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Temporal dynamics in biomass and diversity of phytomacrofauna community in a two-arm lagoon, Southwest, Nigeria

Uwadiae R.E., Akinsanya M., Bello D.

Benthic Ecology Unit, Department of Marine Sciences, University of Lagos Akoka, Lagos, Nigeria

Corresponding author:
E-mail: eferoland@yahoo.com;
ruwadiae@unilag.edu.ng

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ABSTRACT

Background: Temporal variability in time and space is known to shape the distribution of organisms, their interactions and adaptations . In Nigeria, Southwest region in particular, studies investigating patterns in phytomacrofauna attributes are scarce.
Objectives: This study reports the temporal patterns in biomass, density and diversity of phytomacrofauna community in a two-arm lagoon, Southwest, Nigeria.
Methods: Monthly samples collected for seven consecutive times at eight sampling locations were used for this investigation.
Results: Of all the physico-chemical variables investigated only salinity was significantly different (ANOVA, $F = 5.33$, $p < 0.05$) among sampling months. There was a significant difference in the biomass (ANOVA, $F = 2.983$, $p < 0.05$) recorded for the sampling months. Monthly biomass varied between 552 and 2976 gm^{-2}, with November and January recording the lowest and highest values respectively. Of the three phytomacrofauna phyla (Mollusca, Arthropoda, Annelida) collected, mollusca recorded the highest (3548 gm^{-2}) biomass during the study period. Monthly density varied between 960 and 5810 ind/m^2 with May and February recording the lowest and highest values respectively. There was no significant difference in the monthly density (ANOVA, $F = 0.485$, $p > 0.05$) of phytomacrofauna. The phylum arthropoda recorded the highest (15000 ind/m^2) density among the three phyla collected. Temporal variation in density of phytomacrofauna was similar to the pattern displayed by biomass. The month of May supported the highest phytomacrofauna diversity and species richness.
Conclusion: Overall pattern displayed in the results suggests an overwhelming influence of temporal changes in environmental conditions on the phytomacrofauna variables.

Keywords: *Phytomacrofauna, biomass, diversity,* physico-chemistry, *lagoon*

INTRODUCTION

Temporal variability in time and space is known to shape the distribution of organisms, their interactions and adaptations (Palmer and Poff, 1997; Bogan and Little, 2007; Collier, 2008; Mesa *et al*., 2009; Cowell *et al.,* 2014). The temporal distribution of environmental parameters like temperature and salinity is critical in regulating the ecology of many organisms, such as the phytomacrofauna community (Brooks, 2000; Bervin *et al*., 2000; Bogan and Little, 2007; Cowell *et al*., 2014). Since temporal patterns in environmental conditions affect the growth and development of aquatic macrophytes, the animal community associated with these plants is also exposed to temporal influences (Mackay, 1992; Thompson and Townsend, 1999). Characteristics of macrophytes affect animal assemblages and determine biodiversity through a chain of mechanisms, related to habitat complexity, that involve the availability of shelter and feeding sites. The plant community may change during the growing months, resulting in a change in community composition and dominance of species of animal communities attached to them. Macrophytes are very

dynamic habitats where macroinvertebrate community structure may vary throughout the growing season (Bogan and Little, 2007). Hence, temporal effects may be significant as observed in many studies (Bogan and Little, 2007; Cowell *et al*., 2014).

Also, most physical and chemical variables in the aquatic systems are subjected to temporal changes owning to climatic influences. For example, salinity condition which is a major factor determining the distribution of host macrophytes and the attached phytomacrofauna is strongly influenced by temporal changes in rainfall pattern. Other associated variables such as flooding, discharge of run-offs laden with organic matter are also linked to temporal changes. Hence, the overall patterns displayed by phytomacrofauna attributes are related to the prevailing temporal changes in climatic and associated environmental conditions.

In Nigeria, the Southwest region in particular, studies investigating patterns in phytomacrofauna attributes are scarce. Although, Uwadiae (2011; 2017a; b) has investigated different aspects of phytomacrofauna, the scope of these studies did not cover temporal patterns in phytomacrofauna attributes in detail. The objectives of this study therefore, are to investigate the temporal patterns in biomass, density and diversity of phytomacrofauna community in a two-arm lagoon, Southwest Nigeria with a view to ascertaining the extent of influence of temporal changes in environmental conditions. This is important to the understanding of the overall impact of temporal dynamics in environmental factors on aquatic ecosystems in the face of global climate change.

MATERIALS AND METHODS

Study site

This study was conducted in Iyagbe Lagoon in Lagos State, Southwest, Nigeria. Iyagbe Lagoon lies parallel to the Western Nigeria shoreline and is separated from the ocean by a barrier bar system. It is connected to the ocean through the Lagos Habour which connects directly with the Lagos Lagoon. Iyagbe Lagoon is a two-arm lagoon (Fig. 1) located between Latitude 6° 23'N and Longitude 3° 06' E and comprised of the Porto-Novo Creek as one arm and Badagry creek as another arm. The depth of the lagoon in the area used for this study ranged from 0.74 to 1.74 m and transparency varied between 0.39 and 0.7 m. The lagoon experiences an annual dual- seasonal pattern in the rainfall distribution which tends to regulate the salinity and water level. The surface of the lagoon is covered with a varied mass of water hyacinth distributed in patches at different points especially close to the lagoon shore. Eight sampling points were used for this study.

In situ measurements and collection of samples

Sampling for environmental parameters and phytomacrofauna were carried out between 10:00 and 15:00 h on each sampling day at monthly intervals.

Surface water temperature was measured in ^{0}C with a mercury in-glass thermometer. Salinity of water at the sampling stations was measured with a Salinometer (Hiener instrument, Model HI991301) and values recorded in parts per thousand (‰). Transparent and amber coloured reagent bottles of 250 ml volume were used for the collection of water samples for the analysis of Dissolved Oxygen (DO) and Biochemical oxygen Demand (BOD_5), while water samples used for the determination of other physico-chemical parameters were collected in pre-washed 1 litre plastic bottles.

Phytomacrofauna samples were collected within water hyacinth canopy by placing a 0.1m^2 quadrant over stands of the plant, the roots of water hyacinth stands enclosed in the quadrant were carefully placed in a bowl containing 10% formalin solution (this facilitates removal of attached organism). The plants were then vigorously shaken to detach all the animals inhabiting the roots into the bowl. Detached animals were then washed into a screw cap plastic container through a 0.5 mm mesh size sieve. The remaining animals were hand-picked into the plastic container. The samples were fixed in 10% formalin solution and taken to the laboratory for further processing.

Laboratory studies

In the laboratory, phytomacrofauna samples were washed to remove the fixative and sorted into different phyla under a dissecting microscope. Specimens were identified to the lowest possible taxonomic level using guides provided in Edmunds (1978), Yankson and Kendal (2001) and Bouchard (2004). Numbers of individuals of the different phyla expressed as population density (untransformed data of individuals per m^2) in each study month were recorded. The biomass of all sorted organisms was determined by wet method (Holme and Mclntyre, 1971). This involves direct weighing of all the sorted animals of each phylum. The organisms were allowed to dry for one minute after puncturing the shells with a fine needle and the mantle cavity water sucked up with filter paper (in the case of molluscs) and all the animals were drained on a fine sieve until liquid is no longer noticeable. The organisms were then weighed using an electronic scale of 0.001g sensitivity and values approximated to the nearest weight in gramme per square meter (gm^{-2}).

Statistical analysis

One-Way analysis of variance (ANOVA) was used to compare the variations in physico-chemical parameters and phytomacrofauna variables during sampling months. When significant variations are detected, a *post hoc test* using Duncan Multiple Range Test (DMRT) for physico-chemical parameters and Tukey's Honestly Significantly Different (HSD) test for fauna variables were performed to determine the locations of significant differences. Species richness was determined by Margalef's index, Community diversity by Shannon–Wiener index, measure of how evenly the individuals were distributed among the species present in samples was determined by Equitability index, Dominance by Simpson's dominance index, using the formulae for each index as stated in Stephen (2000).

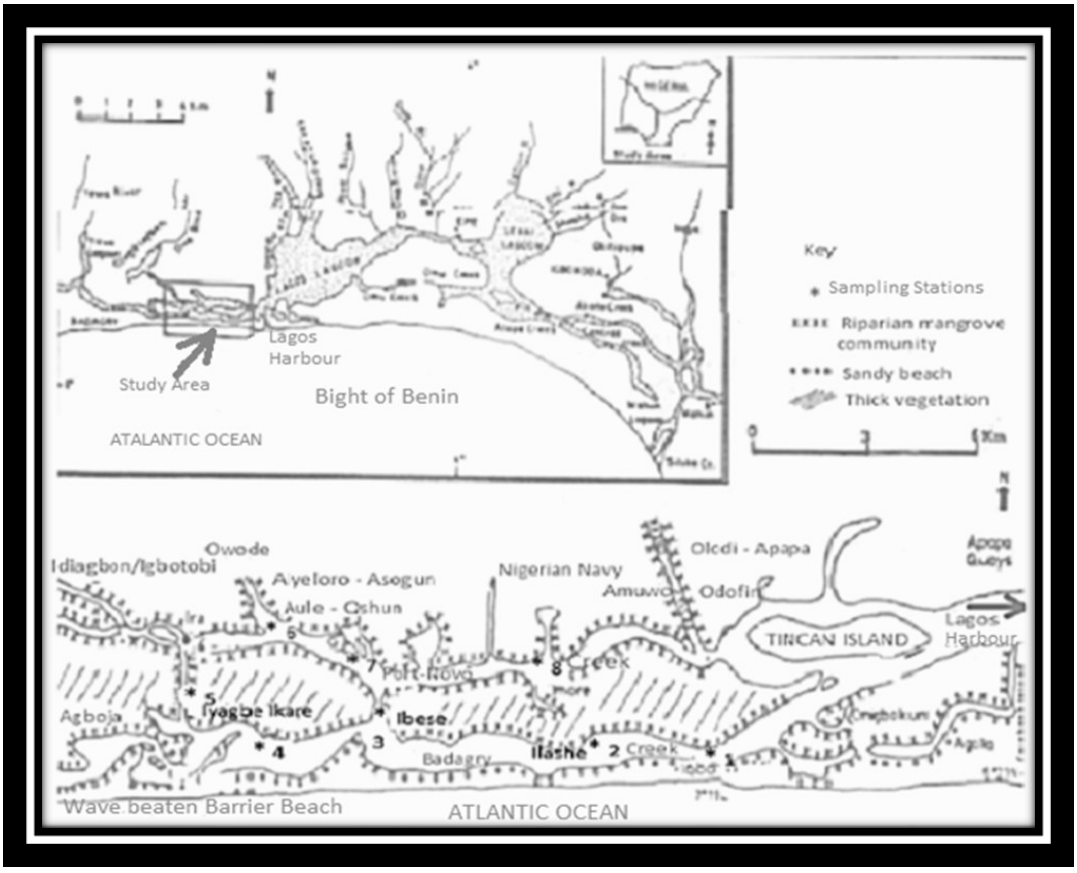

Fig. 1. Map of study area showing sampling stations

RESULTS

Physico-chemical parameters

Summary of values of physico-chemical parameters investigated is shown in Table 1. There were great variations in values for each parameter during the sampling months. Except for salinity, no particular trend was evidenced in values recorded for the physico-chemical variables. Water temperature ranged from 26 to 32˚C. Salinity of surface water fluctuated between 0.01‰ recorded in the months of November, December and May, and (7.8‰) recorded in February and March. There was significant difference (ANOVA, $F = 5.33$, $p < 0.05$) in the values of salinity recorded during the sampling months. A *post hoc test* using DMRT indicates that salinity in the months of November, December, January, April and May were similar and significantly lower than those of February and March.

Dissolved oxygen concentration was relatively uniform during the sampling months. The highest concentration (3.9 mg/L) recorded in November, and lowest value (3.0 mg/L) observed in November, February and April. The Biochemical oxygen demand ranged from 1.1 to 1.6 mg/L. The highest BOD_5 value was recorded in November and the lowest value occurred in most of the sampling months. The values for Total dissolved solids varied between 0.14 and 50 mg/L. The highest value was recorded in December while the lowest occurred in November. Total suspended solids in surface water ranged from 0.02 to 20.10 mg/L. The lowest value was recorded in November, while the highest value was observed in the month of January. Surface water pH values fluctuated between 5.82 and 8.08 with the highest value recorded in February and March, and the lowest value observed in March and April.

Temporal variations in biomass

Summary of values of phytomacrofauna biomass is presented in Table 2. High temporal variability in fauna biomass was observed in this study (Fig. 2). A total phytomacrofauna biomass of 6742 gm^{-2} contributed by three phyla (Mollusca, Arhthropoda and Annelida) was recorded in this study. Total monthly biomass varied between 552 and 2976 gm^{-2}, with November and January recording the lowest and highest values respectively. In the months of December, February and May, 758 gm^{-2}, 1568 gm^{-2} and 888 gm^{-2} respectively were recorded. No Phytomacrofauna was recorded in the months of March and April. There was significant difference in the biomass (ANOVA, $F = 2.983$, $p < 0.05$) recorded for the sampling months, a post –hoc test using Tukey's HSD shows that biomass recorded in the months of November, December and May were similar and significantly lower than those recorded for the months of January and February.

Of the three phytomacrofauna phyla collected, mollusca recorded the highest (3548 gm^{-2}) biomass. The group recorded their highest monthly biomass (216 gm^{-2}) in January while the lowest (89 gm^{-2}) occurred in November. Values observed for other sampling months were; 495 gm^{-2} in December, 438 gm^{-2} in February and 366 gm^{-2} in May. Major contributors to molluscan biomass were; *Pachymelania aurita* (800 gm^{-2}), *Neritina glabarata* (584 gm^{-2}), *P. fusca quadriseriata* (510 gm^{-2}), *Tympanotonus fuscatus* (490 gm^{-2}), *N. kuramoensis* (400 gm^{-2}), *Eulima fisceri* (370 gm^{-2}) and *Gyraulus parvus* (260 gm^{-2}) (Fig. 3).

Arthropoda recorded a total biomass of 3177 gm^{-2} during the study with lowest monthly biomass (263 gm^{-2}) occurring in December and the highest (1129 gm^{-2}) recorded in February. In this group the class Crustacean was dominant and the major contributor and constituted 94.2 % of the arthropoda biomass recorded (Fig. 4). Among the arthropod species recorded, *Penaeus notalis* (1442 gm^{-2}), *Sesarma huzardii* (601 gm^{-2}), *Eurydice pulchra* (472 gm^{-2}), *Amphilochus* sp (272 gm^{-2}) and *Idotea* sp (222 gm^{-2}) were more important. Annelida recorded a remarkably low biomass in this study. A total of 17 gm^{-2} was recorded by this phylum in the months of the sampling exercise. Monthly biomass varied between 1 and 14 gm^{-2} with the lowest observed during most of the sampling months and the highest occurring in January.

Table 2. Summary of values of phytomacrofauna biomass (gm^{-2}) during the study period

Sampling months	Statistics	Phytomacrofauna phyla		
		Annelida	Arthropoda	Mollusca
Nov	Mean±SD	0.125±0.35	58±80	10±9.0
	Min	0	7	0
	Max	1	249	27
Dec	Mean±SD	-	33±17	61±108
	Min	-	13	0
	Max	-	56	314
Jan	Mean±SD	1.6±3.0	100±264	153±250
	Min	0	0	0
	Max	8	419	4.3
Feb	Mean±SD	0.125±0.35	141±193	55±81
	Min	0	0	0
	Max	1	459	132
March	Mean±SD	-	-	-
	Min	-	-	-
	Max	-	-	-
April	Mean±SD	-	-	-
	Min	-	-	-
	Max	-	-	-
May	Mean±SD	0.125±0.35	65±154	50±90
	Min	0	0	0
	Max	1	446	270

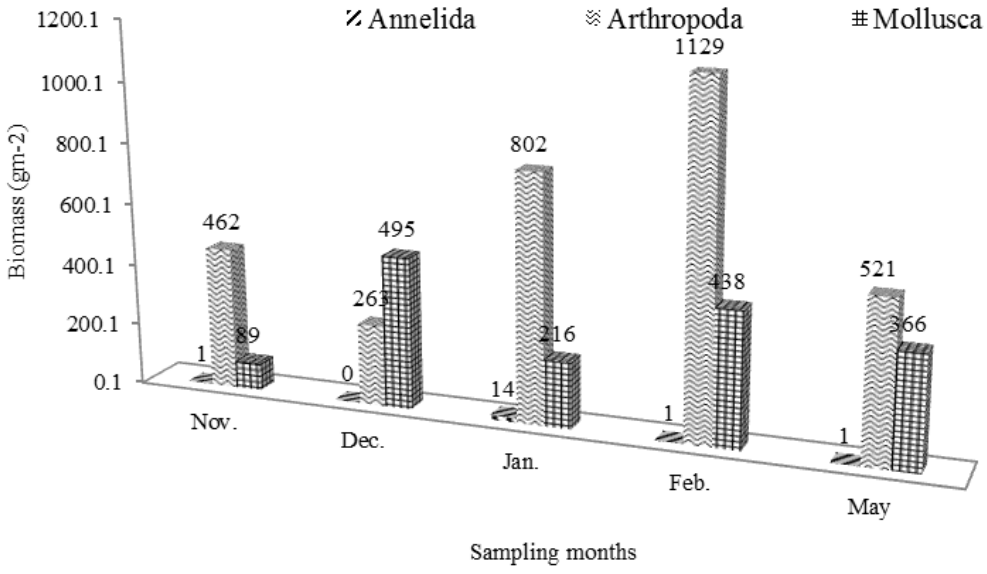

Fig. 2. Temporal variation in phytomacrofauna biomass in the study area.

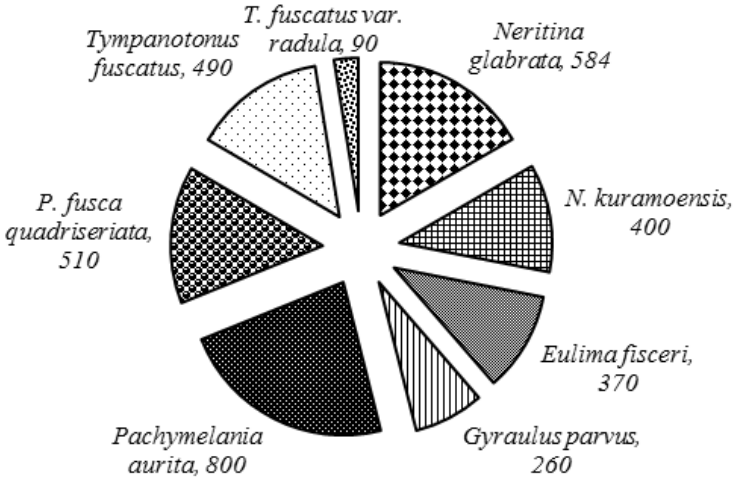

Fig. 3. Relative contributions of molluscan species to phytomacrofauna biomass.

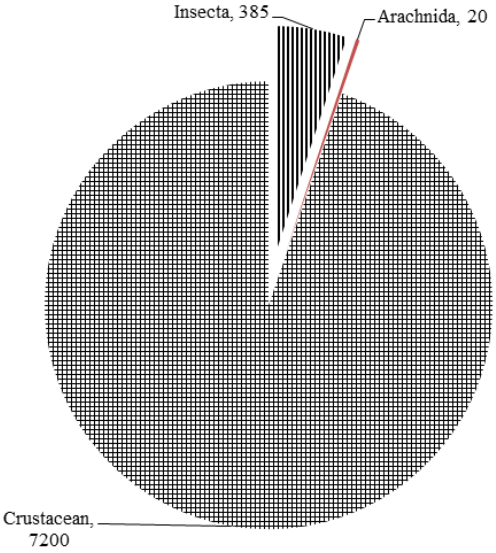

Fig. 4. Relative contributions of classes of arthropoda to phytomacrofauna biomass

Table 3. Summary of values of ecological indices during the study period

	Sampling months						
Ecological index	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Total species diversity (S)	14	20	20	19			20
Total abundance (N)	535	382	270	581	-	-	96
Shannon-Wiener Index (Hs)	0.33	0.61	0.86	0.69			1.09
Menhinick Index (D)	0.61	1.02	1.22	0.79			2.04
Margalef Index (d)	2.07	3.2	3.39	2.83	-	-	4.16
Equitability Index (j)	0.29	0.47	0.66	0.54			0.84
Simpson's Dominance Index (C)	0.7	0.44	0.24	0.32			0.12

Temporal pattern displayed in the values of the different phytomacrofauna phyla showed that, in the first month (November) of sampling, arthropoda dominated the biomass with the 462 gm^{-2} contributed accounting for 84% of the total phytomacrofauna biomass observed. The second sampling month (December) witnessed the dominance of mollusca. This group recorded a biomass of 495 gm^{-2} and accounted for 65% of phytomacrofauna biomass observed for the month. The mollusca also dominated the mass of the animals collected in January, with 2160 gm^{-2} recorded constituting about 73% of the mass of phytomacrofauna for the month. In February and May, arthropoda recorded the highest biomass. With 1129 gm^{-2} in February and 521 gm^{-2} in May. The phylum comprised 72% and 59% of the biomass for the two months respectively.

A critical evaluation of the monthly pattern displayed in the biomass values showed that the dry months (November – February) was the peak biomass period for the phytomacrofauna community. Apart from the fact that, the organisms recorded their highest monthly total biomass, the three phyla (Annelida, Mollusca, Annelida) recorded their highest monthly biomass in this month.

Temporal variations in density and diversity

A total phytomacrofauna density of 18640 ind/m^2 was recorded in this study. Monthly density varied between 960 and 5810 ind/m^2 with May and February recording the lowest and highest values respectively. There was no significant difference in the monthly density (ANOVA, $F = 0.485$, $p > 0.05$) of benthic phytomacrofauna, In the months of November, December and January, 5350 ind/m^2, 3820 ind/m^2 and 2700 ind/m^2 respectively were recorded. Of the three phytomacrofauna phyla collected, arthropoda recorded the highest (15000 ind/m^2) density, followed by mollusca (4540 ind/m^2), while annelida recorded the least (220 ind/m^2) density. Temporal variation in density of phytomacrofauna was similar to the pattern displayed by biomass. The only area of difference was that, although mollusca recorded a higher biomass than arthropoda, its density was lower.

There was high variability in values recorded for all the ecological indices (Table 3). Monthly variation in total species richness ranged from 14 to 20. Whereas the lowest number of species was recorded in the month of November, the highest value occurred in the months of January, May and December. February recorded 19 phytomacrofauna species. Shannon-Wiener's index of diversity for the various sampling months varied between 0.33 observed in November and 1.09 obtained in the month of May. Menhinicks index fluctuated between 0.61 in November and 2.04 in May. Monthly values for Margalef's index of species richness ranged from 2.07 to 4.16 observed in November and May respectively. Index of Equitability was lowest (0.29) in November and highest (0.84) in May. Simpson's Dominance Index for the sampling months were; 0.70 for November, 0.44 in December, 0.32 in February, 0.24 in January and 0.12 in May. The month of May supported highest phytomacofauna diversity and species richness in this study. Highest values of all the ecological indices occurred in this month.

DISCUSSION

Environmental parameters investigated showed results typical of the lagoon systems in Southwest Nigeria. The temporal variation in salinity was remarkable in this study and tends to be the major determinant of the observed pattern in phytomacrofauna variables. The result of the salinity confirms observations of previous workers (Uwadiae, 2009; Uwadiae, 2017a,b) that, there are two salinity seasons per annum in the Lagos Lagoon system. The salinity is low between May and October (rainy season) due to influx of freshwater from rivers, storm water, run-offs and rainwater and high from December to April (dry season).

Temporal variability in phytomacrofauna biomass, density and diversity were strongly influenced by environmental conditions associated with seasonal climatic changes as noted in other studies in different regions of the world (Brewin *et al*., 2000; Bogan and Lyttle, 2007). Seasonal variability is associated with significant differences

in the environmental variables, influencing strongly the community parameters. Phytofauna communities change throughout the year in response to environmental conditions and these changes result from the life histories of individual animal species (Palmer and Poff, 1997; Mesa, 2012).

Biomass of the three phyla was relatively higher at the peak of dry season (November - February). This observation agrees with the findings of Egonmwan (2007). The report noted that, spawning in *Pachymelania* spp which is the major component of the assemblage recorded in this study occurred at end of rainy season and the beginning of the dry season, when the salinity of the water ranged from about 0.5 - 25.5 psu. In addition, monthly changes in the gonad indicated that spermatogenesis is synchronous with oogenesis and the number of individuals with ripe ovaries and testis were more between August and March. This in the view of the author indicates that, the species probably has a defined annual cycle of gametogenesis and a single spawning period of September to February for females and October to March for males. This is also true for *Tympanotonus* spp., another important component of the assemblage. Egonmwan (1985; 1986) reported that spawning in this genus occurred in dry season (December to March) with salinity range of 9.2 -25.5 psu). From May to July (15.5-1.25 psu), the animals were reported to be in their resting phase.

Temporal evaluation of phytomacrofauna diversity and species richness shows that, values were highest at the onset of the rainy season (May). The relatively higher values in months noted for higher amount of rains may be due to the higher water hyacinth mass since the plant experiences luxuriant growth with the rains, increase organic content of water and sediment thereby creating a nutrient rich substratum for the animals. High density of *Eichhornia crassipes* during the rains is known to promote higher taxa richness since it provided enough colonization space for the animals. However, overall species diversity has been reported to be the product of all dynamic spatial and temporal changes affecting the community (Bervin *et al*., 2000; Mesa, 2012; Cowell, *et al.,* 2014). It could also be a reflection of the extent to which an ecosystem has been perturbed by human activity (Lake, 2000).

This study shows that, variability in community biomass, density and diversity was more relevant with respect to months than the presence-absence which did not exhibit a significant pattern of temporal change. This corroborates the observations of Mesa (2012), which reported that, the main influence of temporal variation on macroinvertebrates is often expressed in terms of changed taxa abundance rather than complete species replacement. This assertion compares favourably with the result of this study where the biomass varied temporally while the presence -absence data were similar among sampling months. Results of samples collected during the onset of the rains (April/May) showed a community in a state of recovery from the adverse environmental condition suffered in the dry months. Apart from the absence of annelids in samples collected in December, the phytomacrofauna composition did not change qualitatively during the period and there were no clear differences in monthly taxa composition.

During the dry months salinity in the lagoon increases, this is accompanied by shrinking and subsequent death and elimination of freshwater macrophyte species such as water hyacinth. This was the case with the study area in March and April when no water hyacinth stand was available in the lagoon for sampling. Through resilience and persistence, macroinvertebrates are able to withstand environmental change (Mesa *et al.* 2009). Life history adaptations such as small adult body size, rapid development time, and continuous reproduction, could ensure that adults remain present throughout the adverse season (Lytle, 2001). Hence during this period of high salinity, when there are no water hyacinth stands in the lagoon most phytomacrofauna taxa move to the sediment and recolonize the macrophyte when the rains returns.

Relating the diversity and species richness of phytomacrofauna in the study area to temporal pattern reveal that, the rains favoured all the indices investigated, greater values were recorded in the rainy months. This also corroborates the observations of

Mesa (2012). During the dry months, water hyacinth is reduced in mass and volume of surface water covered. This results in fewer colonization space for the invertebrates and some may therefore, either die for lack of space and exposure to predators or burrow into the sediments (Mesa *et al*., 2009). On the other hand, the rain provides a favourable condition for the luxuriant growth of water hyacinth hence providing more space for colonization of phytomacrofuna community. Large organic materials in addition to high sediment load are carried into water bodies during the rains, these materials act as source of nutrient in the aquatic environment, and they form loci for the colonization of microbes which form important food source for phytomacrofauna. The onset of the rains has also been reported to have great influence in the emergence, reproduction, growth and development of aquatic macroinvertebrates (Lytle, 2001; Lake, 2000) and the seasonal replacement of the organisms (Bogan and Lytle, 2007). This may have accounted for the higher diversity and species richness in May during the sampling exercise.

Some studies have been made on the main influence of temporal variation in terms of change in species abundance rather than complete species replacement (Thompson and Townsend, 1999; Brooks, 2000). Many invertebrate taxa are persistent, species composition and relative abundance remain much the same in the long term (Boulton and Lake, 1992) and resilient, original configuration is quickly reestablished after disturbance (Flecker and Feifareck, 1994).The temporal change in environmental conditions may provide selective pressure for the specific life history characteristics such as short life cycles and continued reproduction and could eliminate poorly adapted colonizing taxa (Flecker and Feifarek, 1994; Lytle and Poff, 2004).

CONCLUSION

Temporal variations in environmental conditions play important role in determining the patterns of phytomacrofauna biomass and diversity. In this study, although macroinvertebrates composition appeared to be relatively stable on the basis of presence-absence of taxa, biomass and diversity fluctuated between the study months. The result obtained in this work is also a demonstration of how phytomacrofauna population may be affected by temporal changes in environmental conditions that host plants may be exposed to.

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