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Macroinvertebrate Community Patterns and Diversity in Relation to Water Quality Status of River Ase, Niger Delta, Nigeria

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Abstract: To understand environmental conditions in River Ase Niger Delta, Nigeria, a study was carried out to assess the faunistic composition of macroinvertebrates as well as the water quality status of the river between the months March and August 2006. Two sampling sites each 25 m long were selected along a 20 km stretch of the stream. Water temperature, flow velocity, dissolved oxygen, pH, conductivity, total alkalinity and phosphates were similar in both stations sampled. $BOD_{(5)}$, water depth and nitrates were significantly higher in station I and showed wide temporal variation. Pearson correlation coefficient analysis indicated temporal trends in macroinvertebrate density and community composition. This was related to changes in environmental characteristics of the river especially BOD_5 and amount of nutrients. These factors produced spatial and temporal heterogeneity and exerted major influence on the macroinvertebrate communities. Thirty-six morphologically distinct taxa representing eleven orders were recorded. The most abundant group was Coleoptera, which made up 38.5% of the total number of macroinvertebrates collected followed by Diptera which accounted for 29.3% of the total. *Dugesia* (Planaria), *Agraylea* (Trichoptera) and aquatic mites (Hydracarina) were only sporadically present. Analysis of faunal similarity using Jaccard's similarity index showed that the fauna of both stations were dissimilar with station II recording comparatively high abundance and diversity of macroinvertebrates. The differences observed could be attributed to the nature of the habitat, general water conditions and substratum at the sites sampled.

Key words: Macroinvertebrates, water quality, Coleoptera, River Ase, Niger Delta

INTRODUCTION

Monitoring the changes of water quality in streams and rivers can be performed through studies of macroinvertebrates living in it. These organisms are sensitive to stress and can reveal the effects of perturbations and habitat alteration (Miserendino and Pizzolon, 2003; Arimoro and Osakwe, 2006).

River Ase is a tributary of the Forcados River, the Western branch of River Niger in the Niger Delta area of southern Nigeria. This river serves as a spawning and nursery ground for a number of fish species, which depend on several macroinvertebrates organisms for survival (Idodo-Umeh, 2002). Detailed studies are therefore required to understand some aspects of the ecology of macroinvertebrate taxa that exist therein.

In Africa and particularly in Nigeria, there is a gradual build up of literatures in macroinvertebrate studies and their use as bioindicators in recent times. Among such documented information are the works of Ikomi *et al*. (2005), Arimoro and Osakwe (2006) and Arimoro *et al*. (2007a and b). These and associated studies (Tumwesigye *et al*., 2000) have resulted in the taxonomic composition of African stream faunas being fairly well known.

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Although the composition, distribution and abundance of macroinvertebrates in Nigeria have been reported in a number of studies (Edokpayi *et al*., 2000; Ogbeibu and Orhibhabor, 2002; Edema *et al*., 2002), only in a few attempts (Atobatele *et al*., 2005; Arimoro and Osakwe, 2006) have authors examined relationships among biotic and abiotic variables. This study therefore seeks to understand the water quality status of the river and how macroinvertebrate communities respond to these changes. Results gathered from this study will have an advantage of facilitating sampling during future studies in addition to giving insight into likely distribution of benthophagous fishes in the river in relation to their food resource.

MATERIALS AND METHODS

Description of Study Area

River Ase marks the geological boundary of the Sombreiro-Warri formation and the meander belts of the upper deltaic plains of the Niger Delta. This river has its confluence at Asaba-Ase (5°.20^{1}N, 6°.17^{1}E) in Delta State, Nigeria. The River is approximately 292 km in length. The typical tropical climate of the area is governed by the northeastern and south western winds which generally influence the climate of Nigeria. The river flows through freshwater swamps and swamp-rubber forests.

For convenience of sampling, the river was demarcated into two sampling stations.

Station I

Station I is upstream and located at Ivrogbo. It has a depth ranging between 2.1 and 4.0 m. The average flow velocity in this station is 0.17 m sec^{-1} and the flow is unidirectional flow. The substratum is a mixture of sand, leaves of trees and remains of dead macrophytes. Floating macrophytes present are *Pistia stratiotes*, *Nymphaea lotus*. The trees present shade only a little part of the river and these include *Havea braziliensis*, *Arstonia* and *Nauclea*. Human activities are intense here and include washing of clothes, bathing and fishing. Sand dredging activities are extensive here.

Station II

This station is located at Ibedeni and it is about 10 km downstream of Station I. It has depth ranging between 1.0 and 1.95 m. The average velocity in this station is 0.25 m sec^{-1}. The substratum is a mixture of sand, silts, leaves of trees and remains of dead macrophytes. Macrophytes present include floating leaved, *Lemna* sp., *Pistia stratiotes* and emergent macrophyte-*utricularia*. The canopy cover is close being partly shaded by trees including *Havea braziliensis*, *Bambusa vulgaris* and *Alstonia bonei*. Human activities are reduced here to washing of farm produce and bathing.

Water Sampling

Water samples were collected monthly from March to August 2006 at each site. Surface water temperatures were recorded with a thermometer. Conductivity, pH, total alkalinity, dissolved oxygen and Biochemical Oxygen Demand (BOD_5) were determined according to APHA (1985) methods. Water velocity measured in mid channel on three occasions by timing a float (average of three trials) as it moved over a distance of 10 m (Gordon *et al*., 1994). Depth was measured in the sample area using a calibrated stick. Nitrate-nitrogen (NO_3-N) and Phosphate-Phosphorus (PO_4-P) were measured spectrophotometrically after reduction with appropriate solutions (APHA, 1985).

Substratum composition in each 25 m sampling reach was estimated visually as percentage of silt, loam and sand (Ward, 1992).

Sampling for Macroinvertebrates

Kick samples of macroinvertebrate were collected monthly with a D-frame net (800 μm mesh) within an approximately 25 m wadeable portion of the river. Four 3 min samples were taken on each

sampling visit to include all different substrata and flow regime zones. This sampling strategy was evaluated by previous sampling performed prior to the main study and four replicates were established to be good enough to capture the maximum number of different macroinvertebrate taxa. As the substrate was disturbed, the operator and net moved upstream for the required time. Samples collected from the net were preserved in 10% formalin. In the laboratory, samples were washed in a 500 μm mesh sieve to remove formalin and macroinvertebrates were then picked from the substrate with the aid of forceps. All animals were enumerated and identified to lowest practical taxon under a binocular dissecting scope following Pennak (1978), Merritt and Cummins (1996), Gerber and Gabriel (2002) and Huxley (2003). Certain dipterans and oligochaete worms were identified under a compound microscope after mounting on a slide using polyvinylchloride.

Community attributes and chemical features of sites were compared using paired t-test. Taxa richness, diversity and evenness indices were calculated using the computer BASIC programme SP DIVERS (Ludwig and Reynolds, 1988). Association between physical and chemical variables and total density were tested with Pearson correlation, incorporating Bonferroni corrections (Rice, 1989). Jaccard index was used in comparing the similarities between the stations.

RESULTS

Physical and Chemical Conditions

All factors with the exception of water temperature, water depth, BOD and nitrate-nitrogen were not significantly different ($p>0.05$) between the two stations sampled. Water temperature and depth were lower in Station II, whereas the value of Nitrate-nitrogen was higher in Station II (Table 1).

Faunal Composition, Abundance and Distribution

Although these results are summarized as the number of taxa and number of individuals for each group, relevant genera and species are mentioned in the text.

A total of 36 taxa, comprising 1138 individuals, were collected from the two stations during the study period. Aquatic insects represented 80.6% of the taxa and 89.8% of all individuals collected (Table 2). The rest of the fauna was composed of Oligochaeta, Decapoda, Arachnida and Gastropoda.

The major components of the benthic community were Coleoptera, Diptera and Ephemeroptera. The abundance and distribution of macroinvertebrate taxa were different at the two stations. The total number of taxa present at Stations I and II were 26 and 31, respectively, while the total individuals collected were 469 and 669. The overall abundance was significantly different at the two stations ($T = 5.72$; $p<0.05$).

Table 1: Summary of the physical and chemical conductions at the study stations values are Mean±SE (minimum and maximum values in parentheses)

Parameters	Station I	Station II	t-test value	Probability
Air temperature (°C)	31.10±0.21 (30.5-32.0)	30.90±0.20 (30.0-31.5)	1.13	p>0.05
Water temperature (°C)	30.40±0.24 (29.5-31.1)	30.10±0.25 (29.0-30.8)	3.51*	p<0.05
Water depth (m)	3.24±0.26 (2.1-4.0)	1.42±0.15 (1.00-1.95)	9.49*	p<0.05
Flow velocity (m sec^{-1})	0.17±0.04) (0.069-0.32)	0.25±0.02 (0.21-0.33)	1.77	p>0.05
Dissolved oxygen (mg L^{-1})	5.40±0.44 (4.2-6.8)	6.47±0.74 (5.2-10.1)	1.49	p>0.05
BOD_5 (mg L^{-1})	3.60±0.23 (2.8-4.1)	2.28±0.15 (1.8-2.9)	4.39*	p<0.05
pH	6.36±0.28 (5.18-6.86)	6.15±0.17 (5.39-6.52)	1.74	p>0.05
Conductivity (μs cm^{-1})	18.95±0.13 (14.00-22.30)	20.45±0.12 (13.20-25.20)	1.42	p>0.05
Alkalinity (mg L^{-1})	2.46±0.79 (0.15-5.17)	2.16±0.65 (6.30-4.54)	1.83	p>0.05
Phosphate-phosphorus	0.029±0.002 (0.023-0.035)	0.028±0.002 (0.021-0.034)	1.46	p>0.05
Nitrates (mg L^{-1})	2.66±0.18 (2.15-3.20)	0.14±0.01 (0.11-0.18)	14.80*	p<0.05

BOD_5: Biochemical Oxygen Demand, pH-Hydrogen ion concentration. *Significantly different at $p<0.05$) detected by t-test, T-critical = 2.57

Table 2: The overall composition, abundance and distribution of macroinvertebrates in River Ase study stations, March-August, 2006

	Station I		Station II		All Stations Combined	
Taxonomic group	No. of Taxa	No. of individuals	No. of Taxa	No. of individuals	No. of Taxa	No. of individual
Platyhelminthes						
Planariidae	1	8	1	2	1	10
Oligochaeta						
Naididae	2	14	3	27	3	41
Decapoda						
Atyidae	1	6	2	26	2	32
Palaemonidae	1	2	2	14	2	16
Arachnida						
Arrenuridae	-	-	1	2	1	2
Ephemeroptera						
Baetidae	4	70	3	63	4	133
Oligoneuriidae	1	12	1	16	1	28
Trichoptera						
Hydroptilidae	-	-	1	2	1	2
Hemiptera						
Naucoridae	1	2	2	4	2	6
Belostomatidae	1	2	-	-	1	2
Coleoptera						
Dytiscidae	2	78	1	80	2	158
Gyrinidae	1	43	1	205	1	248
Hydrophilidae	1	7	1	6	1	13
Hydraenidae	1	19	-	-	1	19
Odonata						
Libellulidae	1	23	1	46	1	69
Gomphidae	1	2	-	-	1	2
Macromiidae	-	-	1	4	1	4
Coenagriidae	1	1	2	12	2	13
Gastropoda						
Planorbiidae	-	-	1	3	1	3
Physiidae	-	-	1	4	1	4
Diptera						
Chironomidae	3	129	3	117	3	246
Ceratopogonidae	2	46	2	23	2	69
Tabanidae	1	5	1	13	1	18
Total	26	469	31	669	36	1138

Table 3: Diversity, evenness and dominance indices of macroinvertebrates in river ase study stations, March-August, 2006

Microinvertebrates distribution	Station I	Station II
No. of taxa	26.000	31.000
No. of individuals	469.000	670.000
Taxa richness (d) (Menhinick's index)	10.480	12.150
General diversity (H)	2.600	2.820
Evenness (E)	0.757	0.870
Simpson dominance	0.134	0.080

Table 4: Pearson correlation coefficient between macroinvertebrate density and some environmental variables

Parameter	Station I	Station II
Water temperature	0.241	0.465
Water depth	-0.678*	-0.742*
Flow velocity	0.092	0.081
Dissolved oxygen	-0.234	0.634*
BOD_5	0.594*	0.176
Total alkalinity	-0.014	0.122
pH	-0.326	0.053
NO_3-N	0.655*	0.431
PO_4-P	0.413	0.216

*Indicates significant difference at p = 0.05

The family Naididae with three representative taxa, *Dero limnosa*, *Stylaria lacustris* and *Chaetogaster limnaei* represented Oligochaeta. These species were collected from both sampling stations except *Stylaria lacustris*, which was restricted to Station II only.

Platyhelminthes was represented by one taxon, *Dugesia* collected in few numbers in both sampling stations. Decapoda was represented by four taxa namely *Caridina gabonensis, Caridina africana* (Kingsley), *Macrobrachium felicinum* and *Potamolpheops monodi* (Powell). These organisms were collected in relatively few numbers with relatively higher density in station II. *Caridina gabonensis* and *Macrobrachium felicinum* were restricted to station II alone.

Only one taxon of water mite (*Arrenurus damkoehlei*, Viets) was collected in Station II. Only two individuals were recorded throughout the period of the study.

Ephemeroptera was represented by five genera. The abundance of this group was not significantly different between the two sampling stations. *Baetis tripunctatus* was the preponderant Ephemeroptera with relatively high density in both stations. Other taxa encountered were *Centroptilum*, *Cloeon bdellum* and *Oligoneuriella. Centroptilum* species was however not collected in Station II.

The paucity of Trichoptera in the study was evident with the presence of *Agraylea* species that was represented by only two individuals in Station II.

Hemiptera was represented by three genera with two genera each occurring in both stations. The genera collected were *Ilyocoris crimicoides*, *Ambrysus mormon* and *Belostoma fluminea*. The Hemiptera formed only 0.9% of the total number of individuals collected.

Coleoptera were represented by five genera in four families. Coleoptera formed a significant percentage (38.4%) of the total density of macroinvertebrates collected. The representative taxa were *Dytiscus marginalis*, *Hyphydrus ovatus*, *Gyrinus*, *Hydrophilus* and *Ochthebius*. Clearly, *Gyrinus* was the preponderant Coleoptera occurring in very high numbers in Station II.

Three anisopteran genera, *Libellula*, *Gomphus* and *Coenogrion* were well represented in the river. These three genera were found in Station I and Station II only recorded *Macromia* species.

Zygopteran nymphs were represented by *Enallagma* and *Coenogrion*. The abundance of this group was higher in Station II than in Station I.

The Dipterans formed a major component of macrobenthic invertebrate in this study. Six genera were recorded. Chironomidae was represented by *Tanypus*, *Cryptochironomus* and *Chironomus transvaalensis*, which was the preponderant Diptera. Ceratopogonidae was represented by *Allaudomyia* and *Forcipomyia* and Tabanidae represented by *Chrysops*. These taxa were all present at both sampling stations. Diptera formed a significant percentage of macroinvertebrate density (29.3%). Diptera abundance was not significantly different between two stations sampled ($p>0.05$).

Taxa Richness, General Diversity and Evenness

The indices calculated for the taxa richness (Menhinick's Index, d), Shannon-Weiner diversity (H) and Evenness (E) at the two stations are presented in Table 3. Station II had better taxa richness, diversity and evenness indices. Hutcheson t-test (t-test = 3.64>Tc = 3.290) for diversity between the two stations showed that difference was significant ($p<0.05$). Faunal similarities between sampling sites evaluated by Jaccard index also showed that the values obtained between Sites I and II were dissimilar (23.9%).

Water depth was inversely correlated with macroinvertebrate density at both stations sampled (Table 4). Dissolved oxygen was positively correlated with macroinvertebrate density in station II. Similarly, BOD and nitrates were positively correlated with macroinvertebrate density in station I. All the other parameters did not show strong correlation with macroinvertebrate density.

DISCUSSION

The water quality status of the River Ase was not significantly different in the two stations sampled except for differences in Nitrate-nitrogen, BOD and Water temperature. The physicochemical qualities of water, immediate substrate of occupation and food availability are important factors affecting the abundance of benthic invertebrates (Rueda *et al*., 2002; Nelson and Roline, 2003; Zabbey and Hart, 2006). The increased human activity in Station I probably led to increase in BOD_5, Nitrate-nitrogen and decrease in dissolved oxygen level at that site. It has been reported in a number of studies that intense human activities resulting from discharge of organic pollutants into streams lead to increase in nutrients levels and in biochemical oxygen demand which in turn affects the distribution and abundance of benthic invertebrates (Atobatele *et al*., 2005; Arimoro *et al*., 2007a and b; Zabbey and Hart, 2006).

The 36 taxa of benthic macroinvertebrates recorded in this study compares favourably with 43 taxa reported by Ogbeibu and Oribhabor (2002) in Ikpoba river and 30 taxa reported by Zabbey and Hart (2006) in Woji Creek, a tributary of Bonny river, Niger Delta. In addition, majority of the animals recorded in this study are widely distributed else where in Nigeria (Edema *et al*., 2002; Adakole and Anunne, 2003; Ikomi *et al* 2005; Arimoro *et al*., 2007a and b) and Africa (Dobson *et al*., 2002). Gastropods and Decapods were very low in abundance. The low pH and low alkalinity may have contributed to the paucity of molluscs and crustaceans in the study stretch.

Insects were the most dominant benthic macroinvertebrate encountered in the study. Coleoptera were dominant group with *Gyrinus* being the preponderant species. It has been reported that this species is found mostly in very clean waters (Pennak, 1978). The presence of Coleoptera in an aquatic system along with other less tolerant species such as Ephemeroptera, Plecoptera, Trichoptera and Odonata have been observed to reflect clean water conditions (Miserendino and Pizzolon, 2003; Adakole and Annune, 2003). In this study however no stonefly nymph (Plecoptera) was collected. This is as expected. Dobson *et al*. (2002) had earlier reported the paucity of stonefly nymphs in tropical African streams. The occurrence of the Coleoptera, *Ochthebius* and the Ephemeroptera, *Oligoneuriella* is perhaps the first mention in Nigerian freshwater system.

Station II had better taxa richness, evenness and diversity indices than station I. The plausible reason for this is that human activities were drastically reduced there. Furthermore, the general water conditions of station II (high dissolved oxygen, low BOD and moderate amount of nutrients) may have translated to high biodiversity indices at that station. The abundance of mayflies particularly, *Baetis* and *Centroptilum*, Coleoptera (*Gyrinus*, *Dytiscus*) and Odonate nymphs in the two sites studied is an indication that these sites are relatively free from gross pollution. Related studies conducted in similar freshwater bodies in Nigeria (Edokpayi *et al*., 2000; Edema *et al*., 2002; Ikomi *et al*., 2005) and elsewhere (Miserendino and Pizzolon, 2003; Walsh *et al*., 2002; Rueda *et al*., 2002; Nelson and Roline, 2003) have associated the presence of these organisms in a site to clean water conditions. These species are very sensitive to reductions in dissolved oxygen and are not found in areas where oxygen levels are consistently low. These organisms are proposed here as indicators of fairly clean water conditions in River Ase and could be used in biomonitoring assessment of similar freshwater bodies in southern Nigeria.

River Ase recorded a remarkable abundance of macroinvertebrates. Our baseline survey therefore addresses the need for more intensive study on the entire length of the river to fully comprehend the general fauna assemblages of the river.

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