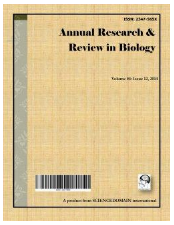

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Aspects of the Population Dynamics of Periwinkle (*Tympanotonus fuscatus*) along the Bonny River, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A two-year data set of Periwinkle (*Tympanotonous fuscatus*) population from a deforested mangrove area was used to assess its population dynamics. Periwinkle snail samples in one hundred (100) 1 m^2 quadrats were collected, each in 2015 and 2016. The summary statistics of the periwinkle population show a mean density of 21 indv/m^2 in 2015 and 12 indv/m^2 in 2016. The length parameter ranged from 0.9 cm-3.6 cm (mean 2.00±0.33) in 2015 and 1.4 cm-5.1 cm (mean 1.76±0.43) in 2016 while the weight parameter ranged from 1.5 g-5 g (mean 1.50±1.51) and 0.4 g-2.53 g (mean 0.70±0.48). The population density indicated a significant change between 2015 and 2016. The total abundance of periwinkle snails between the years declined by forty (40%) percent, varying from a density of 2090 snails in 2015 to 1192 snails in 2016. The distribution statistics also showed that the likelihood of obtaining seven (7) snails in 2016 collections with 1 m^2 quadrats declined by 10%; and 18 and 29 snails by sixty-five (65%) percent. The significant difference in abundance values using the Student's t variance estimate ($p<0.05$) was also observed ($p<0.05$) for

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the variance estimates of the length and weight categories. In the length category, evidence of significant change was indicated by the decline in obtaining the class interval of 1.2 cm-1.6 cm by ten (10%) percent in 2016 collections. Further evidence of significant change in population characteristic was also observed in the weight parameter where the weight class 3 g to 5.5 g was absent in the 2016 collections. The relationship between length-weight was non-collinear in 2015 year collections with a very low R^2 = 0.007, indicating that the contribution of shell length to body weight can only be predicted by 0.3%. In contrast, in the 2016 collections, the length-weight relationship returned a value of R^2 = 0.646971 indicating that the contribution of the shell length to body weight can be predicted by sixty percent (60%). These differences in population characteristics were interpreted as evidence of the snail response to interplay of environmental conditions between the dates of collection which were similar. Harvesting pressure and indiscriminate habitat destruction are noted as extreme drivers that can likely overwhelm the natural balance of ecological factors. Although the influences of habitat conditioning factors were not discussed, evidence of the quantitative variation in the population dynamics is given to direct future research in conservation.

Keywords: Periwinkle; population; mangrove; length; weight; Bonny River.

1. INTRODUCTION

Tympanotonus fuscatus Linnaeus, commonly known as periwinkle, is a brackish gastropod belonging to the family Potamididae. It is small and is characterized by turreted granular and spiny shell with a tapering end. This organism is endemic in Nigeria and West Africa [1]. As part of the fauna of the mangrove community, it occurs mainly in the tidal mudflats of estuarine ecosystems. The genus Tympanotonus, comprises of a single species, which has two varieties -*Tympanotonus fuscatus* var *fuscatus* and *Tympanotonus fuscatus* var *radula* [2]. The potential of the organism as a food source is well documented, together with its medicinal and nutrient capabilities [3-5]; its bioremediation and accumulation abilities [6-8]; and the usage of its shell in construction of roads and buildings [9,5].

Despite the numerous benefits derived from *T. fuscatus*, its sustainability is threatened by human activities as a result of urbanization. Humans in quest for development have over time, reduced the habitat of this organism through land reclamation for housing, crop farming and industries. The Food and Agriculture Organization (FAO) reported in 2010 [10] that global mangrove coverage had declined from 16.1 million ha in 1990 to 15.6 million ha by 2010. The World Rainforest Movement [11] also reported that Nigeria's mangrove area dropped from 9900 km^2 to 7386 km^2 between 1980 and 2006 which represents 25% of the mangrove forest. This massive decline is as a result of an increase in coastal populations, uncontrolled urbanization, exploitation of mangroves for fuel and housing, pollution from hydrocarbon exploitation and oil and gas exploration. The current trend of destruction of Mangrove habitats for urbanization in and around Port Harcourt and along the Bonny River provides a major threat to the local and regional sustainability of this ecosystem resource. Added to these pressures is the dependence for economic benefits by a demographic group with low income livelihood systems. The current study therefore evaluates the temporal population dynamics of Periwinkle (*Tympanotonus fuscatus*) in a Mangrove habitat deforested for urban development.

1.1 Study Area

This study was carried out at a site (Fig. 1) in Bundu-Ama in Port Harcourt Metropolis, Nigeria The site is bounded by geographic coordinates 4.74306°N, 7.00835°E; 4.743043°E, 7.007434°E; 4.739466°E, 7.008119; and 4.740584°N, 7.009694°E. The site is inundated diurnally with tidal waters of the Bonny River. The mangrove species at the site is dominated by *Rhizophora mangle,* and a few stands of *Rhizophora racemosa, Avicennia africana* and *Laguncularia* sp*.* The study area is bordered by a variety of built-up landcover serving commercial and residential purposes. To the northwest of the site is a cement production company. Within the mangrove area are portions that are deforested preparatory for low cost housing development. Many uncontrolled housing and related commercial activities are emerging in the neighborhood.

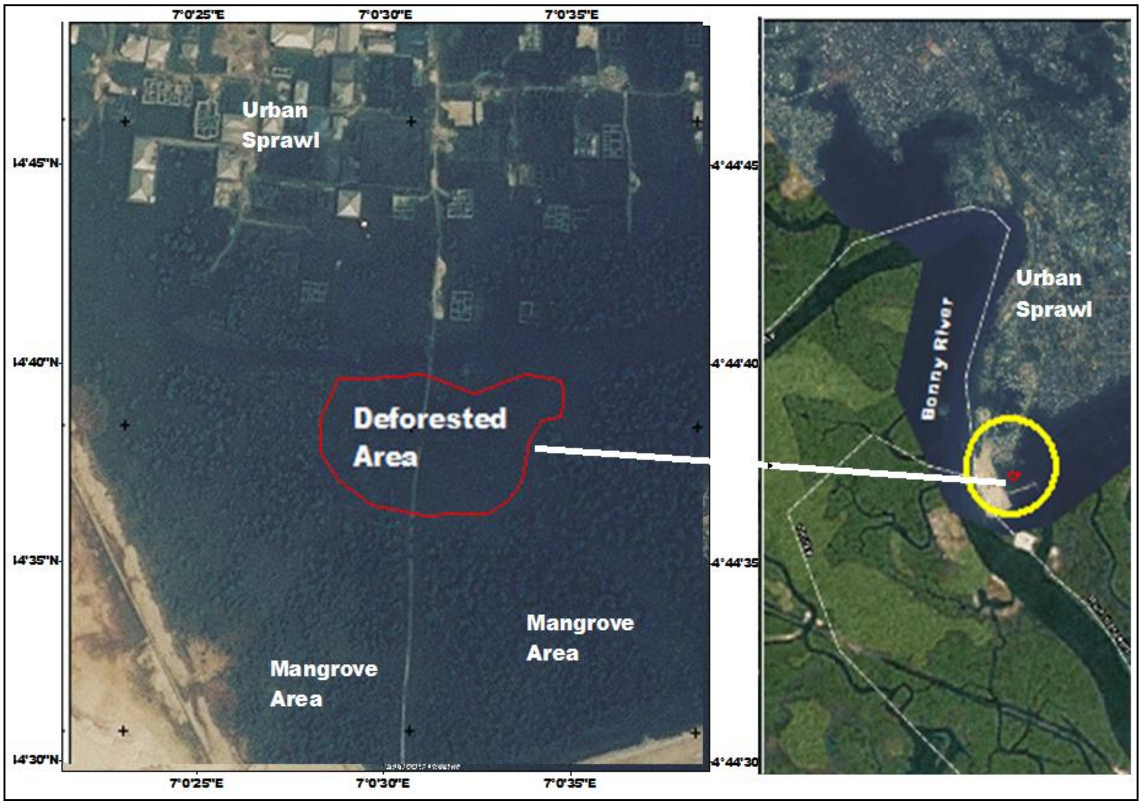


Fig. 1. Study area along the Bonny River catchment showing site of mangrove deforestation

2. MATERIALS AND METHODS

2.1 Collection of Specimens

Periwinkle snails, *Tympanotonus fuscatus*, of different sizes were handpicked with a 1 m^2 quadrat sampler by random sampling from a grid placed over the map of the site. Snails were collected in a total of two hundred (200) 1 m2 quadrats in April of 2015 and 2016. The samples were taken to the University Laboratory for analysis. The snails were washed with water to remove mud particles and preserved in 10% formalin. Shell length in centimeters was measured from the siphonal notch to the apex with a vernier caliper. The weight was measured with a digital balance (1 µg readability) and recorded in grams. The length and weight relationship was calculated from the following formula:

$$W = aL^b \quad (1)$$

Where, W is the body weight [g], L is the total length [cm], and a is known as the regression constant and b is known as the regression coefficient. The above equation is further transformed into a linear regression equation as:

$$\text{Log } W = \text{Log } a + b \text{ Log } L \quad (2)$$

Descriptive Statistics and Student's t variance estimate were applied to the data to determine differences in abundance, length and weight within the years of analysis.

3. RESULTS

3.1 Abundance, Length and Weight Variables

The results of total abundance of snails collected in 2015 and 2016 are shown in Table 1. A total of 2090 and 1192 were collected from 2015 and 2016 respectively; the mean abundances were 20.90±11.37 and 11.92±15.53 respectively; the coefficient of variation were 0.54 for the year 2015 and 1.3 for the year 2016.

Fig. 2 shows the distribution chart of periwinkle abundance per quadrat in the study area between 2015 and 2016. The summary statistics for both years show a mean of 21.44 and 12.08 and a standard deviation of 12.4 and 15.4 for 2015 and 2016 respectively. The distribution analysis shows that in 2015, 10% of the quadrats had approximately seven (7) snails each while 65% had between 11 and 29 snails each. The remaining 25% were between 38 and 61 snails per quadrat. In contrast, the analysis of 2016 distribution shows that 10% of the quadrats had no snails in them while 65% had between one (1) and seventeen (17) snails per quadrat. The remaining 25% had between 30 and 87 snails per quadrat. The cum probability function (CDF) for the 2015 data shows that 80% of the quadrats had slightly less than 30 snails per quadrat while the CDF for the 2016 data shows that 80% of the quadrats contained 20 snails per quadrat.

Table 1. Abundance of periwinkle (*T. fuscatus*) in the study area at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

Year	2015	2016
Total	2090	1192
Mean	20.90	11.92
Standard deviation	11.37	15.53
Coefficient of variation	0.54	1.30

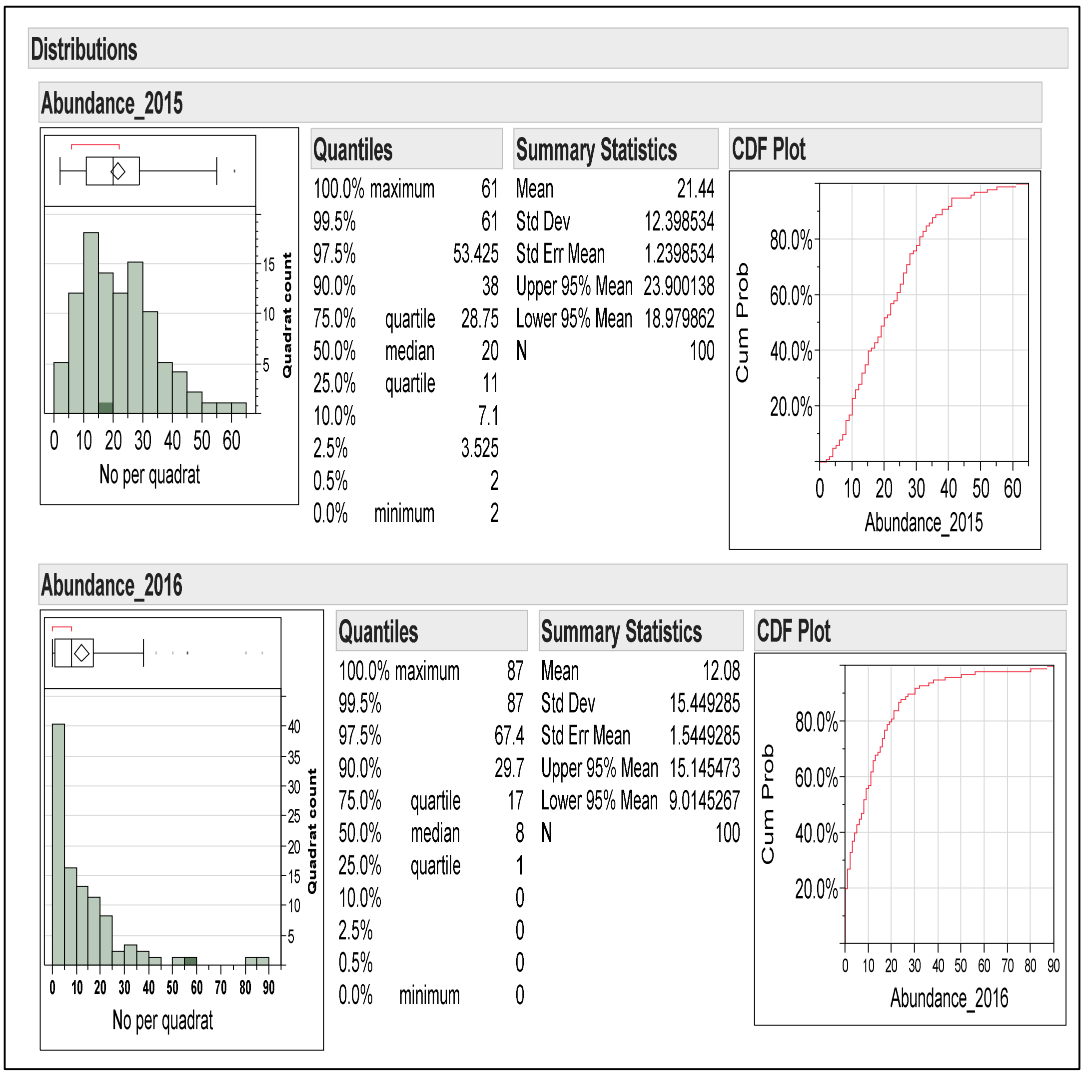


Fig. 2. Distribution analysis of Periwinkle (*Tympanotonus fuscatus)* abundance for 2015 and 2016 at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

Fig. 3 shows the distribution chart of the length (cm) parameter for the 2015 and 2016 year collections. The summary statistics for both years show a mean of 1.95 cm and 1.46 cm and a standard deviation of 0.34 and 0.87 for 2015 and 2016 respectively. The distribution analysis indicates the presence of the class interval 1.2-1.6 cm within 0.5-10% of the collections in 2015. Sixty-five percent (65%) of the data had lengths between 1.8 and 2.1 cm while 25% were within the length interval of 2.3 and 3.6 cm. In 2016 collections, only 65% of the data was observed to occur within the class interval of 1.4 and 1.9 cm. Twenty-five (25%) percent of the data was within the class interval of 2.1 and 5.1 cm. The cum probability function (CDF) for the 2015 data indicates 80% of the length variable was below 2.5 cm. In the 2016 data, 80% of the length variable was below 2.1 cm.

Fig. 4 shows the distribution chart of the weight parameter for the collections in the years of 2015 and 2016. The summary statistics shows a mean of 1.4 g and 0.7 g and a standard deviation of 1.17 and 0.47 for 2015 and 2016 respectively.

The distribution analyses indicate that between 2.5% and 10% of the samples in 2015 were individuals belonging to the weight class of 0.2 g and 0.3 g. Sixty-five (65%) percent of these had individuals belonging to weight classes of 0.6g and 1.8 g. The remaining twenty-five (25%) percent were between 3.6 and 5.0 g. In the 2016 collections, only sixty-five (65%) percent

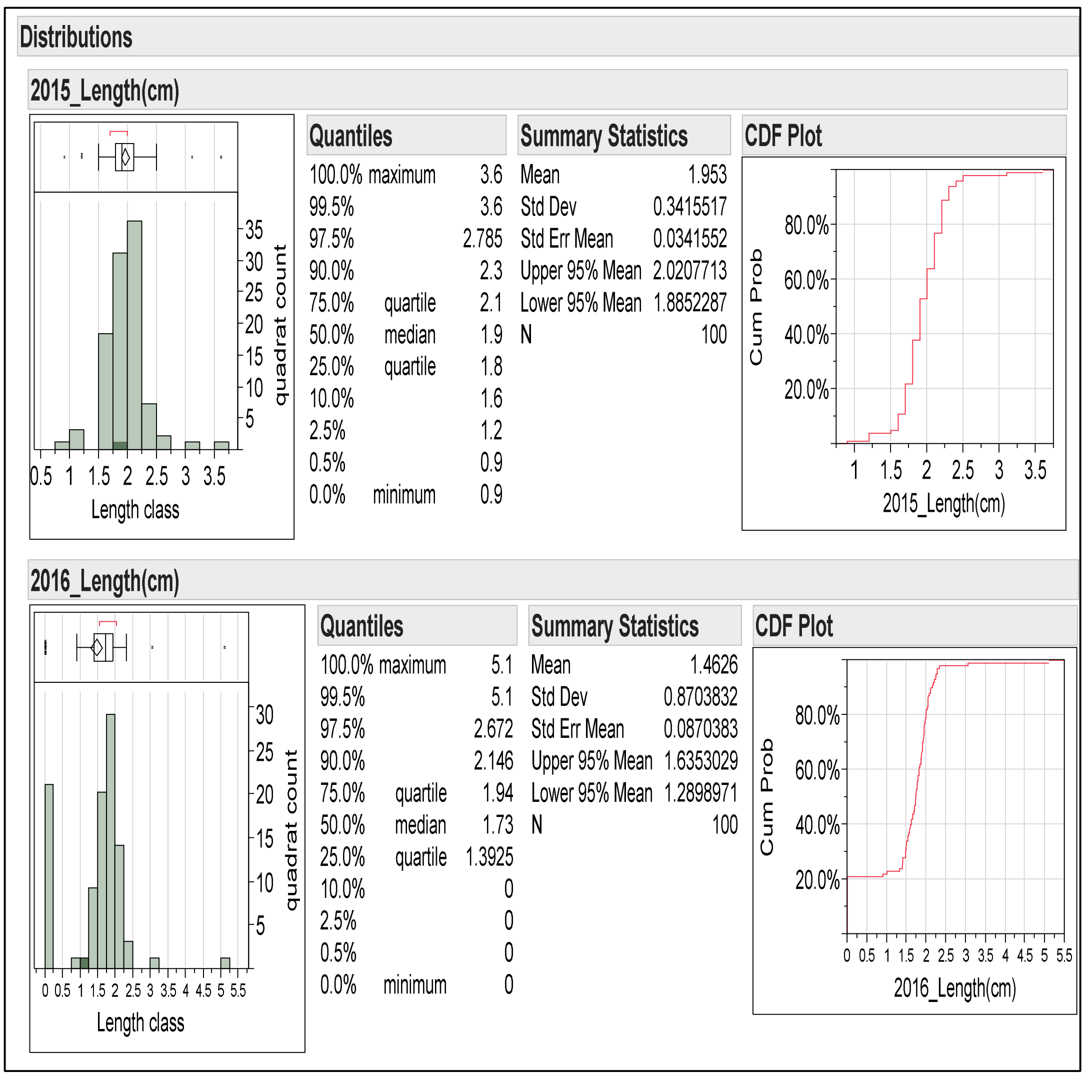


Fig. 3. Distribution analysis of *Tympanotonus fuscatus* length parameter for 2015 and 2016 at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

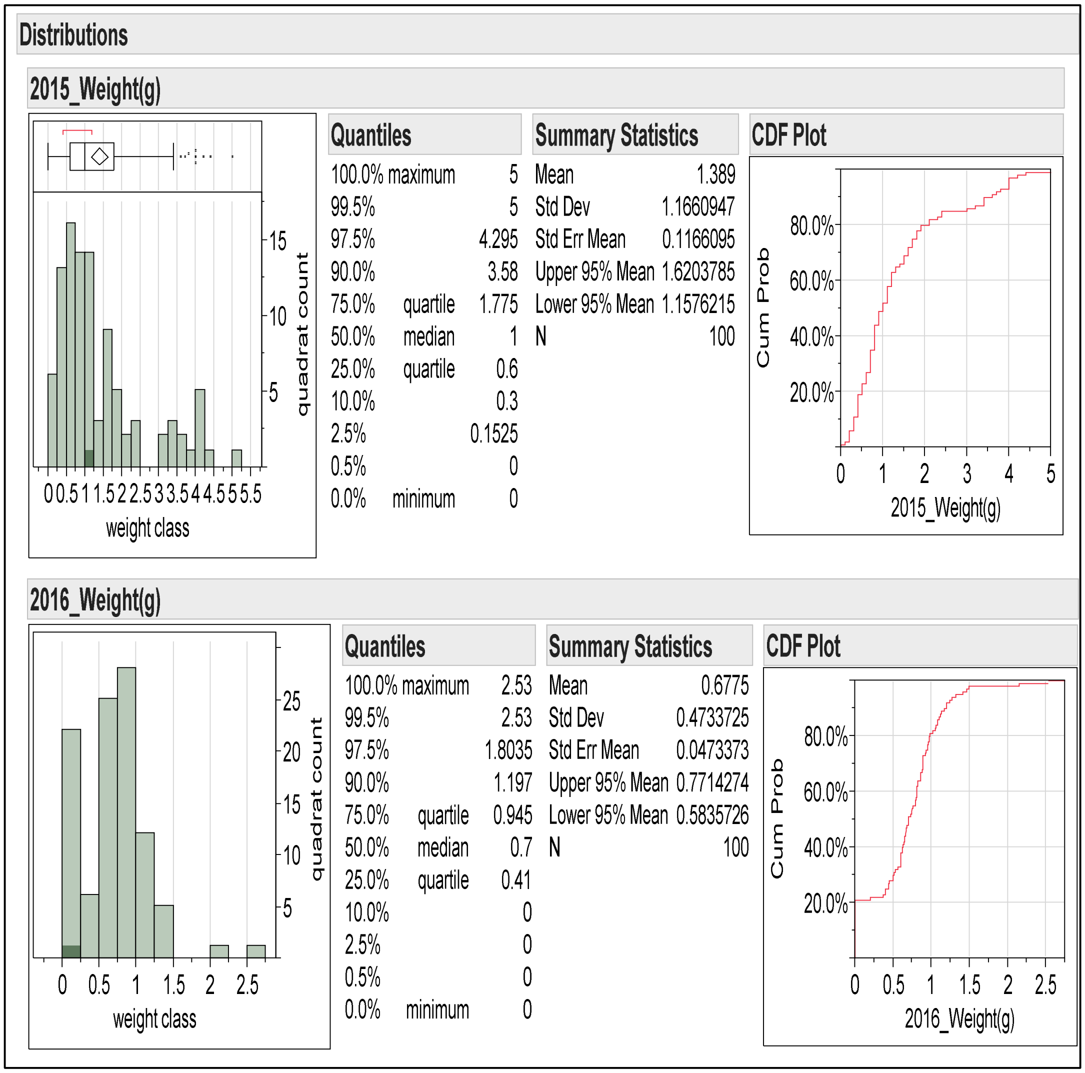
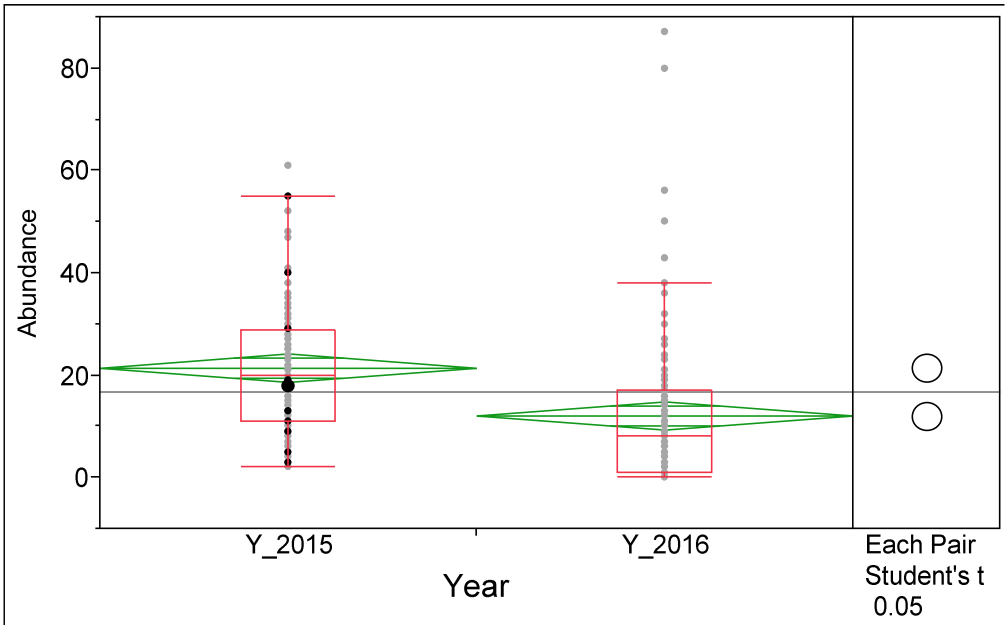


Fig. 4. Distribution analysis of *Tympanotonus fuscatus* weight parameter for 2015 and 2016 at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

belonged to the weight class 0.4 g to 0.9 g. The remaining twenty-five (25%) percent belonged to the weight class 1.2 g to 2.5 g. The cum probability function (CDF) for the 2015 data indicates 80% of the weight variable was below 3 g. In the 2016 data, 80% of the weight variable was below 1.5 g.

Fig. 5 shows the chart of the Student's t comparison of sample means of abundance between the 2015 and 2016 collections in the study area. The chart shows the abundance values with mean diamonds that are above and below the grand mean respectively. The non-overlap of the mean diamonds (the confidence interval) and the Student's t value of p <.0001 shows that the two group means are significantly different at the given confidence level.

Fig. 6 compares the sample means of the length parameter for the 2015 and 2016 collections. The chart shows the length values with mean diamonds that are above and below the grand mean respectively. The non-overlap of the mean diamonds indicates the significant difference among the two group means at the given confidence level. The Student's t summary statistics at p <.0001 value support the significant differences between the length variance estimates of 2015 and 2016 collections.



DF 189.1346
Prob > |t| <.0001*

LSD Threshold Matrix

Abs(Dif)-LSD	**Y_2015**	**Y_2016**
Y_2015	-3.9064	5.4536
Y_2016	5.4536	-3.9064

Positive values show pairs of means that are significantly different.

Fig. 5. Student's t test of abundance of *Tympanotonus fuscatus* between 2015 and 2016 years at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

Fig. 7 compares the weight values of the organisms for the 2015 and 2016 collections. The chart shows the abundance values with mean diamonds that are above and below the grand mean respectively. The non-overlap of the mean diamonds which represents the confidence intervals provides the first evidence that the two group means are significantly different at the given confidence level. The summary statistics of the Students t analysis shows that the p value of <.0001 supports the fact that there are significant differences between the variance estimates of 2015 and 2016 collections.

3.2 Length and Weight Relationship

The linear relationship of the length and weight are shown in Figs. 8 and 9 as regression trends for the 2015 and 2016 collections. In Fig. 8, the least square regression for the collections of the year 2015 shows an intercept of 0.829553 and a slope (b) of 0.2864552 which means that for every one unit increase in length an approximate increase of 0.3 in weight is expected.

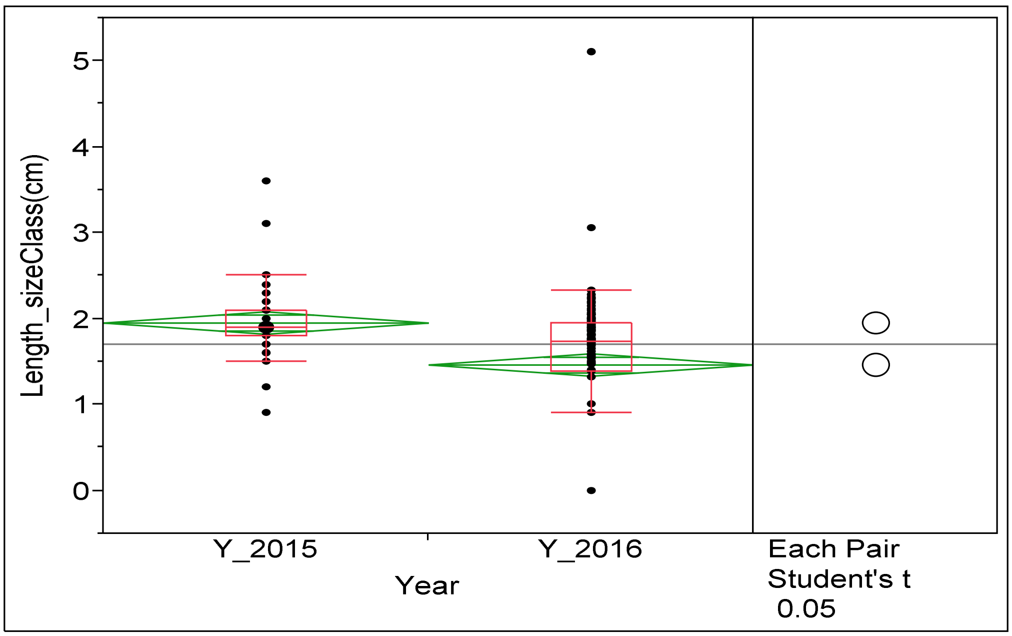
The R-square which is the percent of variance accounted for in the predicted (weight) from the predicting variable (length) is very low at 0.007. This means that only 0.7% of the weight variable is predictable from the length variable leaving 99.3% prediction of variance of the differences within the weight parameter unaccounted. The low b value of 0.3 indicates allometric growth which means weight gain was slower than the length.

In Fig. 9, the least square regression for the collections in the year 2016 show an intercept of

0.0376762 and a slope (b) of 0.4374564 which means that for every one unit increase in length an approximate increase of 0.4 g in weight is expected. The R-square, which is the percent of variance accounted for in the predicted (weight) from the predicting variable (length), is high at 0.6. This means that 60% of the weight variable is predictable from the length variable leaving 40% prediction of variance of the differences within the weight parameter unaccounted. The b value of 0.4 indicates negative allometric growth which means weight gain was slower than increase in length.

4. DISCUSSION

The study provides evidence of Periwinkle abundance dynamics in a mangrove habitat on the Bonny River. The abundance dynamics shows a population with low variance in 2015 (CV <1(54%)) and high variance (CV >1(130%)) in 2016. The variation was observed in the total abundance of periwinkle snails which declined by forty (40%) percent, varying from a density of 2090 snails in 2015 to 1192 snails in 2016. Similarly the number of individuals per unit area which were 2-61 indv/m^2 and 0-87 indv/m^2 in 2015 and 2016 respectively were dissimilar. Such values are consistent and also vary with the findings from other mangrove habitats on the Bonny River, New Calabar River and Cross River [5,12,13]. On the Bonny River and New Calabar River, studies show a consistency with this study in the number of individuals per square meter in slaughter habitat which had 30-50 indv/m^2 and Rumuolemini with a density of 50-72 indv/m^2.



Confidence Quantile

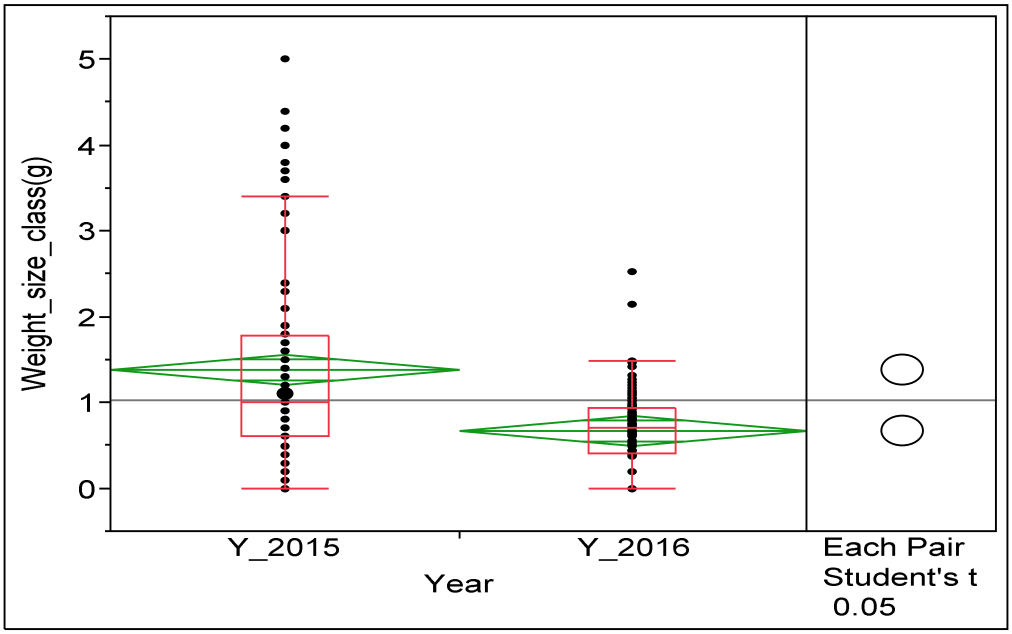
t	Alpha
1.97202	0.05

LSD Threshold Matrix

Abs(Dif)-LSD	Y_2015	Y_2016
Y_2015	-0.18438	0.30602
Y_2016	0.30602	-0.18438

Positive values show pairs of means that are significantly different.

Fig. 6. Student's t test of sample means of *Tympanotonus fuscatus* length (cm) classes between 2015 and 2016 at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria



Confidence Quantile

t	Alpha
1.97202	0.05

LSD Threshold Matrix

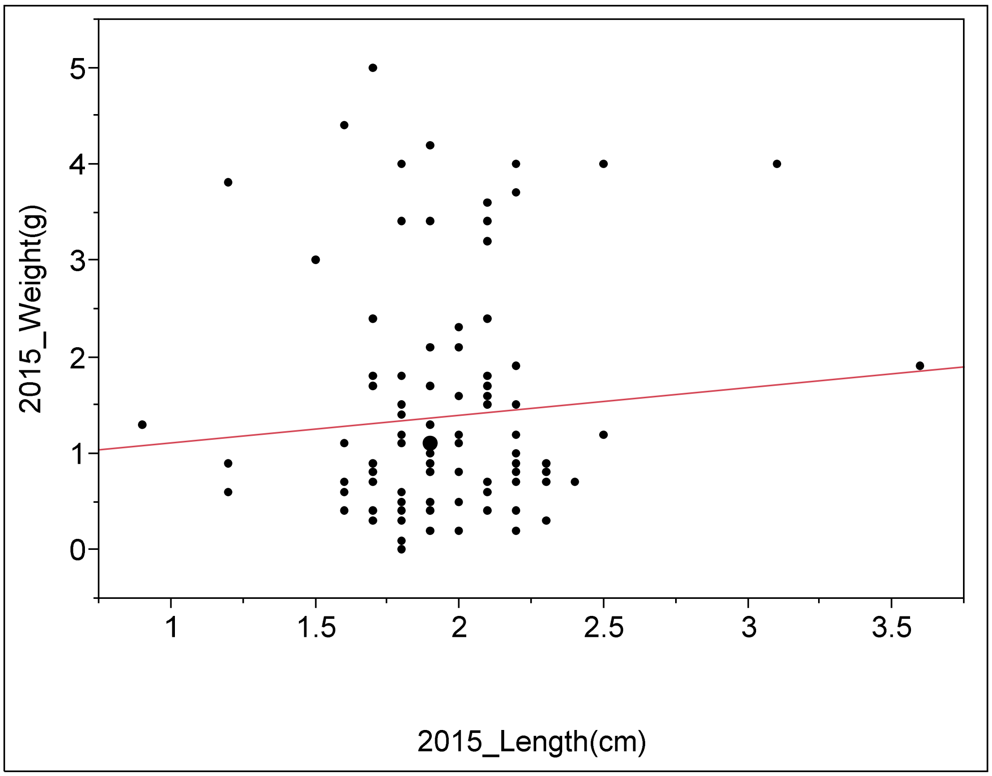
Abs(Dif)-LSD	Y_2015	Y_2016
Y_2015	-0.24818	0.46332
Y_2016	0.46332	-0.24818

Positive values show pairs of means that are significantly different.

Fig. 7. Student's t test of sample means of *Tympanotonus fuscatus* weight classes between 2015 and 2016 at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

In contrast, values inconsistent with this study from other mangrove sites were observed in Azubiae with 100-130 indv/m^2; Okujagu with 60 - 100 indv/m^2 and Oba/Kalio zone with 250-300 indv/m^2.

In the analysis of the length parameter, the periwinkles collected in 2015 were at variance with those of 2016 with smaller lengths in 2015. Many interpretations are possible with the likelihood of intense harvesting from the artisanal population within the area who had unhindered access provided by the deforestation of the mangrove forest for urban housing. In the weight parameter there was a significant observation of the absence of a range of weight in the class of 3 g to 5.5 g in the 2016 collections. This variation between-year in density, length and weight parameters was supported by the collinear and non-collinear values in the population behavior observed in the length-weight relationship between the years 2015 and 2016. In the 2015 year collections, the total length to weight exhibited a very poor linear relationship with R^2 = 0.007 indicating that the contribution of shell length to body weight can only be predicted by 0.3%. In contrast, in the 2016 collections, the length-weight relationship stabilized with R^2 = 0.646971, indicating that the contribution of the shell length to body weight can be predicted by sixty percent (60%). Studies on length-weight relationship of *T. fuscatus* on the Bonny River, Cross River and Lagos lagoon [5,13-16] have consistently shown a linear relationship between length and weight. The linear relationship which expresses the corresponding and equivalent increase in weight with increases in total length provides biologists an indication of the direction and rate of change of form or condition. The regression coefficient b which was 0.29 in 2015 and 0.47 in 2016 show negative allometry which clearly indicates a decrease in condition or elongation in form between the weight and length of the snails in both years. These substantial variance between the two dates in the weight-length relationship and in the abundance structure indicated likely changes in environmental conditions operating singly or in a complex interplay. In its areas of occurrence in Nigeria, such conditions and their effect on population characteristics and structure remain unresolved as the species are reported to have thermal and dehydration tolerance and occurrence in a wide range of salinity. Other studies have also shown inconsistent evidence of the differences in habitat zones (underwater and intertidal) or trophic conditions in affecting population structure and its characteristics [17-21].



Linear Fit
2015_Weight(g) = 0.829553 + 0.2864552*2015_Length(cm)

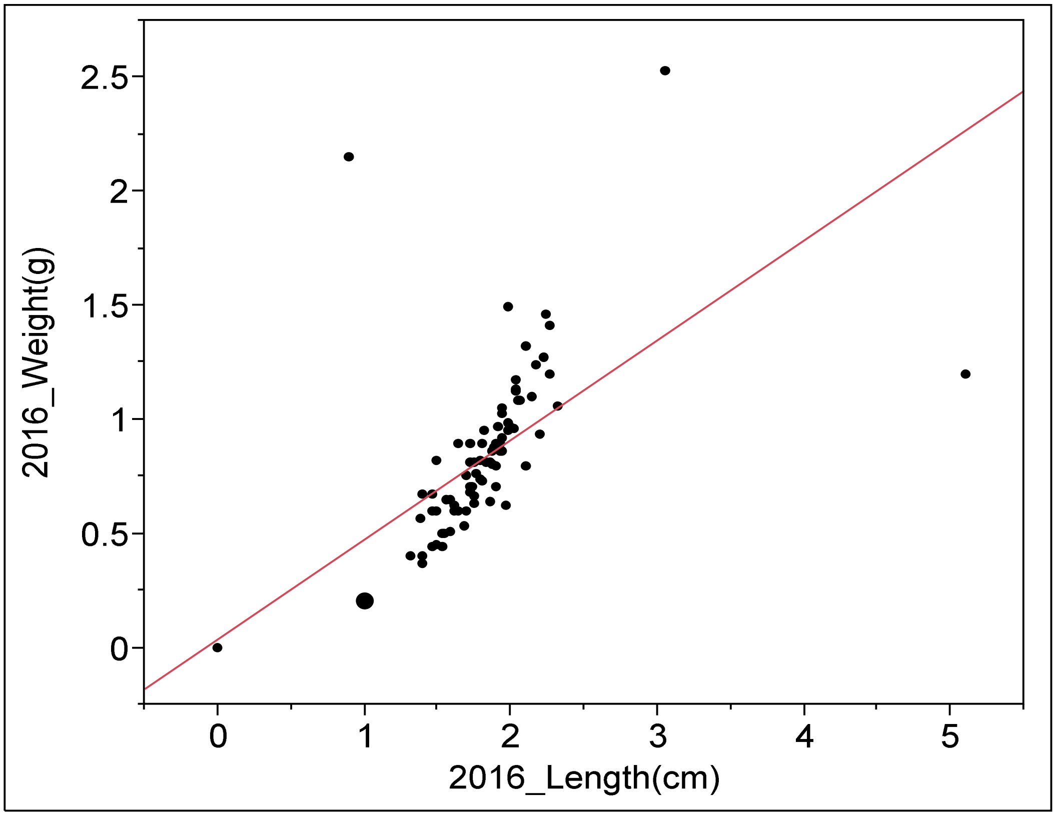
Summary of Fit

RSquare	0.00704
RSquare Adj	-0.00309
Root Mean Square Error	1.167896
Mean of Response	1.389
Observations (or Sum Wgts)	100

Parameter Estimates

Term	Estimate	Std Error	t Ratio
Intercept	0.829553	0.681255	1.22
2015_Length(cm)	0.2864552	0.343661	0.83

Fig. 8. Length and weight relationship of *Tympanotonus fuscatus* in 2015 collections at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria



Regression eqn: 2016_Weight (g) = 0.0376762 + 0.4374564*2016_Length(cm)

Summary of Fit

RSquare	0.646971
RSquare Adj	0.643368
Root Mean Square Error	0.282692
Mean of Response	0.6775
Observations (or Sum Wgts)	100

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0376762	0.055485	0.68	0.4987
2016_Length(cm)	0.4374564	0.032643	13.40	<.0001*

Fig. 9. Length and weight relationship of *Tympanotonous fuscatus* in 2016 collections at Bundu-Ama (4.74306°N and 7.00835°E) in Port Harcourt Metropolis, Nigeria

In illustrating the potential changes in the population dynamics, the study provides the framework for conservation studies required to establish sustainable reproductive capacity in the wide range of habitats they occur in Nigeria. Studies over the years have indicated the species as a mass consumer product [22] rich in protein and amino acids [8,23]. Therefore critical to conservation studies is the knowledge to prevent the effect of extreme habitat conditioning drivers such as indiscriminate and massive mangrove deforestation and Nypa invasion of mangrove habitats. Both drivers can overwhelm the natural balance of ecological processes that control the intrinsic factors of natality and mortality under ideal or limiting conditions. Conservation studies must tackle the paucity of habitat-specific fitness information required for management of natural systems or artificial farming of the snail where there is inevitable habitat modification.

5. CONCLUSIONS

The study provides evidence of significant variation in the population dynamics and characteristics of *Tympanotonous fuscatus* in a deforested mangrove habitat. The snails which were sampled at the same period in 2015 and 2016 provide an example of species whose population characteristics was in a conditioned habitat. Although the influences of the habitat conditioning factors were not discussed, evidence of the quantitative variation in the population dynamics is given to direct future research in conservation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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