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Community structure, biomass and density of benthic phytomacrofauna communities in a tropical lagoon infested by water hyacinth (*Eichhornia crassipes*)

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Abstract. The community structure, biomass and density of benthic phytomacrofauna were examined in a tropical lagoon in Southern Nigeria. A range of 2.0 - 5.1mg/L, 13.1- 114.0 mg/L, 7.7 - 153.0 mg/L, and 40 - 119 cm were recorded for dissolved oxygen, biochemical oxygen demand, chemical oxygen demand and transparency respectively. Values obtained for other parameters ranged between 22 and 623 µS/cm for conductivity, 27 and 34^{O}C for water temperature, and from 5.5 to 6.9 for pH. Annelida, Arthropoda and Mollusca were the phytomacrofauna groups observed in this study. A total phytomacrofauna density of 12400 ind/m^2 and biomass of 236.32g/m^2 were recorded. Arthropoda was dominant in all the study sites and constituted 76.88% of the total population of phytomacrofauna. Spatial and temporal differences in densities of benthic phytomacrofauna were not significantly different (ANOVA, F = 0.685, $p > 0.05$). Their low density and taxa richness, and occurrence of oxygen deficient tolerant taxa such as chironomids, *Physa* sp, *Gyraulus* sp and naidid oligocheates in the study area suggest that the environment is perturbed. The generally low dissolved oxygen and high biochemical oxygen demand observed in the study area further indicate that the water quality condition have impacted negatively on phytomacrofauna assemblage. The spatiotemporal variations in the results recorded do not suggest that the benthic phytomacrofauna communities were influenced by site specific and seasonal factors, but by the generally degraded water quality.

Key words: Water quality, macroinvertebrates, tropical lagoon, water hyacinth

Resumo. Estrutura comunitaria, biomassa e densidade da fitomacrofauna bentônica em uma lagoa tropical infestada pelo jacinto de água (*Eichhornia crassipes*). Foram examinadas estrutura, biomassa e densidade da comunidade da fitomacrofauna bentônica em uma lagoa tropical ao Sul da Nigéria. Foram registrados oxigênio dissolvido, demanda bioquímica de oxigênio, demanda química de oxigênio e a transparência em intervalos de 2,0 – 5,1 mg/L, 13,1- 114,0 mg/L, 7,7 – 153,0 mg/L e 40 - 119 cm, respectivamente. Valores obtidos para outros parâmetros variaram entre 22 e 623 µS/cm para a condutividade, 27 e 34 ^{O}C para a temperatura da água e 5,5 e 6,9 para o pH. Os grupos de fitomacrofauna observados neste estudo foram Annelida, Arthropoda e Mollusca. Foram registradas uma densidade total de fitomacrofauna de 12.400 ind/m2 e uma biomassa de 326,32 g/m2. Arthropoda foi dominante em todos os sítios estudados constituindo 76,88 % do total da população da fitomacrofauna. As diferenças espaciais e temporais nas densidades de fitomacrofauna bentônica não foram significativamente diferentes (ANOVA, F = 0,685; p> 0,05). Sua baixa densidade e riqueza assim como a presença de taxas tolerantes à deficiência de oxigênio tais como quironomidos, *Physa* sp, *Gyraulus* sp e oligoquetos naidideos na área de estudo sugerem que o ambiente está perturbado. O baixo oxigênio dissolvido observado de forma geral na área de estudo, assim como a alta demanda bioquímica de oxigênio, indicam também que a qualidade da água tem tido efeitos negativos sobre a associação de fitomacrofauna. As variações espaço-temporais nos resultados registrados não sugerem que as comunidades bentônicas de fitomacrofauna tenham sido influenciadas pelos fatores específicos dos sítios, nem pela sazonalidade, e sim pela qualidade degradada da água.

Palavras chave: qualidade da agua, macroinvertebrados, lagoa tropical

Introduction

Invasive species are of interest to ecologists, biological conservationists and natural resources managers due to their rapid spread, threat to biodiversity and damage to ecosystems (Mironga 2003). Some may alter the hydrology and physico-chemical properties of water, nutrient cycling and the general ecological balance in the aquatic ecosystem (Schmitz *et al*. 1993). The global extent and rapid increase in invasive species is homogenising the world's flora and fauna (Mooney & Hobbs 2000) and is recognized as a primary cause of global biodiversity loss (Drake & Mooney 1989, Wilcove & Chen 1998). Bio-invasion may be considered as a significant component of global change and one of the major causes of species extinction (Drake & Mooney 1989).

Of all the recorded invasive species of aquatic systems in tropical countries, the most deleterious is water hyacinth (*Eichhornia crassipes*) (Mart) which was listed among the ten most 'notorious' weeds in the world (Greathead & DeGroot 1993). Water hyacinth invaded the Nigerian territorial waters in September, 1984 (Onyla *et al*. 1988, Kusemiju *et al*. 1988) and became established in the Lagos lagoon system in south-western Nigeria where it now dominates the free floating macrophyte community. As a free floating aquatic plant, it has a wide distribution in the tropics and sub-tropics. The matured plants possessed above ground density of about 14 plants/m^2 and biomass of more than 1494g (Sherma & Edem 1988). It out competes other aquatic floating vegetation, for example, competition with water lettuce (*Pistia stratiotes*) showed a progressive increase in fresh weight of water hyacinth (Sherma & Edem 1988). Water hyacinth grows fast from seeds and from shoots that break off and grow into new plants. The number of plants doubles every 5 to 15 days, so in a single season, 25 plants can multiply up to 2 million. This means that if water hyacinth gets into a water body, it grows profusely until it covers the water with a thick floating mat of tangled weed (Sherma & Edem 1988).

Water hyacinth, has become a nuisance for fisheries, navigation, water intake to hydropower plants, irrigation and recreation in many tropical and subtropical aquatic systems and facilitates the spread of such diseases as schistosomiasis and malaria (Mehra *et al*. 1999, Navarro & Phiri 2000). It restricts photosynthesis in other aquatic plants through increased sedimentation and by shading the water column, leading to deoxygenation with a detrimental impact on aquatic organisms, especially invertebrates.

The role of aquatic macrophytes in the structure and function of aquatic system has long been recognized (Dvorak & Best 1982, Jeppesen *et al*. 1998), and numerous studies support the claim that shifts in the species composition of macrophyte communities will likely have significant effects on the community structure, biomass and density of phytophilous macroinvertebrates (Drake & Mooney 1989). Many macroinvertebrate taxa exhibit preferences for specific macrophytes based on plant density and architecture (Dvorak & Best 1982) and associated differences in the composition and abundance of epiphytic forage (Dudley 1988, Cattaneo *et al*. 1998). Other macrophyte characteristics also cited as important factors influencing phytomacrofauna include seasonal patterns of macrophyte growth and senescence (Smock & Stoneburner 1980), and plant-mediated shifts in water quality (Froge *et al*. 1990, Rose & Crumpton 1996, Unmuth *et al*. 2000) and invertebrate vulnerability to fish predation (Junk 1977, Dvorak 1996). Most importantly, the diversities of benthic phytomacrofauna and macrophytes appear to be closely related (Brown *et al*. 1988).

The ecology of aquatic systems is bound to change with the overwhelming preponderance of alien species like the water hyacinth. The weed suppresses and occupies ecological niches previously inhabited by native flora and thus disrupts plant-animal-physical environment interactions and balance. The formation and movement of their floating mats influences the whole aquatic system and may lead to re-distribution of seral stages in which plant succession may be jeopardized (Mironga 2003).

A workshop on the Control of Africa's Floating Water Weeds in 1991 (Greathead & DeGroot 1993) and an earlier conference organized in 1988 in Nigeria to suggest lasting solutions to the eradication of water hyacinth stressed the importance of conducting ecological studies on aquatic ecosystems affected by water hyacinth in order to estimate its impact on biodiversity. To date, however, little attention has been paid to the potential impact of water hyacinth mats on the structural complexity of aquatic systems and its species diversity. This lack of ecological research is probably due to the emphasis given to the many socio-economic problems caused by water hyacinth infestation with its eradication being given priority

(Mironga 2003). In this study, we report the community structure, biomass and density of benthic phytomacrofauna in a water hyacinth infested lagoon. Lekki lagoon was chosen for this study because more than two-thirds of lagoon area was covered by water hyacinth mats, and the lagoon was a major reference point of water hyacinth infestation during the 1988 International workshop/seminar on water hyacinth held in Lagos, Nigeria (Kusemiju 1988).

Materials and Methods

Description of study area

Lekki lagoon (Fig.1) is almost circular in shape and has its long axis parallel to the Atlantic coast. It has a surface area of about 247km^2 (Kusemiju 1981). It is mostly shallow with a maximum mean water depth of about 2.04m at the Iwopin area of the lagoon. The lagoon lies between longitude 4°00’ and 4°15’ E and latitude 6°25’ and 6°37’ N (Kusemiju 1981). It is separated from the ocean by its low lying barrier bar system along the Western Nigeria shoreline, and the only opening to the ocean is through the Commodore Channel which links directly with the Lagos lagoon (Kusemiju 1981). It is connected to the Niger Delta by numerous small channels. It experiences both dry and rainy seasons typical of the South-western part of Nigeria. It is fed by a number of creeks and rivers including rivers Oshun and Oni.

According to Kusemiju (1988), the lagoon supports a major fishery in Lagos State with over 30 fishing villages and settlements at the bank of the lagoon. There are over 2000 fishing canoes in addition to draw net and sudding cutting fishermen accounting for over 10000 active fishermen. Lekki lagoon is used as source of water by the inhabitants of the villages located along its bank, and is also used for motorizesd and non-motorized boating, although these have been greatly impeded by the overwhelming preponderance of water hyacinth in the lagoon.

Vegetation around the lagoon consists mainly of stilt rooted trees, dense undergrowth of shrub and raphia palm (*Raphia sudanica*) and oil palms (*Elaeis guinensis*). The floating grass (*Saccharum* sp.) occurred on the periphery of the lagoon while coconut palms (*Cocos nucifera*) are widely distributed in the surrounding villages (Kusemiju 1981).

Water hyacinth dominates the floating vegetation in the lagoon. More than 91 % of the area of Lekki lagoon is covered with thick mats of this plant forming floating islands on the surface of the water. Other aquatic macrophytes observed in the lagoon include, water lettuce (*Pistia stratiotes*), *Ipomea aquatica, Salvinia nymphellula, Lemna* sp and *Hydrocharis marsus-renae*. Colour of water at the study sites was characteristically brown and the sediment had higher percentages of sand in most study sites (Table I).

Sampling protocol

Sampling for environmental quality parameters and benthic phytomacrofauna were carried out in twelve sites between 10:00 and 15:00 hrs on each sampling day at monthly intervals between December, 2007 and May, 2008, covering parts of the rainy and dry seasons.

In situ measurements and collection of samples

In situ measurements of surface water temperature (^{0}C), pH and electrical conductivity (µS/cm) were carried out using battery operated Horiba U10 Water Quality Checker Model. Transparency was determined using a 20 cm diameter Secchi disk painted black and white. Water samples for the determination of dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected in transparent and amber coloured 250ml reagent bottles. The samples for DO were fixed on the field with 1ml each of Winkler’s solutions A (Manganese sulphate) and B (Sodium hydroxide and sodium hydroxide). Water samples for the analysis of Biochemical Oxygen Demand (BOD) were collected with 250 ml prewashed amber coloured reagent bottles. The water sample in the transparent bottle was fixed with 1ml each of Winkler’s solutions A and B, while the water samples in the amber coloured bottle were taken to the laboratory and incubated for 5 days at 20^{0}C (APHA 1985) . Samples for the analysis of other physico-chemical properties of water were taken below the water hyacinth canopy in each sampling sites before organisms were sampled in order to avoid sampling disturbance of water quality.

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 0.5mm 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.

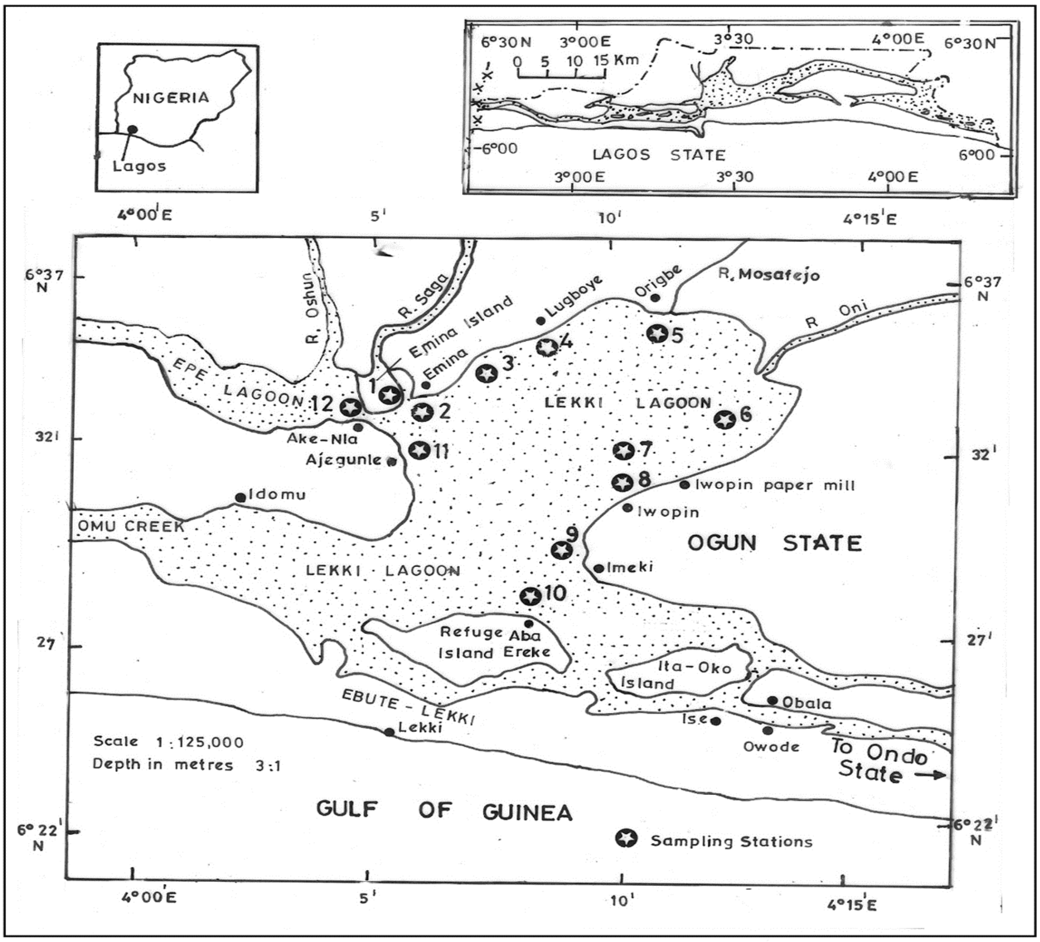


Figure 1. Map of Lekki lagoon showing sampling sites.

Sample analyses

Dissolved oxygen, BOD and COD were determined according to the methods described in APHA (1985). In the laboratory, macroinvertebrate samples were washed to remove the fixative and sorted under a dissecting microscope. Specimens of macroinvertebrates were identified to the lowest possible taxonomic level using the available keys of Edmunds (1978), Yankson & Kendal (2001) and Bouchard (2004). Numbers of individuals expressed as population density (untransformed data of individuals per m^2) in each study site and month were recorded. The method of Slack *et al.* (1979) was used to identify the dominant (>15%), subdominant (>5≤15%), common (<4≥1%) and rare (<1%) taxonomic groups in the sampling sites. Phytomacrofauna biomass was estimated using wet weight method. Specimens of animals were classified into the 3 identified phyla and weighed with an electronic scale of 0.001g sensitivity. Prior to weighing, the animals were drained on a fine sieve, air dried for 5 minutes on absorbent paper and exposed to air until liquid is no longer visible. Biomass of the three phyla observed were recorded for each study site and month.

Statistical analysis

One-Way analysis of variance (ANOVA) was used to compare the variations in macroinvertebrate variables at the study sites. When significant variations are detected, a *post hoc test* using Tukey's Honestly Significantly Different (HSD) test was performed to determine the locations of significant differences. The relationships between biotic and environmental parameters were determined using Spearman rank correlations (Sokal & Rohlf 1981). All statistical analyses were performed with SPSS 10 and Excel 2003; 2007 for Windows.

Results

Environmental conditions in water hyacinth canopy

Summary of environmental conditions in water hyacinth canopy at the study sites is presented in Table II. Overall trends in water quality were relatively consistent for study sites. A range of 2.0 - 5.11 mg/L, 13.1- 114 mg/L, 7.7 - 153.01 mg/L, and

40 - 119 cm were recorded for dissolved oxygen, biochemical oxygen demand, chemical oxygen demand and transparency respectively. Values obtained for other parameters ranged between 22 and 623(µS/cm) for conductivity, 27 and 34^{O}C for water temperature, and from 5.5 to 6.9 for pH.

Table I. Location and some physical attributes of the sampling sites.

Sites	Latitude	Longitude	Approximate Water level (m)	Sediment characteristic
1	06°32.815N	04°05.924E	0.92	Sandy
2	06°32.819N	04°05.115E	1.21	Sandy
3	06°33.065N	04°06.500E	1.13	Muddy
4	06°34.319N	04°07.839E	0.87	Sandy
5	06°35.423N	04°11.118E	1.21	Sandy
6	06°32.423N	04°12.118E	2.01	Muddy
7	06°31.321N	04°11.325E	1.83	Muddy
8	06°31.327N	04°10.431E	1.20	Muddy
9	06°29.020N	04°10.505E	1.02	Sandy
10	06°31.506N	04°05.611E	0.49	Fine sand
11	06°31.014N	04°05.043E	0.59	Fine sand
12	06°32.020N	04°05.010E	0.49	Sandy

Community structure of benthic phytomacrofauna

Three major phytomacrofauna groups (Annelida, Arthropoda and Mollusca) were identified from a total density of 12400 ind/m^2 benthic phytomacrofauna in the study area. Arthropoda was the most abundant group with total density of 9610 ind/m^2 and accounted for 76.9% of the total macroinvertebrate density, it was represented by 3 classes, 11 orders, 34 families and 43 species. Among the Arthropod observed, the amphipod *Gammarus* sp was the most abundant with a density of 4790 ind/m^2 and accounted for 49.8% of Arthropod population. Also significantly represented in the Arthropod group is the isopod, *Excirolana* sp which accounted for 15.9% (density 1530 ind/m^2) of Arthropod population.

Mollusca represented by 2 classes, 2 families and 4 species had a density of 1700 ind/m^2 and accounted for 13.7% of total macroinvertebrate population. *Eulima fisceri* with density 150 ind/m^2, *Physa* sp with density 100 ind/m^2, and *Gyraulus* sp with density 250 ind/m^2 were the major representatives in the Mollusc group. Annelida was represented by 6 species of oligocheates. With a density of 1090 ind/m^2 Annelids constituted 8.8% of the total phytomacrofauna population.

Naidid worms were the major representatives in this group. Of the total 36.3 g/m^2 biomass of benthic phytomacrofauna observed in the study area, arthropods contributed 72.7 g/m^2 constituting 73.1% of the benthic phytomacrofauna biomass in the lagoon. Molluscs and Annelids contributed 57.1 g/m^2 (24.2%) and 6.5 g/m^2 (2.8%) respectively.

The phylum Arthropoda was dominant in all the sites used for this investigation (Fig. 2a) and also recorded highest monthly percentage contributions (Fig. 2b). It was the only group recorded in site 6. The phylum Mollusca was dominant in sites 7 and 8, but assumed a subdominant position in sites 5 and 6, and a common status in sites 1, 3, 4 and 10. Mollusca was rare in site 11. The phylum Annelida was observed in four study sites and was dominant in sites 8 and 10, but assumed subdominant and rare positions in sites 3 and 5 respectively.

Spatiotemporal variations in phytomacrofauna biomass and density

High variability in fauna biomass and density at spatiotemporal scales was observed in this study (Fig. 3). No significant difference was observed in the density (ANOVA, F = 1.860, $p > 0.05$) and biomass (ANOVA, F = 1.061, $p > 0.05$) of

Table II. Summary of environmental conditions in water hyacinth canopy at the study sites

	1			2			3			4			5			6		
	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max
DO (mg/l)	3.59 ±0.2	2.9	4.33	3.74 ±0.1	3.4	4.3	3.4±0.2	2.5	4.1	4.0±0.1	3.4	4.3	4.0 ±0.2	3.7	4.2	4.3 ±0.3	3.2	4.9
BOD (mg/l)	84.7 ±6.4	65.1	101.1	59.0 ±10	19.1	86.2	54.9 ±6.0	36	69.3	42.1±8.4	20.7	74.3	45.5 ±12	23.6	101.2	38.3 ±15.3	13.1	111.2
COD (mg/l)	93.8±19.65	12	145	85.7±12.6	26.8	112	87.2±7.8	57.6	194.4	46.7±5.0	34.6	66.1	43.7±1.5	38.4	48.2	66.5±22.9	7.7	152.2
Conductivity(µS/cm)	251±42.9	137	365	297±54.5	106	397	209.7±41.5	100	324	195.1±41.9	94.5	318.1	140±36.1	22	271	155.2±33.1	91.3	265
Transparency (cm)	92.1±3.2	82	101.5	96.7±12.1	38.3	119	96.7±2.6	89	106	78.9±4.1	61	89.5	78.8±13.1	46.5	117.5	67.7±6.3	37	38
Ph		6.2	6.9		5.8	6.8		6.2	6.7		6.3	6.9		6.3	6.7		6.3	6.7
Temperature	30.7±0.7	28	32	29.6±±0.8	27	32	29.7±0.9	27	32	30.7±0.9	28	34	31±0.7	29	33	30±0.6	28	32

	7			8			9			10			11			12		
	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max	Mean ± SE	Min	Max
DO (mg/l)	4.2 ±0.3	3.1	4.8	3.1± 0.2	2.5	3.7	3.7 ±0.3	3.0	5.1	2.9±0.2	2.0	3.5	3.4 ±0.2	2.6	3.8	4.1 ±0.7	3.8	4.3
BOD (mg/l)	50.0 ±11.2	30.2	98.3	92.0 ±6.2	69.6	114	85.1±5.3	64.4	98.2	58.9±4.9	36.7	71.6	71.2 ±4.2	54.1	83.2	74.5 ±12.5	67.4	78.3
COD (mg/l)	70.9±11.3	42.2	108.2	114±7.2	96.4	134.6	97.1±5.7	83.1	116.2	81.3±6.1	55.7	99.2	116.3±12.4	65.3	153.0	92.4±21	70.4	143.1
Conductivity(µS/cm)	234.4±57	92.7	422	249.6±46.5	135	423	351.6±79.5	162	611	352.9±72.5	2 01	623	328.4±75.5	158.4	164	296.2±89.9	172	577
Transparency (m)	79.4±9.0	55.5	107	83.3±10.8	42	122	102±2.9	89	108	49.4 ±2.4	40	55	41.1±9.1	33	60	77.1±3.1	89	122
Ph		6.11	6.7		5.8	6.7		6.0	6.6		6.2	6.8		6.0	6.8		6.2	6.5
Temperature(OC)	31±1.0	28	34	30±0.8	27	32	31±1.0	28	34	32±0.8	29	34	31±0.4	29	34	31±0.5	29	32

benthic phytomacrofauna community at the study sites. Monthly density and biomass of phytomacrofauna ranged from 770 to 2650 ind/m^2 and between 38 and 128 g/m^2 with lowest and highest values for both variables occurring in March and May respectively. Density of phytomacrofauna correlated with biomass in the study area.

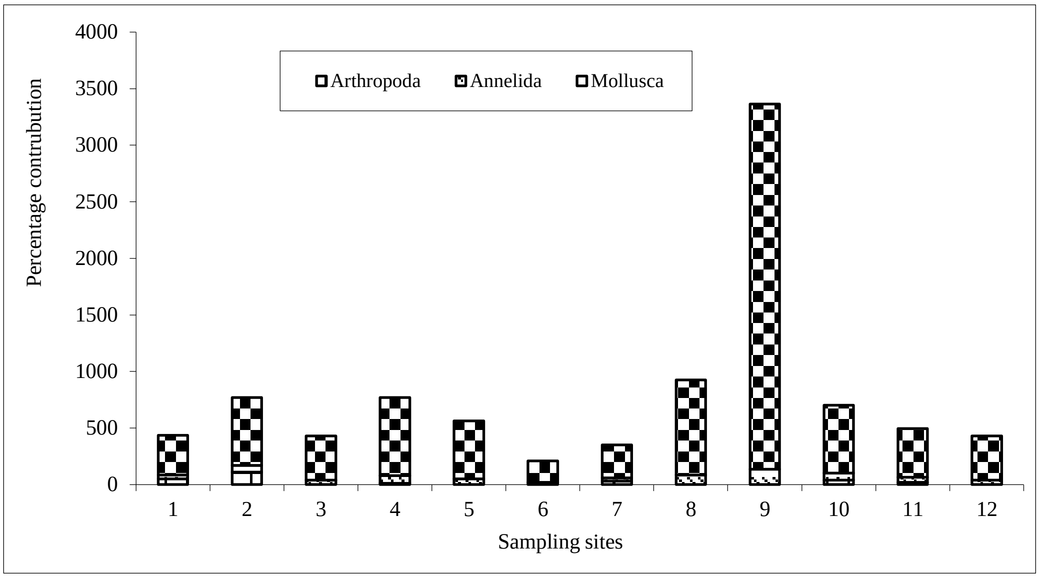
Although there was no significant difference in the monthly density (ANOVA, F = 0.685, $p > 0.05$) of benthic phytomacrofauna, results indicate that monthly biomass recorded were significantly different (ANOVA, F = 2.883, $p < 0.05$), a *post-hoc* test using Tukey's HSD shows that biomass recorded in the months of December, January, and March were similar and significantly lower than those recorded for the months of February, April and May.

Of all the sites used for this study, site 8 had the highest number (22) of species, while site 12 had the least number (5) of species. Site 9 recorded the highest (41.5 g/m^2) biomass while the least (8.32 g/m^2) was observed in site 12. The month of May recorded the highest (70.42 g/m^2) monthly biomass of phytomacrofauna during the study period, while the lowest (16.2 g/m^2) was observed in January.

Spatially, the density (1340 ind/m^2) and biomass (37.6 g/m^2) of Arthropods were highest in site 9, and lowest (density =190 ind/m^2; biomass = 5.7 g/m^2) in site 6. Arthropods recorded the highest monthly density (2210 ind/m^2) and biomass (55.5 g/m^2) in the month of May while lowest values of density (600 ind/m^2) and biomass (13 g/m^2) were observed in the months of March and December respectively. The density of Molluscs was highest (330 ind/m^2) in May and lowest (20 ind/m^2) in the month of December, while their highest biomass (15.3 g/m^2) was observed in April and the lowest (1.2 g/m^2) recorded in the month of December. Annelids occurred in highest density (110 ind/m^2) in site 2 in the month of May, while its lowest density (10 ind/m^2) was observed in site 4. The months of December, February and March, had the lowest monthly Annelid density (20 ind/m^2) during the period of study.

The total biomass of Annelids recorded at the study sites during this study ranged from 0.2 to 2.6 g/m^2, while total monthly biomass ranged between 0.1 and 2.7 g/m^2. Highest Annelid biomass values were observed in May in site 2, while lowest values were recorded in the month of February in

a



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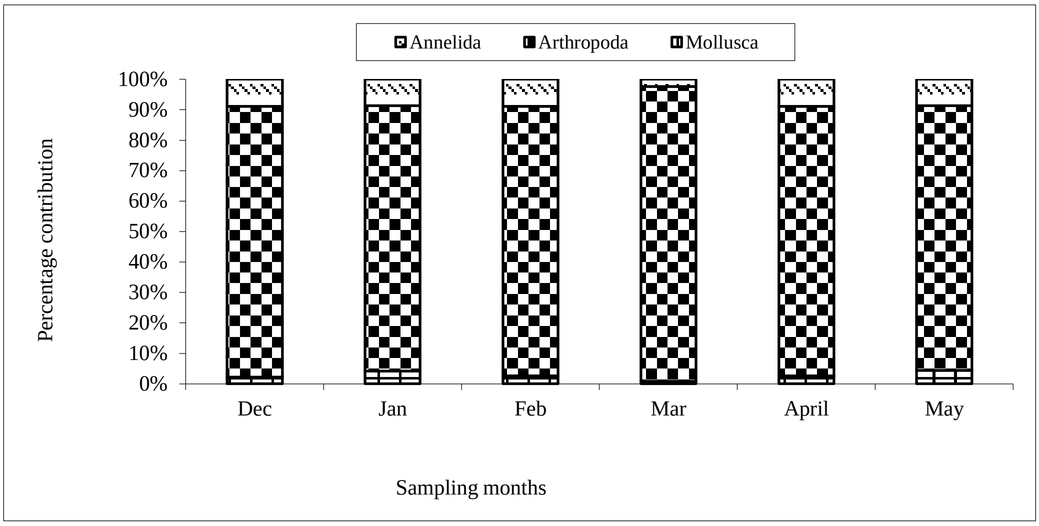

Figure 2. Spatial (a) and temporal (b) variations in percentage contribution of benthic phytomacrofauna groups.

site 10. Temporal differences in phytomacrofauna density were evidenced by increased densities of phytomacrofauna in the bed canopies in May.

Relationship between environmental parameters in water hyacinth canopy and biotic variables

Spearman's correlations between biotic and environmental parameters in the study area (Table III) indicated that there was significant correlation between DO ($r_s = 0.341$; $p < 0.5$), transparency ($r_s = 0.543$, $p<0.5$) and biomass. Transparency also correlated significantly ($r_s = 0.477$, $p<0.5$) with population density of phytomacrofauna. In the overall relationship, transparency and DO had strong effects on biomass, while population density was majorly influenced by transparency.

Discussion

The impact of water hyacinth infestation on the physico-chemical properties and biotic communities of aquatic systems have been widely reported in Nigeria (Akinyemiju 1987, Uka & Chukwuka 2007) and other parts of the world (Ambrose 1997, Mooney & Hobbs 2000, Navarro & Phiri 2000, Mironga 2003). The corroboration of the results of physico-chemical variables observed in this study with those (Mean DO = 1.92±0.29 in water hyacinth infested area) of Uka & Chukwuka (2007) for a similar water body is a strong indication of the degraded status of the study area.

Variability in physical and chemical factors has been emphasized as the primary organizational

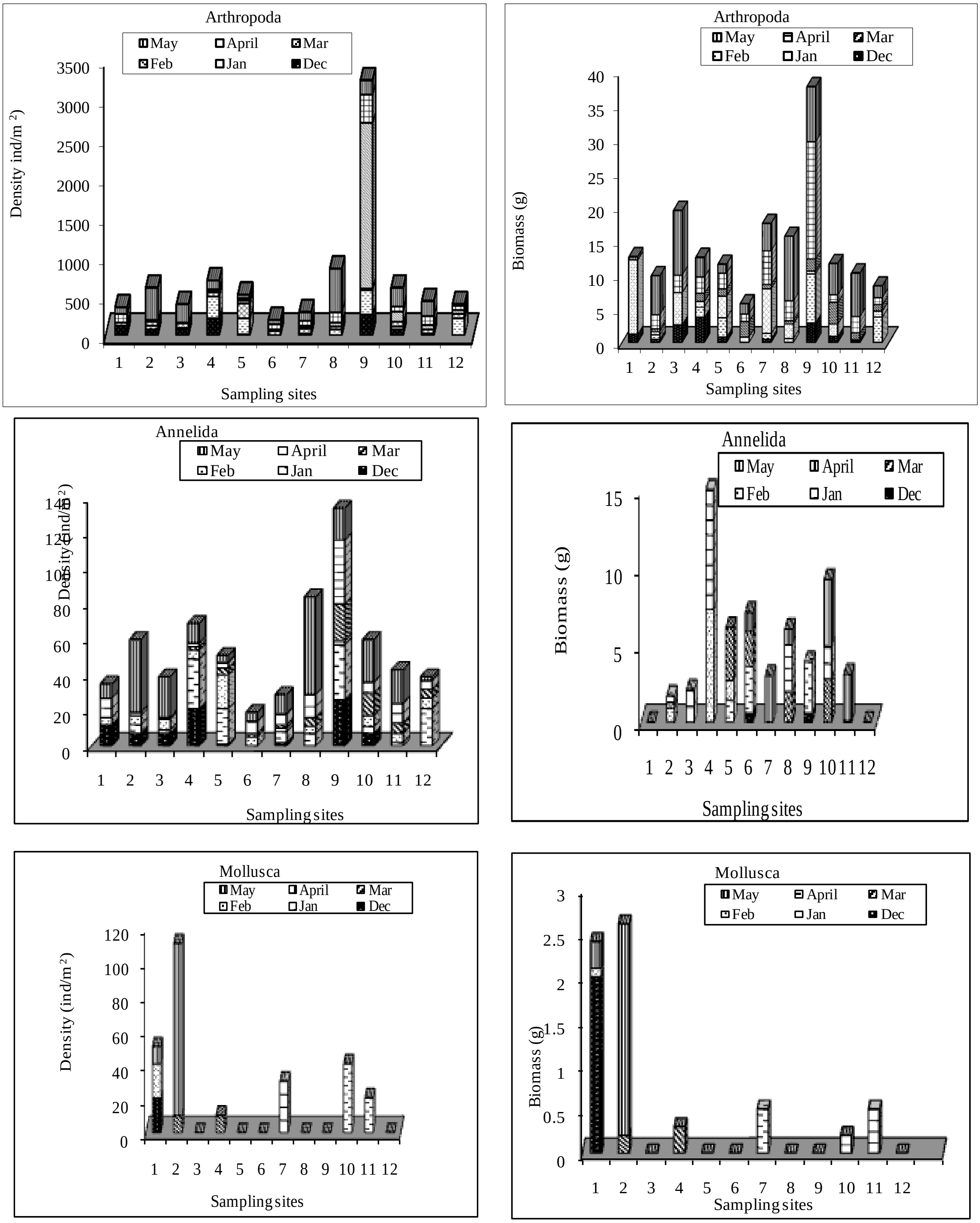

Figure 3. Spatiotemporal variations in total density and biomass of phytomacrofauna groups

force controlling macroinvertebrate communities (Rosenberg & Resh 1993, Ogbeibu & Oribahbor 2002, Bouchard 2004, Uwadiae 2009). Thus, the community structure, biomass and density of phytomacrofauna can be related to abiotic factors. The frequency of low DO (range = 2.0 to 5.1 mg/L) events observed in this study can be harmful to invertebrates.

This may be responsible for the observed assemblage of phytomacrofauna taxa such as chironimids and snails, which are highly tolerant of low DO conditions (McMahon 1983, Ward 1992), or mobile taxa such as amphipods and decapods that can locate normoxic refugia within dense macrophyte stands (Miranda & Hodges 2000).

Dissolved oxygen is an important characteristic of macrophyte beds that can alter nutrient cycling and the quality of beds as habitats for invertebrates (Smock & Stoneburner 1980, Rose & Crumpton 1996, Unmuth *et al*. 2000, Caraco & Cole 2002). When DO falls below 5 mg/L, sensitive phytomacrofauna species can be negatively impacted (Caraco & Cole 2002), and at DO levels below 2.5 mg/L most aquatic organisms are negatively impacted (Frodge *et al*. 1990). Dissolve oxygen can also impact on nutrient cycles and if prolonged may lower nitrification and denitrification (Kemp *et al*. 1990), as well as increase metal and phosphorus release from sediments (Lovley 1993). Low levels of DO can occur regularly in bottom waters of aquatic systems (Wetzel 1983, Rabalais *et al*. 1996) or throughout the water column in systems with heavy organic loads such as may be occasioned by dead or senescing macrophyte parts (Carpenter & Lodge 1986).

Table III. Spearman's correlations between biotic and environmental parameters in the study area; +: positive correlation; -: negative correlation; ns: no significant correlation; p >O.5; *: significant correlation; p <O.5.

	Environmental parameters	
Biotic parameters	DO	Transparency
Population density	-ns	+*
Biomass	-*	+*

Low DO events have been reported as a common phenomenon in thick beds of water hyacinth vegetation (Kaenel *et al*. 2000, Miranda & Hodges 2000). Floating-leaved vegetation like water hyacinth may, however, be more likely to be associated with persistent or frequent low DO (Frodge *et al*. 1990), since some floating leaved macrophytes vent much of their photosynthetically produced oxygen directly into the atmosphere rather than into the water column (Unmuth *et al*. 2000). The densely packed canopy of floating leaves severely lowers light beneath it, shading out photosynthesis by any submergent leaves or attached algae (Cataneo *et al*. 1998). Dense canopies of floating-leaved macrophytes like water hyacinth can also prohibit gaseous exchange and make more severe low DO generated by negative net ecosystem production in the water column.

Our results demonstrated the importance of light penetration to the phytomacrofauna communities, a positive and significant relationship between transparency and biotic variables (density and biomass) was established. Water hyacinth grows rapidly and subsequently forms a dense surface canopy decreasing light penetration (transparency of water) which likely results in lower periphyton densities at greater depths and subsequently supports a fewer number of phytofauna (Akinyemiju 1987). This may be particularly responsible for the low diversity recorded in this study, given the importance of periphyton food resources to the diet of aquatic phytomacrofauna (Cyr & Downing 1988a, b), and may account for the generally low population and biomass of phytomacrofauna observed in the study area.

The conditions at the study sites favoured taxa with small body sizes, short life spans, high reproduction rates and pollution tolerant organisms such as chironomids or oligochaetes. According to Bouchard (2004), some chronimids can tolerate and survive in polluted environments depicted by low DO and high BOD similar to those recorded in the study area. This is because chironomids possess haemoglobin that allows them to store oxygen and survive oxygen deficient conditions. Oligocheates also have high pollution tolerance and are commonly found in severely organically enriched habitats. The occurrence of Mollusc snails such as *Gyraulus* sp, and *Physa* sp in the study area is also indicative of a perturbed environment. They are highly pollution tolerant and like the chironomds can survive in low oxygen conditions.

The density of phytomacrofauna and number of taxa recorded in this study is low when compared to the density (55930 ind/m^2) and number of taxa (32) recorded in a similar environment in a different macrophyte (*Pistia stratiotes*) canopy using the same methodology in a single study site (Edopkayi *et al*., 2009) and also lower than the number (30) of taxa recorded by Saliu (1989) on *Pistia stratiotes* in another study in a similar envronment. The generally low density of phytomacrofauna observed in this study is consistent with those of Edokpayi *et al*. (2008) and Edokpayi *et al*. (2010), who reported a poor representation of macroinvertebrates associated with the roots of *Eichorrnia crassipes* in similar environment.

The high levels of BOD (13 – 114 mg/l) observed in this study is similar to the values (4.0 – 114 mg/l) reported for Epe lagoon (Uwadiae 2009) which is also infested with water hyacinth and also similar to values (12.0 – 259 mg/l) recorded for water courses receiving industrial and domestic wastes in Lagos state by Odiete *et al*. (2003). These values were however, higher than those reported for other water bodies within the Lagos lagoon systems by Nwankwo, 1993 (5.0 – 7.8 mg/l) and Edokpayi *et al*. 2009 (22 – 32 mg/l) respectively. The elevated levels of BOD may be connected with the decomposition of detrital materials from dead and senescing water hyacinth parts common in water hyacinth infested aquatic systems. This may further be responsible for the poor diversity of benthic phytomacrofauna observed.

The compact nature of the water hyacinth mat restricts water circulation and movement of phytomacrofauna, unlike beds of macrophyte species with long, narrow and tape-shaped leaves which permit more light penetration, favour periphyton growth, nutrient exchange, water circulation and movement of phytomacrofauna (Dvorak & Bes 1982, Carpenter & Lodge 1986, Beckett *et al*. 1992, Sloey *et al*. 1997, Mehra *et al*. 1999). Furthermore, beds of macrophyte species with long, narrow and tape-shaped leaves, can favour other critical conditions for phytomacrofauna distributions like DO (Caraco & Cole 2002) which is especially important for species that obtain their oxygen from water such as amphipods and prosobranchs.

The arrival and spread of water hyacinth throughout southern Nigeria, has resulted in large expanses of dense floating aquatic vegetation and a pervasive decline in habitat diversity for phytophilous macroinvertebrates. This study lends support to the findings of Drake & Mooney (1989) that the presence of water hyacinth may result in shifts in invertebrate assemblages depending on the site, and can easily alter the ‘fish-invertebrates’ food web. Such community level effects are typical of habitat-altering invaders like the water hyacinth (Carpenter & Lodge 1986, Jeppesen 1988, Crooks & Khim 1999).

The spatiotemporal variations in the results recorded do not suggest that the benthic phytomacrofauna communities were influenced by site specific and seasonal factors, but by the generally degraded water quality. In the context of global climate changes, water hyacinth infestation should be considered a serious ‘ecological menace’. Since, together with land-use and other anthropogenic disturbances could dramatically alter macrophyte cover and ecology of aquatic systems (Humphries 1996, Hudon 1997, 2004). As macrophyte-epiphyte complexes are important primary producers (Kemp *et al*. 1984, Tokeshi & Pinder 1985), large-scale modifications of these plant assemblages could cause trophic cascades in higher trophic levels of the food web by altering phytophilous macroinvertebrate communities and the fish populations that feed on them (Healey 1984, Bertolo *et al*. 2005).

Further Research Needs

Further research on the effect of water hyacinth infestation on macroinvertebrate communities is required in Nigerian aquatic systems, to fully understand the enormity of the problem. A more detailed research that will reveal the inter play of factors for better understanding of the ecological effect of water hyacinth infestation is needed.

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