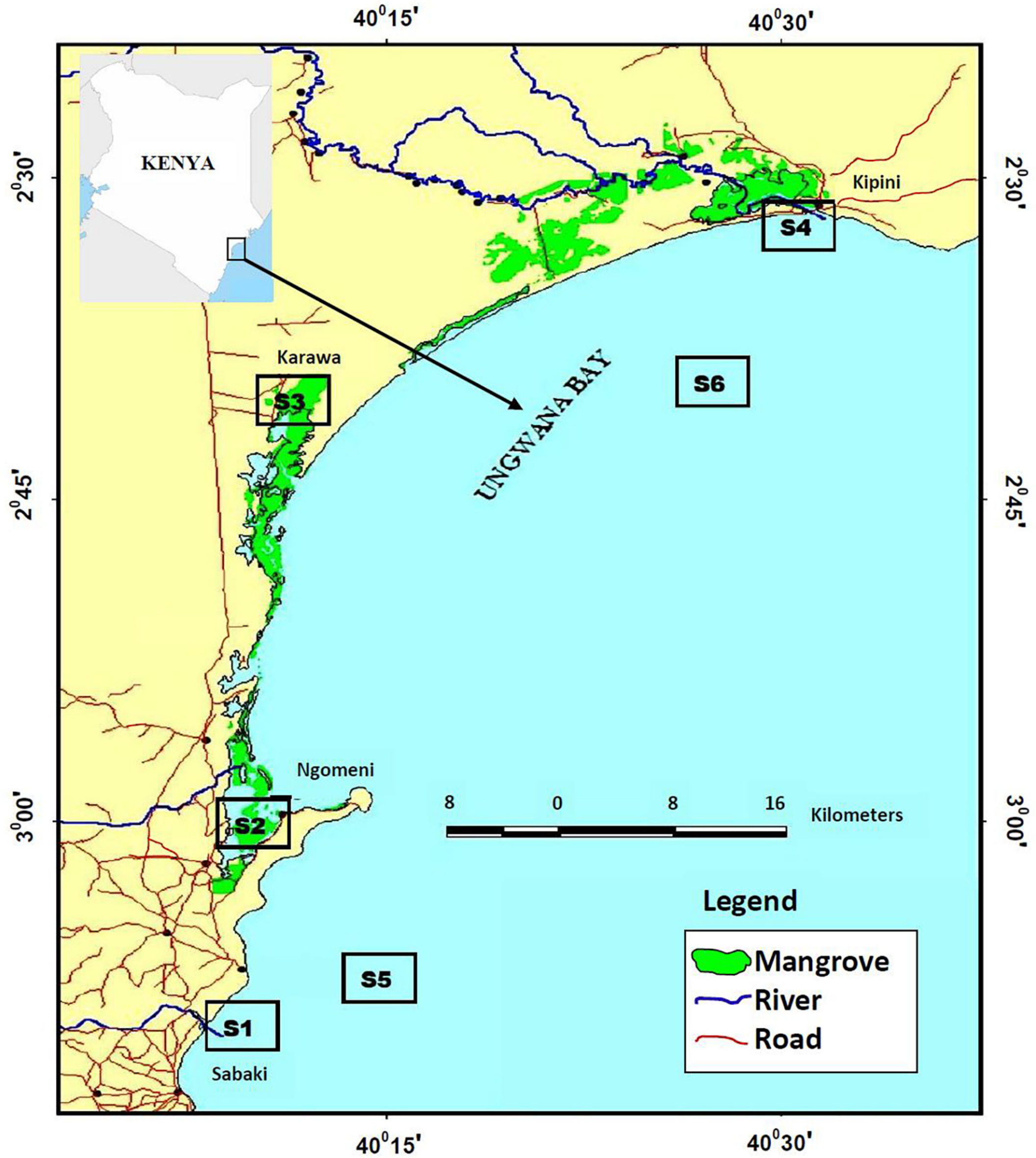

Fig. 1. Map showing the location of the sample stations (S1, S2, S3, S4, S5 and S6) in Malindi-Ungwana Bay.

(234.1 nm^2) for Zone 2, 20–40 m (136.3 nm^2) for Zone 3, and lastly, 40–100 m (38.7 nm^2) represented Zone 4 (Kimani et al., 2012). S5 was located off the mouth of River Sabaki in Zone 3 (S 03° 01′ 36″ – S 03° 11′ 29″; E 40° 10′ 57″ – E 40° 16′ 38″), while S6 was located off the mouth of River Tana in Zone 1 (S 02° 33′ 31″ – S 02° 35′ 31″; E 40° 29′ 12″ – E 40° 31′ 41″).

Data collection

A total of 1238 specimens (429 specimens were collected during the North East monsoon season, NEM, in January to February 2011, while 809 specimens were collected during the South East monsoon season, SEM, in May to June 2011) were studied from six sample stations in Malindi-Ungwana Bay (Table 1). Penaeid shrimps were collected in every monsoon season with SEM being cooler than NEM. Every seasonal sampling had two separate surveys of 10 and 13 days duration conducted for sample collections in the estuary and shallow water sites respectively. Random samples were collected from the estuaries of four main artisanal fishing areas (S1, S2, S3 and S4) and two others within the shallow waters trawling grounds (S5 and S6). Establishment of sample stations were based on factors such as frequent use of the sites by resource users (Artisanal fishermen), presence of high biomass of aquatic vegetation, areas surrounding high influx of fresh water into the ocean, and areas known to be the main trawling grounds by the shallow water shrimp trawlers.

In the estuaries, sampling was done using a 1 in. (25.4 mm) stretched mesh size seine net measuring 20 m long by 1.25 m high. Fishing was undertaken by two people during low tide with 8 hauls made per sampling day. While in the shallow waters' trawling grounds, the Fishing Vessel VEGA (measuring 25 m long and with gross register tones of 146) with 496 horsepower engine capacity and a commercial bottom trawler with a fitted 70 mm mesh size towing net (44.3 m long and 45 mm mesh size cod end) was used to conduct the surveys for one hour at a speed of 2.5 knots. Coordinates for every shallow water trawling transect and sampling point in the estuaries were recorded and depths were taken at the start and end of each tow.

For every small reasonable catch (at least 30 specimens), the whole catch was considered as a single sample, sorted out by species, identified and weighted per species; and whereas the total catch was too large to manage as a single sample, then sampling proportion was performed at 10% of the catch with a desired margin of error at the 95% confidence level as the subsample (Tonks et al., 2008). We consider these samples as being representative of the trawl catch and our sampling procedures allow quantitative comparisons of the samples in relative terms.

The samples were identified morphologically according to Chan (1998). When the identification of the specimens was difficult, they were recognized to the genus level due to lack of distinct characteristics and then subjected to further genetic analysis to identify them to species level. A Vernier caliper was used to measure individuals in each sample for carapace length (CL) and total length (TL) to the nearest 0.1 mm, while body weight (BW) was measured to the nearest 0.1 g using an electronic weighing balance.

Every population sample was sorted out according to the sex composition of each species. The presence of eggs on female shrimps was recorded and the stages of ovarian maturation were classified on the basis of coloration to five stages; undeveloped (I) and developing (II) stages, nearly ripe (III), ripe (IV) and spent (V) stages as described by Amanat and Qureshi (2011).

Data handling and analyses

The length-weight relationship of penaeid species, i.e., total length versus shrimp body weight was calculated using the

Table 1

Summary of seasonal Length-weight relationship parameters of penaeid species from Malindi-Ungwana Bay (n – species sample size; *a* and *b* parameters of length-weight relationship; χ – mean value, S.E. – standard error; R^2 – regression coefficient; *p* is probability of significance of the difference at $\alpha = 0.05$).

Season	Station	Species	n	$\frac{TL(mm)}{\chi \pm S.E}$	$\frac{BW(g)}{\chi \pm S.E}$	a	Regression parameters		Pr > F
							B ± S.E	R^2	
NEM	2	*F. indicus*	27	114.11 ± 3.68	6.48 ± 0.38	0.08460577	0.91 ± 0.39	0.181	0.0270
		M. japonicus	42	118.05 ± 1.55	9.24 ± 0.35	0.00002972	2.64 ± 0.24	0.749	<0.0001
	3	*F. indicus*	22	121.09 ± 2.03	9.55 ± 0.59	0.00000112	3.32 ± 0.47	0.713	<0.0001
		M. japonicus	34	142.29 ± 3.65	19.18 ± 1.57	0.00000103	3.36 ± 0.11	0.966	<0.0001
	4	*F. indicus*	24	153.88 ± 1.32	17.38 ± 0.72	0.00040476	2.12 ± 0.84	0.222	0.0201
		P. monodon	8	208.00 ± 12.14	59.25 ± 1154	0.00000035	3.53 ± 0.14	0.991	<0.0001
	5	*M. monoceros*	29	110.52 ± 4.20	9.76 ± 1.49	0.00000177	3.26 ± 0.15	0.947	<0.0001
		P. canaliculatus	7	156.00 ± 10.26	24.57 ± 4.97	0.00003643	2.64 ± 0.39	0.901	0.0011
		F. indicus	15	150.67 ± 6.74	27.53 ± 4.00	0.00000444	3.10 ± 0.20	0.950	<0.0001
		P. monodon	11	191.91 ± 6.94	49.54 ± 5.30	0.00000848	2.96 ± 0.20	0.964	<0.0001
		P. semisulcatus	30	135.83 ± 3.77	18.50 ± 1.66	0.00000845	2.96 ± 0.11	0.963	<0.0001
	6	*M. monoceros*	46	130.07 ± 2.99	16.13 ± 1.04	0.00000071	3.46 ± 0.10	0.965	<0.0001
		F. indicus	58	152.55 ± 2.22	22.59 ± 1.10	0.00000196	3.22 ± 0.18	0.858	<0.0001
		M. japonicus	32	147.97 ± 2.38	21.84 ± 1.24	0.00000229	3.21 ± 0.21	0.888	<0.0001
		P. monodon	44	195.05 ± 3.85	51.45 ± 3.26	0.00000294	3.15 ± 0.09	0.967	<0.0001
SEM	2	*M. monoceros*	25	113.36 ± 1.01	7.88 ± 0.29	0.00003739	2.59 ± 0.74	0.350	0.0018
		P. semisulcatus	20	110.15 ± 3.53	9.85 ± 1.02	0.00000364	3.14 ± 0.19	0.937	<0.0001
	3	*F. indicus*	42	118.50 ± 1.04	8.45 ± 0.31	0.00000256	3.14 ± 0.44	0.559	<0.0001
		P. monodon	11	119.00 ± 6.24	11.72 ± 1.64	0.00000183	3.26 ± 0.11	0	<0.0001
	4	*P. monodon*	5	112.40 ± 2.32	9.20 ± 0.80	0.00000007	3.95 ± 0.99	0.844	0.0275
	5	*M. monoceros*	49	129.04 ± 2.19	15.78 ± 0.91	0.00000278	3.19 ± 0.20	0.841	<0.0001
		F. indicus	44	156.68 ± 2.53	23.45 ± 1.58	0.00000016	3.71 ± 0.19	0.903	<0.0001
		P. semisulcatus	49	153.08 ± 2.69	28.41 ± 1.66	0.00000305	3.18 ± 0.12	0.934	<0.0001
	6	*M. monoceros*	183	121.45 ± 1.22	12.68 ± 0.49	0.00000022	3.70 ± 0.08	0.914	<0.0001
		P. canaliculatus	5	154.00 ± 3.04	26.80 ± 2.29	0.00000004	4.05 ± 0.64	0.930	0.0080
		F. indicus	188	159.21 ± 0.97	24.55 ± 0.53	0.00000048	3.49 ± 0.09	0.889	<0.0001
		M. japonicus	33	136.39 ± 2.40	18.15 ± 1.18	0.00000259	3.20 ± 0.10	0.970	<0.0001
		P. monodon	49	199.06 ± 4.43	60.06 ± 4.58	0.00010899	2.48 ± 0.25	0.680	<0.0001
		P. semisulcatus	106	136.57 ± 1.50	18.64 ± 0.70	0.00000457	3.09 ± 0.08	0.933	<0.0001

exponential regression formula: $w = aL^a$ (Le Cren, 1951) where, W is BW in grams (g); L is the length in centimeters (cm); a is the constant (intercept); and b is the length exponent (slope). The parameters of length-weight relationship 'a' (intercept) and 'b' (exponent) were estimated from a linear regression function, $Y = a + bX$, by logarithmically expressing this equation as:$\log w = \log a + b \log L$ where, W is BW in grams (g); where L is the length in centimeters (cm); a and b are constants showing the initial growth index and growth coefficient respectively.

Also the Fulton's condition factor (K) for each species in every sample station was determined according to the equation (Froese, 2006): $K = \frac{W}{L^3} \times 100\%$ where, W is BW in grams (g); L is the TL in centimeters (cm); factor 100 is used to bring K close to unity. The isometric or allometric growth patterns, with a confidence level of 95%, were determined according to Froese (2006). By using female shrimp individuals, gonad maturity stages were categorized into two distinct groups, i.e., I and II as immature and III–V as mature (Amanat and Qureshi, 2011), and the length at first maturity (L_{50}) being determined by calculating the proportion of the mature individuals for each length class (Teikwa and Mgaya, 2003). All statistical analyses were calculated using the program Minitab 17.

Results

Length-weight relationships

The analyses of length-weight relationships of penaeid shrimps are summarized in Table 1. During NEM season, *P. monodon* were observed as heavier and big in size in every site wherever they were caught, while *M. monoceros* were observed as lighter and small in size in all sites. Most penaeid shrimps from various sample stations exhibited positive allometric growth with the values of b being greater than 3 ($b > 3$). There are strong relationships between the lengths and weights of these species judging from the regression coefficients in most sample stations except *F. indicus* from S2 and S4 with the models explaining data variability of 18.1% and 22.2% respectively. However, the values of b for most species were significantly different from 3 ($p < 0.05$) during NEM season, same as those from various sample stations during the SEM season. In some few cases, length-weight relationships estimated in the present study showed that penaeid shrimp may be under adverse conditions during NEM season for *F. indicus* ($b = 0.91$) and *M. japonicus* ($b = 2.64$) in S2, *F. indicus* ($b = 2.12$) in S4, *P. canaliculatus* ($b = 2.64$), *P. monodon* ($b = 2.96$) and *P. semisulcatus* ($b = 2.96$) in S5, while the SEM season conditions were more favorable for most species ($b \geq 3.0$) except *M. monoceros* ($b = 2.59$) and *P. monodon* ($b = 2.48$) in S2 and S6 respectively. Moreover, the regression coefficients for length-weight relationships were high for most penaeid species in Malindi-Ungwana Bay, which indicated that length increased with the increase in shrimp weight.

Shrimp condition factors, gonad stages and size at first maturity

The results of K determined for penaeid shrimps in Malindi-Ungwana Bay are shown in Table 2. During NEM season, the highest K of 0.74 was recorded from *F. indicus* in S5, while the lowest K of 0.45 was from the same species in S2. During SEM season, the highest K of 0.76 was recorded from *P. monodon* in S6, while the lowest K of 0.5 was from *F. indicus* in S3. Generally, the condition factors were slightly higher during SEM than NEM seasons. Moreover, the results showed that most of the female penaeid species were either at immature or developing stage in both seasons (Fig. 2). Large proportion of matured females in gonad stage IV and V was mainly dominated by *F. indicus* during NEM season as well as *M. monoceros* in the SEM season. In both seasons, there were almost the same proportions of penaeid shrimps in gonad stage III. Conversely, more penaeid species were abundant in gonad stage IV during the SEM than NEM seasons. There was only one species, *F. indicus*, dominating gonad stage V in NEM season as compared to SEM season.

The carapace length at first maturity (L_{50}) differed according to penaeid species (Fig. 3). The L_{50} for *P. monodon* was found to be 54.2 mm CL, while the smallest females with ripe ovaries had 37.8 mm CL, and the largest size was 77.5 mm CL. This was followed by *M. japonicus* ($L_{50} = 37.1$ mm; 27.8–45.9 mm CL), *F. indicus* ($L_{50} = 35.8$ mm; 24.8–50.3 mm CL), *P. semisulcatus* ($L_{50} = 33.7$ mm; 23.3–45.1 mm CL) and *M. monoceros* ($L_{50} = 30.2$ mm; 19.6–43.9 mm CL).

Table 2
Seasonal condition factors of penaeid shrimps in Malindi-Ungwana Bay (n – species sample size; K – condition factor; SE – standard error).

Station	Species	n	$\frac{\text{NEM}}{K\pm\text{S.E}}$	n	$\frac{\text{SEM}}{K\pm\text{S.E}}$
2	*F. indicus*	27	0.45 ± 0.02	–	–
	M. japonicus	42	0.55 ± 0.01	–	–
	M. monoceros	–	–	25	0.54 ± 0.016
	P. semisulcatus	–	–	20	0.69 ± 0.017
3	*F. indicus*	22	0.53 ± 0.02	42	0.50 ± 0.011
	M. japonicus	34	0.61 ± 0.01	–	
	P. monodon	–		11	0.63 ± 0.015
4	*F. indicus*	24	0.48 ± 0.02	–	
	P. monodon	8	0.59 ± 0.02	5	0.64 ± 0.027
5	*M. monoceros*	29	0.62 ± 0.02	49	0.70 ± 0.018
	P. canaliculatus	7	0.61 ± 0.03	–	
	F. indicus	15	0.74 ± 0.02	44	0.57 ± 0.013
	P. monodon	11	0.67 ± 0.01	–	
	P. semisulcatus	30	0.69 ± 0.01	49	0.75 ± 0.012
6	*M. monoceros*	46	0.67 ± 0.01	183	0.64 ± 0.008
	P. canaliculatus	–	–	5	0.73 ± 0.021
	F. indicus	58	0.61 ± 0.01	188	0.59 ± 0.005
	M. japonicus	32	0.65 ± 0.01	33	0.69 ± 0.007
	P. monodon	44	0.65 ± 0.01	49	0.76 ± 0.084
	P. semisulcatus	–	–	106	0.70 ± 0.006

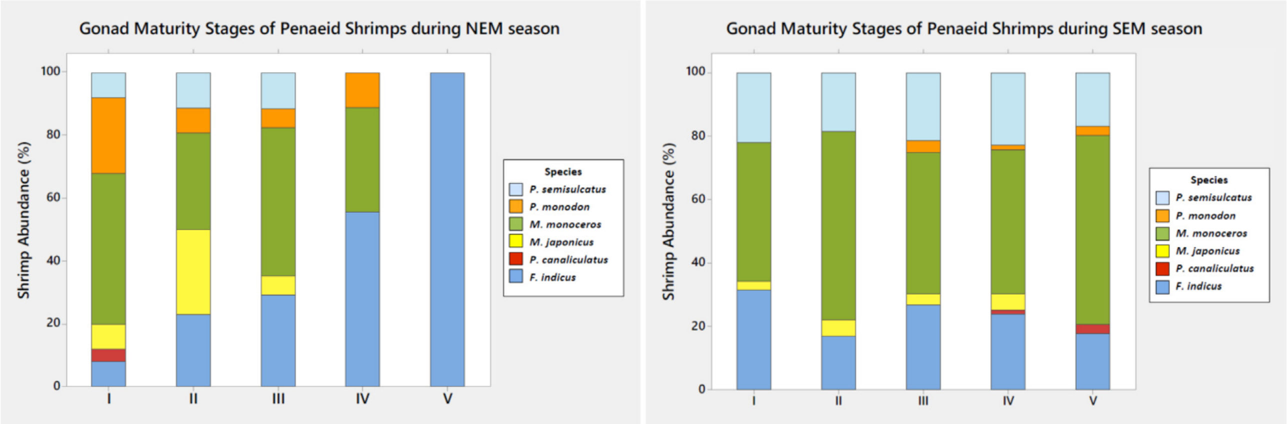

Fig. 2. Seasonal gonad maturity stages of penaeid shrimps from Malindi-Ungwana Bay: I – Undeveloped; II – Developing; III – Nearly ripe; IV – Ripe; V – Spent.

Discussion

Length-weight relationships

In the present study, for both seasons, the relationship between the length and weight for most penaeid species was significant exhibiting positive allometric growth, while a few observations were made on negative allometric growth patterns. Although, some of the sample sizes were relatively small compared with other studies, the current results showed acceptable *a* and *b* values, as tested by plotting log *a* and *b* (Froese, 2006). Maheswarudu et al. (2016) reported positive allometric growth for *P. monodon* cultured in open sea floating cage in the Bay of Bengal with *b* values of 3.08. On the other hand, negative allometric growths for normal pond reared shrimps ($b = 2.72$), loose shelled pond reared shrimps ($b = 2.24$) and the wild-type ($b = 2.49$) were recorded by Gopalakrishnan et al. (2014). In the coastal waters of Iskenderun Bay, North-Eastern Mediterranean, Manasirli et al. (2014) reported allometric growth for *P. semisulcatus* with *b* values of 2.96 and 3.13 for male and female species respectively, while Manasirli (2014) recorded $b = 2.81$ for *M. monoceros*. Okayi et al. (2010) suggested that the lower *b* values could be attributed to crowding and competition for food. These factors inhibit growth, and hence, affect the value of *b* in the length-weight relationship of any species. The regression coefficient (r^2) for length-weight relationships was high for most penaeid species, which indicated that the length increased with the increase in shrimp weight. This was in agreement with previous studies on different fish species from various water bodies (Li et al., 2016; Maheswarudu et al., 2016).

Shrimp condition factors, gonad stages and size at first maturity

The condition factors of a population may depend on not only its age and gender composition, but on environmental elements and season as well (Khristenko and Kotovska, 2017). The Fulton's condition factor (*K*) has often been used for comparing the physical and environmental condition, fatness, or well-being of shrimp (Lalrinsanga et al., 2012). Thus, *K* has become vital as it provides fisheries' managers with insights of the specific condition under which the organisms are developing (Araneda et al., 2008).

In the present study, the condition factors of the same species have varied from one locality to another in every season. The difference in condition factors may have been attributed to the presence of ovigerous females in shallow waters (S5 and S6) during May-June survey, while during January-February survey, they were observed in both estuaries and shallow waters. Generally, the condition factors were slightly higher during SEM than NEM seasons. This suggests that these shrimps were in good condition, healthy and will be suitable for mariculture.

Udoinyang et al. (2016) reported similar observations in condition factors attributed to the presence of ovigerous females in *P. monodon* from the artisanal shrimp fishery of Iko River Estuary, Southeastern Nigeria. Qureshi and Amanat (2014) observed mature females due to the additional weight of the ovaries constituting up to 13% of the total body weight. Those females were usually heavier than the immature ones of the same total length and body length. In Malindi–Ungwana Bay, seasonal patterns are largely influenced by drought conditions during the NEM season and periods of heavy precipitation during the SEM season. Olapade and Tarawallie (2014) reported that during the wet season, as water levels in the coastal waters increase and food availability is also high, thus providing favorable conditions for spawning to occur.

In this study, the spawning season of different penaeid shrimps in the Malindi-Ungwana Bay seems to occur at different periods depending on the growth rates, maturity and proportions of gonads, which were either ripe or spent, and kept changing from one sampling area to another. Villarta et al. (2006) showed spawning activity peaks for female *P. semisulcatus* during SEM, which corresponds to our results. Furthermore, the present results agree with Munga et al. (2013) who recorded seasonal patterns in Malindi-Ungwana Bay for *M. monoceros* and *P. monodon* with slight differences in their proportion for female gonads. Even with the dependence on various environmental conditions for gonad development and subsequent spawning, L_{50} of the five penaeid species in this study differed substantially suggesting that the penaeid species spawn at different sizes with *P. monodon* achieving L_{50} at the largest size and *M. monoceros* at the smallest size. Aryani et al. (2016) reported that the variations in the condition factor with the increase in length may yield evidences concerning the size at first maturity. The L_{50} values in the present study were within the range of those obtained by Kumlu et al. (1999) for *P. semisulcatus* collected off Iskenderun Bay (North Eastern Mediterranean), Teikwa and Mgaya (2003) for *F. indicus* off Bagamoyo coastal waters in Tanzania, and Munga et al. (2013) for all penaeid species except *P. monodon* of Malindi-Ungwana Bay. However, the discrepancy between our study and Munga et al. (2013) could be attributed to slight differences in their sampling techniques as Munga et al. (2013) collected their samples from trawl areas different from ours whereas our results had more samples from the estuaries.

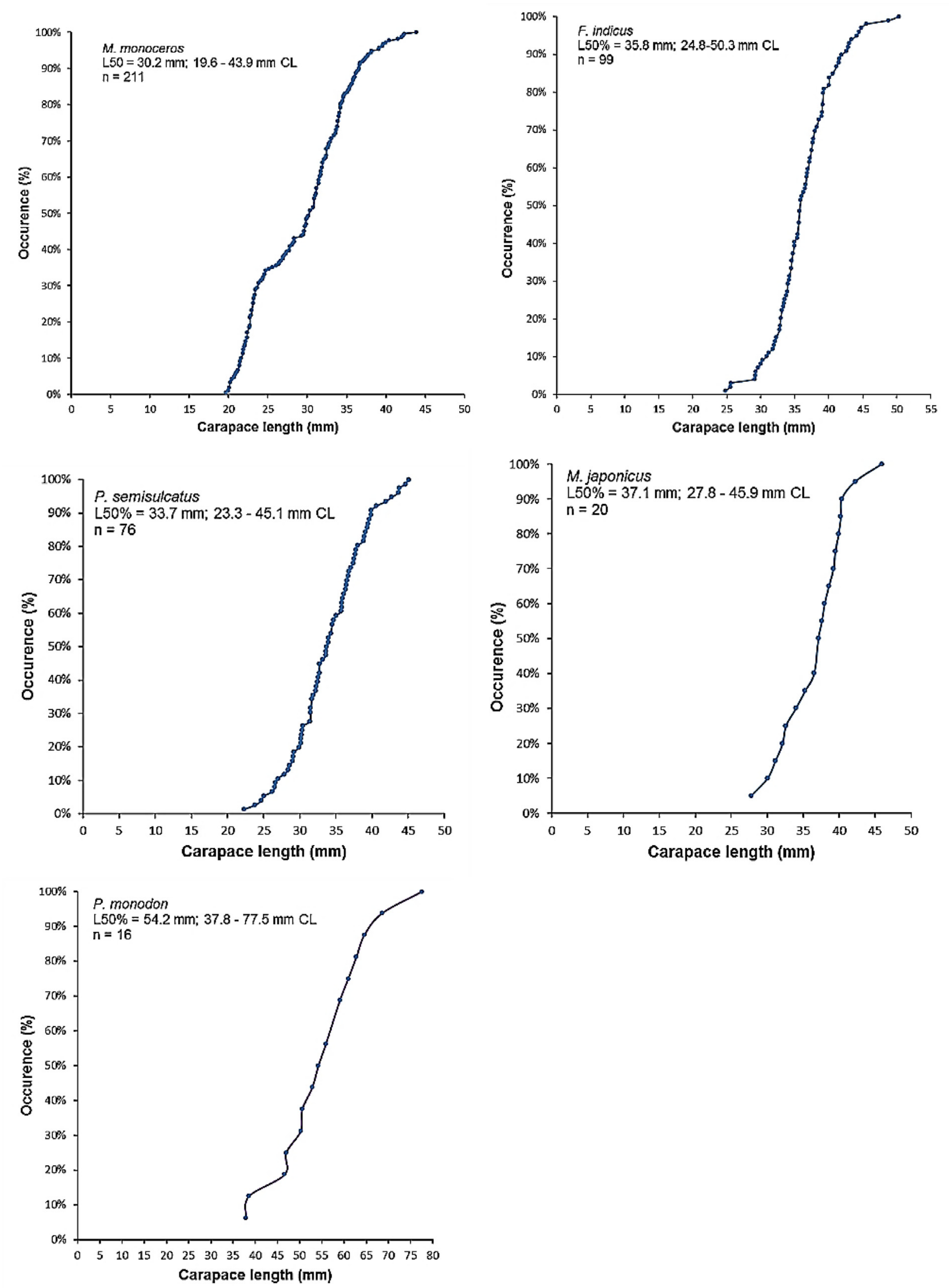

Fig. 3. The size at first maturity (L_{50}) for the five penaeid shrimps in Malindi-Ungwana Bay.

Conclusions

The findings of the present study provide the first hand information about the growth pattern and condition factors of penaeid shrimp from its in-situ habitat. This study has shown that Malindi-Ungwana Bay is suitable for the survival and reproduction of penaeid shrimps. Following the abundance of *F. indicus* and *M. monoceros* with matured gonads in both seasons, we recommend the suitability of *F. indicus* and *M. monoceros* for sustainable shrimp culture production in Kenya. Mariculture practice is gaining momentum with significant information on the seasonal availability of quality seed in the wild taken as breakthroughs in the development of shrimp industry. Since penaeid shrimp is part of the commercially important species of Kenya, this study recommends that it is important to have a record of their length and weight from different habitats for proper management decision.

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References

Abila, R., 2010. Economic Evaluation of the Prawn Fisheries of Malindi-Ungwana Bay Along the Kenya Coast. KMFRI Tech. Rep. 66pp.

Amanat, Z., Qureshi, N.A., 2011. Ovarian Maturation Stages and Size at Sexual Maturity of *Penaeus indicus* (H. Milne Edwards, 1937) in the Lagoon Water of Sonmiani Bay, Balochistan. Pakistan J. Zool. 43, 447–459.

Araneda, M., Pérez, E.P., Gasca-Leyva, E., 2008. White shrimp *Penaeus vannamei* culture in freshwater at three densities: Condition state based on length and weight. Aquaculture 283, 13–18. https://doi.org/10.1016/j.aquaculture.2008.06.030.

Aryani, N., Suharman, I., Hasibuan, S., 2016. Length-weight relationship and condition factor of the critically endangered fish of Geso, *Hemibagrus wyckii* (Bleeker, 1858) bagridae from Kampar Kanan River, Indonesia. J. Entomol. Zool. Stud. 4, 119–122.

. FAO Species Identification Guide For Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Cephalopods, Crustaceans, Holothurians and Sharks vol. 2, 687–1396.

Froese, B.R., 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. J. Appl. Ichthyol. 22, 241–253. https://doi.org/10.1111/j.1439-0426.2006.00805.x.

Gatune, W.C., 2012. Feeding Ecology of Penaeid Shrimp in Kenya Mangrove Ecosystems: Implications for biological shrimp aquaculture. Ghent University, Belgium. PhD Thesis.

Gopalakrishnan, A., Rajkumar, M., Rahman, M.M., Sun, J., Antony, P.J., Venmathi maran, B.A., Trilles, J.P., 2014. Length-weight relationship and condition factor of wild, grow-out and "loose-shell affected" giant tiger shrimp, *Penaeus monodon* (Fabricius, 1798) (Decapoda: Penaeidae). J. Appl. Ichthyol. 30, 251–253. https://doi.org/10.1111/jai.12269.

Guino-o II, R.S., 2012. Length-weight and length-length relationships and fulton condition factor of philippine mullets (Family Mugilidae: Teleostei). Silliman J. 53, 176–189.

Khristenko, D.S., Kotovska, G.O., 2017. Length-weight relationship and condition factors of freshwater bream *Abramis brama* (Linnaeus, 1758) from the Kremenchug Reservoir, Middle Dnieper. Turkish J. Fish. Aquat. Sci. 80, 71–80. https://doi.org/10.4194/1303-2712-v17.

Kimani, E., Manyala, J., Munga, C., Ndoro, C., 2011. Shallow-water prawn trawl survey. SWIOFP Component 2 for SWIOFP 2011C201a. SWIOFP Surv. Tech. Rep. 90pp.

Kimani, E.N., Fulanda, B., Wambiji, N., Munga, C., Okemwa, G., Thoya, P., Omukoto, J., 2012. Spatial Mapping of Trawl Fishery Resources of Malindi-Ungwana Bay, Kenya. SWIOFP Components 2 (Crustaceans). SWIOFP Surv. Tech. Rep. 28pp.

Kumlu, M., Avşar, D., Eroldǒan, T., Başusta, N., 1999. Some biological aspects of penaeid shrimps inhabiting Yumurtalik Bight in Iskenderun Bay (north-eastern Mediterranean). Turkish J. Zool. 23, 53–59.

Lalrinsanga, P.L., Pillai, B.R., Mahapatra, K.D., Sahoo, L., Ponzoni, R.W., Nguyen, N.H., Mohanty, S., Sahu, Swagatika, Sahu, Sovan, Kumar, V., Patra, G., Patnaik, S., 2012. RETRACTED ARTICLE: Length–weight relationship and condition factor of nine possible crosses of three stocks of giant freshwater prawn, *Macrobrachium rosenbergii* from different agro-ecological regions of India. Aquac. Int. 23, 401. https://doi.org/10.1007/s10499-012-9595-4.

Le Cren, E.D., 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). J. Anim. Biol. 20, 201–219.

Li, Y., Zhou, F., Ma, Z., Huang, J., Jiang, S., Yang, Q., Li, T., Qin, J.G., 2016. Length–weight relationship and condition factor of giant tiger shrimp, *Penaeus monodon* (Fabricius, 1798) from four breeding families. Springerplus 5. https://doi.org/10.1186/s40064-016-2979-6.

Maheswarudu, G., Rao, G.S., Ghosh, S., Ranjan, R., Dash, B., Muthukrishnan, P., Veena, S., 2016. Experimental culture of black tiger shrimp *Penaeus monodon* (Fabricius, 1798) in open sea floating cage. Indian J. Fish. 63, 47–54. https://doi.org/10.21077/ijf.2016.63.2.46459-07.

Manasirli, M., 2014. Population dynamics of the *Metapenaeus monoceros* (Fabricius, 1798) in North-eastern Mediterranean Sea, Iran. J. Fish. Sci. 13, 955–966.

Manasirli, M., Kiyaga, V.B., Perker, M., 2014. Reproduction, growth, mortality and exploitation rate of *Penaeus semisulcatus* De Haan, 1844 (Decapoda, Penaeidae) from iskenderun bay (northeastern mediterranean). Crustaceana 87, 385–400. https://doi.org/10.1163/15685403-00003290.

Mkare, T.K., Von Der Heyden, S., Groeneveld, J.C., Matthee, C.A., 2014. Genetic population structure and recruitment patterns of three sympatric shallow-water penaeid prawns in Ungwana Bay, Kenya, with implication for fisheries management. Mar. Freshw. Res. 65, 255–266. https://doi.org/10.1071/MF13047.

Mojekwu, T.O., Anumudu, C.I., 2015. Advanced techniques for morphometric analysis in fish. J. Aquac. Res. Dev. 06, 6–11. https://doi.org/10.4172/2155-9546.1000354.

Munga, C.N., Mwangi, S., Ong'anda, H., Ruwa, R., Manyala, J., Groeneveld, J.C., Kimani, E., Vanreusel, A., 2013. Species composition, distribution patterns and population structure of penaeid shrimps in Malindi-Ungwana Bay, Kenya, based on experimental bottom trawl surveys. Fish. Res. 147, 93–102. https://doi.org/10.1016/j.fishres.2013.04.013.

Munga, C.N., Mwangi, S., Ong, H., Ruwa, R., Manyala, J., Groeneveld, J.C., Kimani, E., Vanreusel, A., 2014. Fish catch composition of artisanal and bottom trawl fisheries in Malindi-Ungwana Bay, Kenya: a cause for conflict? West. Indian Ocean J. Mar. Sci. 13, 177–188.

Mwatha, G.K., 2002. Assessment of the Prawn Fishery, Bycatch, Resource Use Conflicts and Performance of the Turtle Exclusive Device, in: Current Status of Trawl Fishery of Malindi-Ungwana Bay. KMFRI Tech. Rep. 12/2002. pp. 43–64.

Okayi, G., Ataguba, G., Nyishagba, O., 2010. Biology of two freshwater prawns (*Palaeomonetes africanus* and *Demoscaris bislineata*) from MU River, Makurdi – Benue State, Nigeria Okayi. J. Anim. Plant Sci. 5, 544–549.

Olapade, J.O., Tarawallie, S., 2014. The length-weight relationship, condition factor and reproductive biology of *Pseudotolithus senegalensis* (Valenciennes, 1833) (croakers). African J. Food, Agric. Nutr. Dev., vol. 14, pp. 2176–2189.

Pérez-Castañeda, R., Defeo, O., 2002. Morphometric relationships of penaeid shrimps in a coastal lagoon: Spatio-temporal variability and management implications. Estuaries 25, 282–287. https://doi.org/10.1007/BF02691315.

Qureshi, N.A., Amanat, Z., 2014. Reproductive biology and size at sexual maturity of *Penaeus Merguiensis* (De Man, 1887) from the Sonmiani Bay Lagoon, balochistan, Pakistan. J. Anim. Plant Sci. 24, 503–511.

Rasowo, J., Radull, J., 1985. Inoculation of Brime Shrimp, *Artemia sauna*, in Kenya; expected impact on aquaculture development. In: Huisman, E.A. (Ed.), Aquaculture Research in the Africa Region. Pudoc Wageningen 1986, Kisumu, Kenya, p. 276.

Teikwa, E.D., Mgaya, Y.D., 2003. Abundance and reproductive biology of the penaeid prawns of Bagamoyo Coastal Waters, Tanzania. West. Indian Ocean J. Mar. Sci 2, 117–126.

Tonks, M.L., Griffiths, S.P., Heales, D.S., Brewer, D.T., Dell, Q., 2008. Species composition and temporal variation of prawn trawl bycatch in the Joseph Bonaparte Gulf, northwestern Australia. Fish. Res. 89, 276–293. https://doi.org/10.1016/j.fishres.2007.09.007.

Udoinyang, E.P., Amali, O., Iheukwumere, C.C., Ukpatu, J.E., 2016. Length-weight relationship and condition factor of seven shrimp species in the artisanal shrimp fishery of Iko River Estuary, southeastern Nigeria Udoinyang EP, Amali O, Iheukwumere CC, Ukpatu JE. Int. J. Fish. Aquat. Stud. IJFAS 4, 109–114.

Villarta, K.A., Norte-campos, A.G.C., Campos, W.L., 2006. Some aspects of the population biology of the green tiger prawn Penaeus semisulcatus (De Haan, 1844) from Pilar and Capiz Bays, Northern Panay, West Central Philippines. Sci. Diliman 18, 1–10.

Wanjiru, C., 2009. Integrated aquaculture in mangrove areas of Mtwapa creek, Kenya. Inst. Int. Educ. Washingt. D.C. 20005, 25 pp.