First estimates of growth, recruitment pattern and length-at-first-capture of *Nematopalaemon hastatus* (Aurivillius, 1898) in Okoro River estuary, southeast Nigeria

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Abstract. The *Nematopalaemon hastatus* prawn fishery in Okoro river estuary, Nigeria, is of great ecological value and forms the bulk of economic rent and livelihood of the artisanal fishers and rural households. The fishery lacks vital scientific information needed for its management and sustainability. This study provides information on its growth parameters, recruitment pattern and length-at-first-capture using FAO–ICLARM Stock Assessment Tools (FiSAT II) software to analyse its consecutive 12-month length-frequency data (April 2011 to March 2012). The von Bertalanffy length (*Lt*) growth function was established as: $L_t = 76.13\,(1 - exp^{-1.0\,(t-(0.11)})$; optimum length, L_{opt} = 52.47 mm, potential longevity, $t_{max} \approx$ 2.73 years and overall growth performance index, φ' = 3.8046. The shrimp exhibited the continuous bimodal recruitment pattern (the major being in the rainy season and minor - early dry season). The recruitment pattern closely corresponds to its spawning season, implying need for reduced exploitation during this reproductive period. The length-at-first-capture, L_c = 22.29 mm suggests exploitation of the juvenile population; which was confirmed by the critical size ratio (L_c/L_∞) of 0.292; indicating need for increase in mesh size to reduce fishing pressure on the stock and to improve the health status of the fisheries resource.

Key Words: crayfish, fishery policy, overfishing, resource sustainability.

Introduction. Growth, recruitment and length-at-first-capture are among vital scientific information needed for the management and sustainability of a fishery. Other key factors are fecundity and mortality (natural or by interaction with fishing gear). These biological parameters qualify the resilience of a fishery. Growth is generally regarded as increment in size in terms of length and weight while recruitment has multiple meanings in fisheries science in terms of number, area or size. Recruitment is described as births, i.e., number of fish born within a given time period that survive to the juvenile stage. Such may include the number of eggs spawned, the number of larvae hatching from those eggs, the number of juveniles which survive from the larval stage, or the number of individuals surviving to any particular age (Kilduff et al 2009). Recruitment also refers to the entrance or addition of young fish each year into an exploited fishing area where they become vulnerable to a particular size: i). due to growth of smaller-sized individuals and/or ii). due to migration into the fishing area (like movement of young fish from nursery area into the main fishing ground) or iii). due to type of fishing gear (Kilduff et al 2009). Recruitment is typically described in terms of 'annual recruitment', the number of survivors in each year, also known as a 'cohort' or 'year-class' (Pauly 1984). This paper is concerned with the second usage of recruitment. Consequently, growth and recruitment are major sources of variability in fish populations. The recruitment pattern is also a consequence of gear selectivity; the mean age of the recruits generally depends on the type of gear applied. Recruitment pattern allows the identification of the number of recruitment pulses per year and evaluating the relative importance of these pulses when compared to each other. The general recruitment pattern of a species may be obtained by comparing the size composition of actual catches with known selectivity of gear (Pauly 1984). The length-at-first-capture is an important input in the computation of relative yield-per-recruit, relative biomass-per-recruit and in determining the exploitation level that produces the maximum yield-per-recruit (E_{max}).

Nematopalaemon hastatus (Palaemonidae; Aurvillus, 1898) is a major component of the shrimp fisheries in Okoro river estuary and of great economic and ecological importance in the structure of the ecosystem. It is a valuable commodity in diet of Nigerians, and forms the bulk of economic rent of rural communities and livelihood of the artisanal fishers in southeast Nigeria; all of which depend on its harvestable stock. The nutritional data of *N. hastatus* shrimps in Okoro river estuary indicates it is rich in protein (54.3%) and moisture contents (65.30%), yet very low in fat and calorie content. Hence, it is a healthy food, snack or food ingredient suitable for children, the elderly and for animal feed component (Ukpatu & Udoh 2016). Egwari & Oniha (2014) further demonstrated the potential of exoskeleton of *Penaeus notialis* shrimps (including *N. hastatus*) as culture media to support microbial growth for assessing microorganisms.

Several authors have reported on aspects of the biology and management of this species. Enin et al (1991) studied the *N. hastatus* fishery in the outer Cross River Nigeria estuary and identified the negative impact of the intensive fishing activity in the area to include growth overfishing, i.e., shrimps harvested are not allowed to attain their potential maximum size. Ofor & Kunzel (2013) described the fishery and reproductive cycle of *Nematopalaemon hastatus* in the Cross River estuary while Omoregie (2016) showed that abiotic factors such as pH (6.7-7.5), temperature (27.5-28.2°C), depth (24.5-121 cm), and primary productivity nutrients are the major determining factors to the distribution and survival of the palaemonid shrimps in inland freshwaters. Eniade & Bello-Olusoji (2011) further observed the species were sub-lithoral, inhabiting areas with soil textures ranging from silty-loam to silty-clay at maximum mean depth of 0.67±0.025 m with macrophytes such as *Eichhornia crassipes*, *Paspalum vaginatum*, and *Pistia stratiotes* providing cover at breeding grounds

A frame survey of the *Nematopaleamon* shrimp fishery in the study area established excessive fishing effort with a mean of 3±1 crew men per canoe; 1539 canoes manned by 4457 fishers in a total of 26 fishing villages in/around the estuary (Ukpatu et al 2015) while 85% of the catch comprised shrimps (seven shrimp species) with 14% bycatch; generally, juveniles (0.32-46 cm total length) of 41 fish species of 29 families (mainly Sciaenidae and Clupeidae); and 0.81% crabs/squids. *N. hastatus* is the dominant species (71.93%) in the coastal waters of Ondo State, southwest Nigeria (Olawusi-Peters & Ajibare 2014) while Ngodigha et al (2015a) recorded 90% catch of the target shrimps (mainly *Palaemon maculatus* and *N. hastatus*) in the River Nun Estuary with by-catch (10%) comprising juvenile fishes (8%) and macro-invertebrates (1.55%) and other non-target shrimps (0.45%). The gears employed in the shrimp fishery are particularly non-selective and destructive. Such includes bag net (Ngodigha et al 2015a; Ukpatu & Ambrose 2016), dug-out motorized canoes (12 m long) equipped with 8-45 Hp and non-motorized canoes (8 m long) equipped with 3x3x3 polythene sail and paddles (Ukpatu et al 2015). Others are beach seine, push net and trap (single chamber, non-return, valve trap) (Nwosu 2010). In solving the bycatch problem associated with shrimp fishery, Ambrose & Isangedighi (2016) suggested incorporating a flapper bycatch reduction device (BRD) to the stow net bunts of conventional artisanal fishing. The BRD achieved a significant ($p < 0.01$) 54.4% reduction in the bycatch of juvenile fishes with no significant reduction (5%) in the quantity of the target shrimps, *N. hastatus* ($p > 0.01$). Several authors recorded bimodal recruitment pattern for *N. hastatus* and other palaemonid shrimps (Pauly et al 1984; Nwosu & Wolfi 2006; Dash et al 2013; Ngodigha et al 2015b; Ukagwu & Deekae 2016).

This study seeks to provide some vital baseline information and reference points for the sustainable management of the *N. hastatus* stock in the Okoro River estuary of Nigeria (which are presently lacking) and for comparison with *Nematopalaemon* populations of similar tropical environments.

Material and Method. The study was conducted in the Okoro River estuary, located in the Niger Delta region, southeast of Nigeria on latitude 4°33’N and 4°55’N and longitude 7°45’E and 7°55’E (Figure 1). It has an area of about 1000 km^2, maximum length of 132-135 km, maximum width of 65-105 km and maximum depth is approximately 58.2 m (AKUTEC 2006), and it empties into the open sea - Atlantic Ocean. The Okoro River estuary forms a nexus of 13 tide-dominated creeks and 22 tributaries (Udoidiong 2005), with little fresh water input, thus, creating a complex but rich aquatic ecosystem and habitat.

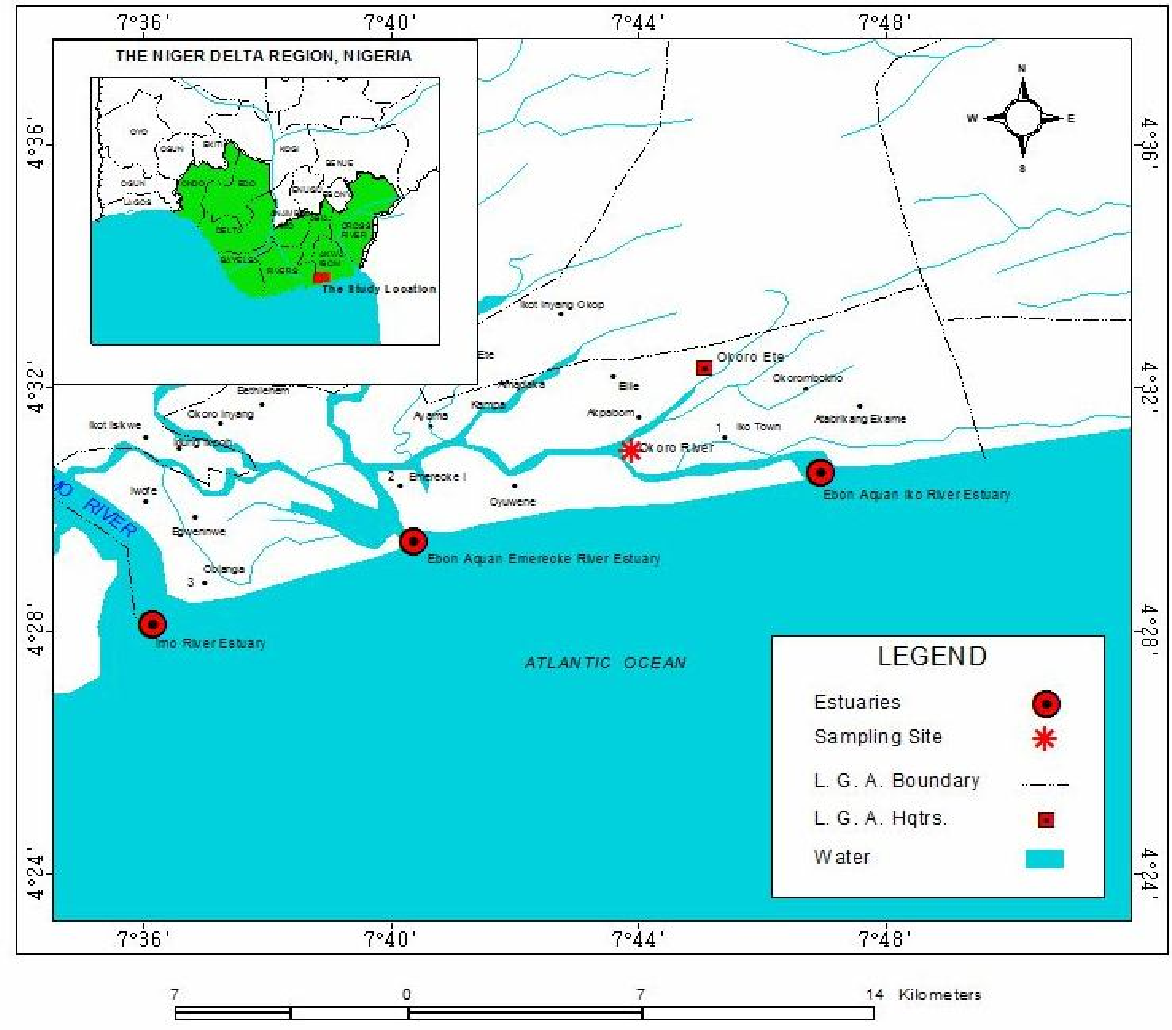

Figure 1. Location of sampling site, Eastern Obolo, Southeast Nigeria.

Sampling procedure. A total of 6,768 individuals of *N. hastatus* were collected over 12-consecutive months (April 2011 - March 2012) from shrimp artisanal fishers in Okoro River estuary, Southeast Nigeria, at the Elekpon Okoro fishing villages (04°50’N and 07° 55’E). The shrimpers utilized anchored conical trap nets (*Anyima*) of nylon materials, with a rectangular opening (2.5 m wide and 2.0 m high, opening coefficient of 0.8) and 7 m long net with mesh size of 0.9 cm at the cod-end to 2.8 m near the mouth. In the laboratory, samples were identified using the keys of Powell (1980) and Schneider (1990), sorted, sexed; and carapace length (CL) measured to the nearest 0.1 mm, from the base of the eye socket to the tip of the telson using vernier calipers and the total weight (TW) measured by an electronic balance (model: Ohaus Scout Pro SPU402) to the nearest 0.01 g. The length-frequency data were grouped into 5 mm size-class intervals.

The FAO–ICLARM Stock Assessment Tool (FiSAT II, Version 1.1.2) software (Gayanilo & Pauly 1997; Gayanilo et al 2002) was used to analyse the monthly length-frequency data (Table 1). The ELEFAN procedure in FiSAT was then used to sequentially arrange and restructure the monthly length-frequency data set from which a preliminary L_∞ value was seeded. The ELEFAN-1 routine (Pauly & David 1981) was used to fit the Von Bertalanffy Growth Function (VBGF): asymptotic length (L_∞) and growth coefficient (K), using equation proposed Pauly & Gaschutz (1979):

$$L_t = L_\infty (1 - exp^{-K(t-t_0)})$$

where:
L_t = length at age, t (in age);
L_∞ = asymptotic length (cm);
K = Von Bertalanffy growth coefficient (year^{-1});
t_0 = age of the fish at zero length.

Pauly's (1980) empirical equation: $Log_{10}(-t_0) = -0.3922 - 0.2752\, Log_{10} L_\infty - 1.038\, Log_{10} K$ estimated the t_o while $L_{opt} = L_\infty[3/(3 + M/K)]$ estimated the optimum length, L_{opt}, where L_∞ and K are parameters of the von Bertalanffy growth function, and M is the instantaneous rate of natural mortality (Froese 2006). The potential longevity was estimated as: $t_{max} = 3/K$ (Pauly 1980). The Pauly & Munro (1984) equation: $\varphi' = \mathrm{Log}\, K + 2\, \mathrm{Log}\, L_\infty$ quantified the overall growth performance index, φ' to assess the reliability of L_∞ and K. The instantaneous rate of natural mortality (M) was estimated from Pauly's (1980) empirical formula: $Log\, M = -0.0066 - 0.279\, Log\, L_\infty + 0.6543 log K + 0.463\, Log\, T$, where T was 29.0°C (the mean annual surface water temperature in the study area).

The FiSAT II routine, using NORMSEP (Pauly & David 1981; Enin et al 1996; Etim & Sankare 1998) automatically decomposes and reconstructs the recruitment pattern by backward projection of the length-frequency data onto a one-year time scale (Pauly 1984). With asymptotic length (L_∞), growth coefficient (K), growth performance index (φ') and the slowest growth period or winter point (WP), as input parameters; the FiSAT II procedure fits the recruitment pattern with one or two normal distributions (pulses) per year, indicating the relative strength of each pulse.

The probability of capture, P, of each length class *i* of *N. hastatus* was estimated using the ascending left arm of the carapace length-converted catch curve (Pauly 1987). This involves dividing the numbers actually sampled by the expected numbers (obtained by backward extrapolation of the straight portion, i.e. the right descending part of the catch curve) in each length class of the ascending part of the catch curve. Plotting the cumulative probability of capture against mid-length of class interval results in a curve from which the carapace length at first capture, CL_c, was derived. The CL_c is taken as corresponding to the cumulative probability at 50%. This represents the size at which 50% of the catches are retained by the gear or 50% of the recruits are under full exploitation. The carapace length at 25% and 75% exploitation (CL_{25} and CL_{75}), respectively, were also estimated for the shrimps under study. The probabilities were smoothed using a running average procedure and logits transformation.

Results. The monthly length-frequency data of 6,768 specimens of *N. hastatus* collected for 12 months used in the present analysis are provided in Table 1. The best values of the seasonalized VBGF were estimated as: K = 1.1 yr^{-1}, L_∞ = 76.13 mm; the amplitude of growth oscillation, C = 0.95 and the Winter Point, WP (period when growth is slowest) = 0.25. The parameter (theoretical age, t_o) of the von Bertallanffy growth model could not be calculated from length frequency data alone; however, it was estimated empirically as, t_o = - 0.11. From these parameters, Von Bertalanffy length (Lt) growth function for the species was established as: $L_t = 76.13\,(1 - exp^{-1.0\,(t-(0.11)})$. The optimum length, L_{opt} = 52.47 mm while the instantaneous rate of natural mortality, M = 1.4880. The potential longevity of the shrimp, $t_{max} \approx$ 2.73 years while the overall growth performance index, φ', was quantified as 3.8046.

Table 1

Length-frequency data of *Nematopaleamon hastatus* from Okoro River estuary, southeast Nigeria: April 2011-March 2012 (n = 6,768; Size-class intervals = 5 mm)

ML	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Total*
7.5	6	0	0	0	0	0	4	2	8	4	2	4	30
12.5	44	6	2	2	8	4	54	8	20	16	42	36	242
17.5	138	14	10	8	16	6	172	84	70	12	104	60	694
22.5	52	28	16	12	24	34	70	76	82	180	130	142	846
27.5	50	42	36	20	22	80	78	90	60	104	100	160	842
32.5	86	52	40	46	48	66	54	60	86	94	112	178	922
37.5	78	84	80	58	72	90	56	96	76	80	62	100	932
42.5	48	78	62	72	30	44	40	42	48	134	52	86	736
47.5	22	46	32	28	32	60	32	50	42	106	50	72	572
52.5	18	34	22	18	24	20	30	38	50	30	32	48	364
57.5	14	24	18	10	20	6	28	20	38	20	26	20	244
62.5	12	16	14	6	14	4	26	16	30	24	18	16	196
67.5	8	8	6	2	6	2	20	8	24	6	14	14	118
72.5	2	0	2	2	2	0	2	0	8	4	0	8	30
Sum	578	432	340	284	318	416	666	590	642	814	744	944	6768

ML = mid-length (mm).

Probability of capture (length-at-first-capture). The computed length-at-first capture, L_{50} or L_c (length at which 50% of *N. hastatus* entering the gear are retained) was L_c = 22.29 mm total length (TL) and (L_c) = 21.54 mm TL, by logistic transformation and running average routines, respectively.

Recruitment pattern and proportions of ovigerous females and juveniles. Table 2 and Figure 2 show continuous recruitment throughout the year with many micro-cohorts. The recruitment pattern shows two peaks (i.e., bimodal recruitment) of unequal pulse strengths in a year overlapped in time to give a continuous year-round pattern (Figure 2).

Table 2

Recruitment pattern of *N. hastatus* from Okoro River estuary, southeastern Nigeria

Sampling months	*% Recruitment*
April, 2011	1.24
May, 2011	2.98
June, 2011	3.75
July, 2011	6.12
August, 2011	9.28
September, 2011	13.19
October, 2011	15.17
November, 2011	18.16
December, 2011	18.58
January, 2012	10.46
February, 2012	1.08
March, 2012	0.00

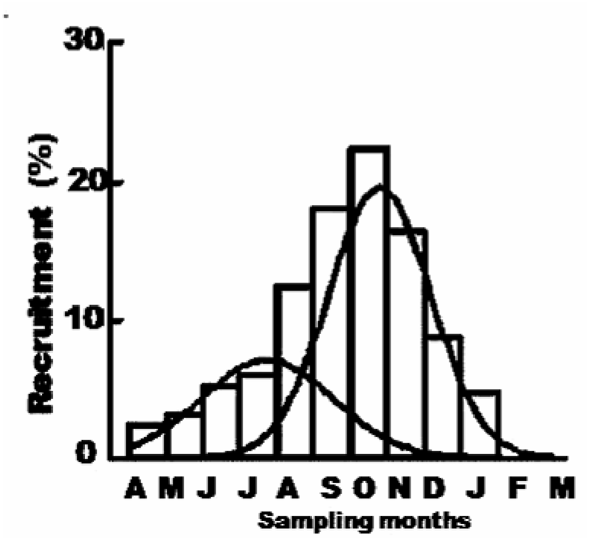

Figure 2. Continuous bimodal recruitment pattern of *N. hastatus* exhibiting micro-cohorts and two peaks of unequal pulse strengths; decomposed using NORMSEP routine and fitted with two Guassian distributions.

The major pulse is in September (10.36% recruitment) between July and October; the minor mode was in April (19.63%), between March and May. Temporal variations in the spawning stock (proportion of gravid females) and percentage abundance of juveniles of *N. hastatus* are also shown in Figure 3. Reproduction/spawning activity peaked in March and September, hence, juveniles (i.e., specimens ≤ 17.5 mm mid-length class; Table 1) blossomed in April and October-November (Figure 3a). This indicates that increase in the size of parent stock in March and September is accompanied with increases in recruitment in April and October, correspondingly; thereafter, the population stabilizes or varies randomly.

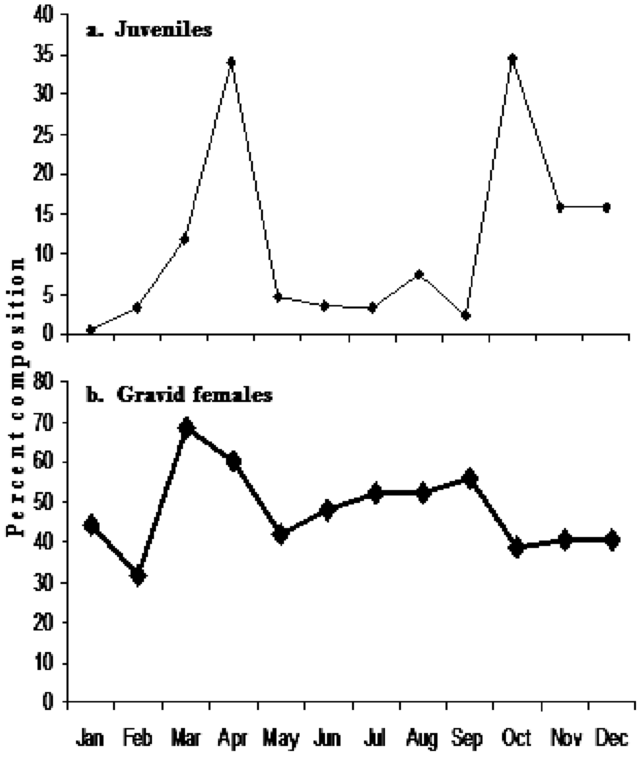

Figure 3. Temporal variation in the proportion of juvenile (a) and gravid females (b) of *N. hastatus* in Okoro River estuary, Southeast Nigeria.

Discussion. The growth and von Bertalanffy growth function (VBGF) parameter, L_∞, is a major parameter in evaluating the status of the population. The computed L_∞ = 76.13 mm in this study compares with 73.4 mm for related *Nematopalaemon tenuipes* from the Saurashtra Coast, India (Kizhakudan & Deshmukh 2009) but higher than L_∞ = 13.38 and 16.7 mm reported for this species by Ngodigha et al (2015b) and Enin et al (1996), respectively. The *K* value of 1.1 per year estimated in this study is higher than *K* = 0.62 yr^{-1} (Enin et al 1996) but comparable to *K* = 1.50 yr^{-1} (Ngodigha et al 2015b) for the same species; all of which falls within the range of value estimated for various stocks of shrimp species: 0.39 and 1.6 per year (Pauly et al 1984).

The amplitude of growth oscillation, *C* = 0.95, indicates that growth does not completely cease, but slows down during the unfavourable period. The Winter Point (WP) value of 0.25 indicates that growth of *N. hastatus* is poorest in the period between February and March, in the dry season. Two factors may inform this condition: first, the reproductive activity of the species comes to a peak in March (Enin et al 1996). At such period, ingested or stored energy is largely channeled into reproductive activity for maximum spawning successes, thereby slowing down growth at this period. Second, during the months of February and March the surface water temperature of the Okoro River estuary was higher (34.2^{o}C) than the average (28^{o}C). Such higher temperatures cause greater expenditure of energy, reduced feeding and slowing down of growth. The abundance and dynamics of the copepod community (food of shrimps) fluctuates with water temperature. Enin et al (1996) obtained C = 1.0 and WP =0.1, for the same species, comparable to this study.

The overall growth performance index, *φ'* = 3.8046, of this study is higher than the estimated values for other Palaemonid shrimp species stocks (2.43 reported for the same species by Enin et al (1996) and Ngodigha et al (2015b); 2.05 for *M. vollenhovenii* in Lagos Lagoon - Abohweyere & Falaye (2008); 2.48 for *M. macrobrachion* in the Cross River estuary, Nigeria – Enin (1995); 2.28 obtained by Etim & Sankare (1998); 2.75 and 2.69 for *P. notialis* males and females, respectively - Nwosu & Wolfi (2006)). These disparities may be attributed environmental peculiarities at the different locations

Length-at-first capture. Probability of capture analyses provide reasonable estimates of mean size-at-first-capture L_c for *N. hastatus* to be 22.29 mm and 21.54 mm, using logistic transformation and running average methods, respectively (Figure 4).

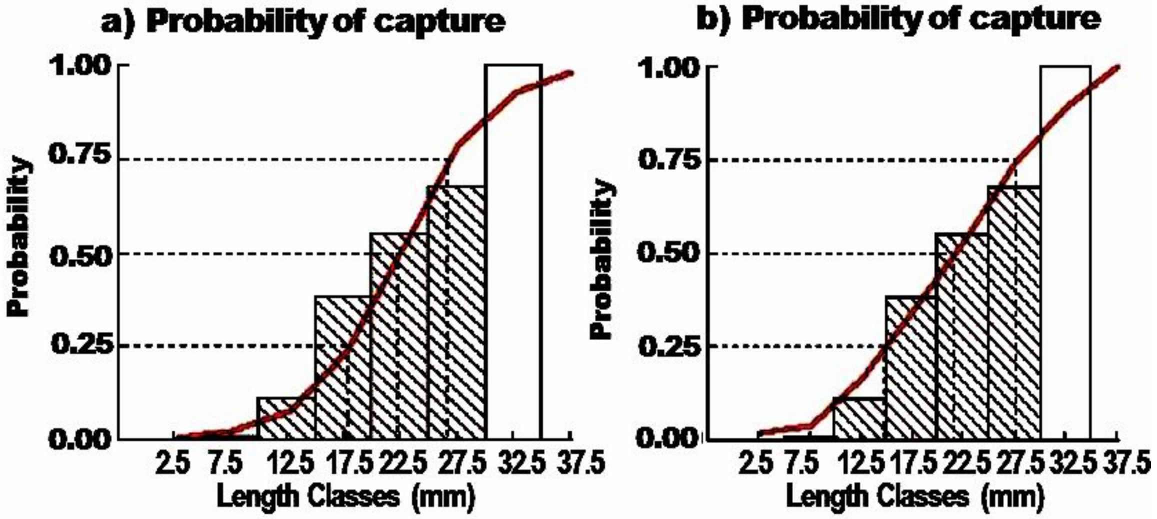

Figure 4. Probability of capture by length class of *N. hastatus* estimated from the ascending arm of the catch curve (Y = -5.56 + 0.25X, r = 0.96). The lengths-at-first-capture are L_{50} = 22.29 mm, L_{25} = 17.89 mm, L_{75} = 26.70 mm and L_{50} = 21.54 mm, L_{25} = 14.77 mm, L_{75} = 27.75 mm by logistic transformation (a) and running average routines (b), respectively. The estimated length-at-first-capture (dotted lines at the middle) is one of the inputs in computing the relative yield-per-recruit, relative biomass-per-recruit and plotting of the yield isopleth.

The logistic curves assume selection is symmetrical or nearly so, while the running averages smoothen the data sets by extrapolating the selection parameters. The estimated L_c in this study agrees with the values of 22.17 mm TL reported for this species off the Cross River estuary, Nigeria (Enin et al 1996). From the results, it implies that the smallest sizes susceptible to the exploitation method are juveniles. The critical size ratio (L_c/L_∞) which is a proxy for mesh size is 0.292, indicating overfishing. From the management point of view, the mesh sizes of the gear used in the resource exploitation should be increased to allow escape of young shrimps and to decrease the fishing pressure. This would enable more females participate in the reproductive activity and also to allow the young recruits to grow and reproduce in order to assure resource availability and sustainability.

Recruitment pattern. The bimodal recruitment pattern recorded for *N. hastatus* in this study (Figure 2) displayed continuous and varied intensity in recruitment (1.08 to 18.58%) with the two peaks having 1.24% and 18.46% recruitment, implying probably two cohorts were produced in the year. This bimodal recruitment was equally observed in *N. hastatus* populations in River Nun Estuary, Niger Delta, Nigeria (Ngodigha et al 2015b), in Cross River estuary off the Southeast coasts of Nigeria (Enin et al 1996); and in other palaemonid shrimps, such as *M. felicinum* and *M. vollenhovenii* in Akor River in Ibere Ikwuano, southeast Nigeria (Ukagwu & Deekae 2016), *M. vollenhovenii* from Cross River estuary, Nigeria (Nwosu & Wolfi 2006) and *M. vollenhovenii* from the Lagos – Lekki Lagoon system, Nigeria (Abohweyere & Falaye 2008). The continuous recruitment pattern with one or two pulses observed in this study conforms to the assertion of year-round recruitment common in tropical fish species and short-lived species (Dash et al 2013). The year-round recruitment and breeding is a typical feature of tropical species because of the relatively stable and elevated water temperatures in the tropics (Etim & Sankare 1998). The observed double peaks could probably be due to environmental factors that prevailed in the study area. Mueter et al (2007) assert that abundance and productivity of fish stock vary on inter-annual and interdecadal time scale as a result of environmental variations, species interactions and fishing activities. Moses (2001) also established that linear relationship exists between the inter-annual variations in the hydro-regime and the yearly fluctuations in the population structure of some coastal and estuarine fishes.

The position of the recruitment peaks was inferred to be the months of April and October which coincided with the preponderance or peaks of juveniles (Table 2, Figure 2), indicating juvenile recruitment pattern (window and intensity) into the fishery. This corresponds closely to the recruitment pattern exhibited by this same species off the Cross River estuary, with minor peak in March/April and major peak in October (Enin 1994). Other authors (Enin 1994; Enin et al 1996; Nwosu & Wolfi 2006; Abowei et al 2008) also made similar observations for this same species. September to November and February were the observed peaks for *M. vollenhovenii* in the Lekiki Lagoon in Lagos, southwest Nigeria (Abohweyere et al 2008); May and August in *P. sanguinolentus* (Dash et al 2013) and June and November for *N. hastatus* in Cross River estuary (Ofor & Kunzel 2013). Generally, recruitment patterns reflect length frequencies of catches (Nwosu & Wolfi 2006).

The works of earlier authors (Enin 1995; Enin et al 1996; Ofor & Kunzel 2013; Eniade & Bello-Olusoji 2013; Omoregie 2016) and this study uphold the assertion that reproduction in the West African population of *N. hastatus* peaks in the rainy season while recruitment peaks in the dry season (November-March). The logical consequence of this is that juveniles take advantage of the food resources in the estuaries during the dry season period while spawning or parent stock exploits the abundant resources of the estuaries and continental shelf during the rainy season.

Conclusions. The *N. hastatus* in Okoro River estuary, Southeast Nigeria, exhibits the typical bimodal recruitment pattern; the major in the month of April and the other in October. The length-at-first-capture (L_c= 22.29 mm) indicate capture of juveniles, yet to grow. This lower value may be attributed to higher fishing pressure on the stock. Proper management of this resource requires reduced exploitation and fishing pressure, particularly during the reproductive period or spawning peaks to enable more females participate in the reproductive activity and also to allow escape of young recruits to grow and reproduce in order to assure resource availability and sustainability. Food availability, spawning pattern, nature of breeding grounds and breeding habits coupled with shelter, hydro-regime and migration pattern are also major factors influencing the recruitment pattern of *N. hastatus* of the Okoro River estuary, Nigeria.

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References

Abohweyere P. O., Falaye E. A., 2008 Population parameters of *Macrobrachium vollenhovenii* in the Lagos-Lekki Lagoon System, Nigeria. Journal of Fisheries International 3(1):27-33.

Abohweyere P. O., Anyanwu A. O., Williams A. B., 2008 Recruitment pattern of *Macrobrachium vollenhovenii* in the Lagos-Lekki lagoon system, Nigeria. The Zoologist 6:55-60.

Abowei J. F. N., Davies A. O., Ngodigha S. A., 2008 The recruitment patterns of two palaemon shrimps and some physicochemical characteristics in the River Nun estuary, Nigeria. International Journal of Natural and Applied Science 4(4):396-401.

AKUTEC, 2006 Final Report for the Implementation of Akwa Ibom State University, 202 pp.

Ambrose E., Isangedighi I., 2016 Sea evaluation of flapper bycatch reduction device in stow net shrimp fishery. Nature and Science 14(12):1-6.

Dash G., Sen S., Koya K. M., Sreenath K. R., Mojjada S. K., Zala M. S., Pradeep S., 2013 Fishery and stock assessment of the three-spot swimming crab *Portunus sanguinolentus* (Herbst, 1783) off Veraval, Gujarat. Indian Journal of Fisheries 60(4):17-25.

Egwari L. O., Oniha M. I., 2014 Process and mathematical model in the formulation of microbiological media from the exoskeleton of crustaceans. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 5(8):206-209.

Eniade A. A., Bello-Olusoji A. O., 2011 The abiotic ecology of breeding ground of palaemonid prawns in the Ilaje Estuary, Ondo State, Nigeria. Continental Journal of Fisheries and Aquatic Science 5(1):31-37.

Eniade A. A., Bello-Olusoji A. O., 2013 Eco-morphological features and sex distribution pattern of palaemonid prawns in Ilaje estuary, South-western Nigeria. In: African fish and fisheries: diversity, conservation and sustainable management. Fifth International Conference of the Pan African Fish and Fisheries Association (PAFFA5), Bujumbura, Burundi, 16-20 September, 2013, Book of Abstracts, pp. 107.

Enin U. I., 1994 Length-weight parameters and condition factor of two West African prawns. Revue de Hydrobiologie de Tropicale 27(2):121.

Enin U. I., 1995 First estimates of growth, mortality and recruitment parameters of *Macrobrachium macrobrachion* Herklots, 1851 in the Cross River estuary, Nigeria. Dana 2(1):29-38.

Enin U. I., Lowenberg U., Kunzel T., 1991 The *Nematopalaemon hastatus* (estuarine shrimp) fishery in the outer estuarine region of the Cross River, Nigeria. Archives for Fischereiwissenschaft 41(1):67-88.

Enin U. I., Lowenberg U., Kunzel T., 1996 Population dynamics on the estuarine prawn (*Nematopalaemon hastatus*) (Aurivillius, 1898) off the southeast coast of Nigeria. Fisheries Research 26:17-35.

Etim L., Sankare Y., 1998 Growth and mortality, recruitment and yield of the freshwater shrimp, *Macrobrachium vollenhovenii,* Hoirklots, 1851 (Crustacea, Palaemonidae) in the Fahe Reservoir, Cote d'Ivoire, West Africa. Fisheries Research 38:211-223.

Froese R., 2006 Cube law, condition factor and length-weight relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology 22:241-253.

Gayanilo Jr. F. C., Pauly D. (eds), 1997 The FAO-ICLARM stock assessment tools (FISAT) reference manual, FAO Computerized Information. Series 8 (Fisheries), (FAO, Rome), 262 pp.

Gayanilo F. C., Sparre P., Pauly D., 2002 The FAO – ICLARM stock Assessment Tools (FISAT-II) User's guide. Computerized Information series FAO, Rome, Italy, 168 pp.

Kilduff P., Carmichael J., Latour R., 2009 Guide to fisheries science and stock assessments. Atlantic States Marine Fisheries Commission, National Oceanic and Atmospheric Administration Grant No. NA05NMF4741025, 74 pp.

Kizhakudan J. K., Deshmukh V. D., 2009 Fishery and population dynamics of the spider prawn, *Nematopalaemon tenuipes* (Henderson) along the Saurashtra Coast. Indian Journal of Fisheries 56(2):81-86.

Moses B. S., 2001 The influence of hydroregime on catch abundance and recruitment of the catfish, *Chrysichthys nigrodigitatus* (Bagridae) and the bonga, *Ethmalosa fimbriata* (Clupeidae) of southeastern Nigeria's inshore waters. Environmental Biology of Fishes 61:99-109.

Mueter F. J., Boldt J. L., Megrey B. A., Peterman R. M., 2007 Recruitment and survival of northeast Pacific Ocean fish stocks: temporal trends, covariation and regime shifts. Canada Journal of Fisheries and Aquatic Sciences 64:911-927.

Ngodigha S. A., Alagoa K. J., Daworiye P., Eremasi Y. B., 2015a Catch composition of bag net used in Palaemon fishery in River Nun Estuary, Bayelsa State, Niger Delta, Nigeria. International Journal of Advanced Research in Biological Sciences 2(5): 119-125.

Ngodigha S. A., Alagoa K. J., Alfred-Ockiya J. F., Abowei J. F. N., 2015b Aspects of the population dynamics of *Nematopalaemon hastatus* (Aurivillius 1898) in River Nun estuary, Bayelsa State, Niger Delta, Nigeria. International Journal of Current Research in Bisciences and Plant Biology 2(4):161-167.

Nwosu F. M., 2010 Species composition and gear characteristics of the *Macrobrachium* fishery of the Cross River Estuary, Nigeria. Journal of Ocean University of China 9(1):71-75.

Nwosu F. M., Wolfi M., 2006 Population dynamics of the giant African river prawn *Macrobrachium vollenhovenii* Horklot 1957 (Crustacea, Palaemonidae) in the Cross River Estuary, Nigeria. West African Journal of Applied Ecology (WAJAE) 9:1-14.

Ofor C. O., Kunzel T., 2013 Aspects of the fishery and reproduction of *Nematopalaemon hastatus* (Crustacea: Palaemonidae) in the Cross River Estuary, Nigeria. African Journal of Tropical Hydrobiology and Fisheries 13:1-4.

Olawusi-Peters O. O., Ajibare A. O., 2014 Species abundance and distribution patterns of some shellfishes in coastal waters of Ondo State, Southwest of Nigeria. International Journal of Fauna and Biological Studies 1(4):19-24.

Omoregie I. P., 2016 The abiotic ecology and prevalence of palaemonid shrimps (Crustacea: Palaemonidae) of Osse River, Edo State, Nigeria. Journal of Applied Life Sciences International 9(3):1-11.

Pauly D., 1980 On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal de Conseil International pour l'Exploration de la Mer 39(2):175-192.

Pauly D., 1984 Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM, Studies and Reviews 8, 325 pp.

Pauly D., 1987 Length-based methods in fisheries research. ICLARM Conference Proceedings 13:7-34.

Pauly D., David N., 1981 ELEFAN-1 BASIC program for the objective extraction of growth parameters from length frequency data. Meereforsch 28(4):205-211.

Pauly D., Gaschutz G., 1979 A simple method for fitting seasonally length growth data with a program for pocket calculators. International Council for the Exploration of the Sea, Demersal Fisheries Committee 1979/G/24, 26 pp.

Pauly D., Munro J. L., 1984 Once more on the comparison of growth in fish and invertebrates. Fishbyte 2(1):21.

Pauly D., Ingles J., Neal R., 1984 Application of objective methods for the estimation of growth, mortality and recruitment related parameters of shrimp stocks from length frequency data (ELEFAN 1 and 2). In: Penaeid shrimps - their biology and management. Gulland J. A., Rothschild B. J. (eds), Fishing News (Books), Surrrey, pp. 220-234.

Powell C. B., 1980 Key to shrimps and prawns (Crustacea: Decapoda, Natantia) of the Niger Delta Basin Development Authority Area. Consultancy Report, 5 pp.

Schneider W., 1990 Field guide to the commercial marine resources of the Gulf of Guinea. FAO species identification sheets for fishery purposes food and agriculture organization of the United Nation's Rome: FAFR/FUGO/Z, 268 p.

Udoidiong O. M., 2005 Studies on the impact of nipa palm (*Nypa fruticans* Wurmb) on the epibenthic communities of mangrove swamps of eastern Obolo Local Government Area, Akwa Ibom State, Nigeria. PhD Thesis, Department of Animal and Environmental Biology, University of Port Harcourt, Nigeria, 235 pp.

Ukagwu J. I., Deekae S., 2016 Sex population structure of *Macrobrachium felicinum* and *Macrobrachium vollenhovenii* in the Akor river, Ibere Ikwuano, Abia State. International Journal of Fisheries and Aquatic Studies 4(4):19-23.

Ukpatu J., Ambrose E., 2016 Analysis of shrimp bycatch in the *Nematopalaemon* shrimp fishery of Okoro River Estuary, southeastern Nigeria. Academia Arena 8(5):1-9.

Ukpatu J., Udoh J. P., 2016 Nutritional data on *Nematopalaemon hastatus* in Okoro river estuary, southeast Nigeria. International Journal of Fisheries and Aquaculture Research 2(3):34-42.

Ukpatu J., Etim L., Ambrose E., 2015 First record of artisanal fishing effort and characteristics of the *Nematopalaemon* shrimp fishery in the Okoro river estuary, southeastern Nigeria. International Journal of Fisheries and Aquatic Studies 4(2): 347-354.

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