THE ECOLOGY AND GROWTH BIOLOGY OF *Farfantepenaeus notialis* (Pérez-Farfante, 1967) FROM AN OPEN TIDAL ESTUARY IN NIGERIA

***AKINJOGUNLA, V.F. & MORUF, R. O.**
Shellfish Biology Unit, Department of Marine Sciences, University of Lagos, Akoka, Lagos State, Nigeria
*Correspondence: vicakin@yahoo.com, +234 8092643007

ABSTRACT
The environmental factors controlling the distribution of F. notialis in Lagos Lagoon in relation to its growth biology were investigated. The physico-chemical parameters obtained in this study showed variations with season. The most important ecological parameter, salinity generally alternated between 5.4‰ recorded in June and 23‰ in April, 2016. Carapace length ranged from l.4cm to 12.lcm and weight from 1.1g to 23.7g. The shrimp exhibited negative allometric growth (b < 3). Correlation co-efficient 'r' ranged between 0.3067 and 0.3536 showing a positive relationship between carapace length and total weight. The highest K-values were recorded for the small size group (1.0 - 1.4 cm) and the female had the highest K value. K-values decreased with increasing size of shrimp. The shrimps could be said to be detritivorous in their mode of feeding with algae, diatom and plant materials constituting the most important food items. Sex ratio was 1: 0.46 while the Chi- squared value at 1 d.f and 5% significant level was 83.63. Males were significantly (P < 0.05) more numerous than females. From this our findings, a biological database is established for use by fishery managers and in further research on the aquaculture potentials of this species.
Keywords: Morphometric, Length-Weight relationship, feeding habits, reproduction, Lagos

INTRODUCTION

Penaeid shrimps are decapod crustaceans well known globally in terms of its economic importance and aquaculture potentials. *Farfantepenaeus notialis* is a marine/estuarine species of shrimp in the family Penaeidae. According to Isabel and Brian (1997), the genus *Penaeus* has been taxonomically restructured following a proposition of Pérez Farfante and Kensley using genital characteristics and physiological differences of these species. The southern Pink shrimp, like other members of the commercially important penaeid shrimps, can be differentiated from other shrimp families using their antennae, which are longer than their body lengths (Amos and Amos, 1997). As described by Lawal-Are and Akinjogunla (2012), the integument of the southern pink shrimp is thin, translucent and the overall body colour is highly variable and the sides of the animal are somewhat flattened. The carapace has a medial carina that extends nearly to the posterior end of carapace and is bordered by a broad, rounded groove on either side while the rostrum may have 1 to 3 teeth (Carvajal and Nebot, 1998).

Farfantepenaeus notialis is harvested both locally and by foreign trawlers. In the report of FAO (2009), the countries with the largest catches were Nigeria and Senegal with 27,341 tonnes and 4,887 tonnes respectively. A portion of the life cycle is spent in the open ocean, resulting in the development of two fisheries: artisanal fishery, which centres on the capture of penaeids within estuaries and during migrations from the estuaries to the sea, and a larger-scale commercial trawling fishery in the deeper waters offshore (King, 1995). It was further reported by FAO (2009) that captured shrimps accounted for 3,120,556 tonnes in 2008 declining from 3,307,856 tonnes in 2003 while shrimp culture has increased at the rate of 10% per annum over the last 10 decades increasing from 2,049,011 tonnes, in 2003 to 3,399, 103 tonnes in 2008.

According to Kusemiju (1975), the adult pink shrimp stock off Lagos coast has been reported to be replenished by the juveniles and sub-adult from the adjacent Lagos Lagoon and its creeks. He further pointed out that the pink shrimp population off Lagos coast had its nursery ground in the Lagos Lagoon and in the estuarine system. He noted the occurrence of the shrimp juveniles in the Lagos Lagoon and in the Port-Harcourt area of Nigeria and hence suggested that the concentration of adults of the species may occur off entrance of such brackish water environments It therefore follows that the population of the southern pink shrimp off the Lagos coast depend primarily on the annual recruitment from the Lagos Lagoon.

The distribution of the adult pink shrimp off shore at depths of 15 -25 fathoms (27 -46m) has been reported by Adetayo and Kusemiju (1994). *F. notialis* can be found in both estuaries and inhabiting the inner littoral zone along coasts (Lawal-Are and Akinjogunla, 2012). Primary habitats for adults are sand, sand- shell, or coral-mud bottoms from the intertidal (Ansa, 2005). The youngest size classes seek out shallow, less saline areas in estuarine nursery habitats and are often found abundantly in sea-grasses, with older shrimp more likely to utilize patchily distributed sea-grass areas and younger shrimp more likely to be found in areas with denser coverage (Sanchez, 1997). As shrimp grow, they seek out progressively more saline areas, eventually migrating out of estuaries entirely and returning to offshore habitats (Bureau *et al*., 2000).

While predation is a major cause of death in shrimp, environmental factors also play a large role in the success of the annual shrimp crop(Cristei and Luis, 2009).Their limited ability to handle cold temperatures and their preference for hard, sandy bottoms is

important to understanding why large numbers are caught off lagoons (Cristei and Luis, 2009).

Growth activity depends on sex, stage and environmental factors such as food quantity and quality, water temperature and salinity (Dall *et al*., 1990). Due to the economic importance of penaeid shrimps worldwide, particularly in aquaculture, a great effort to understand the growth biology of *Penaeus spp.* has been made in recent years. This include studies on the influence of environmental factors such as temperature (Wyban *et al*., 1995; Miao and Tu, 1996; Lopez Martinez *et al*., 2003), salinity (Lemos *et al*., 2001) and lunar cycles (Griffith and Wigglesworth, 1993) on shrimp growth. This study therefore stands to further the knowledge of the ecology and growth biology of the Southern Pink Shrimp, *Farfantepenaeus notialis* taking into account the ecological parameters in relation to the size composition, growth pattern, feeding habits and sex ratio of the shrimp.

Study Area

The Lagos lagoon (3°10'E and 3°45' E and 6°15N and 6°36'N) is a part of the continuous system of lagoons found along the coast of Nigeria from the border of the Republic of Benin to Niger-Delta (Lawal-Are and Owolabi, 2012) (Fig. 1).It receives freshwater from Lekki Lagoon via Epe Lagoon in the North-east, and discharges from Majidun, Agboyi and Ogudu creeks as well as Ogun River in the North-West (Akinjogunla *et al*., 2017;).Lagos Lagoon is an open tidal estuary situated within the low-lying coastal zone of Nigeria (Moruf and Lawal-Are, 2017). The lagoon characterized with seasonal fluctuation in salinity - high brackish water during the dry season (December - May) while freshwater condition exists in the rainy season (June - November) (Ugwumba and Kusemiju, 1992). Lagos Lagoon has supported decades of small scale fisheries which have shown sign of continuous decline (Solarin, 1998).

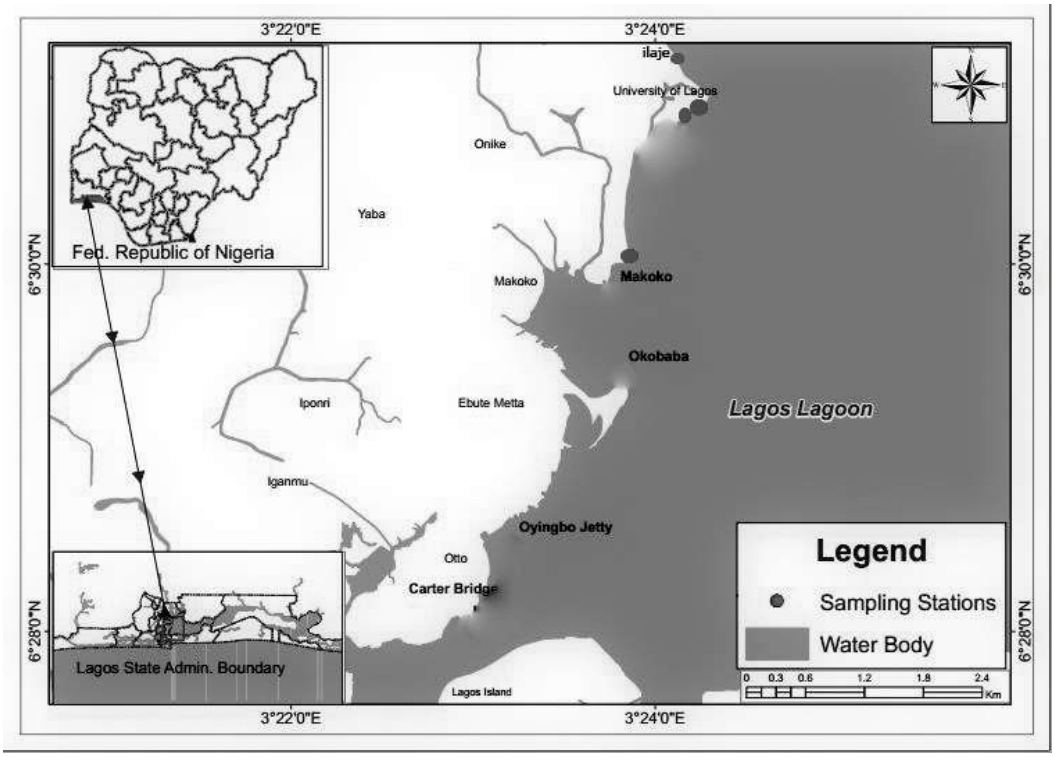

Fig. 1: Map of Lagos lagoon showing the sampling sites

MATERIALS AND METHODS

Sampling and Water quality analysis

Random sampling of *Farfantepenaeus notialis* and the determination of the physico-chemical parameters of the lagoon water were conducted monthly. The shrimps were immediately preserved in an ice-chest and subsequently transported into a deep freezer at temperature of -20 ^{o}C in the laboratory for further biological analysis. Water samples were collected in 250 mL reagent bottles and 1500 mL plastic containers and analyzed in Lagos State Environmental Protection Agency (LASEPA) laboratory for physico-chemical analysis. Using the methods recommended by APHA (1998). Air and water temperature were measured in-situ using mercury-inglass thermometer and readings taking to the nearest 0.10C.

Carapace-length/weight relationship

The total length (TL), carapace length (CL) and rostral length (RL) of the shrimp samples were measured in centimetres (cm) using the graduated meter ruler, while the body weight (BW) and carapace weight (CW) were measured using a Sartorius weight balance (Model 1100). Total length measured was obtained by stretching out the curved body and taking measurements from the telson to the base of the eyestalk. Carapace length was obtained by cutting off the cephalothoraxes and measurements were taken from the posterior end of

the carapace to the base of eyestalk. All measurements were to the nearest 0.1 cm; while weight was measured to the nearest 0.1 g.

The carapace-length/weight relationship was expressed by using the equation:

$W = aL^b$……. (Pauly, 1983)

Where W= weight of the shrimp in grams.
L = total length of the shrimp in cm.
a = regression constant
b = regression coefficient

The values of constant "a" and "b" were estimated from log transformation equation as:

$Log\ W = Log\ a + bLog\ L$…… (Parsons, 1988)

The condition factor (K) of the crab was determined using the formula:

$K = \frac{100W}{L^b}$……. (Bannister, 1976)

Where K = condition factor
W = weight of the shrimp (g)
L = length of the shrimp (cm)
b = regression coefficient

Food and feeding habits

The stomachs of the collected shrimp were examined and scored with regards to whether they are empty ($^0/_4$), ¼ full, ½ full, ¾ full and/or full ($^4/_4$). Each stomach was dissected out with the contents washed into a Petri dish. The extracted contents were mixed with little water and examined under a binocular microscope using the numerical and occurrence methods by Hyslop (1980). The food items were identified according to method of Anderson (1999).

Sex ratio

The sex ratio of the specimens was determined monthly. The sex ratio was tested for any deviation from the expected 1:1 ratio by using chi-square analysis. Level of significance was tested at 5% level of significance ($p < 0.05$).

Statistical analysis

Data generated from this study were analyzed using Microsoft Excel 2010 and SPSS software. Lines and scattered graphs were used to depict trends in the distributions and relationships between the lengths and weights of *Farfantepenaeus notialis.* Analysis of Variance (ANOVA) was used to compare the means and standard deviations values of the samples used in this study and to test for statistically significant differences of means in sex ratio of the samples at 0.05 level.

RESULTS

Physical and chemical parameters

The monthly variations in the physico-chemical parameters of waters of Lagos lagoon are represented in Table 1. The air temperature ranged from 27.0 – 31.5 ºC (mean = 28.9 ± 1.6). The surface water temperature fluctuated between 26^0C and 31^0C. The highest recorded was recorded in April while the lowest was recorded in June. Salinity of sampling site ranged between 5.4 and 23.0 ‰ with the values being higher in the dry months. The Dissolved oxygen of the water during the study period fluctuated between 4.0 and 5.6 mg/l with the highest value recorded in April and lowest recorded in January. The mean value was 4.8 mg/l and the standard deviation was ± 0.5. The lowest transparency was observed mainly during the wet season 40 cm while highest in January (138 cm). The conductivity values ranged between 7440 and 34700 µS/cm. The pH values ranged between 7.5 in January and 8 in April. The mean pH value was 7.7 and the standard deviation was ± 0.3. The water was essentially alkaline during the sampling period. The Biochemical oxygen demand values recorded were higher above FEPA permissible limits of 50 mg/l. The chemical oxygen demand values were also higher than FEPA limits of 20 mg/l except in the month of February.

Size composition

A total of 720 specimens of *Farfantepenaeus notialis* were collected throughout the study period.271 (37.6%) specimens were obtained in the dry season (January – March, 2016) while 449 (62.4%) of the specimens were collected during the rainy season (April– June, 2016). The pattern of occurrence of the shrimp is shown in Tables 2

The length frequency distribution of the shrimp the lagoon is shown in Figures 2. The total length of larger specimen of *F. notialis* ranged from 1.4cm and 12.1cm. The shrimp exhibited unimodal size distribution, revealed from size frequency distribution (Fig.2).

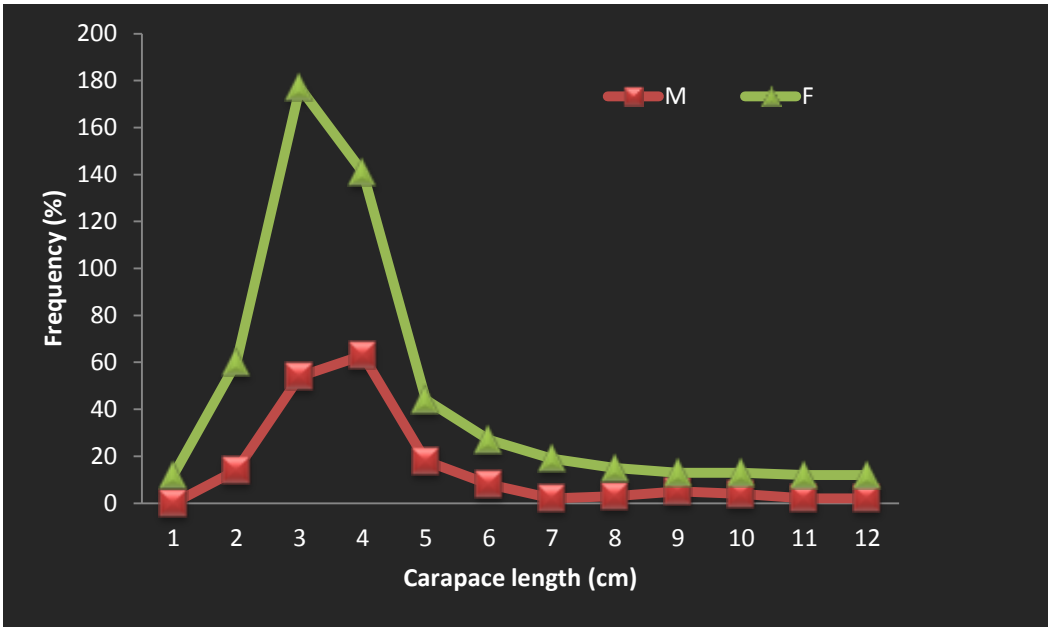

Fig. 2: Carapace Length Distribution of *F. notialis* from Lagos Lagoon from (Jan. - June, 2016)

Growth Pattern

F. notialis from Lagos Lagoon ranged incarapace length from 1.4 cm to 12.1 cm and total weight 1.1 g to 23.7 g. The Log length/Log weight relationships are shown in Figures 3. The *F. notialis* showed a linear relationship between the length and weight of the shrimp.

The least square common fit of the transformed data gave the following linear equation:

Males: $Log\ TW = 4.3816 + 0.0908 Log\ CL$

$(r = 0.3378, n = 271)$

Females: $LogTW = 4.9966 + 0.7579 Log\ CL$

$(r = 0.3067, n = 449)$

Combined sexes: $LogTW = 4.6522 + 1.1348 Log\ CL$

$(r = 0.3536, n = 720)$

In the Carapace length – Total weight relationship regardless of sex, reflected a common general increase in total weight with increasing carapace length. The values of the correlation co-efficient 'r' ranged between 0.3067 and 0.3536 showing a very positive correlation between the carapace length and the total weight in the species from Lagos Lagoon. Negative allometric growth was observed as revealed by the values of "b", the regression coefficient which were 0.0908, 0.7579 and 1.1348 for the males, females and combined sexes respectively.

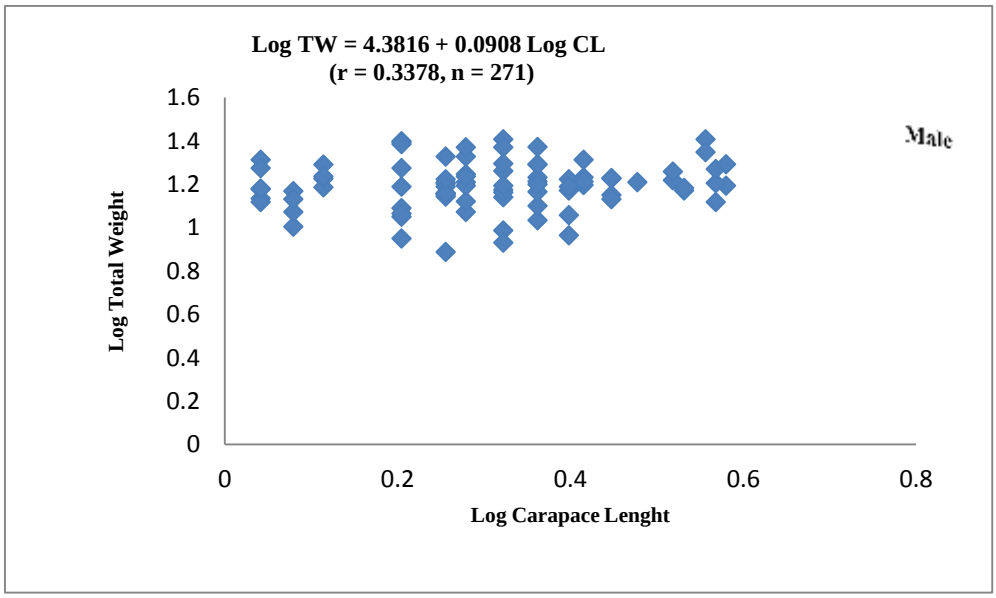

Fig. 3: Log carapace length / Log weight relationship of male*F. notialis* from Lagos Lagoon (Jan. – June 2016)

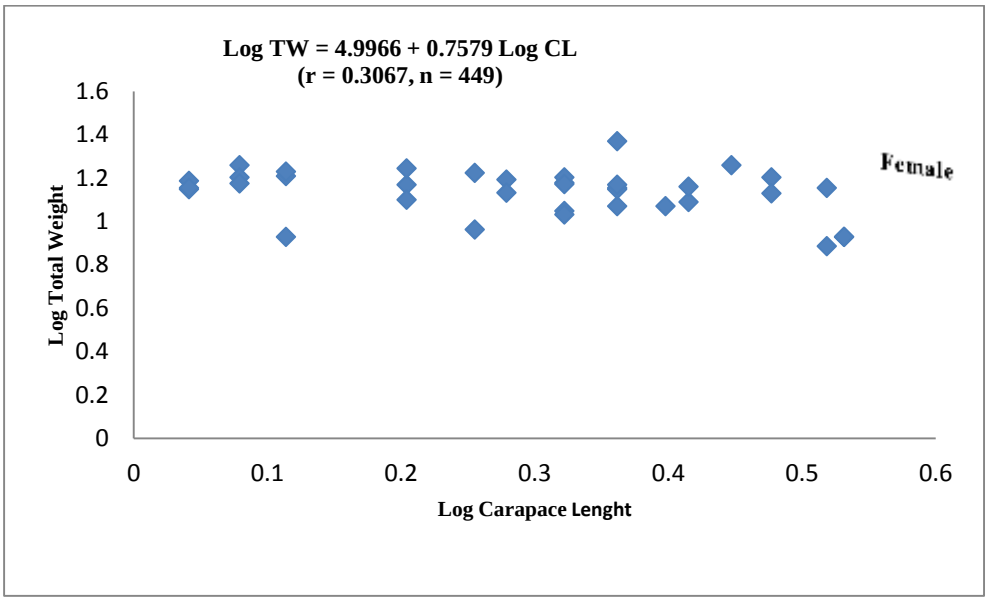

Fig. 4: Log carapace length /Log weight relationship of female *F. notialis* from Lagos Lagoon (Jan. – Jun. 2016)

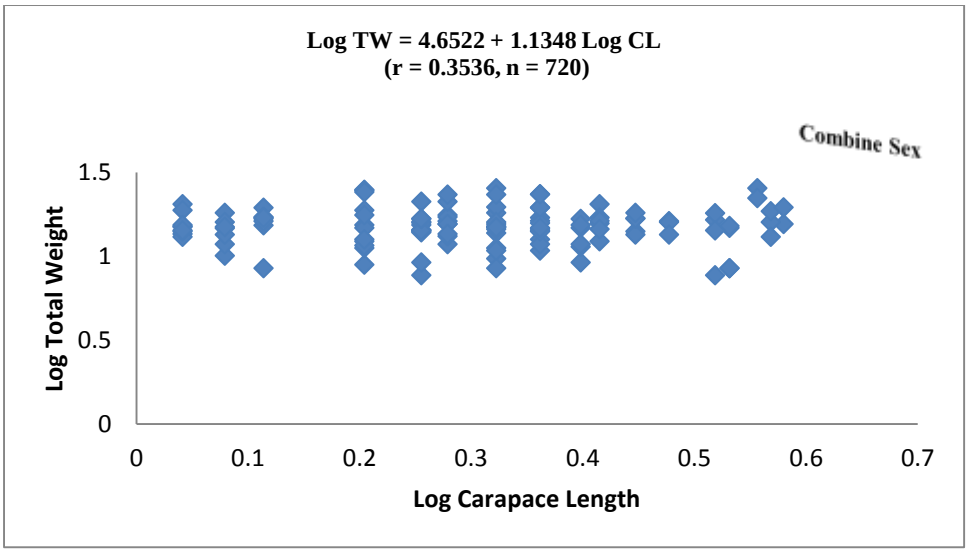

Fig. 5: Log carapace length / Log weight relationship of combined sexes *F. notialis* from Lagos Lagoon (Jan.– Jun. 2016)

Table 1: Monthly variation in water quality indices of Lagos Lagoon (January – June, 2016)

Parameter	Jan.	Feb.	March	April	May	June	Mean	S.Deviation
Air Temp. (ºC)	28	27	31.5	30	29	28	28.9	1.6
Water Temp. (ºC)	28	28	30	31	28	26	28.5	1.8
Ph	7.5	7.6	7.9	8	7.8	7.3	7.7	0.3
Salinity (‰)	14	18	21	23	10	5.4	15.2	6.7
Dissolved Oxygen (Mg/L)	4	4.8	5.2	5.6	4.8	4.6	4.8	0.5
Transparency (cm)	138	62	41	44	40	40	60.8	38.7
Conductivity (µS/cm)	14775	33200	34700	27355	13900	7440	21895	11359.1

Table 2: Monthly collection inrelation to sex of *F. notialis* in Lagos Lagoon from Jan. – Jun., 2016

Months	*Farfantepenaeus notialis*			
	Male	**%**	***Female***	**%**
Dry Season	215	79.3	56	20.7
Rainy Season	281	62.6	168	37.4
Total	**496**		**224**	

Table 3: Condition factor by sex and size of *F. notialis* from Lagos Lagoon (January – June, 2016)

Carapace	MALE				FEMALE				COMBINED SEX			
length (cm)	N	CL(cm)	TW(g)	K	N	CL(cm)	TW(g)	K	N	CL(cm)	TW(g)	K
0.5 - 1.4	0	0	0	0	12	1.4	3	109.3	12	1.4	2.2	80.2
1.5 - 2.4	14	2.2	2.8	26.3	60	2	3.2	40.0	74	2.1	3	32.4
2.5 - 3.4	54	3	3.6	13.3	177	3.1	3.3	11.1	231	3.1	3.5	11.7
3.5 - 4.4	63	3.9	3.6	6.1	141	3.9	2.5	4.2	204	3.9	3.1	5.2
4.5 - 5.4	18	4.7	2.6	2.5	44	4.9	2.8	2.4	62	4.4	2.7	3.2
5.5 - 6.4	8	5.8	2.8	1.4	27	5.7	2.6	1.4	35	5.8	2.7	1.4
6.5 -.7.4	2	6.7	3.2	1.1	19	6.7	1.6	0.5	21	6.7	2.4	0.8
7.5 - 8.4	3	8.1	2.1	0.4	15	8	3.6	0.7	18	8.1	2.9	0.5
8.5 - 9.4	5	9	2.8	0.4	13	8.7	2.3	0.3	18	8.9	2.6	0.4
9.5 - 10.4	4	10	1.8	0.2	13	10.1	1.9	0.2	17	10.1	1.9	0.2
10.5 – 1.4	2	11.3	1.5	0.1	12	10.7	1.7	0.1	14	11	1.6	0.1
11.5 - 2.4	2	11.5	2.1	0.1	12	11.8	2.2	0.1	14	11.7	2.2	0.1
Total	175				545				720			

Keys: N: Number; CL: Carapace Length; TW : Total Weight; k: Condition factor

Table 4: Stomach Contents of *F. notialis* from Lagos Lagoon (January – June, 2016)

Food items	Numerical Method		Occurrence Method	
	No	%	No	%
Diatoms	311	35.3	19	100
Green algae	347	39.4	16	84.2
Polychaetes fragments	126	14.3	15	78.9
Crustaceans	27	3.1	10	52.6
Fish fragment (bones and Scales)	33	3.7	2	10.5
Plant materials	37	4.2	19	100
Unidentifiable masses	-	-	19	100
Total	881	100	-	-

Table 5: Monthly variations in sex ratio of *F. notialis* from Lagos Lagoon (January – June, 2016)

Month	Male	Female	Sexratio	Chi-Square Test χ^2
January	66	34	1:0.51	10.24*
February	60	40	1:0.67	4.00*
March	57	43	1:0.75	1.96
April	79	21	1:0.27	33.64*
May	70	30	1:0.42	16.00*
June	81	19	1:0.23	153.76*
Total	413	187	1:0.46	

* = significant

Table 6: Chi- square test for sex ratio of *F. notialis* from Lagos Lagoon (January – June 2016)

Sex	Observed Number	Expected Number	Calculated χ^2 Value	Tabulated χ^2 Value
Male	412	300		
Female	188	300	83.63	3.48
Total	600	600		

Calculated χ^2(1d.f.5%)=83.63(*significant)

Tabulated χ^2(1d.f.5%)=3.84

Condition Factor

The Condition Factor (K) by size and sex of *F. notialis* from the Lagos Lagoon is presented in Table3. The K values ranged from 0.1 – 26.3 (male), 0.1 – 109.3 (female) and 0.1 – 80.2 (combined sexes). The highest K-values were recorded for the small size (1.0 - 1.4 cm) group. In term of sex, there is a marked variation in the condition factor as the female had the highest K value. K-values decreased with increasing size of shrimp in the lagoon.

Food Analysis

A total of 461(64%) of the 720 specimens of *F. notialis* examined in this study had empty stomachs. The summary of the stomach contents is given in Table 4. Diatoms and Green algae constitutes the most important food items accounting for 100% and 84.2% by frequency of occurrence method respectively while they accounted for 35.3% and 39.4% respectively in Numerical method. The polycheates also occurred in the stomach of the shrimps in form of fragments recognized by the chaetae and accounted for 14.3% in Numerical method and 78.9% by Frequency of occurrence method. The crustaceans are found in the stomach of the pink shrimps in disassembled forms and they constitute about 3.1% by Numerical method and 52.6% by Frequency of Occurrence method.

The fishes also occurred in the stomach of the pink shrimps in form of scales and bones accounting for about 3.7% by Numerical method and 10.5% by Frequency of Occurrence method. The unidentified masses observed in the stomach of the pink shrimp constituted 100% by Frequency of Occurrence method while the plant materials accounted for 4.2% by Numerical and 100% by Frequency of Occurrence method.

Sex Determination

The total of 600 specimens of *F. notialis* examined for sex determination were made up of 413 males and 187 females giving a sex ratio of 1:0.46 (male: female).The result showed that there was more of male *F. notialis* from Lagos Lagoon. The monthly sex ratio (Table 5) showed that males were more than the females throughout the period of study. Chi square (χ^2) values of the sex ratio were significantly different ($P < 0.05$) throughout except in March, 2016 which showed insignificant difference. Chi-square test (Table 6) carried out to test if there was any significant difference in the sex ratio of the pink shrimps gave 83.63 at 1 d. f. and 5% level. This is greater than the tabulated value of 3.48 at 1d.f. and 5% level.

DISCUSSION

Physical and Chemical parameters

Lagos Lagoon at different periods of the year experiences different ecological measure; the dry season is characterized by the influx of sea water into the Lagoon and evaporation, while the rainy season is characterized by water runoff from the rivers and the rain (Onyema *et al.*, 2007). The air and surface water temperatures obtained in this study showed variations with the seasons. The temperatures were generally lower during the rainy season due to cloud cover while they were highest during dry season. These results are in similarity with those obtained by Adetayo and Kusemiju (1994) and Lawal-Are *et al.*, (2010). The temperature ranges of Lagos Lagoon obtained between the periods studied were slightly different from the results reported by Dublin-Green (1990) who worked on physico- chemical parameters in Niger - Delta waters.

The variation of pH values of Lagos Lagoon observed in this study is in agreement with results of Dublin-Green (1990) in Bonny River, Niger- Delta where the highest pH values were recorded in the dry season and lower values of pH in the rainy season. Similar trend was reported by Ekeh and Sikoki (2003) in the New Calabar River and by Ansa (2005) in Andoni flats of the Niger Delta area. The seasonality in the pH of Lagos Lagoon water may be due to the influx and buffering effects (Onyema *et al*., 2007) and decay of debris in the area as well as imbalance level of H^+ ions input from surface run- offs during the rains. However, the hydrogen ion concentration (pH) values recorded in this study were well within the preferred pH of 6.5 to 9.0 recommended (Abowei, 2010).The range of dissolved oxygen between 4.0mg/l recorded in January and 5.6mg/l recorded in April was still within the acceptable limit of aquatic life (Abowei, 2010). This could principally be due to the reduced amount of fresh water discharged into the Lagoon and high rate of evaporation. On the contrary, low salinity period coincided with the rainy season which could have been due to the high rate of fresh water discharges from the rivers and the amount of rainfall.

The results of the study showed that salinity of the study area generally alternated between 5.4‰ recorded in June and 23‰ in April. The highest salinity of 23‰ and the lowest salinity of 5.4‰ were recorded in April and June, 2016, respectively. These results agreed with earlier observations by Adetayo and Kusemiju (1994) and it was attributed to the fact that the water of Lagos Lagoon becomes very turbid and salinity is generally reduced during the rainy season. Salinity regimes in the Lagos Lagoon have been related to rainfall distribution. According to Nwankwo (1996) and Onyema *et al.*, (2007), salinity is an environmental barrier in the distribution of biota. Salinity has long been considered a major factor affecting the survival and growth of the penaeid shrimps.

Size composition and growth pattern

More samples of *F.notialis* were caught during the rainy season and unimodal size distribution was exhibited by the shrimp. This collaborated the work of Adelugba and Bernard (2014) who worked on a penaid shrimp from Lagos Lagoon. The carapace lengths observed for the sounthern pink shrimps were l.4cm and 12.lcm. The linear relationship between the carapace

length and the total length reflected a common general increase in total length with increasing carapace length and these results are in conformity with the results of Lawal-Are and Owolabi (2012) who worked on *Macrobechium sp*. of Lagos and Lekki Lagoons. It was stated from their works that the carapace length – weight relationship of prawns from the three lagoons also exhibited a negative allometric growth, thus indicating that the prawns body forms did not grow at the same proportion (growth in length is not proportional to weight).The result showed that female *F.notialis* had a higher K value than the male. This was in conformity with the report of Anetekhai (2002), that male shrimp are usually bigger than the females Thus, the K-values decrease with increase in size.

Feed and Feeding Habit

Generally, there were high percentages of empty stomachs throughout the study period; this could be attributed to the duration of the sampling periods prior to their feeding periods. This is in contrary to the findings of Lawal-Are and Owolabi (2012) who recorded low percentage empty stomach for *Macrobechium sp.* of Lagos and Lekki Lagoons. The variation of the stomach contents of *F. notialis* examined showed that it fed mainly on plant parts both in the rainy and dry seasons. Diatoms and Green algae constitutes the most important food items accounting for 100% and 84.2% by frequency of occurrence method respectively while they accounted for 35.3% and 39.4% respectively in Numerical method. This agreed with the findings of Adetayo and Kusemiju (1994) who reported that *Penaeus spp* are detritivorous and omnivorous with filamentous algae and detritus constituting the most important food items while Oluboba (2015) gave a similar report on the same *Penaeus spp*.

Sex Ratio

The total observed sex ratio for the period of study was 1: 0.46 while the Chi- squared value at 1 d.f and 5% significant level was 83.63. This is in agreement with Kusemiju (1975) that reported that there was significant difference in sex ratio from the expected ratio of 1:1 in the population of southern pink shrimps off Lagos coast. In this study, no berried females were encountered as the sampling site only serves as a nursery ground for the juveniles while the matured species migrates back to the open sea for mating and reproduction.

CONCLUSION

The similarity in the life history and ecology of *F. notalis* with *P. monodon* raises several problems as the latter is an invader competing for space and food. Hence, the lagoon ecosystem should be effectively monitored for the conservation of *F. notalis*. From this our findings, a biological database is established for use by fishery managers and in further research on the aquaculture potential of this species.

ACKNOWLEDGEMENT

The authors are grateful to the University of Lagos, Faculty of Science, Marine Sciences Department for the facilities provided and Assoc. Prof. A.O. Lawal-Are for her guidance during this research work.

REFERENCES

Abowei, J. F.N. (2010). Salinity, Dissolved Oxygen, pH and Surface Water Temperature Conditions in Nkoro River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology*, 2(1): 36-40, 2010.

Adelugba, T. and Bernard, E. (2014). Biology of the pink shrimp, *Penaeus notialis* (Perez-Farfante) in Lagos Lagoon, Nigeria. *International Journal of Agricultural Sciences and Natural Resources*, 1(4): 81-87.

Adetayo, J. A. and Kusemiju, K. (1994). Some aspects of the biology of pink shrimp, *Penaeus notialis* in the Lagos Lagoon, Nigeria. *Journal of Science Research and Development*, 1(1): 80-84.

Akinjogunla, V. F., Lawal-Are, A. O. and Soyinka, O.O. (2017). Proximate composition and mineral contents of Mangrove Oyster (*Crassostrea gasar*) from Lagos Lagoon, Lagos, Nigeria. *Nigerian Journal of Fisheries and Aquaculture* 5(2): 36 – 49.

Amos, W. H. and Amos. S. H. (1997). National Audubon Society Nature Guides: Atlantic and Gulf Coasts. Alfred A. Knopf, Inc., New York. 121pp.

Anderson, D.T. (1999). *Invertebrate Zoology*. Oxford University Press, New York. 467pp.

Anetekhai, M.A. (2002). *Fisheries and National Empowerment*. 13th Inaugural Lecture delivered at the Lagos State University, 39pp.

Ansa, E. J. (2005). Studies of the benthic macro fauna of the Andoni flats inthe Niger Delta Area of Nigeria. Ph.D Thesis, University of Port Harcourt, Port Harcourt, Nigeria. 242pp

Bannister, J. V. (1976). The length- weight relationship, Condiion factor and gut content of the dolphin fish, *Coryphaena hippunes* (L) inthe Mediterranean. *Journal of Fish Biology*, 9: 335 -338.

Bureau, D.P.,Azevedo, P.A.,Tapia-Salazar, M. andCuzon, G. (2000).Pattern and cost of growth and nutrient deposition in fish andshrimp: Potential implications and applications. *In*: Cruz -Suárez, L.E., Ricque-Marie, D., Tapia-Salazar, M., Olvera-Novoa, M.A. y CiveraCerecedo, R., (Eds.). Avances en Nutrición Acuícola V. Memorias del V Simposium Internacional de Nutrición Acuícola. 19-22 Noviembre, Mérida, Yucatán, Mexico.

Carvajal, R. and Nebot, A. (1998). Growth model for white shrimp in semi-intensive farming using

inductive reasoning methodology. *Computers and Electronics in Agriculture*, 19: 187 - 210

Crislei, B and Luis, V. (2009). Combined effect of body weight, temperature and salinity on shrimp *Litopenaeus vannamei* oxygen consumption rate. *Brazilian Journal of Oceanography*, 57(4):305-314,

Dall, W., Hill, B. J., Rothlisberg, P. C. and Staples, D. J. (1990). *Biology of the Penaeidae*. In: Blaxter, J.H.S., Southward, A.J. (Eds.), Advances in Marine Biology, vol. 27.Academic Press, London. 489pp.

Dublin-Green, C. O. (1990). Seasonal variations in some physico-chemical parameters of the Bonny Estuary, Niger Delta. NI01fR Technical Paper, 59: 21-25.

Ekeh, I.B. and Sikoki, F.D. (2003). The state and seasonal variability of some physico-chemical parameters in the New Calabar River, Nigeria. *Supplementa Ad Acta Hydrobiologica*, 5: 45 - 60.

FAO, (2009). Cultured aquatic species fact sheets. Edited and compiled by *Valerio Crespi* and Michael New Rome. FAO-CD-ROM (Multilingual).

Griffith, D. R. W. and Wigglesworth, J. M. (1993).Growth rhythms in the shrimp *Penaeus vannamei* and *P. schmitti. Marine Biology*, 115(2): 295–299

Hyslop, E.J. (1980). Stomach content analysis: a review methods and applications. *Journal of Fish Biology*, 17: 411-414.

Isabel Pérez Farfante and Brian F. K. (1997). Penaeoid and Sergestoid Shrimps and Prawns of the World: Keys and Diagnoses for the Families and Genera. Mémoires du Muséum national d'histoire naturelle. 175.

King, M. (1995). *Fisheries biology, assessment and management*.Fishing News Books, Blackwell Scientific Publications Ltd,Oxford. 341 pp.

Kusemiju, K. (1975). The binomics and distribution of the pink shrimp, *Penaeus duorarum* (Burkenroad) off Lagos coast, Nigeria. *Bulletin de I' Institut Fondamental d'Afrique Noire*, 37 (4): 775-783.

Lawal-Are, A.O. and Akinjogunla, V.F. (2012). *Penaeus notialis* (Pink shrimp): Length-Weight relationships and condition factor in Lagos Lagoon, South-West, Nigeria. *Science and Technology*, 2 (3): 32-40.

Lawal-Are, A. O., Onyema, I. C. and Akande, T. R. (2010).The Water Chemistry, Crustacean Zooplankton and Some Associated Fauna Species of a Tropical Tidal Creek In Lagos, Nigeria. *Journal of American Science*, 6(1):81-90.

Lawal-Are, A.O. and Owolabi, A.T. (2012). Comparative Biology of the Prawns *M. macrobrachion* (Herklots, 1851) and M. vollenhovenii (Herklots, 1857) from two interconnecting fresh/brackish water lagoons in South-West Nigeria. *Journal of Marine Science Research and Development*, 2: 108-116.

Lemos, D. Phan, V. N. and Alvarez, G. (2001). Growth, oxygen consumption, ammonia, excretion, biochemical composition and energy content of *Farfantepenaeus paulensis* Perez-Far/ante (Crustacean, Decapoda, and Penaeidae) early post-larvaem different salinities. *Journal of Experimental Marine Biology and Ecology*, 261: 55-74.

Lopez-Martinez, J., Arreguin-Sanchez, F., Hernandez Vazquez, S., Garcia-Juarez, A. R. and Valenzuela-Quinonez, W. (2003). Inter-annual variation of growth of the brown shrimp *Farfantepenaeus californiensis* and its relation to temperature. *Fisheries Research*, 61: 95-105.

Miao, S. and Tu, S. (1996). Modelling the effect of thermic amplitude on growing Chinese shrimp, *Penaeus chinensis* (Osbeck). *Ecological Modelling* 88: 93-100.

Moruf, R.O. and Lawal-Are, A.O. (2017). Size composition, Growth pattern and Condition factor of two Portunid crabs, *Callinectes amnicola* (De Rochebrune) and *Portunus validus* (Herklots) from Lagos Coast, Nigeria. *Nigerian Journal of Fisheries and Aquaculture*, 5(1): 15 – 21.

Nwankwo, D. I. (1996). Phytoplankton diversity and succession in Lagos Lagoon, Nigeria. *Archiv fur Hydrobiologie*, 135 (4): 529-542.

Oluboba T.A. (2015). Comparative Biology of the Pink Shrimp, *Penaeus notialis* (Perez- Farfante), and Giant Tiger Shrimp, *Penaeus monodon* (Fabricius), in the Lagos Lagoon, Nigeria. *Journal of Biology, Agriculture and Healthcare*, 5 (17): 97-108.

Onyema, 1. C., Okpara, C. U., Ogbebor, C. I. Otudeko, O. and Nwankwo, D. I. (2007). Comparative studies of the water chemistry characteristics and temporal plankton variations at two polluted sites along the Lagos lagoon, Nigeria. *Ecology, Environment and Conservation*, 13(1): 1 – 12

Parsons, R. (1988). *Statistical Analysis: A Decision making Approach*. Second edition Harper and Row publishers, New York, 791 pp.

Pauly D. (1983). Some simple methods for the assessment of tropical stocks. FAO Fish. Tech. Pap., 234: 52.

Sanchez, A. J. (1997). Habitat preference of *Penaeus duorarum*. (Burkenroad) (Crustacea: Decapoda) in a tropical coastal lagoon, southwest Gulf of Mexico. *Journal of Experimental Marine Biology and Ecology*, 217: 107-117.

Solarin, B. B. (1998). The hydrobiology, fishes and fisheries of the Lagos Lagoon, Nigeria. Ph.D Thesis, University of Lagos, 235 pp.

Ugwumba, A. O. and Kusemiju, K. (1992). Aspect of the reproductive biology of the ten pounder *Elops lacerta* (Vais) from the Lekki Lagoon, Lagos lagoon and off the Lagos Coast, Nigeria. Nigerian Journal of Science, 26: 305-315.

Wyban, J., Walsh, W. A. and Godwin, D. M. (1995). Temperature effects on growth, feeding rate and feed conversion of the pacific white shrimp (*Penaeus vannamei*). *Aquaculture*, 138: 267-279.