

Biometric analysis of the invasive Asian Black Tiger Prawn, *Penaeus monodon* along the Nigerian coastal waters

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ABSTRACT

Length-weight and length-length relationships and condition factor were assessed for *Penaeus monodon* collected from four locations along the Nigerian coasts. While individuals from New Calabar River (NCR) and Ibeno Beach (IBB) exhibited negative allometric growth pattern ($b < 3$), those of Apapa Creek (APC) and Andoni Rivers System (ARS) exhibited positive allometric growth pattern ($b > 3$) in the Length-Weight Relationships. The growth pattern relating total length to other length measurements were negative allometry with b values ranging between 0.22677 and 1.0108. Average condition factor (K) calculated for this species ranged from 0.63 to 0.89, indicating favorable factors in living habitats. These basic information on invasive *P. monodon* will be useful in the aquaculture, monitoring and evaluation of the impact of the animal on the fisheries sector of Nigeria's coastal environment.

Keywords: Length-length, allometric growth, *Penaeus monodon*, biometric

INTRODUCTION

The Penaeid prawns have a cosmopolitan distribution, occurring in tropical and subtropical regions where they constitute important commercial fisheries resources along coastal waters (Holthuis 1980; Garcia and le Reste, 1981; Dall *et al.*, 1990; Nandakumar and Maheswarudu, 2003). At least 4 species belonging to 2 genera have been reported in Nigeria's coastal waters (Ogbonna, 2001). These penaeid shrimps commercially exploited by industrial and artisanal fisheries in the Nigerian coastal waters inhabit the soft mud substrate of the Niger Delta, eastwards to Cross River and Lagos West Grounds (Ogbonna, 2001).

However, the species, *Penaeus monodon* occurs naturally distributed in the Indo-West Pacific Ocean from Eastern Africa to Australia including South Asia, Southeast

Asia and the Philippines (Pérez-Farfante and Kensley 1997; Benzei, 2000). In the past 3 decades, it has been reported as invasive in many coastal waters of the world outside its distribution range due aquaculture and other anthropogenic activities. Rising global connections through trade appears to be the driving force of massive invasions. In South America, *Penaeus monodon* has been recorded in the wild in Brazil (Fausto-Filho 1987; Coelho *et al.*, 2001; Santos and Coelho, 2002), and in the Caribbean waters of Venezuela (Aguado and Sayegh, 2007), Colombia (Gómez- Lemos and Campos, 2008), Cuba (GiménezHurtado *et al.*, 2013) and Mexico (Wakida-Kusunoki, 2013). Knott *et al.*, (2012) also reported the presence of *P. monodon* in natural waters of USA, Puerto Rico and the Dominican Republic while first occurrence of the animal in Egypt from Abou Qir Bay, Alexandria have been

reported (Khafage *et al.*, 2019). In Nigeria, the animal was first recorded in the wild in 1999 (FAO, 2000). Disturbingly, this report indicated that over 2 tons of the animal were caught in trawlers in the Niger Delta. Since then, it has become a permanent feature of artisanal fisheries along the coastal waters of Nigeria.

Penaeus monodon possess biological characteristics which favours its aquaculture around the world. These characteristics include fast growth, tasty flesh, euryhalinity and tolerance to pollution. Therefore, the animal has been introduced either advertently or otherwise to many regions of the world outside the distribution range where conditions are suitable, e.g., Western Africa and areas of the Caribbean including Florida, USA (Salisbury, 2004; Fuller *et al.*, 2014). It has become obvious that the native Southern pink shrimp, *Farfantepenaeus notialis* the major exploited commercial shrimp resource in Nigeria is decreasing in abundance and size (Zabbeyet *et al.*, 2010). Since *P. monodon* is now established in these waters in Nigeria, its aquaculture potentials has to be exploited. The length weight (LWR) and length-length relationships (LLR) are used for assessment of fish and shellfish stocks and provide information on the condition and growth patterns (Ricker, 1968). LWR can be used to compare life history and morphological parameters of different populations of fish or shellfish

(Petrakis and Stergiou, 1995). Furthermore, LLR are very important because several ecological and physiological parameters are more length dependent (Hossainet *et al.*, 2006).

Biometric relationships including morphometric relationships are used by fisheries managers to evaluate the production and biomass of a fish population (Anderson and Gutreuter, 1983). The condition Factor (K) is calculated from the relationship between the weight of a fish and its length, with intention of describing the wellbeing of fish populations (Froeseet *et al.*, 2006). K values are influenced by the state of sexual maturity, degree of food sources availability, age, sex and environmental conditions (Gomiero and Braga, 2005).

The aim of this paper is to assess the LWR, LLR and Condition Factor of *P. monodon* along the coastal waters of Nigeria.

MATERIALS AND METHODS

Study locations and sampling

This study was carried out along the coastal waters of Nigeria. Four locations, namely Lagos lagoon at Apapa creek (APC), Ibeno beach (IBB), Andoni River System at Oyorokoto (ARS) and New Calabar River (NCR) were sampled (Table 1; Fig. 1). *P. monodon* samples were purchased from local fishers at landing sites, transported to the laboratory in wet ice and then preserved with 70% ethanol.

Table 1: Sampling locations, condition factor (K) and range of total length and weight of each population

Sampling Location	Description	Sampling Period	n	Total length range (cm)	Weight Range (g)	K
APC	3°22'E - 6°28'N	Feb. 2019	29	11.5 – 18.90	9.2 – 49.90	0.67
IBB	7°58'E – 4°34'N	Sept. 2019	26	20.7 – 28.70	70.9 – 202.2	0.89
ARS	7°45'E - 4°28' N	July 2019	30	15.5 – 22.70	28.0 – 91.20	0.74
NCR	7°60'E – 5°45'N	Oct. 2019	35	9.70– 18.50	6.4 - 38.20	0.63

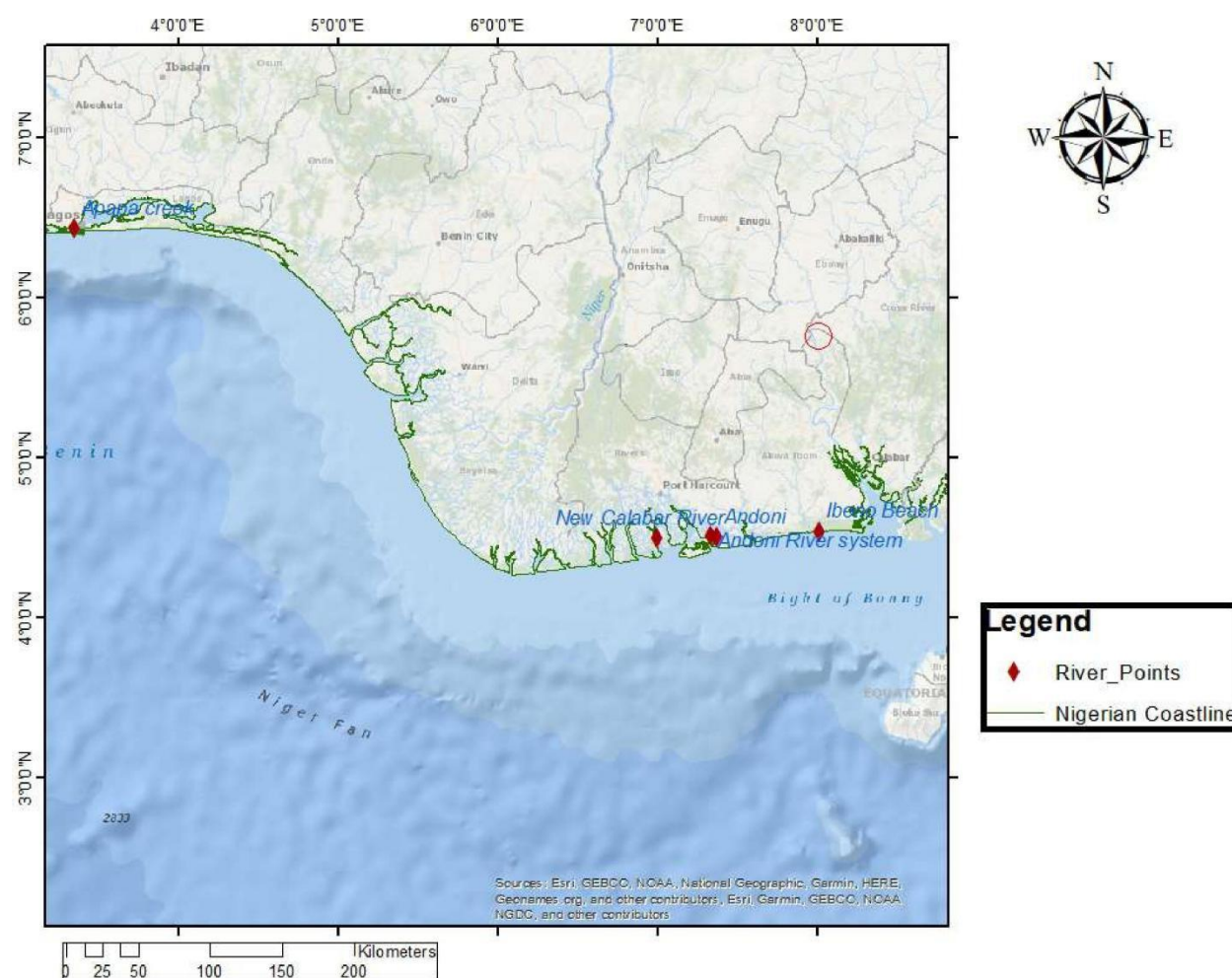


Fig. 1. Coastline of Nigeria showing sampling locations

Laboratory procedure and data collection

The samples were weighed individually (nearest gram) using a sensitive weighing scale. The Total length (TL) was measured from the tip of the rostrum to the tip of the telson on a standard transparent meter rule graduated in centimeter (cm). The Rostral Length (RL) was measured from the tip of the rostrum to the last rostral tooth while the Carapace Length (CL) was measured from the last rostral tooth to the post orbital border of the carapace using a Vernier caliper.

Data analysis

Length-length relationships: The length-length relationship with total length among different body lengths were determined by

the method of least squares to fit a simple linear regression model as $Y = a + bX$, where Y = various body lengths, X = total length, a = proportionality constant and b = regression coefficient (Alamet *et al.*, 2012).

The length-weight relationship: This was calculated using the equation $W = aL^b$ (Pauly, 1983); where W is the total body weight (g), L is the total length (cm), a = coefficient related to the body form and b = exponent indicating isometric growth when equal to 3. Parameters “ a ” and “ b ” were estimated by linear regression.

The Fulton’s condition factor (K) was used to determine the physical and environmental condition of shrimp as enumerated by Le Cren (1951). It is used for comparing the

condition, fatness, or well-being of fish or shrimp. The condition factor (K) for *P. monodon* was calculated using the following equation;

$$K = 100 W/L^3 \text{ (Pauly and Gayanilo, 1997)}$$

Where, K= condition factor: W= weight of fish (g) and L= length of fish (cm).

The significance of condition factor was tested by ANOVA.

Statistical tools such as Analysis of variance (ANOVA), mean and standard error were used to analyze the data. Analysis of variance (ANOVA) as implemented in SAS software was used to determine the significant difference for weight and total length. Excel and Past 3.25 (Hammer *et al.*, 2001) were used to determine the slope (b), intercept (a) as well as the coefficient of determination (R^2) which shows the strength of the relationship between variables while p-value was used to determine the significance of the relationship.

Results

Length-length relationship: The length measurements from the body parts of *P. monodon* used for the calculation of the length-length relationships are presented in Table 1. The range of total length and weight for the four population are shown in Table 1. The mean TL and weight were 12.78 ± 0.32 cm and 14.92 ± 1.78 g, 22.12 ± 0.36 cm and 96.3 ± 5.56 g, 19.3 ± 0.35 cm and 52.77 ± 3.10 g and 14.32 ± 0.38 cm and 20.10 ± 2.23 g for NCR, IBB, ARS and APC, respectively. There was significant difference among populations with respect to length and weight ($P < 0.05$).

The regression coefficients (b) values for TLvs CL, TLvs RL, TLvs AL and TLvs TEL ranged from 0.47666 in NCR - 0.8362 in APC, 0.73234 in IBB - 1.008 in APC, 0.8711 in APC - 1.1203 in IBB and 0.22677 in NCR - 0.8344 in IBB populations, respectively (Table 2). This means that *P. monodon* grows at a lower rate in terms of CL, RL, TEL and AL relative to TL. The regression equations were found highly significant with correlation coefficient, R ranging in values from 0.523 – 0.975.

Table 2: Length-length relationships with total length of different body lengths of four Populations of *P. monodon* collected along the coastal waters of Nigeria

Population	Relationship	Mean \pm SE (cm)	Regression	R
IBB TL=22.115 \pm 0.36 (cm)	CL	3.215 \pm 0.086	Log TL = 0.54167 Log CL + 1.0705	0.886
	RL	4.512 \pm 0.099	Log TL = 0.73234 Log RL + 0.80762	0.859
	TEL	2.711 \pm 0.044	Log TL = 0.8344 Log TEL + 0.98304	0.853
	AL	11.588 \pm 0.155	Log TL = 1.1203 Log AL + 0.15242	0.947
NCR TL=12.786 \pm 0.315 (cm)	CL	1.674 \pm 0.050	Log TL = 0.47666 Log CL + 0.99887	0.592
	RL	3.306 \pm 0.069	Log TL = 0.89153 Log RL + 0.64263	0.829
	TEL	1.497 \pm 0.057	Log TL = 0.22677 Log TEL + 1.0668	0.523
	AL	6.360 \pm 0.140	Log TL = 0.98242 Log AL + 0.31653	0.88
ARS TL=19.30 \pm 0.350 (cm)	CL	2.787 \pm 0.088	Log TL = 0.50568 Log CL + 1.0615	0.858
	RL	4.803 \pm 0.085	Log TL = 0.94593 Log RL + 0.64062	0.912
	TEL	2.397 \pm 0.049	Log TL = 0.7874 Log TEL + 0.98665	0.883
	AL	9.82 \pm 0.172	Log TL = 1.0108 Log AL + 0.28255	0.972
APC TL=14.317 \pm 0.383 (cm)	CL	1.924 \pm 0.052	Log TL = 0.8362 Log CL + 0.91765	0.860
	RL	3.748 \pm 0.095	Log TL = 1.008 Log RL + 0.57701	0.952
	TEL	1.710 \pm 0.051	Log TL = 0.77881 Log TEL + 0.9745	0.922
	AL	7.386 \pm 0.223	Log TL = 0.8711 Log AL + 0.39977	0.975
POOLED TL=16.805 \pm 0.383 (cm)	CL	2.347 \pm 0.067	Log TL = 0.76926 Log CL + 0.9426	0.940
	RL	4.243 \pm 0.087	Log TL = 1.0793 Log RL + 0.54754	0.972
	TEL	2.037 \pm 0.052	Log TL = 0.6822 Log TEL + 1.0147	0.879
	AL	8.606 \pm 0.205	Log TL = 0.94044 Log AL + 0.34677	0.985

Length-weight Relationship

The regression equations for the four populations are as shown in Table 3. The LWR showed significant linear relationship for all populations. The coefficient of correlation, R for the LWR ranged from 0.864 in NCR to 0.980 in APC and it was 0.985 in the combined population, indicating

a good fit (Table 3). An allometric growth pattern with coefficient of regression 2.4955 and 2.4800 was obtained for IBB and NCR populations while APC, ARS and the pooled populations showed positive allometry with registered regression coefficient of 3.4695, 3.0483 and 3.3278, respectively.

Table 3: Length-weight relationships of four Populations of *P. monodon* collected along the coastal waters of Nigeria

Location	LWR	Coefficient of correlation, R
IBB	Log W = 2.4955 Log L - 1.9870	0.960
APC	Log W = 3.4695 Log L - 2.7487	0.980
NCR	Log W = 2.4800 Log L - 1.5971	0.864
ARS	Log W = 3.0483 Log L - 2.2111	0.960
POOLED	Log W = 3.3278 Log L - 2.5476	0.985

The LWR and LLR regression graph for each population and the combine populations are shown in Figs. 2-6. The LWR graphs (Figs.

2a, 3a, 4a, 5a and 6a) showed strong allometric trend.

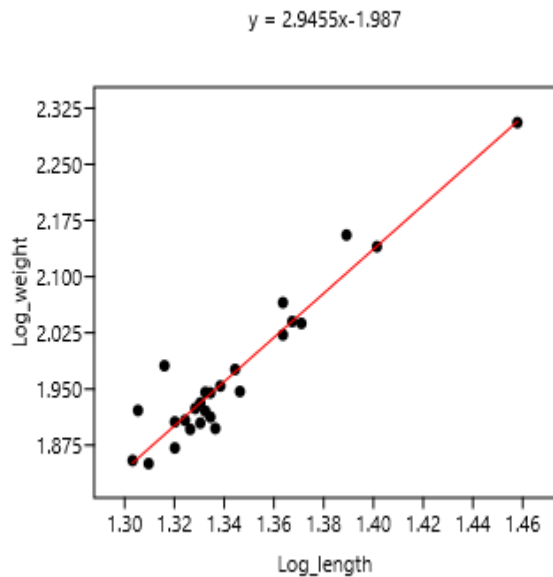


Fig. 2a. Log length/ Log weight relationship of *P. monodon* from Ibeno Beach

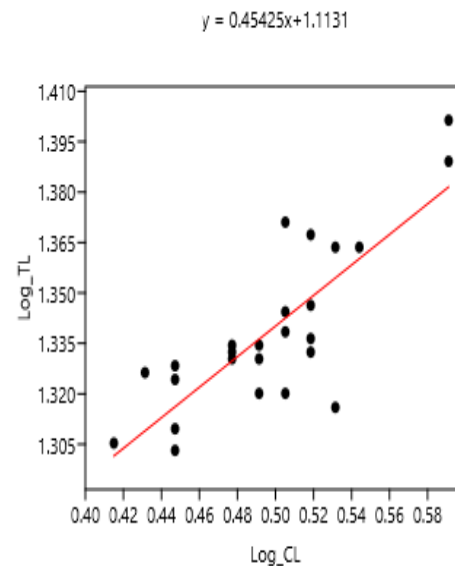


Fig. 2b. Log CL/ Log TL relationship of *P. monodon* from Ibeno Beach

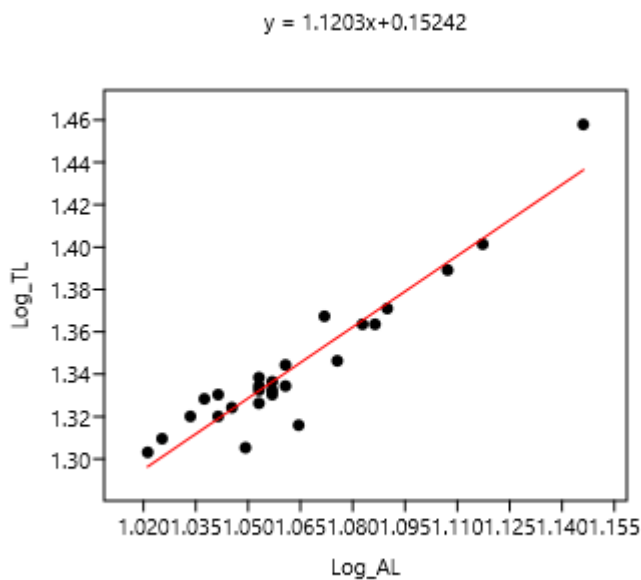


Fig. 2c. Log AL/ Log TL relationship of *P. monodon* from Ibeno Beach

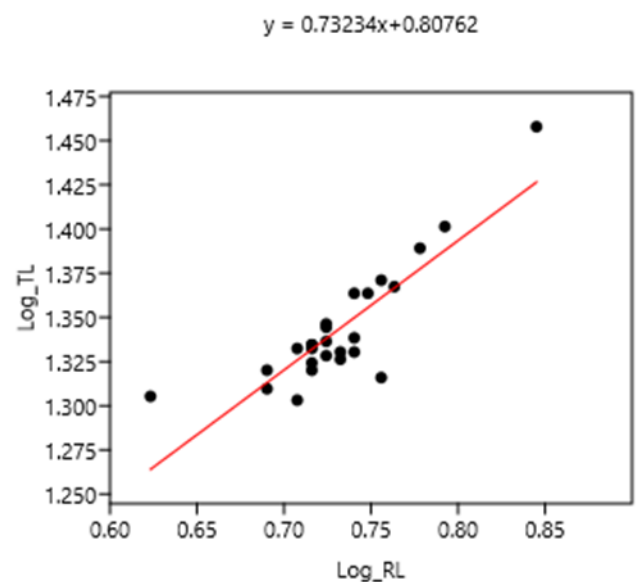


Fig. 2d. Log RL/ Log TL relationship of *P. monodon* from Ibeno Beach

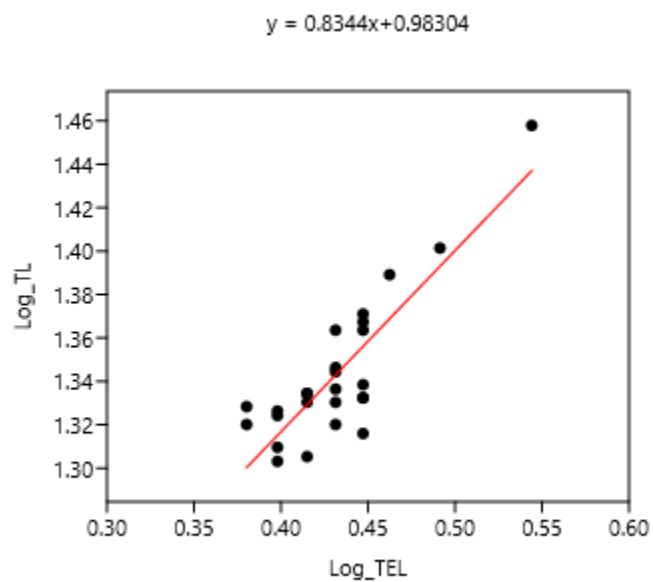


Fig 2e: Log TEL/ Log TL relationship of *P. monodon* from Ibeno Beach

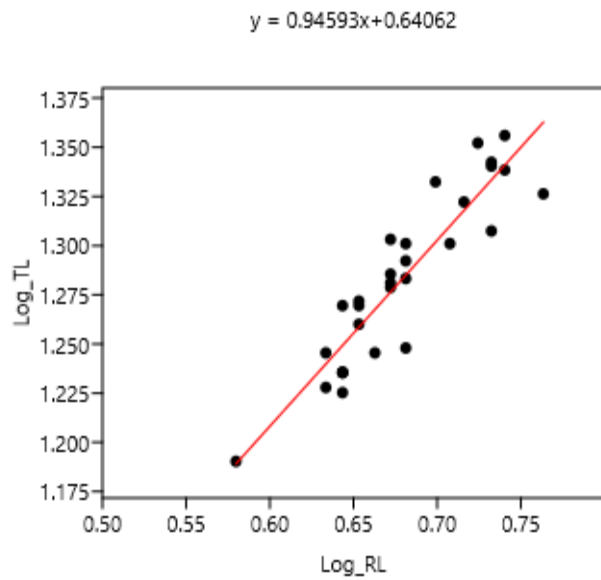


Fig. 3a. Log length/ Log weight relationship of *P. monodon* from Oyorokorto, Andoni River System

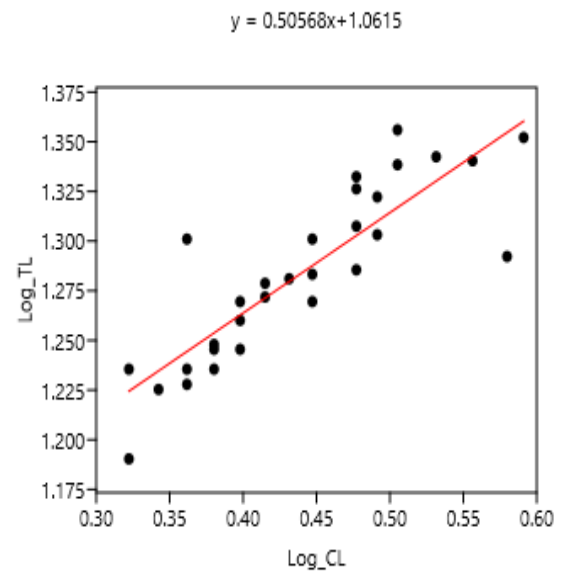


Fig. 3b. Log CL/ Log TL relationship of *P. monodon* from Oyorokorto, Andoni River System

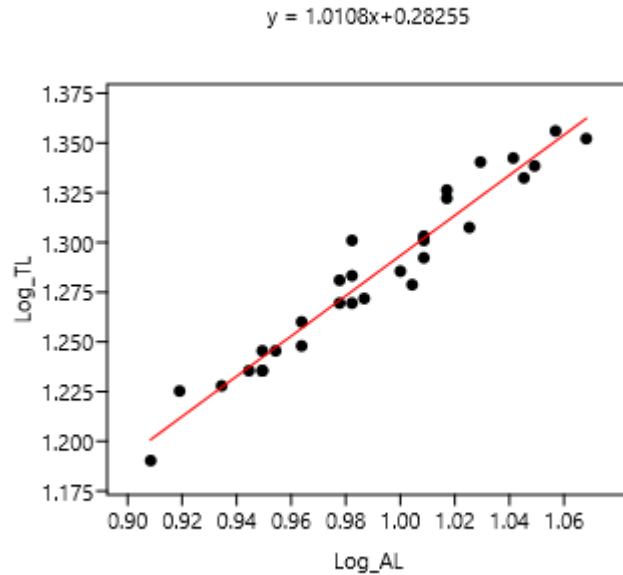


Fig. 3c. Log AL/ Log TL relationship of *P. monodon* from Oyorokorto, Andoni River System

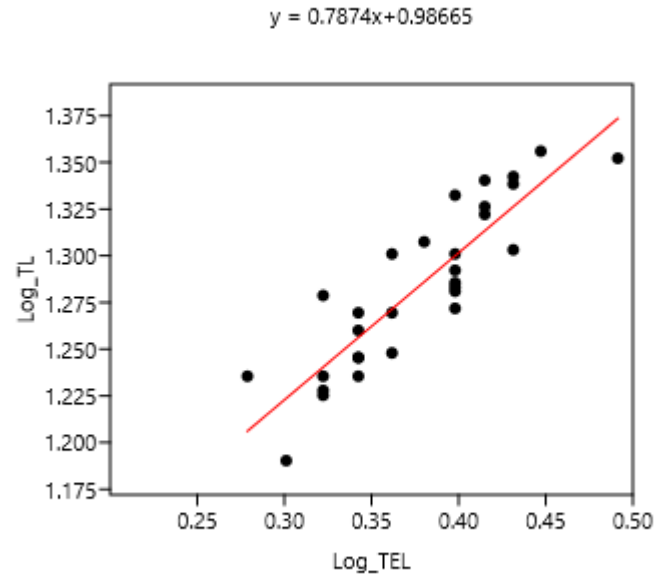


Fig. 3d. Log TEL/ Log TL relationship of *P. monodon* from Oyorokorto, Andoni River System

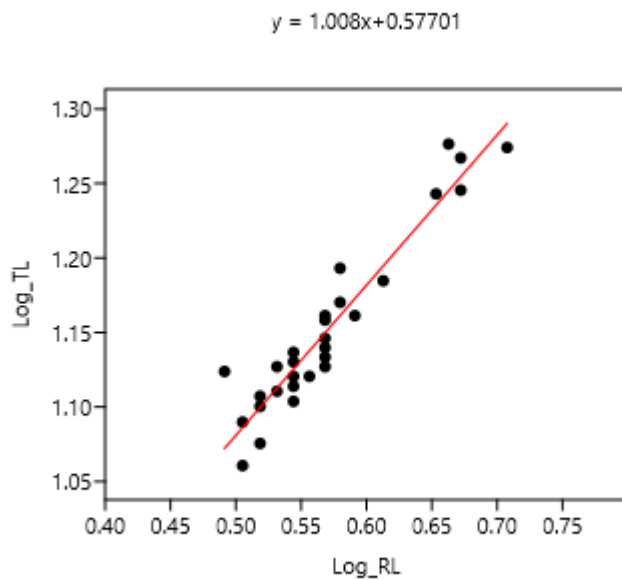


Fig. 4a. Log length/ Log weight relationship of *P. monodon* from Apapa Creek

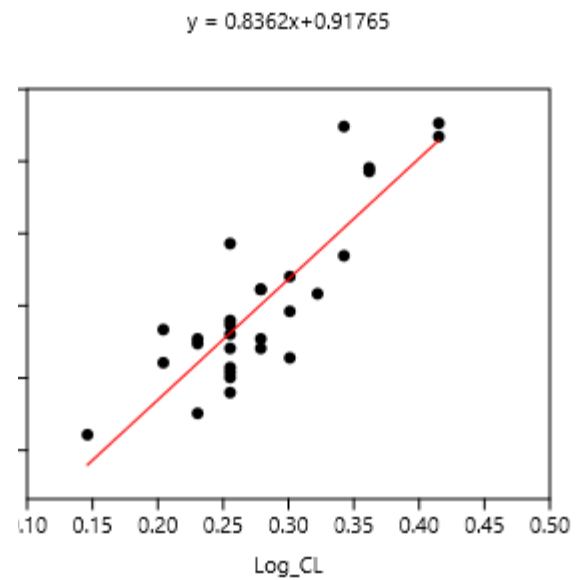


Fig. 4b. Log CL/ Log TL relationship of *P. monodon* from Apapa Creek

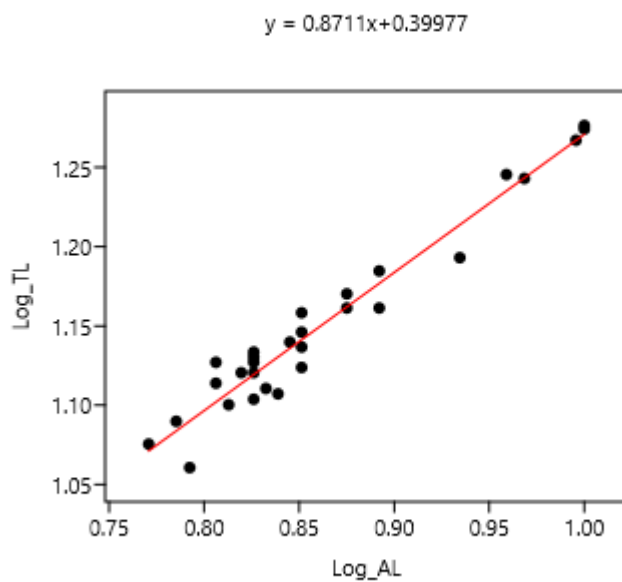


Fig. 4c. Log AL/ Log TL relationship of *P. monodon* from Apapa Creek

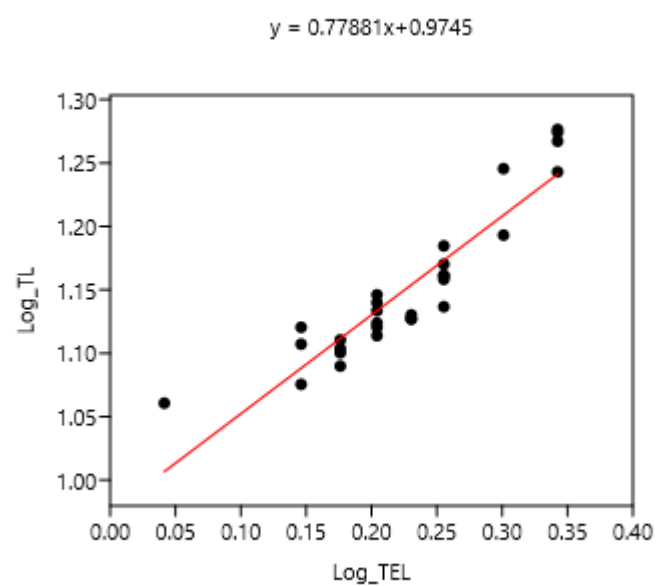


Fig. 4d. Log TEL/ Log TL relationship of *P. monodon* from Apapa Creek

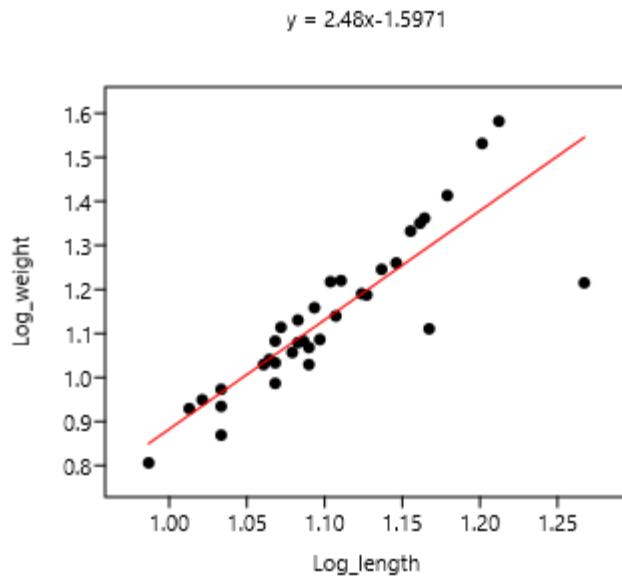


Fig. 5a. Log length/ Log weight relationship of *Penaeus monodon* from New Calabar River

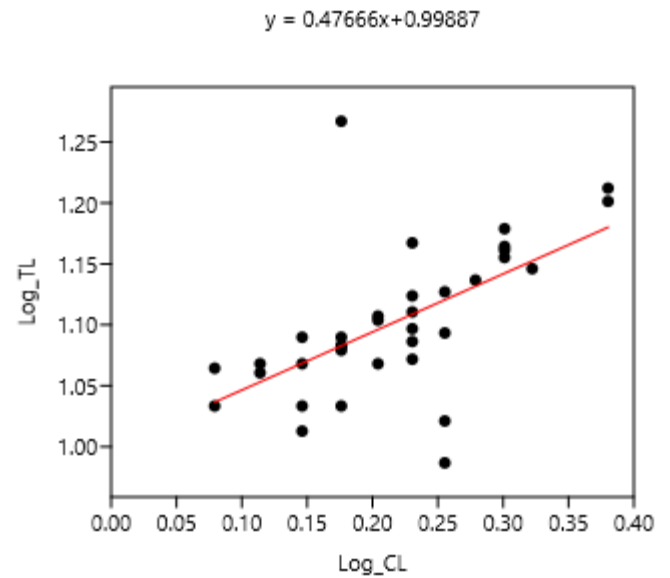


Fig 5b: Log CL/ Log TL relationship of *Penaeus monodon* from New Calabar River

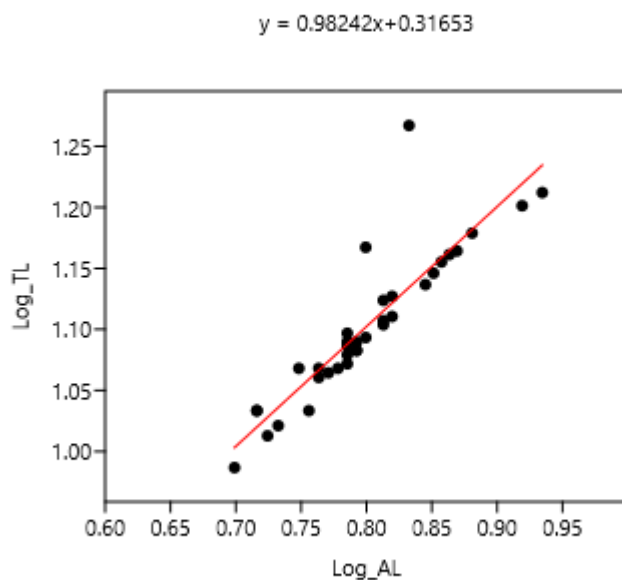


Fig. 5c. Log AL/ Log TL relationship of *Penaeus monodon* from New Calabar River

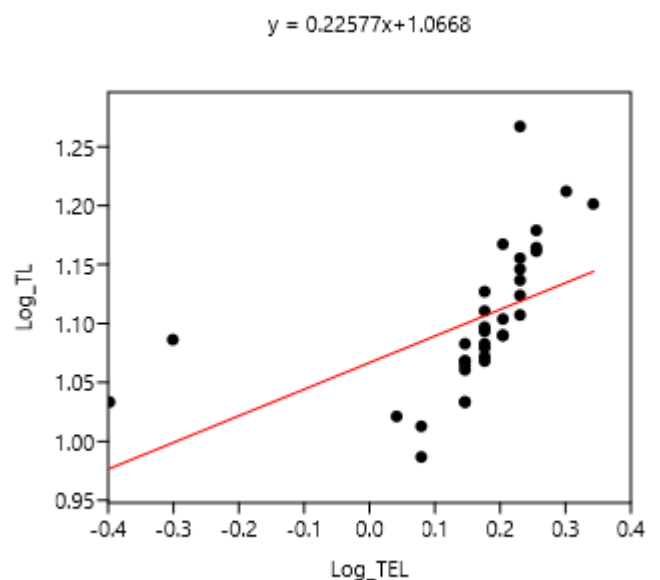


Fig. 5d. Log TEL/ Log TL relationship of *Penaeus monodon* from New Calabar River

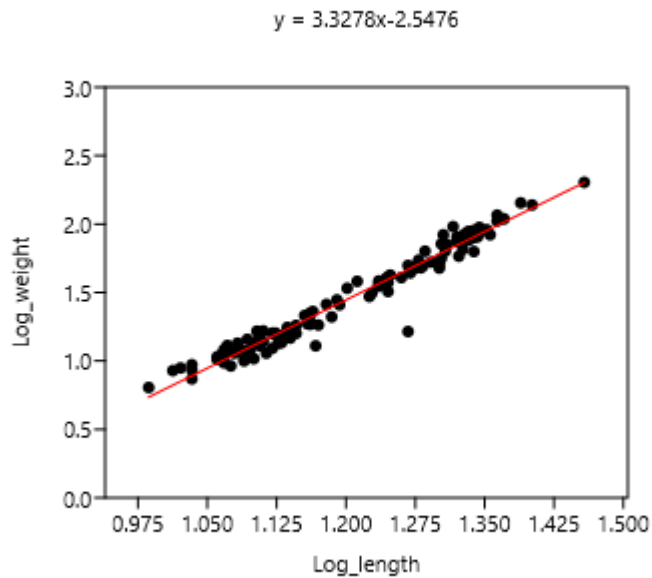


Fig. 6a. Pooled Log length/ Log weight relationship of *Penaeus monodon* from Nigerian coastal waters

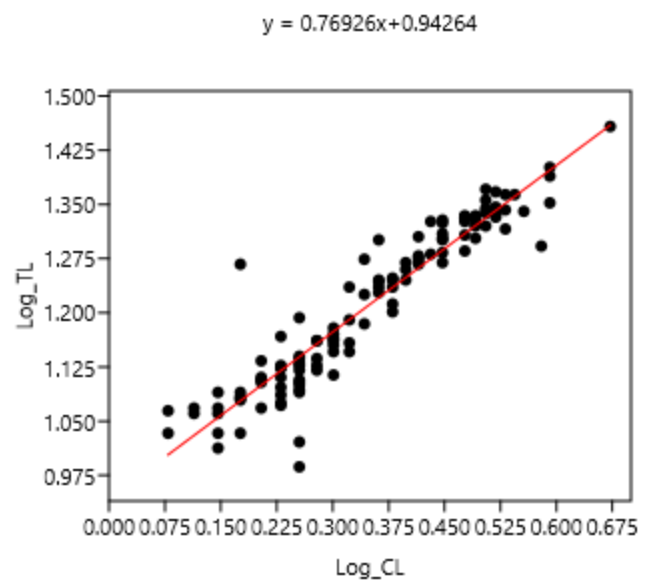


Fig. 6b. Pooled Log CL/ Log TL relationship of *Penaeus monodon* from Nigerian coastal waters

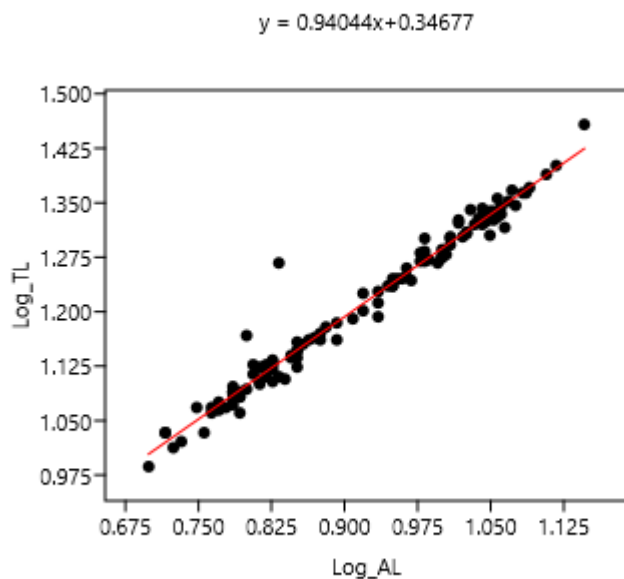


Fig. 6c. Pooled Log AL/ Log TL relationship of *Penaeus monodon* from Nigerian coastal waters

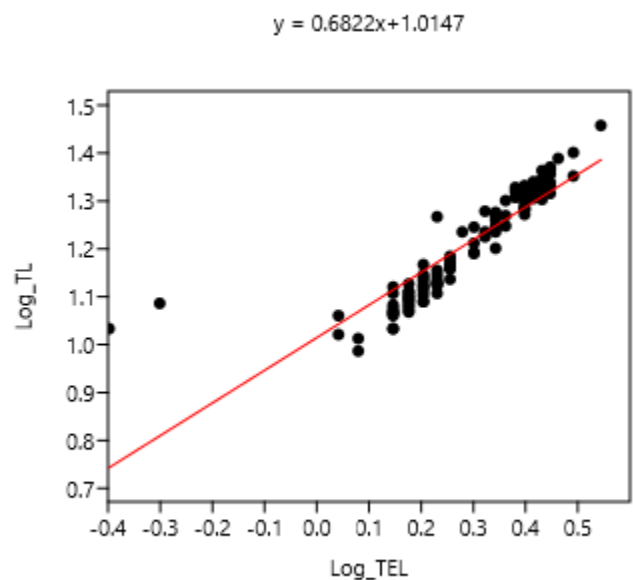


Fig. 6d. Pooled Log TEL/ Log TL relationship of *Penaeus monodon* from Nigerian coastal waters

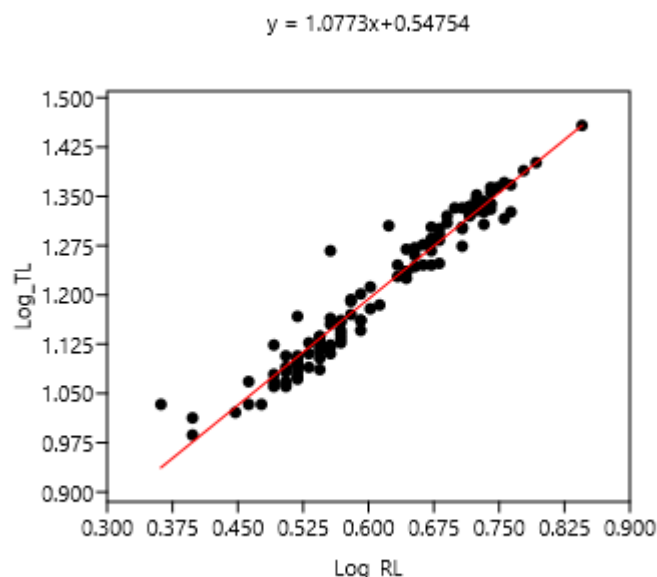


Fig. 6e. Pooled Log RL/ Log TL relationship of *Penaeus monodon* from Nigerian coastal waters

The condition factor of *P. monodon* from IBB, APC, ARS and NCR ranged from 0.63-0.89 (Table 1). The IBB population had the highest condition factor of 0.89, an indication that they were in better condition when compared with the three other locations. NCR had the lowest condition factor, indicating that they are in relatively poorer conditions.

DISCUSSION

The regression equation of LLRs for *P. monodon* along Nigerian coasts suggests that the species shows non-isometric growth pattern. The R values were significantly greater than 0.500, indicating moderate to very strong correlation between total length of the prawn and body parts, that is, the rostrum length, carapace length, abdominal length and telson length. In the present study, the coefficient b of the TL-CL, TL-RL, TL-TEL and TL-AL relationships demonstrated a negative allometric growth with a higher rate of growth in TL compared to other body

parts. The values of the equations clearly revealed that the lengths of the body parts are proportional to the total length which agreed with Tandon et al (1993). The interrelationships among aforementioned length parameters were also found highly significant ($p < 0.05$) with all 'R' values being ≥ 0.523 from the multiple correlation analysis.

The parameters (a and b) in LWR are useful in fisheries science to estimate weight of individual fish from its length, calculate condition indices, compare life history and morphology of populations of different regions. Significant scores of positive correlation coefficient were recorded for length-weight relationships of all the populations ($p < 0.05$) in this study, meaning that weight can be predicted from specific length and that a proportionate increase in weight accompanies increase in total length in *P. monodon*. Based on the results of the

current study, b value is significantly less than 3.0, indicating negative allometric growth pattern for *P. monodon* in IBB and NCR populations along the Nigerian coast. Negative allometry growth connotes that the rates of weight gain are relatively higher than the length incremental rate of invasive tiger shrimp in Nigerian waters. These are in concordance with Lawal-Are and Apapa (2014) who obtained b values of 2.89 for females and 2.95 for males of the animal off the Niger Delta coastal area. Interestingly, the other 2 populations, ARS and APC exhibited positive allometric growth with b values greater than 3.0. This pattern of isometric growth displayed by *P. monodon* along the coasts of Nigeria was an indication that this species have heterogeneous groups in their populations with body weights varying differently with the total lengths. The current study agrees with Kaka *et al.* (2019) who also found regression coefficient ranging from 2.48 to 3.95 in Malindi–Ungwana Bay in Kenya. Different populations of the pink shrimp, *Farfantepenaeus paulensis* from Rio de Janeiro coast (SE Brazil), exhibited similar growth patterns as those from Sepetiba Bay presented a negative allometry ($b < 3$, W-TL relationship) while those from Guanabara Bay presented a positive allometry, $b > 3$ (Carvalho *et al.*, 2019). Carvalho *et al.* (2019) attributed such variation in to the influence of environmental conditions on certain body structures such as size and shape of carapace, rostrum and abdomen.

The Condition Factors (K) were less than 1.0 for all populations in Nigerian coastal waters. IBB was weighed and measured before preservation, which may account for the better condition factor. APC was preserved for a longer period. Preservation method and duration can significantly affect the value of K (Nwafili and Onwuka, 2013). Results of previous studies did not contradict the current results. The range of 0.63 – 0.89 obtained in

this study fall within the report by investigators including Komi and Francis (2017) and Lawal-Are and Apapa, (2014) the species in the Niger Delta..

CONCLUSION

The LWRs showed both positive and negative allometric growth which might be attributed to environmental conditions or linked to adaptation of morphological trait to dynamic environment of the the Nigerian coastline. This is because the coastline may differ in the sampling locations in terms of physicochemical parameters and pollution levels. The relationship between length and weight were strong, the coefficient of correlation being close to 1.0 in all cases. The condition factors show that the entire coastline is supporting the healthy growth of the animal. The information from this research constitute a valuable guideline for establishing future biometric studies for fish collected through the Lebanese coastal line. In general there is the need for a sex based assessment of the LWR, LLR and K along the coastline with larger sample size to fine tune and support the current estimates.

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