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VARIATIONS IN MORPHOMETRIC TRAITS OF THE INVASIVE ASIAN BLACK TIGER SHRIMP, PENAEUS MONODON (FABRICIUS, 1798) IN THE COASTAL WATERS OF NIGERIA

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ABSTRACT

The present study aimed to assess the morphological variations of the invasive Asian tiger shrimp, Penaeus monodon along the coastal waters of Nigeria. A total of 120 individuals were obtained from four locations (New Calabar River, Andoni River System, Apapa Creek, and Ibeno Beach), from February to October 2019. A total of 14 morphometric traits were measured on each individual. The morphometric traits were subjected to Principal Component Analysis using morphometric parameters to identify intra-specific morphological variation. P. monodon exhibited high levels of morphometric variation and the PCA grouped the populations into at least two clusters. It is concluded that environmental differences along the coastal waters and the possibility of multiple pathways of invasion may account for the variations. There is a need to complement the result with DNA analysis.

Keywords: *Penaeus monodon*, Asian Tiger prawn, morphometric variations, Nigeria,

INTRODUCTION

Nigeria has a coastline totaling 853km and an EEZ covering 210,900km2 (World Resources, 1990; Isidor, 2004) over which she has exclusive rights to the fish and other natural resources. This coastline lies between Latitude 4^{o}10’ to 6^{o}20’ and Longitude 2^{o}45’ to 8^{o}35’E. The coastal waters of Nigeria especially those of the Niger Delta, provide a rich environment characterized by a heavy load of organic debris for various shrimps to thrive (Amire, 2003). Early inventory of shrimps belonging to the family Penaeidae in Nigerian coastal waters includes at least four species: the southern pink shrimp *Farfantepenaeus notialis*, pink *Farfantepeenaeus duorarum*, guinea shrimp *Parapenaeopsis Atlantica* and giant tiger shrimp *Penaeus kerathurus* (Osisanya, 1970; Bayagbona *et al*., 1971; Marioghae, 1980). These rich shrimp resources have attracted international shrimpers into the area. However, in the past three decades, the Asian Tiger Prawn, *Penaeus monodon* not known to the Nigerian waters was reported by trawlers (FAO, 2000) and it has become a permanent feature of artisanal and industrial fisheries. Nowadays, the species is harvested throughout the Nigerian coast in all sites traditionally fished for the native pink shrimp, *Penaeus notialis*.

The Asia Tiger prawn is native to the Indo-west pacific and areas of distribution include South Africa, Tanzania, Kenya, Somalia, Madagascar, Saudi Arabia, Oman, Pakistan, India, Bangladesh, Sri Lanka, Indonesia, Thailand, Malaysia, Singapore, Philippines, Hongkong, Taiwan, Korea, Japan, Australia, and Papua New Guinea, where they inhabit shore areas and mangrove waters (Motoh, 1985). This prawn is cultured throughout its distribution range due to its fast growth rate, attainment of large size, ability to tolerate a wide range of environmental conditions, and high market value (Foster and Beard, 1974; Shailende *et al*., 2012). During the past several decades, the species has invaded different parts of the world including the USA, West Africa, and South America, etc. Its occurrence was first reported in trawler catches in the Niger delta to the tune of 2 tons in 1999 (FAO, 2000) at the time the popular native southern pink shrimp fishery was decreasing and becoming scarce (Zabbey *et al*., 2010). The rapid rate of globalization, expanding trade, transport, aquaculture, and tourism are exacerbating the frequency of this type of invasions (CAB International, 2004; Hulme, 2009; Katsanevakis et al., 2013).

There is still very little known regarding the presence and impact of the non-native species on Nigeria’s coastal environments. The inventories of alien species are not complete without their characterization in the new ‘home’. According to Grosholz, 2002 and Carlton (1996), one of the greatest obstacles for understanding the role of alien species within the tropics is that inventories of native species are incomplete, and non-native species are occasionally cryptogenic. Now that the species has been established (Ayinla *et al*., 2009; Anyanwu *et al*., 2011), the need to examine its morphometric variations in the coastal waters of Nigeria is important. The aim of this research, therefore, is to assess morphometric variations of *P. monodon* captured from different locations along the coastal waters of Nigeria. Morphometric variation among traits usually provides the framework for the establishment of base populations and genetic improvement of the trait of interest.

MATERIALS AND METHODS

Collection of samples

A total of 120 specimens of *P. monodon* were collected from four locations along the

Nigerian coastal waters, from February to October 2019 (Table 1; Fig. 1). The samples were obtained from local fisherfolks and Atlantic Shrimpers. Immediately after collection, samples were transported in ice-cooled boxes to the laboratory at the Department of Fisheries, University of Port Harcourt for identification and morphometric measurements.

Table 1: Sampling locations of *P. monodon* along the coastal waters of Nigeria

Sampling locations	Description	Sampling Period	Source	N	Total Length Range (cm)	Weight Range (g)
APC	3°22'E - 6°28'N	Feb. 2019	Atlantic Shrimpers	29	11.5 – 18.90	9.20 – 49.90
IBB	7°58'E – 4°34'N	Sept. 2019	Local fishers	26	20.7 – 28.70	70.90 – 202.2
ARS	7°45'E - 4°28' N	July 2019	Local fishers	30	15.5 – 22.70	28.00 – 91.20
NCR	7°60'E – 5°45'N	Oct. 2019	Local fishers	35	9.70– 18.50	6.40 - 38.20

Key: IBB = Ibeno Beach; NCR = New Calabar River; ARS = Andoni River System; APC = Lagos Lagoon; N = Sample size.

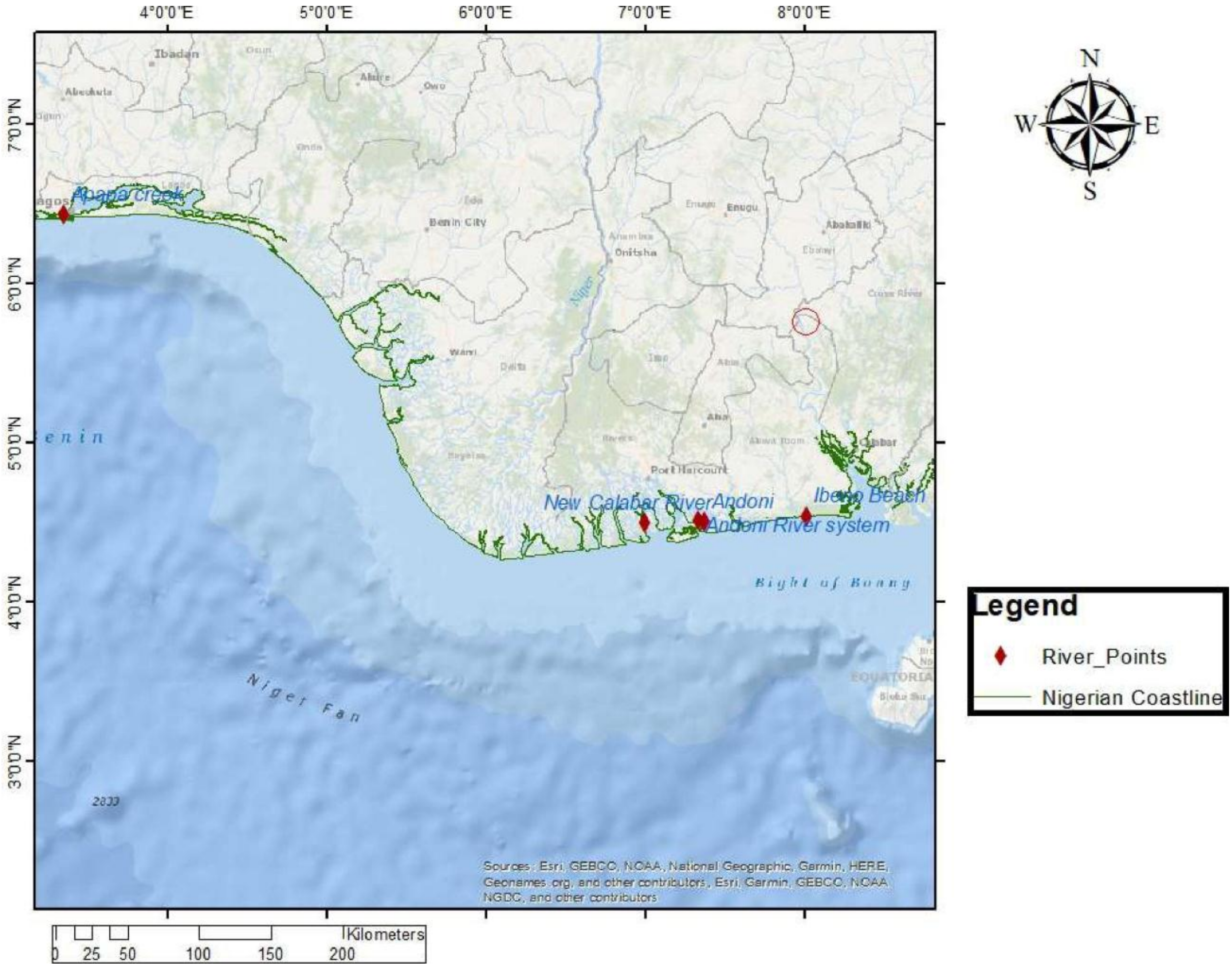

Fig. 1. Sampling locations along the Nigerian coastal waters

Collection of Morphometric data

A total of 13 morphometric characters were measured (cm) using a white measuring board (Table. 2). They include Total length (TL), Rostral length (RL), Carapace Length (CL), Carapace Width (CW), Carapace Height (CH), Abdominal length (AL), First Segment Length (FSL), Second Segment Length (2SL), Third Segment Length (3SL), Fourth Segment Length (4SL), Fifth Segment Length (5SL), Sixth Segment Length (6SL) and Telson Length (TEL), Also, the weight of each individual was measured using an electronic weighing balance to the nearest 0.01g.

Table 2: Description of morphometric traits in *P. monodon* examined

S/N	Trait	Description	Reference
1	Total length (TL)	Distance from the tip of the rostrum to the tip of the telson	Carvalho et al., 2019
2	Rostral Length (RL)	Length from the tip of the rostrum to the postorbital margin of the carapace	Ming et al. 2016
3	Carapace Length (CL)	Distance from the last rostral tooth to the postorbital border of the carapace	Ming et al. 2016
4	Carapace Height (CH)	The vertical distance from the top of the carapace to the bottom	Dall, 1957
5	Carapace Width (CW)	The widest distance at the last rostral teeth	Lester, 1983
6	Abdominal length (AL)	distance from the postorbital border of the carapace to the tip of the sixth abdominal segment	Lester, 1983
7	First Segment Length (FSL)	Distance between the posterior carapace margin and posterior margin of the first abdominal segment along the mid-dorsal line with the abdomen fully extended.	Natarajan et al., 2011
8	Second Segment Length (2SL)	Distance between the posterior margin of the first and posterior margin of the second abdominal segment	Natarajan et al., 2011
9	Third Segment Length (3SL)	Distance between the posterior margin of the second to the posterior margin of the third segment	Natarajan et al., 2011
10	Fourth Segment Length (4SL)	Distance between the posterior margin of the third segment to the posterior margin of the fourth segment	Natarajan et al., 2011
11	Fifth Segment Length (5SL)	Distance between the posterior margin of the fourth to the posterior margin of the fifth segment	Natarajan et al., 2011
12	Sixth Segment Length (6SL)	Distance from the posterior margin on the fifth segment to the posterior margin of the sixth segment	Natarajan et al., 2011
13	Telson Length (TEL)	Distance from the tip to the base of the telson	Dall, 1957
14	Total Weight (WT)	Total weight of the whole body	Dall, 1957

Data Analyses

To complement the body parts measurements, the following morphometric ratios were calculated: RL/TL, CL/TL, AL/TL, TEL/TL, CL/RL, RL/AL, and CL/AL.

Morphometric variability was expressed as the coefficient of variation (CV) as follows:

CV = $\frac{SD}{mean}\ x\ 100$ (Power, 2007)

where SD is standard deviation.

For each specimen, Pearson's correlation coefficient (R) was calculated between every two morphometric features to indicate the relationship between the two traits.

The Statistical programmes SPSS version 16, SAS, PAST, and MICROSOFT EXCEL, 2013 were used for data analysis. ANOVA and Principal Component Analysis (PCA) were performed to assess the significance of variation among the morphometric characters per locality of the sampled population and when combined. The morphometric ratio or index analysis was performed to obtain the coefficient of interpersonal relationships within a population by calculating the distance coefficient or Euclidean distance and the coefficient of similarity. The coefficient values were mapped into the dendogram to visualize the similarities and differences among individuals in the populations of *P. monodon*

RESULTS

Morphometric variables were measured to detect variation among the random samples of *P. monodon* from different locations along the Nigerian coastal waters. The range of the total length and weight of the species is shown in Table1. The TL ranged from 9.70cm to 28.70cm while the wet weight varied from 6.40g to 202.20g. The descriptive statistics of seven morphometric ratios show that CL/RL, CL/TL, TEL/TL, and CL/AL had the highest coefficient of variation of 12.9805, 10.9333, 10.6629, and 10.5036 %, respectively. The least CV was found between AL/TL (4.2795%). The CV of the morphometric ratios and mean ratios of the variables are shown in Table 3,

Table 3: Descriptive Statistics of Seven Morphometric Ratios of *Penaeus monodon* along Nigerian Coastal waters

	RL/TL	CL/TL	AL/TL	TEL/TL	CL/RL	RL/AL	CL/AL
Min	0.1946	0.0811	0.3676	0.0370	0.3750	0.3750	0.2033
Max	0.2869	0.1939	0.5604	0.1384	0.7917	0.5769	0.3725
Mean	0.2545	0.1383	0.5110	0.1206	0.5457	0.4987	0.2707
Std. error	0.0014	0.0014	0.0020	0.0012	0.0065	0.0032	0.0026
Variance	0.0002	0.0002	0.0005	0.0002	0.0050	0.0012	0.0008
Stand. Dev	0.0154	0.0151	0.0219	0.0129	0.0708	0.0350	0.0284
Coeff. Var	6.0471	10.9333	4.2795	10.6629	12.9805	7.0090	10.5036

The CV revealed a high magnitude of variation in body weight ranging from 29.45 to 59.79 %, exceeding 80% in the pooled population (Fig. 2). However, the length associated measurements exhibited low to high levels of variation, ranging from 6.83 to 50.01%. These remained relatively high in the combined population with a range of 22.49 – 34.80%.

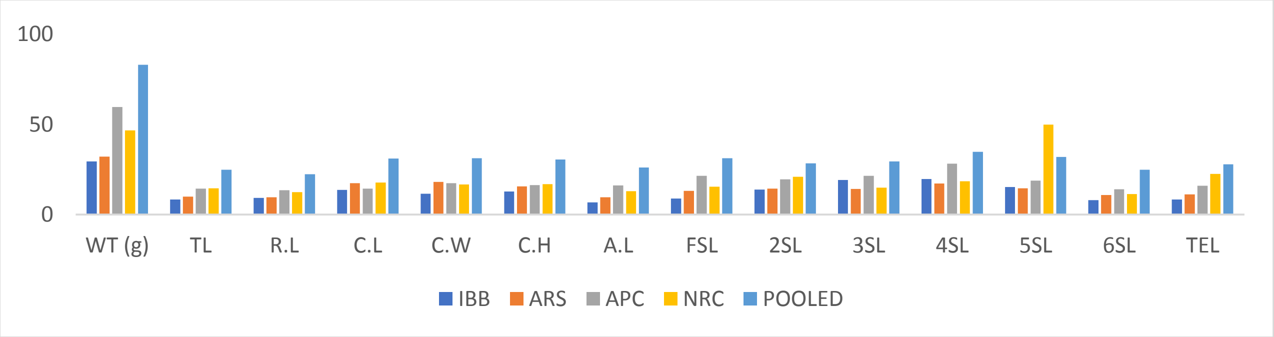

Fig. 2: Coefficient of variation for 14 morphometric traits in *P. monodon* along the coastal waters of Nigeria.

The correlation matrix of five morphometric traits showed a significant correlation between variables for each population ($P < 0.05$). However, the correlation between TEL and the other traits was not strong, ranging from 0.178 to 0.243 in all the populations put together (Table 4). It, however, became stronger in each population: 0.3459-0.5229 in NCR, 0.82208-0.92225 in APC, 0.76819-0.86311 in IBB and 0.5464-0.72387 in ARS (Table 5-8)

Table 4: Correlation coefficient of five morphometric traits for the combined population (N=120), of *P. monodon*

	T.L	R.L	C.L	AL	TEL
TL					
RL	0.97185				
CL	0.93988	0.92672			
AL	0.9853	0.96956	0.94532		
TEL	0.21651	0.20229	0.17781	0.24317	

Table 5: Correlation coefficient of Five Morphometric variables of *P. monodon* (N = 35) from the New Calabar River

	T.L	R.L	C.L	AL	TEL
T.L					
R.L	0.82935				
C.L	0.59184	0.58391			
AL	0.88795	0.884	0.73456		
TEL	0.5229	0.37756	0.3459	0.58704	

Table 6: Correlation coefficients between Five morphometric traits of *P. monodon* (N = 29) from Lagos Lagoon

	T.L	R.L	C.L	AL	TEL
T.L					
R.L	0.95166				
C.L	0.85974	0.81195			
AL	0.97525	0.91135	0.7915		
TEL	0.92225	0.83583	0.82208	0.87172	

Table 7: Correlation coefficients between five morphometric traits of *P. monodon* (N = 26) from Ibeno Beach, Akwa Ibom State

	TL	RL	CL	AL	TEL
TL					
RL	0.85943				
CL	0.88601	0.83267			
AL	0.94748	0.79657	0.87485		
TEL	0.85352	0.76819	0.86311	0.85309	

Table 8: Correlation coefficients between five morphometric traits of *P. monodon* (N = 30) from Andoni River System, Rivers State

	T.L	R.L	C.L	AL	TEL
T.L					
R.L	0.91227				
C.L	0.858	0.75031			
AL	0.97203	0.8579	0.85306		
TEL	0.69965	0.63931	0.5464	0.72387	

In general, there was a high correlation between the morphometric traits at population levels ranging from 0.8895 in NCR to 0.97525 in APC for TL and AL. For the combined population, the correlation between TL and AL was 0.9853

A dendrogram based on morphometric distance data shows that distances of squared Euclidean similarity were nearest between ARS and IBB. ARS and IBB formed one cluster while NRC and APC formed different clusters. The population groups are Ibeno and Andoni, and APC, and NCR (Fig. 2). Interestingly, Apapa, that is, APC is closer to IBB and ARS.

Similarly, Principal component analysis revealed three components and indicated that the accumulated variance for the three principal components (PC) represented 99.665% of the total (Table 9; Fig. 2 and 3). According to Hammer *et al.*, (2001) when most of the variance is accounted for by the first one or two components, the PCA analysis successful and useless when the variance is spread more or less evenly among the components. Table 9 shows that the first 2 Components accounted for roughly 98% of the variance. The 'Screen plot' (not shown) also indicated two significant components.

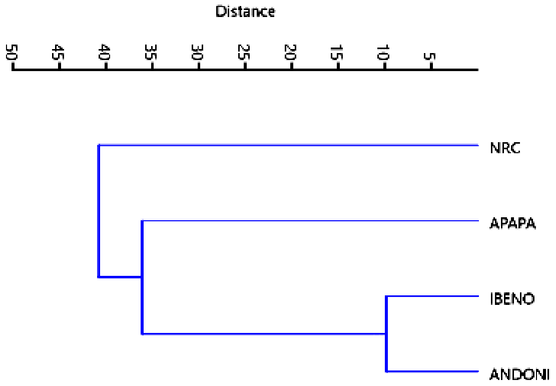

Fig. 2: Dendrogram of hierarchical cluster analysis between four populations of *P. monodon* along Nigerian Coast obtained from the coefficient of similarity/ Euclidean distance of five morphometric characters.

Table 9: Eigenvalues and percentage of variance for the three components of *P. monodon* for morphometric measurements

PC	Eigenvalue	% variance
1	0.058342	60.008
2	0.037088	38.147
3	0.001269	1.3048
4	0.000349	0.35859
5	0.000177	0.18179

The plot against the first and the second principal components showed an overlap of populations, which indicates that there is a great resemblance among three populations, namely Andoni (ARS), Ibemo (IBB), and Apapa (APC).

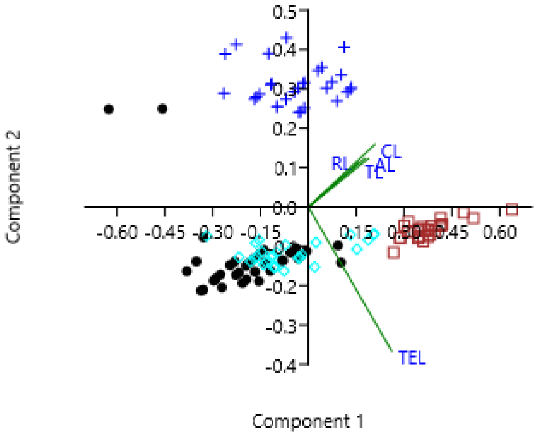

Fig. 3: Principal component analysis showing New Calabar River

NCR = Blue; Andoni River System, ARS =Black; Lagos Lagoon, APC = Brown and Ibeno Beach, IBB= Aquamarine

Analysis of variance (ANOVA) showed significant differences for means of some metric traits (Table 8).

Table 10: Analysis of variance (ANOVA) of 13 morphometric traits in *P. monodon* from Nigerian coastline

	IBB	ARS	APC	NCR	Sig
TL	22.12 ± 0.36^{d}	19.3 ± 0.35^{c}	14.32 ± 0.38^{b}	12.79 ± 0.32^{a}	0.000
RL	5.41 ± 0.10^{d}	4.80 ± 0.08^{c}	3.75 ± 0.09^{b}	3.31 ± 0.69^{a}	0.000
CL	3.22 ± 0.9^{d}	2.79 ± 0.09^{c}	1.92 ± 0.05^{b}	1.67 ± 0.05^{a}	0.000
CW	2.57 ± 0.06^{c}	1.55 ± 0.05^{b}	$1.48 \pm 0.05^{a,b}$	1.37 ± 0.4^{a}	0.000
CH	3.07 ± 0.08^{c}	2.52 ± 0.72^{b}	1.67 ± 0.05^{a}	1.69 ± 0.05^{a}	0.000
AL	11.59 ± 0.16^{d}	9.82 ± 0.17^{c}	7.39 ± 0.22^{b}	6.36 ± 0.14^{a}	0.000
FSL	2.52 ± 0.04^{d}	2.10 ± 0.05^{c}	1.47 ± 0.06^{b}	1.26 ± 0.03^{a}	0.000
2SL	1.94 ± 0.05^{c}	1.81 ± 0.05^{c}	1.27 ± 0.046^{b}	1.12 ± 0.04^{a}	0.000
3SL	1.77 ± 0.07^{d}	1.61 ± 0.04^{c}	1.14 ± 0.05^{b}	1.00 ± 0.03^{a}	0.000
4SL	1.68 ± 0.06^{c}	1.67 ± 0.05^{c}	1.12 ± 0.06^{b}	0.87 ± 0.07^{a}	0.000
5SL	1.31 ± 0.04^{b}	1.27 ± 0.03^{b}	0.92 ± 0.03^{a}	0.87 ± 0.07^{a}	0.000
6SL	2.67 ± 0.04^{d}	2.46 ± 0.05^{c}	1.74 ± 0.04^{b}	1.57 ± 0.03^{a}	0.000
TEL	2.71 ± 0.05^{d}	2.40 ± 0.05^{c}	1.71 ± 0.05^{b}	1.50 ± 0.06^{a}	0.000

† *Rows with the same superscript are not significantly different*

The ANOVA detected more similarity between IBB and ARS in measurement to segments of the abdominal region. The AL, RL, CL, TEL, CH, and TL were significantly different in each population (Table 8).

DISCUSSION

Researchers have found that morphometric characters in fish and shellfish tend to exhibit a high level of phenotypic plasticity in response to the dynamics of environmental conditions. According to Allendorf and Phelps (1988), Swain *et al.* (1991), Wimberger (1992), and Swain and Foote (1999), the condition suggests that phenotypic plasticity may be adaptive, allowing populations to change appearance and morphology to match ecological reality. Steams (1983) observes that the phenomenon of phenotypic plasticity allows fish and shellfish to respond adaptively to environmental change by physiological and behavioural modifications which lead to changes in their morphology, reproduction, or survival to accommodate the effects of environmental change. In the present study, results obtained from ANOVA analysis showed that eight out of 13 morphometric data were significantly different in *P. monodon* populations inhabiting Nigerian coastal waters. The significant variation in this study is in agreement with Kaka *et al.* (2019) who also found significant morphometric variations among groups of populations of *P. monodon* in Malindi–Ungwana Bay, Kenya. These variations among individuals or populations may be due to local adaptation (Bagherian and Rahmani (2007). The PCA also grouped the four populations into at least two clusters, indicating that populations are morphologically heterozygous with total length and rostral length accounting for about 60 and 38% of the variances Table 9 and Fig. 3). Similar studies along the Indian coastal water indicated a homogenous population of the species (Munasinghe, 2014; Rebello, 2003). However, Sun et al. (2014) reported an extensive morphometric variability for *P. monodon* populations in the Indian Ocean due to variation in carapace length and width, with males presenting more evident phenotypic differences among sampling locations. Our result is consistent with the hypothesis that high morphological variability derives from multiple sources of invasion (Lavergne and Molofsky, 2007; Ward et al., 2008). This is because invasion from a single source or population usually suffers reduced diversity as a result of founder effects and population bottleneck. In the vast oceans, distinct morphological variability is quite uncommon because of the lack of an effective barrier to gene flow. Therefore, perhaps, distinctive environmental conditions of the Niger Delta and Lagos Lagoon Complex may underlie the morphological differentiation among the locations. In Nigeria, large environmental changes are expected to occur along the coasts depending on the scale of commercial and industrial activities taking place.

The high levels of CV observed in some parameters were similar to other penaeid shrimps. Carvalho *et al.* (2019) found a high CV ranging from 57.5% to 115.7% for body weight in the pink shrimps, *Farfantepenaeus brasiliensis*, and *Farfantepenaeus paulensis* The CV they obtained for other parameters also fall within the range obtained in this study. Soewardi and Imron (2007) obtained values ranging from 27-35% for weight-associated traits and low to medium values (8-14%) for length based traits in *P. monodon* from Indonesian waters. Jiang *et al.* (2017) obtained an estimate of 42.98% CV for *P. monodon* from four different populations in Indonesia, Thailand, Mozambique, and China. The high CV for weight and other parameters implies an advantage for their selective breeding (Jiang *et al*., 2017). The parameter targeted in shellfish genetic improvement programs is growth-related traits such as weight, total length, abdominal length, and tail weight. From the perspective of genetic improvement programs, particularly those applying conventional selective breeding, high variation in these body parts simply means the possibility to improve or modify them to suit consumers' demand. In this study. The total weight and abdominal segments (FSL, 2SL, 3SL, 4SL, 5SL, and 6SL) displayed a high CV while total length exhibited moderate CV. The moderate to high levels of CV observed in this study indicate that the traits varied enough with good potential to respond quickly to selective breeding and genetic improvement programmes.

CONCLUSION

Adequate knowledge of morphometric information of potential culturable shellfishes is necessary before commencing breeding programmes. The morphometric characterization of populations and variations found within and among them will have consequences on genetic progress and genetic gain in breeding programmes. Thus, our results provide baseline information that could be useful in selective breeding and management of the animal. Traits with high CV as observed in this study have good potentials for selective improvement. The present study has provided basic and vital information concerning the morphological variability of *P. monodon* populations along the coasts of Nigeria and suggests that at least 2 clusters of *P. monodon* are now established in Nigeria. Perhaps, separating populations into sex and distinct or specific length classes could be necessary for the meaningful description of morphometric differences ((Bookstein *et al.*, 1985; Chen *et al*., 2009). Environmental conditions, food availability, and maturity may cause variation in morphological characteristics

RECOMMENDATIONS

The morphological diversity observed may be purely due to environmental forces. Pollution interferes with growth in shrimp. There is insufficient data to compare pollution levels along the Coastal waters of Nigeria. There is an urgent need to examine the demographic history of *P. monodon* in Nigeria to gain insight into the pathways of invasion. This will be useful to formulate strategies to prevent and manage similar invasions in the future.

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