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Full Length Research

The mean condition dynamics of *Pachymelania byronensis* (Wood, 1828) (Gastropoda: Thiaridae) in the Cross River, Nigeria

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ABSTRACT: The monthly mean condition index (K_{mean}) of *Pachymelania byronensis* was computed from a unique combination of the body weight–shell height relationship parameters (i.e. a, b). Shell height (H) and weight (W) were measured for each specimen. There was a wide (827.7 –fold) variation, from a minimum of 0.012 in October to a maximum of 9.932 in December. Mean annual value was 8.064. The relatively low values of the condition index in February – May, August -- October were attributed to declines in body weight as the gametes are released during spawning. This gastropod species spawns three times a year, a feature that is responsible for the high density of the gastropod in the river and its capacity to sustain a year-round strong fishing pressure. The monthly condition indices significantly correlated with river hydrological parameters, including rainfall, surface temperature, discharge, transparency, pH, and dissolved oxygen concentration.

Keywords: Condition index, Cross River, hydrological parameters, *Pachymelania byronensis*.

INTRODUCTION

The study investigates the body condition of *Pachymelania bryonensis* in Cross River. There is no universally accepted definition of the term ‘body condition’ or ‘condition factor’ in fisheries biology. However, for the understanding of this paper, body condition may be defined as the dimensionless morphometric expression or quantification of the overall physiological status (Blackwell *et al.*, 2000), wellness and fatness (Bagenal and Tesch, 1978), plumpness or robustness of a given species. It provides a measure of the ecophysiological fitness and collective functional efficiency of the homeostasis of the body. It is an indicator of the growth and feeding intensities of fish (Ighwela *et al.,* 2011). The magnitude of the condition indices also shows the adequacy of the habitat synecological conditions or fitness (Le Cren, 1951; Jisr *et al.,* 2018) for sustaining the life history of the organism. It is also an index of species average size (Alam et al., 2014).

The values of condition factors depend on factors such as the physiological features of the specimen especially maturity, spawning, life cycle, environmental factors and food availability in a water body (Ujjania, 2012). Body condition consequently provides an indirect measure of the meat quality available for human consumption. Hence, this parameter is of great importance in fishery assessment particularly for proper exploitation and management of the fishery population (Asadi *et al.,* 2017; Jewel *et al.*, 2019). There are variations in body condition and each fish family has its own range depending on the fish shape (Ragheb, 2023). Variations in body conditions have been used to evaluate breeding seasonality among fishery specimens.

In Cross River, there is a considerable population of *P. bryonensis* which supports a year round artisanal dive fishery in some South Eastern communities of Nigeria. Besides the provision of a widely acceptable and affordable animal protein source (Anyim and Ikpeazu,

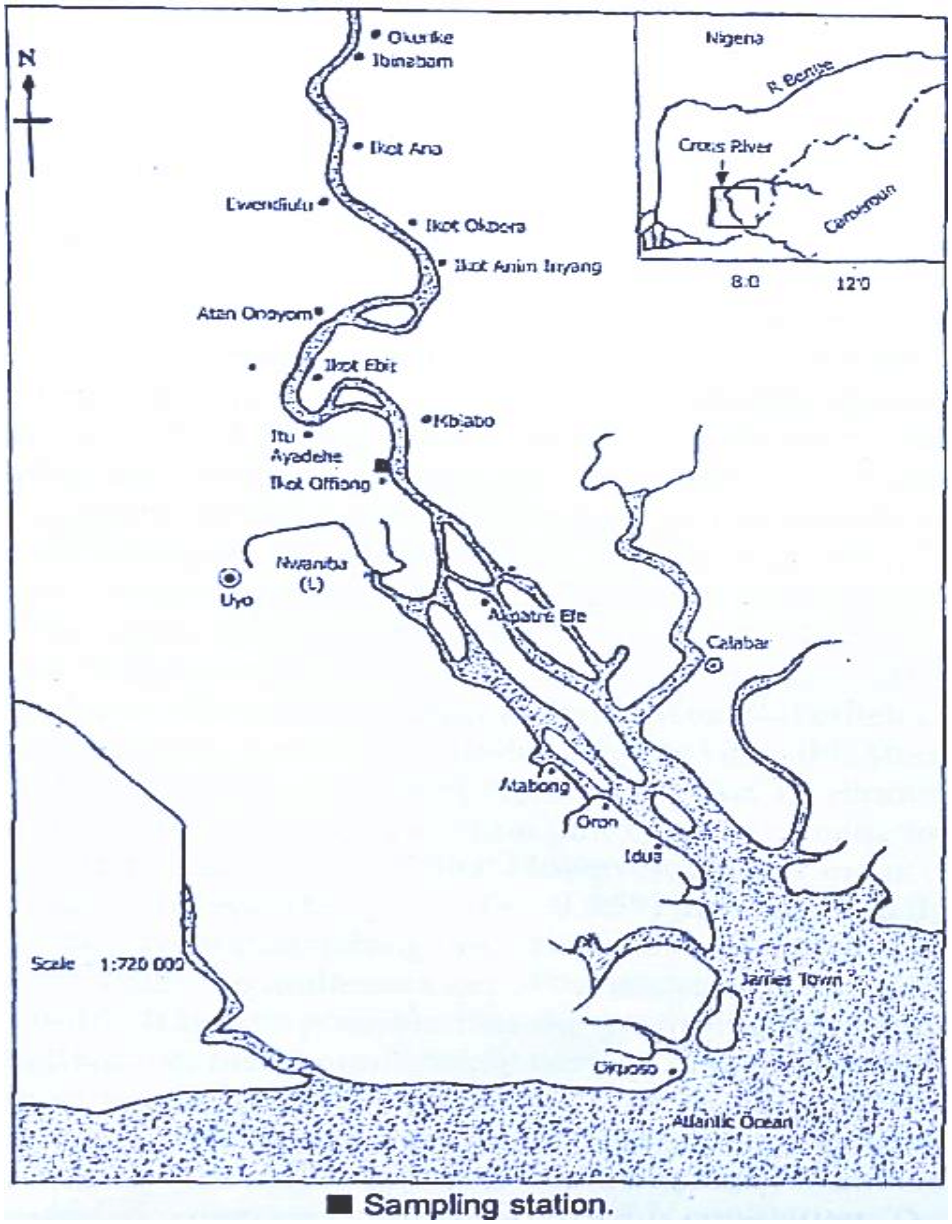

Figure 1. Map of Lower Cross River showing the sampling station.

2018), this gastropod fishery provides livelihood and income to the fishers and marketers of this resource (King and Akpan, 2020). The empty shells are used for local soil stabilization and erosion control as well as manufacturing of scouring powder and livestock feed. They are also commonplace household ornaments. This gastropod species is not adequately studied biologically and ecologically despite its socio-economic values resulting in scarcity of information about it. Some available publications on this species include Oyenekan (1984), Akpan and King (2010), King (2013), and King and Akpan (2020). Secondly, *P. bryonensis* has been included in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2011) based on the report of Kristensen and Stengaard (2006). These therefore became preludes to this study to determine the seasonal dynamics in its mean condition index in Cross River. This will help in the effective management of this natural stock for sustained human consumption and other benefits.

MATERIALS AND METHODS

The specimens were from Cross River at Ayadeghe in Itu Local Government Area (5^{o} 12`N; 7$^{o}$ 58`E), Akwa Ibom State, Nigeria (Figure 1). Detailed information on the study area is given by Moses (1987, 1979, 1990), Etim and

Table 1. Monthly mean rainfall, rainy days and water level for the Cross River at Ayadeghe, Itu, Nigeria.

Months	Mean rainfall* (mm)	Rainy days* (No)	River level(m)
January	37	2	1.8
February	58	2	1.3
March	57	9	1.4
April	194	12	1.9
May	287	12	2.9
June	317	14	5.2
July	340	17	6.6
August	279	15	7.7
September	374	19	8.3
October	288	17	8.1
November	155	8	4.1
December	34	2	3.6

*Based on Tahal Consultants (Nigeria) Ltd (1982).

Enyenihi (1990), Etim (1996), Etim and Umoh (1992), King (2013) and Ekpo *et al*., 2015). A thirty (30) year rainfall profile for the area (Tahal, 1982) (Table 1) revealed the existence of six ecoclimatic seasons: The Early Dry Season (EDS ~ November); Mid Dry Season (MDS ~ December – February); Late Dry Season (LDS ~ March – April); Eary Wet Season (EWS ~ May – July); Mid Wet Season (MWS ~ August); and Late Wet Season (LWS ~ September – October). There are two rainfall peaks, one in July and another in September. December and January are the driest months of the year. The monthly changes in river level closely follow the rainfall regime, with minimum and maximum values in February and September, respectively. The ranges of the key hydrological parameters of the study area are as follows: surface temperature ~ 24.5 – 28.8°C; transparency ~ 0.29 – 1.75 m; discharge ~ 195 – 8540 m^3s^{-1}; dissolved oxygen concentration ~ 3.5 -6.5 mg/l; and pH ~ 5.9 – 7.3. Further details on the study area are given by Teugels *et al*. (1992), King (1998) and King and Akpan (2010).

Gastropod samples were obtained from transects across the river with a Petersen grab (540 cm^2 opening) operated from a dugout canoe. Each sample was placed in a polythene bag and transported to the laboratory where they were washed clean of all adhering substrate particles and air-dried on absorbent paper.

The selected specimens were measured for shell height (mm H) and weight (total body weight, g W). Shell height (maximum anterior-posterior axis) of each specimen was measured in millimetres (mm) using Vernier callipers while the weight of each was measured in grammes (g) with electronic Mettler balance. The height–weight relationship was computed on a monthly basis according to Akpan and King (2010). The height–weight parameters (i.e. a & b) were used to estimate the mean condition index (K_{mean}) of Froese (2006) for the 30 mmH specimens thus:

$$K_{mean} = [aH^{b-3}]100 \quad (1)$$

Where a and b are the monthly height-weight relationship parameters. The 30 mmH sizes was used because it occurred in all monthly samples as the dominant size. The monthly specific rate of change (MSRC,%) in K_{mean}–was estimated from the equation:

$$MSRC = [\ln (Cf.\ Ci^{-1})]\ 100 \quad (2)$$

where Ci = initial condition index in month i; C_f = final condition index in month f (i.e. the month after i).

In this equation, the value of MSRC could be negative (i.e. decline in body condition) or positive (i.e increase in body condition). The extent of the monthly fluctuation in K_{mean} (i.e stochasticity or randomness) was evaluated by the mean Euclidean distance (MED) that seperates the monthly condition indices. The MED was estimated thus:

$$MED = [\ \Sigma(X_2 - x_1)^2]0.05\ /n \quad (3)$$

Where X_1 = value of condition index in month 1; X_2 = value of condition index in month 2 (i.e the month preceding month 1); n = number of months for the study period (here n =12).

The MED was scaled such that MED < 1.000 depicted low condition stochasticity; MED = 1.000 – 2.999 depicted moderate stochasticity; and MED ≥ 3.000 portrayed high stochasticity.

RESULTS

The overall height–weight relationship of *P. byronensis* was (r^2 = 0.98, n=360, p< 0.002):

$$W = 9.260 \times 10^{-5} H^{3.011} \quad (4)$$

Table 2. The monthly weight - height parameters of *Pachymelania byronensis* in the Cross River, Nigeria.

Months	N	H_{min} (mm)	H_{max} (mm)	H_{mean} (mm)	$\hat{W}$ (g)	a	b	r^2
J	25	13	40	26.5	1.13	0.00003	3.326	0.988
F	31	18	40	29.0	1.35	0.00005	3.159	0.980
M	37	24	40	32.0	2.64	0.00090	2.298	0.935
A	30	22	40	31.0	2.42	0.00010	2.866	0.941
M	27	21	40	30.5	1.80	0.00020	2.718	0.976
J	27	14	40	27.0	2.31	0.00007	3.088	0.982
J	22	19	40	29.5	2.82	0.00020	2.787	0.984
A	23	16	40	28.0	3.54	0.00010	2.963	0.990
S	22	20	40	30.0	4.89	0.00008	3.063	0.994
O	34	12	40	26.0	1.77	0.00020	2.856	0.988
N	37	10	40	25.0	1.49	0.00008	3.037	0.996
D		12	40	26.0	2.73	0.00010	2.998	0.976

N = sample size; Hmin = minima shell height; Hmax = maxima shell height.

Table 3. The monthly mean condition index (K_{mean}) and monthly specific rate of change of *Pachymelania byronensis* in the Cross River, Nigeria.

Months	K_{mean}	K_{mean} (% overall K_{mean})	MSRC (%)
January	9.092	94.580	-8.837
February	8.587	89.327	- 5.715
March	8.266	85.988	-3.810
April	6.340	65.952	-26.527
May	7.665	79.736	+18.979
June	9.443	98.232	+20.861
July	9.692	100.822	+2.603
August	8.818	91.729	-9.451
September	9.912	103.110	+11.695
October	0.021	0.208	-615.698
November	9.073	94.383	+606.854
December	9.932	103.318	+9.046
Annual K_{mean}	9.613	-	-

MSRC = monthly specific rate of change.

Using the parameters from equation 4, the overall mean condition was: K_{mean} = 9.613. This value was taken as the population optimal condition and was used as the base for comparing the monthly K_{mean} values (Table 3)

The estimated monthly weight – height parameters and related statistics of *P. byronensis* are shown in Table 2. All relationships were significant at $p < 0.05$ or better. The monthly a and b parameters were used in computing the monthly mean condition index (K_{mean}), using equation 1. The spectrum of

monthly mean condition indices (K_{mean}) of *P. byronensis* (Table 3) revealed a 827.7 –fold variation, from a minimum K_{mean} = 0.012 in October to a maximum K_{mean} = 9.932 in December. Annual mean value was K_{mean} = 8.064.

The gastropod was in good body condition for most months of the year as the annual average K_{mean} was exceeded in 9 months or 75.0% of the year but the annual mean value only exceeded the monthly averages in 3 months or 25.0% of the year. The mean Euclidean distance that separates monthly K_{mean} values (MED = 1.156) showed moderate stochasticity in the monthly condition indices of the gastropod.

Morphological correlates

The monthly K_{mean} values were significantly correlated with gastropod mean shell height ($\hat{H}$, mm) (r^2 = 0.3851, n=12, p<0.05) and mean body weight ($\hat{W}$, g) (r^2 = 0.3357, n=12, p<0.05). The respective equations for these relationships are:

$$K_{mean} = 0.332\hat{H}^6 - 5.6907\,\hat{H}^5 + 405.6\,\hat{H}^4 - 1539\,\hat{H}^3 + 328380\,\hat{H}^2 - 4E{+}06\,\hat{H} + 2E + 07 \quad (4)$$

K_{mean} = 1.1292Ŵ^4 – 13.923 Ŵ^3 +60. 488 Ŵ^2 -107.84 Ŵ +73.197 (5)

Equations 4 and 5 respectively explained 38.5 and 33.6% of the changes in body condition.

The spectrum of monthly mean condition index of *P. byronensis* (Table 3) revealed an 827.7 –fold variation, from a minimum K_{mean} = 0.021 in October to a maximum K_{mean} = 9.932 in December. Annual average K_{mean} = 9.613. Thus, this annual value was exceeded in 9 months (75.0% of the year). Only 3 months (25.0%) of the year had K_{mean} values < annual average K_{mean}. These results indicate that the gastropod was in relatively high body condition for most months. Condition decreased in January – April, August and October.The monthly specific rate of change (MSRC), showed decreases (negative values) in January – April, August and October. Increases in body condition (positive values) were noted in May – July, September and November – December. The sum of the decrease factors was: Σ -MSRC =- 670.038 while the sum of the increase factors was Σ +MSRC = + 670.038. Therefore, the decrease and increase factors balanced each other. The mean Euclidean distance that separates monthly pairs of K_{mean} (MED = 1.155) depicts moderate stochasticity in body condition.

Hydrophysical correlates

The monthly K_{mean} values were significantly correlated with river hydrophysical parameters, including rainfall (R, mm) (r^2 = 0.349, n =12, p<0.05), surface temperature (T, ^oC) (r^2 = 0.350, n=12, p<0.05), discharge (Q, m3/s) (r^2 = 0.4065, n=12, p< 0.05) and transparency (TR, m) (r^2 = 0.3752, n=12, p<0.05). The respetive equations for these relationships are:

K_{mean} = -0.0208R + 10.443 (6)

K_{mean} = -0.7445T^2 +41.657T – 573.33 (7)

K_{mean} = 1E -10Q^3 -1E -06Q^2 + 0.0035Q +6.9563 (8)

K_{mean} = - 153.29(TR)^5 + 834.66(TR)^4 – 1706.6(TR)^3 +1610.4(TR)^2 -686.49 (TR) +111.1 (9)

The respective coefficients of determination are: 34.9, 40.7, 40.7 and 37.5%. Therefore, ambient temperature and discharge are the most important hydrophysical determinants of body condition of *P. byronensis.* Equation 6 was linear while equations 7, 8 and 9 were polynomial, hence wave functions. Therefore, K_{mean} increased and decreased with these habitat conditions.

Hydrochemical correlates

The monthly K_{mean} values were significantly correlated with river hydrochemical parameters, including hydrogen ion concentration (pH) (r^2 = 0.382, n=12, p<0.05) and dissolved oxygen concentration (O, mg/l) (r^2 = 0.441, n=12, p<0.02). The respective equations for these relationships are:

K_{mean} = 3E – 19(pH)$^{22.838}$ (10)

K_{mean} = - 2.5332O^3 + 37. 156O^2 – 175.39+272.31 (11)

From these equations, K_{mean} increased with increasing pH and dissolved oxygen concentration. Equations 10 and 11 respectively accounted for 38.0 and 44.0% of the changes in body condition. Equation 10 is a power function. The magnitude of the exponent depicts a considerable increase in K_{mean} per unit increase in pH. Equation 11 is polynomial and hence, wave function. The coefficients of determination (*vide supra*) show that dissolved oxygen concentration is the most important hydrochemical determinant of the changes in K_{mean}. Figure 2 illustrates that K_{mean} was higher under diminished dissolved oxygen levels than under increased dissolved oxygen concentrations.

Figure 3 shows the proportional representation of average K_{mean} values in the six ecoclimatic seasons of the Cross River. This figure suggests that spawning occurs in the Late Wet Season while maximal gonadal investments occur in the Early Dry Season, Mid dry Season and Early Wet Season. Intermediate gonadal investments occurred the Late Dry Season and Mid Wet Season.

DISCUSSION

Fulton (1902) was the first to propose a mathematical quantification of fish body condition. Thereafter, the Fulton`s condition index (K) persisted in the scientific literature for several years during which it also underwent various modifications (Bolger and Connoly, 1989). This long term persistence is mainly because its foundational theory is simple and easy to understand while the index is also easy to compute and interpret. The mean condition index (K_{mean}) (Froese, 2006) was formulated 104 years after Fulton but has not been widely used probably because its theoretical foundation is complicated and not easily understood by potential users. Moreover, its computation is not straightforward. Furthermore, the index lacks upper and lower limits, thus making interpretation of trends difficult. An important attribute of K_{mean} is that it is computed for populations or sub-populations and not for individuals as per the Fulton`s condition. Therefore, the K_{mean} is a better population attribute than K.

To our knowledge, this is the first time that the mean condition index is being applied on a shellfish species. Consequently, there are no previous data and information for comparison with the present results. Habitat temperature is an important driver of biochemical and

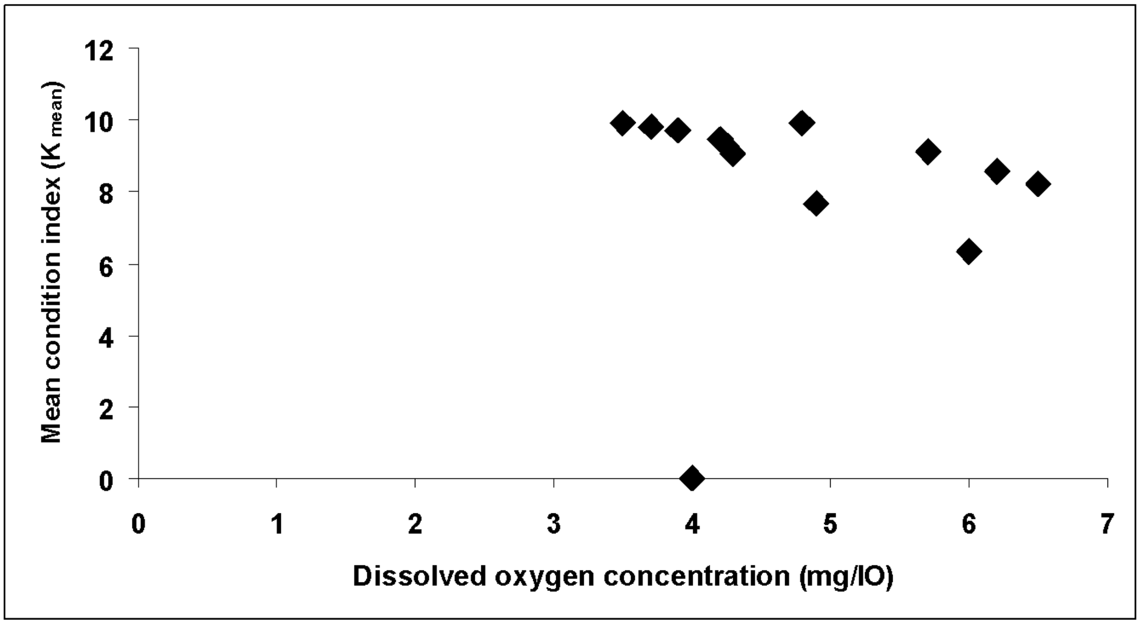

Figure 2. The relationship between habitat dissolved oxygen concentration and the mean condition index of *Pachymelania byronensis* in the Cross River, Nigeria.

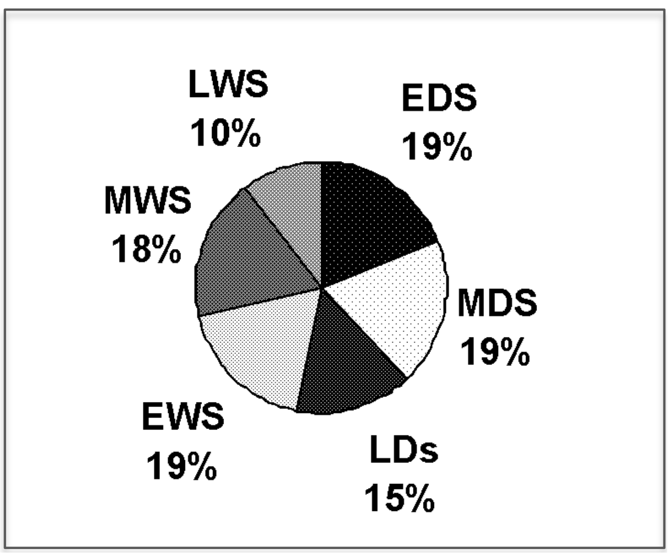

Figure 3. The proportional representation of the average K_{mean} values of *Pachymelania byronensis* in the CrossRiver, Nigeria. EDS =Early Dry Season; MDS =Mid Dry Season; LDS = Late Dry Season: EWS = Early Wet Season; MWS = Mid Wet Season; LWS = Late Wet Season.

physiological processes in organisms. In general, the rates of these processes double for every 10°C increase in ambient temperature (Boyd and Lichtkopper, 1979). In the Cross River system, the amplitude of annual temperature change is very narrow. This may, in part, explain the inverse interaction between ambient temperature and K_{mean} (Eqn.6; *vide supra*). Moreover, it is possible that anabolism (hence, energy allocation) takes place at a relatively low optimum temperature in this species. The positive transparency – K_{mean} interaction (Eqn. 7; *vide supra*) is probably because clear water (i.e. water with limited suspended clay/silt particles) is required for the optimal performance of the respiratory structures (i.e gills). The power increase in K_{mean} of *P. byronensis* with pH (Eqn. 10; *vide supra*) suggests that the anabolic biochemical and homeostatic processes in this species operate optimally under alkaline conditions. Hence, the increase in K_{mean} to the magnitude power order of 22.838 per unit increase in habitat pH (Eqn.10; *vide supra*). In pond fishes, the desireable pH range for optimal growth and production is 6.5 – 9.0 (Boyd and Lichtkopper, 1979; Shuang-Yao *et al*., 2018). Lower and higher values are detrimental to growth, reproduction and production (Swain *et al*. 2020; Dos Santos *et al.* 2020). In the Cross River, the pH is dominated by alkaline conditions which appear to be conducive for the homeostatic and anabolic processes, thus culminationg in the power increase in K_{mean} per unit increase in pH (Eqn. 10).

The diminishing concentration of habitat dissolved oxygen may be a desirable phenomenon in the life history of some aquatic organisms. For example in fishes, it serves as the master factor in inducing the transition from juvenile to adult (Pauly and Munrro, 1984). It is also possible that a decrease in dissolved oxygen concentration in the Cross River accelerates anabolism and vice versa thus resulting in the polynomial relationship between habitat dissolved oxygen concentration and the K_{mean} of *P. byronensis* (Eq.10; *vide supra*). Fin fishes and shell fishes are generally known to lose body weight as the gametes are released during spawning. Thus, body condition also declines during spawning (Etim and Enyenihi, 1990; Herbst *et al.*, 2013; Rösch *et al.*, 2018). In this regard, the relatively low values of the mean condion in February – May, August and October may be attributed to spawning. *P. byronensis* therefore spawns a minimum of three times in the year. This multiple progeny production may, in part, explain the high population density of the gastropod in the Cross River (King and Akpan, 2010; King, 2013) as well as its ability to sustain a year-round fishery.

Conclusion

The stock of *P. bryonensi*s in Cross River should be properly managed to sustain its socioeconomic benefits to man.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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