

Population density dynamics of *Pachymelania byronensis* (Wood, 1828) (Gastropoda: Thiaridae) in the Cross River, Nigeria

King, R. P.¹ and Akpan, B. E.²

¹Ex-Department of Fisheries and Aquatic Environmental Management, University of Uyo, Nigeria

²Department of Animal and Environmental Biology, University of Uyo, Nigeria

*Corresponding author email: bassyakpan2015@gmail.com

Abstract

The ecology of an exploited population of the commercially important molluscan species, *Pachymelania byronensis* (Wood, 1828) was studied (January-December, 2018) in the lower Cross River, Nigeria, using density [number per hectare (N. ha⁻¹)] as measure of stock abundance. The results revealed that the river supports a considerable stock of the gastropod (density range: $D_{\text{range}} = 508000 - 12510000$ N. ha⁻¹; mean: $D_{\text{mean}} = 4849833$ N. ha⁻¹). The density decreased by 12002 N. ha⁻¹ (i.e. 10001667 N. ha⁻¹ mo⁻¹) between January and December, a reflection of the increasing human exploitation as the year progressed. However, the monthly density changes scored low stochasticity (randomness), a product of the resilience of the population to human exploitation. The monthly densities were significantly correlated with river limnological parameters, including surface temperature, discharge, water level, transparency, dissolved oxygen concentration and hydrogen ion concentration. The coefficients of determination showed the decreasing order of the importance of these parameters as: transparency (67.8%), water level (57.0%), surface temperature (43.5%), pH (40.5%), dissolved oxygen concentration (36.1%) and discharge (34.3%). The monthly values of biotic potential (r_{max}) were used to show trends in the population dynamics. Major density decreases were noted in February ($r_{\text{max}} = -5.456$) and December ($r_{\text{max}} = -2.931$) whereas notable density increases were recorded in January ($r_{\text{max}} = +3.204$) and November ($r_{\text{max}} = +3.052$). The value of the annual mean biotic potential (mean: $r_{\text{max}(\text{mean})} = -0.191$) portrayed the general effect of heavy human exploitation on the mollusc. Hence, the gastropod total mortality rate was high ($Z = -3.204$ yr⁻¹) The river carrying capacity of the gastropod was estimated at 12510000 N ha⁻¹. The monthly biotic potential correlated significantly with habitat temperature and dissolved oxygen concentration, two important life support parameters.

Keywords: *Pachymelania byronensis*; density; biotic potential; exploitation; Cross River; Nigeria.

Accepted: 17 December, 2020.

Introduction

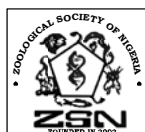
The macrobenthic gastropod mollusk, *Pachymelania byronensis* (Wood, 1828) inhabits large and medium – sized rivers in West Africa where it constitutes a relatively cheap animal protein source and can meet human nutritional requirements (Anyiam and Ikpesu, 2018). The artisanal fishery also provides employment and livelihood to several people throughout its geographic range.

The tidal freshwater lower Cross River, Nigeria, harbours a particularly large population of *P. byronensis* (King and Akpan, 2010) which supports a year-round artisanal dive fishery. The gastropod empty shells were used for the commercial production of scouring powder and animal feed. Thus the gastropod meat (flesh) and shells are of considerable economic importance. The exploitation of the Cross River, *P. byronensis* is not managed and there were no conservation strategies in place for this aquatic living resource. This was probably due to the dearth of published information on the biology and ecology of this species. Besides, King and Akpan (2010) and King (2013),

there were no other studies on the biology and ecology of this species. This study focuses on the population density dynamics of the species in the lower Cross River, Nigeria.

Materials and methods

Monthly samples of *P. byronensis* were collected (January-December, 2018) from the tidal freshwater lower Cross River at Ayadehe (Fig. 1) in Itu Local Government Area, (5° 12'N; 7° 58'E) Akwa Ibom State, Nigeria. The area is bounded in the north by Cross River State, west by Ibiono Ibom Local Government Area, east by Uruan Local Government Area and south by Uyo Local Government Area (Ekpo *et al* 2015). Detailed information on the study-area is given by Etim (1996); Etim and Enyenihi (1990); Etim and Umoh (1992); King (1998, 2013); Moses (1979, 1987, 1990); Teugels *et al* (1992). Long-term (30years) precipitation data for Itu (Tahal, 1979) indicates the existence of six seasonal periods: Early Dry Season (EDS ~ November), Mid Dry Season (MDS ~ December-



<http://dx.doi.org/10.4314/tzool.v18i1.10>

© *The Zoologist*, 18: 57-61 December 2020, ISSN 1596 972X.

Zoological Society of Nigeria



Textflow Limited

February), Late Dry Season (LDS ~ March-April), Early Wet Season (EWS ~ May – July), Mid Wet Season (MWS ~ August) and Late Wet Season (LWS ~ September-October).

The monthly mean water level closely followed the rainfall pattern. The water level starts to fall in November and reaches its minimum level in February- March. It starts to increase in May-June as the rains increase and reaches its maximum level in September.

The ranges of the key limnological parameters of the study area are: surface temperature (24.5-28.8°C), water level (1.3-8.3 m), discharge (195-6880 m³/s), transparency (0.29-1.75 m), pH (5.9-7.3) and dissolved oxygen concentration (3.5-6.5 mg/l). From these data, the decreasing order of the amplitude of variation ($AVR = X_{\max}/X_{\min}$) is: discharge ($AVR = 35.28$), river level ($AVR = 6.39$), transparency ($AVR = 6.03$), dissolved oxygen concentration ($AVR = 1.86$), pH ($AVR = 1.24$) and surface temperature ($AVR = 1.18$).

Sampling was conducted in across channel transects at Ayadehe using Petersen's grab (area of opening: 540 cm²) operated from a dugout canoe. Each grab sample was placed in a labelled polythene bag and transported to the laboratory where the gastropods were washed clean of adhering sediment particles and air-dried. Ecological density was expressed as the number of gastropods per hectare of available habitat area (D , N.ha⁻¹). The month-to-month percent change in density (%C) was estimated according to LaMont *et al.* (1977) and Whitsitt *et al.* (1985) while the month-to-month maximum rate of population increase or biotic potential (r_{\max}) was estimated according to Odum (1971). Limnological parameters were taken from records maintained by the Department of Fisheries and Aquatic Environmental Management, University of Uyo, Nigeria. The monthly density stability or randomness was evaluated by computing the mean Euclidean distance (MED) for the month-to-month change in density. The MED was computed thus:

$$MED = [(x_2 - x_1)]^{0.5} / N \quad \dots 1$$

where x_2 = density in month x_2 ; x_1 = density in the month (x_1) preceding x_2 ; N = number of sample units (here $N=12$). The MED was scaled such that $MED < 1.000$ depicted low stochasticity; $MED = 1-5.000$ depicted moderate stochasticity; and $MED \geq 5.000$, high stochasticity or randomness. All statistical analyses were performed with the Excel package in Microsoft Word 2013.

Results

Density evolution and limnological correlates

A total of 360 grab samples were taken during this study of which 69 (19.2%) were positive with gastropod specimens while 291 (80.8%) were negative without gastropod specimens. The spectrum of monthly mean density estimates (Table 1) revealed a 24.6-fold variation, from a minimum density of $D_{\min} = 508000$ N.ha⁻¹ in December to a maximum density of $D_{\max} = 12510,000$ N.

ha⁻¹ in January. The annual mean density was $D_{\text{mean}} = 4849833.3$ N.ha⁻¹. The months with notable mean densities included February (9.2%), March (7.7%), May (8.1%), June (7.9%), October (7.9%), and November (16.3%). Densities were particularly low in August (4.8%), September (3.4%) and December (0.9%). Between January and December, the density decreased by 12002,000 N. ha⁻¹ (i.e. 2362.6%). This translates to an average monthly population density decrease of 100166.7 N. ha⁻¹mo⁻¹. The January – December decline in density yielded an annual total mortality rate of $Z = -3.204$ yr⁻¹. The gastropod density decreased as the mean individual weight (t) increased ($r^2 = 0.4697$, $n=12$, $p<0.02$) according to the linear equation:

$$D = 2E + 06W - 1E + 07 \quad \dots 2$$

Table 1: Monthly mean density (D , N.ha-1), %D, percent change (%C) and biotic potential (r_{\max}) of *P. byronensis* in the Cross River, Nigeria.

| Months | W (g) | Density (D) (N. ha ⁻¹) | %D | %C | r_{\max} (mo ⁻¹) |
|--------|-------|------------------------------------|-------|---------|--------------------------------|
| J | 1.13 | 12510000 | 21.4 | + 95.9 | 3.204 |
| F | 1.35 | 5340000 | 9.2 | -134.3 | -5.456 |
| M | 2.64 | 4480000 | 7.7 | -19.2 | -0.176 |
| A | 2.42 | 3290000 | 5.7 | -36.2 | -0.309 |
| M | 1.80 | 4700000 | 8.1 | +30.0 | 0.357 |
| J | 2.31 | 4570000 | 7.9 | -2.8 | -0.028 |
| J | 2.82 | 3980000 | 6.8 | -1048.2 | -0.138 |
| A | 3.54 | 2770000 | 4.8 | -43.7 | -0.363 |
| S | 4.89 | 1950000 | 3.4 | -42.1 | -0.351 |
| O | 1.77 | 4570000 | 7.9 | -42.1 | 0.852 |
| N | 1.49 | 9530000 | 16.4 | +57.3 | 3.052 |
| D | 2.73 | 508000 | 0.9 | +52.1 | -2.931 |
| Total | | 58198000 | 100.0 | -1775.9 | |
| Mean | | 4849833 | | | -0.191 |

W = mean individual weight; %C = percent change index.

which explained 46.9% of the variation in density. The percent density change indices (Table 1) showed that density increases in January, May, October and November while density decreases were evident in February, March, April, June, July, August, September and December. The sum of the increase factors (i.e. positive change indices) was +%C = 208.3 while the sum of the decrease factors (i.e. negative change indices) was -%C = 2025.4. The arcsine-transformed versions of these figures (i.e. 14.4 vs 45.0) revealed that the decrease factors significantly exceeded the increase factors ($X^2 = 7.958$, $df=1$, $p<0.005$). The sum of the decrease factors was 9.7 times the sum of the increase factors. Figure 1 shows the logistic curve that describes the monthly evolution of the mean density of *P. byronensis*. This is based on the rearrangement of the monthly mean densities in Table 1, from lowest to the highest. This curve was described by a cubic function of the form ($r^2 = 0.5351$, $n=12$, $p<0.01$):

$$D = 43541M^3 - 726221M^2 + 3E + 06M \quad \dots 3$$

which accounted for 53.5 % of the variation in mean density. In Equation 3, M = months (i.e $M_1 - M_{12}$ for

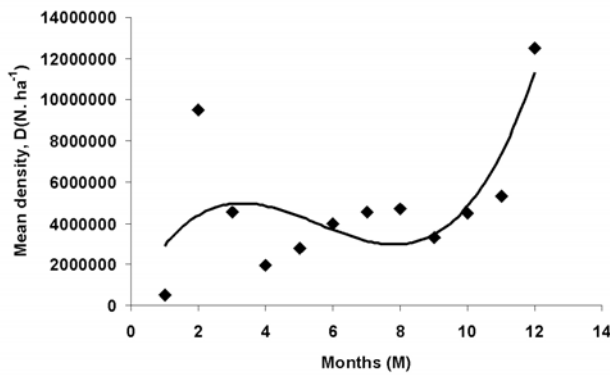


Figure 1: Logistic curve of the monthly mean density evolution of *Pachymelania byronensis* in the Cross River, Nigeria.

December – January). Figure 2 shows an asymptote or river carrying capacity at $D = 12510000 \text{ N. ha}^{-1}$. The mean Euclidean distance for the month –to – month change in population density was: $MED = 0.555$. This indicates low stochasticity in the density evolution.

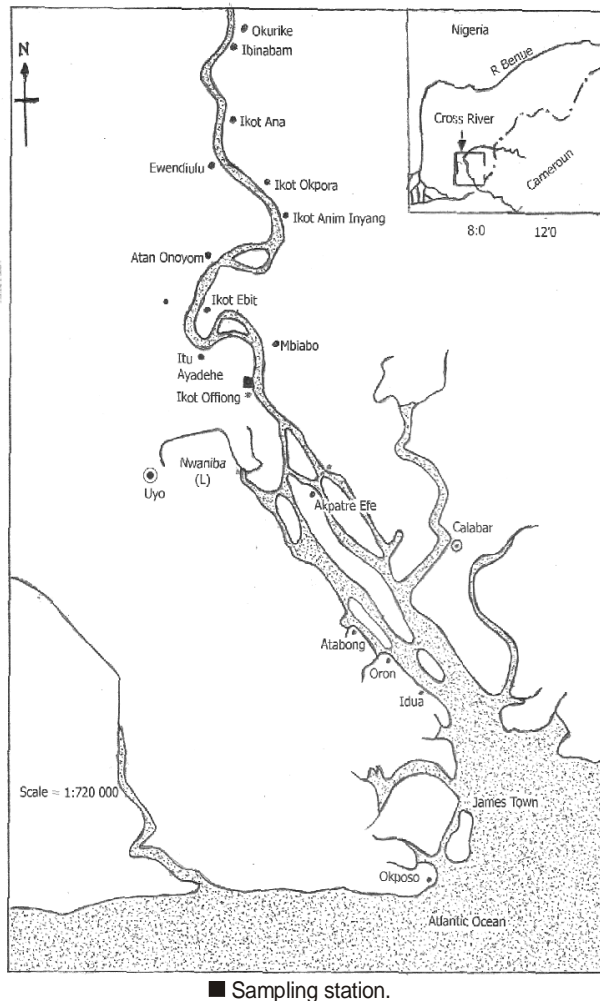


Figure 2: Map of lower Cross River showing the sampling station.

The monthly mean densities of *P. byronensis* were found to significantly correlate with some river limnological parameters, including surface temperature (T, oC) ($r^2 = 0.4351, n=12, p<0.05$), discharge ($Q, \text{m}^3/\text{s}$) ($r^2 = 0.343, n=12, p .05$), transparency (TR, m) ($r^2 = 0.6783, n=12, p<0.001$), river level (L, m) ($r^2 = 0.3703, n=12, p<0.05$), dissolved oxygen concentration ($O, \text{mg/l}$) ($r^2 = 0.3608, n=12, p<0.05$) and hydrogen ion concentration (pH) ($r^2 = 0.4047, n=12, p<0.05$). The respective equations for these relationships were:

$$D = 170.46T - 3938.5 \dots 4$$

$$D = 606.1e^{-0.000Q} \dots 5$$

$$D = 27.945 (TR)^2 - 336.42 (TR) + 1349.6 \dots 6$$

$$D = -18570L^6 + 559129L^5 - 7E + 06L^4 + 4E + 07L^3 - 1E + 08L^2 + 08L \dots 7$$

$$D = -61.735O^4 + 1204.5O^3 - 8859.7O^2 + 292570 \dots 8$$

$$D = 1562.7 (\text{pH})^4 - 6945(\text{pH})^3 + 69948 (\text{pH})^2 - 3E + 06(\text{pH}) + 5E + 06 \dots 9$$

The monthly biotic potentials (Table 1) revealed both positive and negative values. These portrayed respectively, density increases and decreases. In this regard, the minimum and maximum density increases were registered respectively in May and January whereas the minimum and maximum density decreases occurred respectively in June and February. The January-December biotic potential was $r_{\text{max}} = -3.204$. This marked the annual density decrease from January-December. Major population density decreases were noted in February ($r_{\text{max}} = -5.456$) and December ($r_{\text{max}} = -2.931$) whereas notable population density increases were observed in January ($r_{\text{max}} = 3.204$) and November ($r_{\text{max}} = 3.052$). The mean of the negative biotic potentials was $r_{\text{mean}} = -1.219$ while the mean of the positive biotic potential was $r_{\text{mean}} = 1.866$. If the sign is ignored, then the mean of the negative biotic potential exceeded the mean of the positive biotic potential by 26.6%. The monthly biotic potentials were significantly correlated with river temperature (T, oC) ($r^2 = 0.4269, n=12, p<0.05$) and dissolved oxygen concentration ($O, \text{mg/l}$) ($r^2 = 0.7847, n=12, p<0.002$) according to the equations:

$$r_{\text{max}} = 0.6799T^3 - 53.787T^2 + 1415.9T - 12403 \dots 10$$

$$r_{\text{max}} = 5.4813O^6 - 160.160.86O^5 + 1948O^4 - n12457O^3 + 44371O^2 - 834 + 64782 \dots 11$$

which respectively explained 42.7% and 78.5% of the variation in biotic potential.

Seasonality in density

The seasonal regime in the density of *P. byronensis* (Figure 3) showed the following decreasing order of abundance: Early dry season (32.0%), Mid dry season (20.0%), Early wet season (15.0%), Late dry season (13.0%), Late wet season (11.0%) and Mid wet season (9.0%).

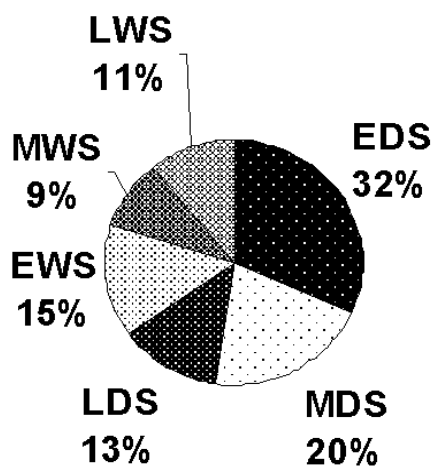


Figure 3: Seasonal variation in the mean density of *Pachymelania byronensis* in the Cross River, Nigeria. EDS = Early Dry Season; MDR = Mid Dry Season; LDS = Late Dry Season; EWS = Early Wet Season; MWS = Mid Wet Season; LWS = Late Wet Season.

Discussion

This study that involved the establishment of the density status of *P. byronensis* in the lower Cross River, Nigeria, is important for the rational management of the resource because the numerical catch is directly proportional to the stock size as well as to the fishing mortality rate (Tyler and Gallucci, 1980). Therefore, armed with the information on the resource stock size, fishing quotas can be allotted to fishers after estimating the optimal fishing mortality rate that can be adopted without impacting adversely on the long-term sustainability of the resource stock size.

There are no previous reported population density estimates of *P. byronensis* for comparison with the present results. However, the current density figures are closely comparable to the density estimates for *Pachymelania aurita* in Lagos Lagoon, Nigeria [3980000-6000,560,000 $N. ha^{-1}$; Brown and Ajao (2004)]. The annual mean density of the Cross River *P. byronensis* ($D_{mean} = 4849833.3 N ha^{-1}$) shows the occurrence of a considerably large population size of this gastropod in the river. Nonetheless, this figure may represent an underestimate since this study was based upon an exploited population base. The annual mean density estimate for a virgin (unexploited) population would have been much higher. However, the low index of population stochasticity (MED = 0.557) indicates that the monthly gastropod fishing operations have limited impact on the monthly population sizes of the gastropod population stability. It is also possible that the gastropod has strong resilience to the operational fishery or else the monthly biotic potentials are high enough to rapidly replace individuals fished out of the population on monthly basis. It is also possible that the compensatory density-dependence concept is operational in this population. This concept stipulates that when the density is reduced by whatever cause (e.g. fishing), the productivity of an individual increases, body growth rate increases,

reproductive output is heightened and the probability of death decreases (Tyler and Gallucci, 1980). The cumulative effect of these factors compensate the population for individuals removed *via* the various mortality agents.

The Cross River *P. byronensis* has a shell height range of 1-68 mmH with 30 mmH as the dominant size (King and Akpan, 2010). The generally small body size of this gastropod intrinsically ensures the sustenance of a high population density. The decrease in density with increasing mean body weight (Eqn. 2) is probably because the small gastropods are more tightly packed (by virtue of their smallness) than large individuals. Equation 3 provides a good functional predictive model for pragmatic management purpose as it permits the estimation of available gastropod stock size in any month of the year although such estimates may not necessarily be very accurate. However, they provide good figures on which rational resource management decisions can be taken. For instance, it is from such data, that fishing quotas can be logically allotted to the active gastropod fishers within the lower Cross River.

This study showed significant relationships between gastropod density and some river limnological parameters (Eqns. 4-9). However, these limnological parameters are generally referred to as 'density-independent parameters' (Odum, 1971; Dajoz, 1977). Therefore, the individual's direct roles in population density regulation is obscured. Temperature and dissolved oxygen supply enhance growth and survival and hence, increased density. Renaud *et al* reported that turbidity, PH and phosphorus concentration strongly influenced the distribution of snails. Strong river discharge can dislodge and disperse *P. byronensis* along with the bottom deposit. This probably explains the inverse exponential relationship between density and river discharge (Eqn. 5).

The decrease in gastropod biotic potential (r_{max}) from January to December (Table 1) may be attributed to increased human exploitation pressure as the year progressed. This is because exploitation intensity generally increases as the rains gradually recede and river discharge/water level decrease. Furthermore, it could be due to the progressive increase in the gastropod mean body weight (Table 1). The significant relationship between river temperature and biotic potential (Eqn. 10), agrees with Dajoz (1977) that r_{max} is generally temperature-dependent. Additionally, the present study demonstrates that r_{max} also depends on the amount of available habitat dissolved oxygen concentration (Eqn. 11). Thus, r_{max} fluctuates with limnological parameters that are related to life support and growth, i.e. habitat temperature and dissolved oxygen content). For fisheries purpose, this study indicates that active fishing is best done in the Early Dry Season (November) when a substantial stock of the gastropod is available for exploitation. Conversely, the Mid Wet Season (August) supports the least available stock for exploitation (Figure 3). It may be necessary to close fishing during the Mid Wet Season and Late Wet Season in order to allow

the stock size to build up for fishing during other seasons of the year.

References

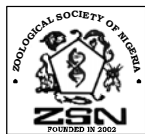
- Anyiam, I. V. and Ikpesu, T. O. 2018. Microbiological quality and biochemical composition of water snail (*Pachymelania bryonensis*) of lower Niger River basin. *Emergent Life Sci. Res.*, 4: 1-10.
- Brown, C. A. and Ajao, E. A. 2004. Effects of topographical modification on the composition and abundance of macrofauna in southern Lagos Lagoon (Ikoyi). *West Afr. J. App. Ecol.*, 7: 41-49.
- Dajoz, R. 1977. *Introduction to Ecology*. Hodder and Saunders Company, 416pp.
- Ekpo, I. Essien-Ibok, M. and Effiong, E.E. 2015. Biology of bigmouth sleeper, *Eleotris vittata* (Dumeril, 1861) (*Pisces: Eleotridae*) in the Cross River, Nigeria. *Int. J. Fish. Aqu. Stu.*, 3(2): 346-352.
- Etim, L. 1996. Determination of reproductive cycle in a population of *Egeria radiata* (Lam, 1804) (*Bivalvia: Donacidae*) using condition index and histological examination of gonads. *Annals. Limnol.*, 32(2): 105-113.
- Etim, L. and Enyenihi, U. K. 1990. Seasonal cycle of condition index and flood-season spawning in the freshwater donacid clam, *Galatea paradoxa* in the Cross River, Nigeria. *Trop. Freshwater Biol.*, 2(2): 233-240.
- Etim, L. and Taege, M. 1993. Comparison of condition indices and their seasonal variation in the freshwater clam, *Egeria radiata* (Lamarck) (Tellinacea: Donacidae) from the Cross River, Nigeria. *Aquacult. Fish Manage.*, 24: 603-612.
- Etim, L. and Umoh, E. 1992. Gamete production and growth of the bivalve, *Egeria radiata* (Donacidae) from the Cross River (Nigeria). *Acta Hydrobiol.*, 40(1): 25-34.
- Etim, L. and Taege, M. 1993. Comparison of condition indices and their seasonal variation in the freshwater clam, *Egeria radiata* (Lamarck) Tellinacea: Donacidae) from the Cross River, Nigeria. *Aquacult. Fish Manage.*, 24: 603-612.
- King, R. P. 2013. Ecomorphological patterns in the population density of the gastropod, *Pachymelania byronensis* (Wood, 1828) (Thiaridae) in the Cross River, Nigeria. *Ecophila*, 1: 73-84.
- King, R. P. and Akpan, B. E. 2010. Ecomorphological regimes of the gastropod, *Pachymelania byronensis* (Potamididae) in the Cross River, Nigeria. *Asian J. Microbiol., Biotech, Envi. Sc.*, 12(4): 693-700.
- LaMont, M. D., Douglas, L. L. and Oliva, R. A. (1977). *Calculator decision-making sourcebook*. Texas Instruments Incorporated, Texas, USA.
- Moses, B. S. 1979. The Cross River: its ecology and fisheries, *In: Proceedings of the International conference on Kainji Lake and River basins Development in Africa*. Kainji Lake Research Institute, New Bussa, Nigeria, pp. 355-371.
- Moses, B. S. 1987. The influence of flood regime on fish catch and fish communities of the Cross River floodplain ecosystem, Nigeria. *Env. Biol. Fish.*, 18(1).
- Moses, B. S. 1990. Growth, biomass, mortality, production and potential yield of the West African clam *Egeria radiata* (Lamarck) (Lamellibranchia: Donacidae) in the Cross river system, Nigeria. *Hydrobiologia*, 196: 1-15.
- Odum, E. P. 1971. *Fundamentals of Ecology*. W. B Saunders Company, 574pp.
- Renaud, A. J., Yves, B. K., Felix, K. K. and Emmanuel, A. N. 2017. Assemblage of freshwater snail's community in the Aghien Lagoon in relation to environmental variables. Cote d'Ivoire, West Africa. *Int. J. Scienti. Res. Pub.*, 7(12): 693-702.
- Tahal Consultants (Nigeria) Ltd. 1979. Qua Iboe River Basin Feasibility Study. Cross River Basin Development Authority, Nigeria. 2 Annex IIA. 1-14.
- Teugels, G.G. S., Reid, M. G. and King, R. P. 1992. Fishes of the Cross River Basin (Cameroon-Nigeria) Taxonomy Zoogeography, Ecology and conservation). *Annals Sciences Zoologiques, Musee Royal De L'Afrique Centrale*, Teruven Belgique, 132pp.
- Tyler, A. V. and Gallucci, U. F. 1980. Dynamics of fish stocks. *In: Lackey, T. R. and Nielsen, L. A. (Eds). Fisheries Management*. Blackwell Scientific Publications Oxford, pp. 111-147.
- Whitsitt, R.E., Kelly, K. A., LaMont, M. D. and Oliva, R. A. 1985. *Texas Instruments ~ Scientific Guide Book*. Texas Instruments Incorporated.

Citation: Richard P. King and Bassey E. Akpan

Population density dynamics of *Pachymelania byronensis* (Wood, 1828)

(Gastropoda: Thiaridae) in the Cross River, Nigeria

<http://dx.doi.org/10.4314/tzool.v18i1.10>



The Zoologist, 18: 57-61 December 2020, ISSN 1596 972X.

Zoological Society of Nigeria.