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Length-Weight Relationship, Condition Factor and Aspects of Growth Parameters of the Black Tiger Shrimp (*Penaeus monodon*) in the Andoni River System, Niger Delta, Nigeria

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I. Introduction

The study of length-weight relationship and condition factor of the black tiger shrimp (*Penaeus monodon)* in the Andoni River System, comes on the heels of the invasion and establishment of the black tiger shrimp in the coastal waters of Nigeria. Its invasion was first reported in 1999 by a trawl fishing company (FAO 2000). The natural distribution is Indo-West-Pacific, ranging from the eastern coast of Africa, the Arabian Peninsula, South-east Asia and the sea of Jordan as well as eastern Australia and the Mediterranean Sea. Further invasive populations have become established in Hawaii and the Atlantic coast of the USA --Florida, Georgia and South Carolina (Suthep, 2015; Fuller *et al*., 2014).

a) *Length-weight relationship*

Length and weight data studies are used to estimate growth rates, age structure and other aspects of crustacean population (Nahavandi *et al.,* 2010). Length-weight relationship is an indicator of condition of marine crustaceans which reflects fluctuations in energy uptake, utilization and well being of the stock. Factors that affect crustacean morphometry include overcrowding, disease outbreak, stress, food, and reproductive cycle (Nahavandi *et al*., 2010, Pauly, 1993; Chu *et al*., 1995). Length-weight relationship varies among species, sexes, sampling sites and seasons. Seasonal changes in length-weight relationship of wild shrimp populations correlate with seasonal variation in reproductive biology and mature shrimps have heavier weight at length than immature ones (Nahavandi *et al*., 2010, Chu *et al*., 1995).

In the use of the formula $W = aL^b$ for length-weight relationship, 'a' which is the intercept while 'b' is the slope which indicates the growth coefficient or relative growth rate (Amin *et al*., 2009). A characteristic feature of length-weight relation is the exponent "b". When the value of b is 3, growth in weight is said to be isometric (without changing shape). This is on the assumption that weight increase is proportional to the cube of length increment. When 'b' value is less than or greater than 3, weight growth is said to be allometric (crustacean changes weight as it grows larger). If slope value 'b' is significantly less than 3 (negative allometric), it implies that the crustacean becomes slender as it increases in length whereas b> 3 (positive allometric) indicates stoutness (Kurup *et al*., 2000).

b) *Condition Factor*

Condition factor (K) is an index of the interaction between living and non-living factors on the physiological condition of an aquatic organism (shrimp). It is an index of the well-being of a given population assessed based on the weight at a given length of the species (Lalrinsanga *et al.,* 2012). Condition factor is an indicator of the energetic condition or energy reserves in a species (Lambert and Dutil, 1997). Though condition factor (K) does not show the qualitative (protein, lipid, Ash, nitrogen free extract and moisture content) value of a fish, it is complementary to proximate analysis (Sutton *et al.,* 2000). Condition factor indicates recent biological and physical interactions and fluctuations especially as

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it relates to feeding condition, parasitic infections, physiological factors, food reserves and general well-being of fish (Le Cren, 1951, Lalrinsanga *et al.,* 2012). Condition factor K determined by Lalrinsanga *et al*. (2012) ranged from 0.79 to 1.41. Kunda *et al*. (2008) reported condition factor K of 1.09 in *Metapanaeus rosenbergii*. Okayi, & Iorkyaa (2004) reported condition factor of 1.014 and 2.031 for *Atya gabonensis* and *Macrobrachium felicinium* in Mu River. Araneda *et al.* (2008) reported high condition factor (K) of 0.674 in 180shrimpm^{-2} treatment, 0.670 in 130shrimpm^{-2} and 0.663 in 90shrimpm^{-2} treatments of the Pacific white shrimp *Litopenaeus vannamei* cultured in fresh water. Okayi *et al*. (2012) attributed low condition factor to poor adaptability to fresh water. Condition factors of fresh water shrimp *A. gabonensis* from two water bodies in Nigeria ranged from 1.875 for species in Jebba Lake to 3.330 for species at Lokoja river suggesting habitat difference and changing conditions all year round (Okayi *et al*., 2012).

c) Age and Growth

Amin *et al.* (2009) used the estimated growth coefficient (K=1.4yr^{-1}) of *A. japonicus* to predict longevity (t_{max} = 3/k) to be 2.14 years. It is assumed as in ELEFAN-I analysis that the value of the third parameter of the Von Bertalanffy growth function 't_0' to be zero. Hence, the sizes attained by *A. japonicus* were 6.16mm, 10.7mm, 14.64mm, 17.70mm, 19.98mm and 21.91mm at the end of 2, 4, 6, 8, 10, and 12 months of age, respectively, given that L_∞ = 29.08mm and K=1.4yr^{-1}. Yassien (2004) used the Von Bertalanffy growth equations to describe the age-at-length of *Penaeus semisulcatus* L_t = 19.721 (1-e$^{-1.104}$ (t-0.018) for females. Estimating L_∞ = 19.721, K = 1.104, t_o = -0.230 and Φ = 2.056 for males and L_∞ = 22.149 cm, K =1.004, t_o = 0.018 and Φ = 2.090 for females. Lalitha (1987) reported Von Bertalanffy growth parameters in *Penaeus monodon*, *Metapenaeus monoceros* and *M. dobsoni*. L_∞, K and t_0 in *P. monodon* were estimated to be 35.7cm, 1.206 and 0.41 respectively, in females while 29.69cm, 2.316 and 0.138 respectively, in males. In *M. monoceros* the values were L_∞ = 21.62cm, K = 0.996 and t_c = -0.044 in females while in males L_∞ = 20.84cm, K = 0.972 and t_a = -0.063. In *M. dobsoni* the value of L_∞ = 14.00cm, K = 1.69 and t = 0.115.

In the assessment of tiger shrimp (*P. monodon*) in Kuala Bara, Miri Sarawak, male shrimp sizes ranged from 10.35cm (total length, weight of 20g) to 22.07cm (total length and weighed 156g). The size of female shrimps caught ranged from 16.3cm (total length, weight of 30g) to 28.2cm (total length, weighed 210g) (Hadil & Albert, 2001). The Asymptotic length (L_∞) and growth constant (K) of some penaeid shrimps of Bangladesh (Khan et al., 2003) were L_∞ = 29.0cm and K = 1.29yr^{-1} for males of *P. monodon* while females were L_∞ = 32.5cm and K = 1.2yr^{-1}. *P. semisulcatus* L_∞ = 24.7cm and K = 1.36yr^{-1} for male, L_∞ = 25.6cm and K = 1.28yr^{-1} for females. P. *merguiensis* L_∞ = 17.92, K = 1.235 for males while L_∞ = 22.10 and K = 1.299 for female. In males of *Metapenaeus monoceros* L_∞ = 17.50cm and K = 1.40yr^{-1} while female L_∞ = 18.0cm and K = 1.32yr^{-1}. All available research on penaeid shrimps show *P. monodon* to have the highest asymptotic length. *Metapenaeus elegans* has maximum length of 4.26cm at 1.3yr^{-1} growth rate (K) (Suradi, 2010).

Dinh *et al*., (2010) reported the growth of eight species of shrimps in littoral marine waters of the Mekong Delta as follows: *Haliporodes sibogae* L_∞ = 12.8cm and K = 0.77yr^{-1}, *Harpiosquilla harpax* L_∞ = 21.0cm and K = 0.89yr^{-1}, *Metapenaeus affinis* L_∞ 19.0cm and K = 1.00yr^{-1}, *Metapenaeus brevicomis* L_∞ = 15.5cm and K = 0.87yr^{-1}, *Metapenaeus tenuipes* L_∞ = 14.5cm and K = 0.78yr^{-1}, *Parapenaeopsis cultrirostris* L_∞ = 19.0cm and K = 0.45yr^{-1}, *Parapenaeopsis* gracillima L_∞ = 10.2cm and K = 0.79yr^{-1} and *Parapenaeopsis maxillipedo* L_∞ = 13.5cm and K = 1.30yr^{-1}. The largest size shrimp (*Harpiosquilla harpax*) was 21.0cm while the smallest (*Parapenaeopsis gracillima*) was 10.2cm (Dinh *et al.,* 2010). Shrimps grow rapidly and reach reproductive maturity at the age of six months. Commercial value increase as they grow larger over 9 to 12 months (Dichmont *et al*., 2007).

This research was necessitated by the paucity of knowledge in length-weight relationship, condition factor, age and growth of this economically important invasive shrimp species which is established in Nigeria's waters. The study therefore, aimed at providing a baseline data on some aspects of the biology of the black tiger shrimp (*Penaeus monodon*) for further investigation.

II. Materials and Methods

a) Study Area

The Andoni river is located between latitudes 4^{0}28' to 4^{0}45' N and longitudes 7^{0}45' E (Figure 1). It is a major fish nursery in the Niger Delta region of Nigeria, West coast of Africa.

The Andoni River, which is one of the numerous rivers through which rivers Niger and Benue drain into the Atlantic Ocean, is located within the rainforest belt of Nigeria (Francis, 2003).

The fishers use tide movement to aid their transport during fishing since they primarily use dugout canoe (unmotorized canoe) in fishing. The Andoni river is brackish with annual salinity range of 10 – 28% (Yoloye, 1976), 5% to 22% (Francis, 2003).

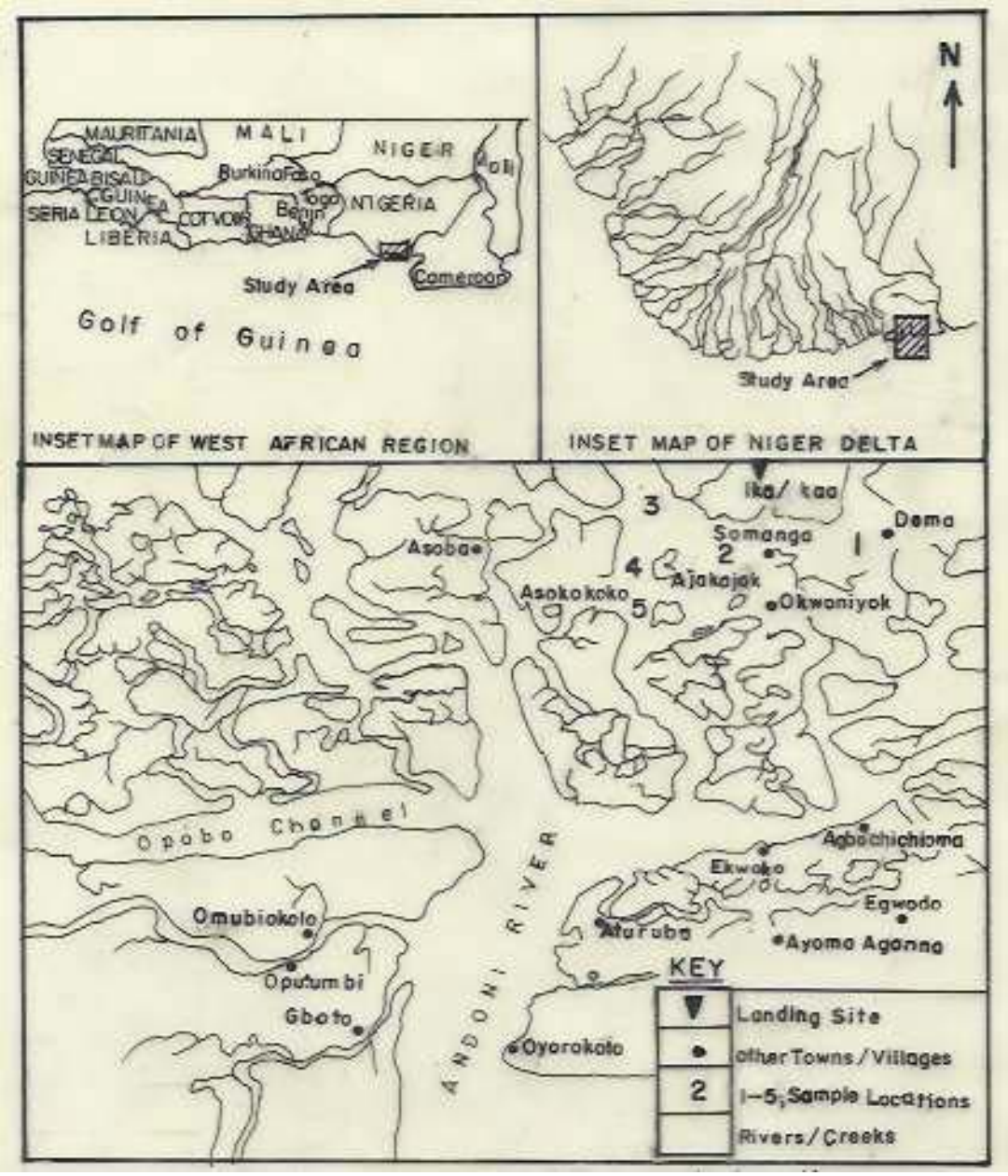

Fig. 1: Map of Andoni river system showing sample locations (Source: Francis *et al.*, 2007)

The Andoni river system has two main landing sites viz; Kaa water front and Oyorokoto fishing settlement. Kaa water front is located between $4^0$33.915'N to $4^0$34.248'N and $7^0$21.746'E to $7^0$22.637'E (fig 1). Kaa (Ika) fish market is the major point of sales of live, fresh and smoked fish products.

b) Research design

Landing survey, otherwise known as catch assessment survey described by Stamatopoulos (2002), was conducted at Kaa landing site once in every first week of the month for a period of twelve months (from March, 2012 to February, 2013). The data collected included quantity of catch, species composition, associated effort, and other secondary data such as prices, weight and length of the black tiger shrimp landed (Sobo, 2004).

c) Fish Sampling

A representative minimum sub-sample of 30 pieces of the Black tiger shrimp (*P. monodon)* was collected monthly at Kaa landing site. The sub-sample was an estimated fraction of the entire catch landed per day.

d) Length Measurement

Total length (distance from tip of rostrum to the tip of telson) of each shrimp of the sub-sample was measured using a digital Vernier caliper and transparent plastic ruler. Measurement of lengths was recorded in centimeter.

e) Weight measurement

The weight of each specimen was determined using Ohaus electronic weighing balance. Measurement of weight of shrimp was done by zeroing the weight of a plastic bowl and then placing the specimen in the bowl. Weight was measured in grams.

Length analysis was in accordance with FAO ICLARM Stock Assessment Tool (FiSAT) software format Gayanilo and Pauly (1997) in which only the mid-lengths and mean weights of the classes were employed. ELEFAN1 method (Gayanilo *et al.,* 1989) incorporated in FiSAT software with starting sample 11 and starting length 27.50 gave the best score function of 0.911. This generated the best combination of growth parameters.

f) Length-Weight Relationship

The length-weight relationship of the shrimp was estimated using linear regression (Pauly, 1983). The technique is incorporated in the FAO ICLARM Stock Assessment Tool (FiSAT) Gayanilo and Pauly (1997) which is used in fisheries.

The length-weight relationship was obtained from the equation;

$$W = aL^b \quad \text{(Pauly, 1983; Sparre } et.al.,\text{ 1989)----------} \quad (1)$$

Where
W = Weight of shrimps (g)
L = Length of shrimps (cm)
a = Intercept
b = Slope

The values of 'a' and 'b' was given a logarithmic transformation according to the following formula:

$$\text{Log}_{10}\, W = a + b \log L \text{ (Pauly, 1983) ----------} \quad (2)$$

The intercept "a" in the formula was estimated with the formula:
Where $Y = \log_{10} W$
and $X = \log_{10} L$
Y = Weight of shrimps
X = Length of shrimps

This formula corresponds to the linear regression routine option 3 in FiSAT (FAO-ICLARM Stock assessment tool) software used for the analysis. The data used in this analysis were lengths and weights measurement of *P. monodon* landed at Kaa landing site of the Andoni river system from March 2012 to February 2013.

g) Condition factor

Condition factor is the plumpness of a shrimp. It determines the well being of shrimp species in a particular water body. The condition factors of the shrimps were estimated from Fulton's Condition (K) as suggested by (Enin, 1995; Gayanilo *et al.,* 1989).
For isometric growth

$$K = \frac{100W}{L^3} \quad \text{.....(3)}$$

For allometric growth

$$K = \frac{100W}{L^{3.5}} \quad \text{.....(4)}$$

Where K = Condition factor
W = Wet weight of sampled shrimp (g)
L = Total length of the shrimp (cm)

The data used in this analysis were the monthly lengths and weights measurements of *P. monodon* landed at Kaa landing site of the Andoni river system.

h) Age and growth

Age structure of the shrimps obtained during the period of study was estimated using the modified Peterson method also known as the integrated method (Pauly, 1983; Sparre *et al*., 1989). Monthly length measurement was pooled and plotted on a graph to obtain length frequency distribution for the period of study (March, 2012 to February, 2013) at 5cm class interval. The same process was repeated along the time axis on the assumption that growth pattern repeats itself from year to year. Pauly's integrated frequency model is based on the assumption that growth in length is rapid initially, then decreasing smoothly, passing through most of the discrete peaks. The single smooth curve is assumed to represent the average growth of *P. monodon* as the growth pattern repeats itself yearly.

The relative age and corresponding modal lengths of *P. monodon* from the Andoni river system were read from the length-frequency distribution plot. The data obtained from the relative ages and their modal lengths were fed into FiSAT as length- at-age data to produce estimates of asymptotic length ($L\infty$), growth performance index (ϕ), slope (b), growth rate (K), and longevity (t_{max}). The relative ages and modal lengths of *P. monodon* were determined by tracing the progression of modes identified in the Pauly (1983) integrated distribution curve (Figure 3) and represented in Table 3.

III. Results

a) Length-Weight Relationship

The parameters of length-weight relationships (Table 1) for combined sexes of *P. monodon* from the Andoni river system indicated that the 'b' values ranged from 1.2999±0.0692 to 1.4604±0.0828, while 'a' values varied from -0.0332 to -0.1567 and the regression coefficient 'r' ranged from 0.9401 to 0.9781during the period of the study. The regression between total length and total body weight (Figure 2) showed negative allometric growth pattern.

b) Condition Factor

The Condition Factor (K) from March 2012 to February 2013 ranged from 0.5914 to 0.6909 (Table 2). Variation was very negligible indicating that the species grew in the same habitat and are exposed to the same condition throughout the period of study.

Table 1: The Regression of Length-Weight Relationship of *P. monodon* in the Andoni river system

Month	N	A	b±SD	95% CI of b	R
Mar-12	30	-0.0332	1.3813±0.0562	1.2661-1.4965	0.9776
Apr-12	30	-0.1567	1.4604±0.0828	1.2906-1.6302	0.9578
May-12	30	-0.1515	1.3920±0.0954	1.1964-1.5875	0.9401
Jun-12	32	-0.0742	1.2999±0.0692	1.1587-1.4412	0.96
Jul-12	30	-0.1015	1.3677±0.0781	1.2076-1.5279	0.9572
Aug-12	32	-0.1101	1.4063±0.0777	1.2479-1.5647	0.9572
Sep-12	32	-0.0552	1.3838±0.0537	1.2741-1.4934	0.9781
Oct-12	30	-0.0712	1.3904±0.670	1.2530-1.5277	0.969
Nov-12	32	-0.0738	1.4074±0.0674	1.2700-1.5448	0.9673
Dec-12	30	-0.0863	1.4232±0.0672	1.2854-1.5610	0.9701
Jan-13	33	-0.0889	1.3754±0.0702	1.2335-1.5173	0.9619
Feb-13	35	-0.0738	1.3923±0.0616	1.2692-1.5155	0.9692

Where N=Sample size, a and b= parameters of the Length-weight Relationship, SD= standard deviation of slope b, CI= Class Interval, r= Coefficient of correlation.

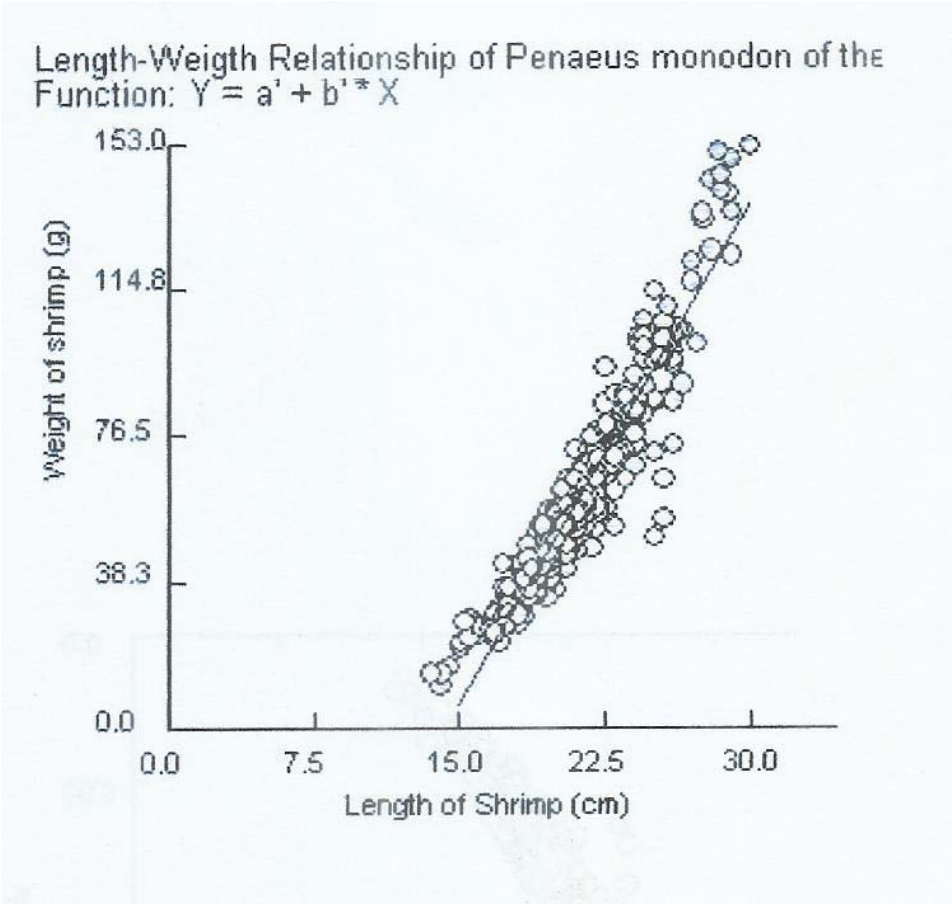

Fig. 2: Length-Weight Relationship of *P. monodon* of the Andoni river system

Table 2: Condition Factor of *Penaeus monodon* of the Andoni river system (March, 2012 to February, 2013)

S/N	Month	Mean Weight(g)	Mean Length(cm)	Condition Factor (K)
1	Mar-12	68.37	22.18	0.6266
2	Apr-12	65.59	21.35	0.6739
3	May-12	47.64	19.83	0.6109
4	Jun-12	38.26	18.4	0.6142
5	Jul-12	52.13	20.48	0.6069
6	Aug-12	60.79	21.38	0.622
7	Sep-12	66.74	22.3	0.6018
8	Oct-12	67.28	22.49	0.5914
9	Nov-12	63.53	20.95	0.6909
10	Dec-12	72.07	22.52	0.631
11	Jan-13	54.56	20.72	0.6133
12	Feb-13	58.81	50.57	0.6757

c) Age and growth Determination

Figure 3 showed that age was proportional to annual increment. As the stock gets older, growth slows down. The curve cutting through the ages (Figure 3) describes the growth pattern relative to age. Specimens were at their growth peak at age 2+. Five cohorts were identified. The 0+ cohort had a modal length (L_T) of 14cm while the 5th cohort had a modal length of 30cm as seen on Table 3.

From the length frequency distribution *P. monodon* of length 21cm was most abundantly caught during the fishing seasons. This length corresponds to two years (2+) of age (Table 3).

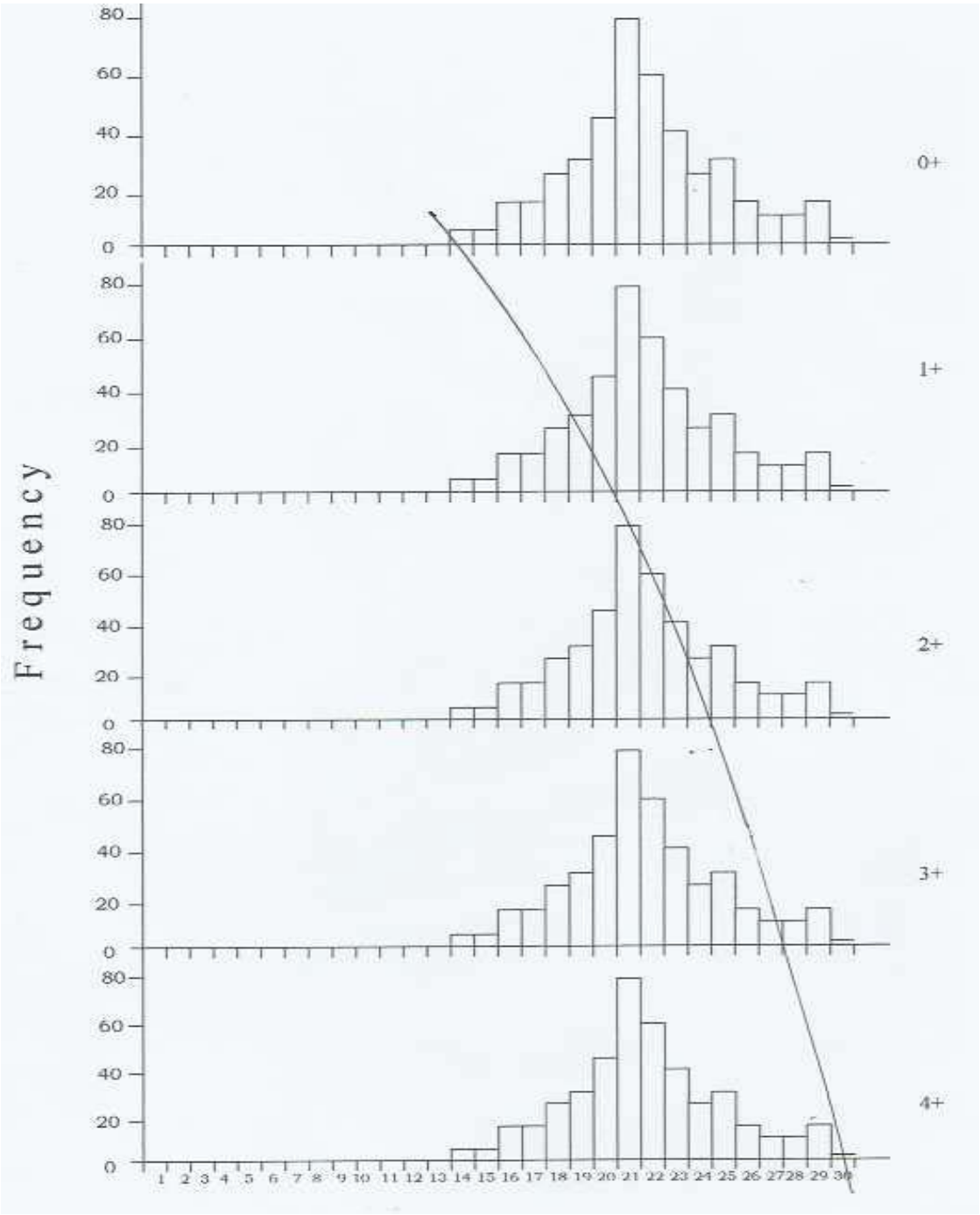

Figure 3: Pauly's Integrated Length-Frequency Method for estimating relative age of *P. monodon*

Table 3: Length at age and annual length increment of *P monodon* in Andoni river system

Age	Modal length L_T (cm)	Annual Increment	L_T+1
0+	14	14	19
1+	19	5	21
2+	21	2	27
3+	27	6	30
4+	30	3	

L_t +1 = Length separated by one year interval

III. Discussion and Conclusions

a) Length-Weight Relationship

The length-weight relationship of *P. monodon* in the Andoni River indicated negative allometric growth pattern. The slope 'b' of the length-weight regression ranged from 1.2999 $\pm$ 0.0692 to 1.4604 $\pm$ 0.0828. These values are significantly less than 3 implying that the black tiger shrimp (*P. monodon)* becomes slender as it increases in length (Kurup *et al.*, 2000, Lalrinsanga *et al.*, 2012). Hadil and Albert (2001) reported negative allometric growth pattern in *P. monodon* of Kuara Baram (b = 2.16 & 2.43 for males & females respectively). Lalitha (1987) observed isometric growth in *P. monodon* (b = 3.19 & 3.25 for males & females respectively) of Kakinada. In Tanzania, Teikwa & Mgaya (2003) reported isometric growth in males and negative allometric growth patterns in females of *P.monodon* (b = 3.106 in males & b = 2.299 in females).

The growth rate of the black tiger shrimp (*P. monodon)* in the Andoni river system may likely be influenced by competition and adaptation challenges. Being an alien species, *P. monodon* requires some more time before population explosion can occur.

The low 'b' values indicated lower weight gained relative to increase in length. Similar low weight gain was reported by Lalrinsanga *et al.* (2012) in their studies on giant freshwater prawn. The low 'b' value reported in this study can also be attributed to lack of berried females in the landed population. Weight of maturing and berried females increases the b values (Lalrinsanga *et al.*, 2012). Peixoto *et al.* (2003) attributed about 8% of total body weight of *P. monodon* to additional weight of ovaries while in wild *Fenneropenaeus paulensis* 13% of body weight is attributed to the weight of ovaries.

b) Condition factor

The condition factor (K) of the black tiger shrimp (*P. monodon)* from the Andoni river system ranged from 0.5914 to 0.6909. These values are relatively lower compared to those of Lalrinsanga *et al*. (2012) where K ranged from 0.79 to 1.41, Okayi, & Iorkyaa (2004) where K = 1.014 and 2.031 and Okayi *et al.* (2012) in which K was 1.875 for *A. gabonensis* in Jebba River.

Indigenous species seem to have higher condition factor than exotic species. However, upon adaptation, exotic species compete favourably and in most cases dominate the population. The low condition factor of the black tiger shrimp can be attributed to competition and physico-chemical parameters of the new environment.

c) Age and growth

The asymptotic length ($L\infty$) of the black tiger shrimp (*P. monodon)* in the Andoni river system was 31.5cm and the growth coefficient (K) = 0.87yr^{-1}. Asymptotic length, however, ranged from 25.8 to 36.3cm. This is comparable to the asymptotic length ($L\infty$) of 35.7cm reported by Lalitha (1987) for *P. monodon* in Kakinada, India.

The black tiger shrimp in Andoni river system is estimated to live up to 3.5yrs which is relatively higher than that of *Acetes japonicus* whose t_{max} is 2.14 years (Amin *et al.,* 2009). This is as a result of difference in species. *Penaeus notialis* (Farfantepenaeus) was estimated to live for 22 to 23 months and referred to as short-lived considering their longevity (Nwosu, 2009).

Length-at-age of the black tiger shrimp (*P. monodon)* in Andoni river system were 14cm, 17cm, 19cm, 21cm and 26cm for ages of 0, 1, 2, 3 and 4 years. Shrimps grow rapidly and reach reproductive maturity at 6 months of age. The larger the size, the higher the commercial value (Dichmont *et al.*, 2007), hence, the black tiger shrimp (*P. monodon)* was the most expensive shrimp species.

The growth performance index of the black tiger shrimp (*P. monodon)* (Φ = 2.936) was an indication of rapid growth rate which enhances the aquaculture potential of the species. Amin *et al*. (2009) reported the growth performance index of *Acetes japonicus* to be 3.073 which is quite high compared with 2.10 and 1.97 for females and males *Acetes chinensis* respectively (Oh and Jeong, 2003).

The length-weight relationship, condition factor, age and growth parameters are comparable to works done by earlier researchers indicating that the Andoni river system was suitable for the growth and wellbeing of the black tiger shrimp. A comparative study of the growth parameters of the native species of shrimps with the exotic black tiger shrimp (*P. monodon*) is however required for a holistic assessment of the quality of the brackish water condition of Andoni river system for sustainable production of the stocks.

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