Macroinvertebrates functional feeding groups as indices of biological assessment in a tropical aquatic ecosystem: implications for ecosystem functions

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Abstract. The composition and abundance of functional feeding groups of the benthic macroinvertebrate communities were investigated along the stretch of Epe lagoon in south-west Nigeria, between September, 2004 and August, 2006. The hypothesis being tested was that functional feeding groups of benthic macroinvertebrates can be used as surrogate for biological assessment. Quantitative benthic samples were collected monthly at 8 sites. Total dissolved solids of the overlying water, total organic, sand and mud contents of sediment were assessed. The amount of dissolved solids recorded in this study ranged between 18 and 15,200mg/L. There was significant difference ($P<0.05$) in total dissolved solids at the study stations. The total dissolved solids at stations 1 to 3 were similar and significantly lower ($P<0.05$) than those at stations 4 to 8.The study area was predominantly sandy (range = 54.4 to 93.6%) intermixed with varying proportions of mud (range = 1.01 to 44.6%). A comparatively higher proportion of mud in sediment was recorded in station 3. Total organic content ranged between 1.01 and 10.45%. In terms of relative abundance, collector-filterers and shredders were the predominant groups at most sites. They contributed 77 and 15% respectively to the total benthic macroinvertebrate population. Predators had low abundance in all the study sites and were absent in sites 6 and 8. Correlation between Total organic content and density of collector filterers at the study sites was significant ($P < 0.01$). Although there was a marked variation in the density of the observed functional feeding groups in the stations used for this study and sequential downstream changes in species composition, most functional feeding groups (apart from predators) were represented down the whole length of the study stretch. The implications of the observed pattern of variation in the density of functional feeding groups, for water quality assessment and ecosystem functions are discussed. [New York Science Journal 2010;3(8):6-15]. (ISSN: 1554-0200).

Key words: Feeding functional groups, water quality assessment, tropical ecosystem.

1. Introduction

Ecological functions can be described by a multitude of general biological traits that reflect the adaptation of species to environmental conditions (Townsend and Hildrew, 1994). Feeding strategies are typical traits reflecting the adaptation of species and they could form part of a unified measure across communities differing in taxonomic composition (Statzner *et al*., 2004). Functional feeding classification of aquatic organisms enhances the knowledge of trophic dynamics in aquatic systems by simplifying the benthic community into trophic guilds – functional feeding groups (FFGs) (Cummins, 1995).

Feeding measures or trophic dynamics encompass functional feeding groups and provide information on the balance of feeding strategies (food acquisition and morphology) in the benthic assemblage. Many studies (including Vannote *et al*., 1980) have shown that the pattern of FFG distribution has been related to the environmental gradient in the aquatic system, and this is currently used in some water quality systems, e.g. Index of Trophic completeness (Pavluk *et al*., 2000). Without relatively stable food dynamics, an imbalance in functional feeding groups will result, reflecting stressed conditions. Trophic metrics are surrogates of complex processes such as trophic interaction, production and food source availability (Merrit *et al*., 2002).

Macroinvertebrates play fundamental roles in aquatic ecosystems, being consumers at intermediate trophic levels and thus serving as channels by which bottom-up and top-down forces are transmitted (Wallace *et al*., 1999). Different food sources utilized by macroinvertebrates include: the epilithic layer that grows on the surfaces of substrates (consumed by scrapers); the coarse detritus, composed mainly of leaves falling down from riparian vegetation (consumed by shredders); the fine detritus, either deposited on the substrate (consumed by gatherers) or suspended in the water column (consumed by filterers); and finally, live animals (consumed by predators).

The functional composition of macroinvertebrate communities, quantified as the proportions of these different functional feeding groups (FFGs), has important implications for ecosystem functioning (Minshall *et al*., 1983). Ecological patterns and processes in aquatic ecosystems have been shown to vary at multiple spatial scales, between and within aquatic habitat (Meritt *et al*., 2002). However, there have been very few attempts of studying how the functional composition of macroinvertebrate communities changes with spatial scale in relation to habitat conditions.

The aim of this study therefore, was to describe the general distribution of FFGs in the study area and determine if the observed pattern of distribution can be used as a basis for biological assessment of the study area.

2. Materials and Methods

2.1 Description of study Area

This study was carried out in a tropical lagoon (fig. 1) situated between latitudes $3^0 50'$ – $4^0 10'$N and longitudes $5^0 30'$ – $5^0 40'$E. The lagoon lies within the rainforest belt of southern Nigeria which experiences two major seasons, the rainy season concentrated between May and November, and dry season occurring between December and April. The seasonal rainfall has a bimodal distribution with a major peak in June, and a minor one in September or October each year. The study area is composed of sandy and muddy sediments. Annual rainfall ranged from 6 to 330mm during the study period. Riparian vegetation at the bank of the lagoon consists mainly of grasses and secondary rainforest. Land use in the study area includes agriculture, and human activities in the study stretch include sand mining and artesinal fisheries. Stations 1-5 were covered with thick mat of water hyacinth, a phenomenon that has been linked to pollution in the study area (Nwankwo and Onitiri, 1992). The study area is a rural setting with most of the population concentrated along the bank of the lagoon leading to the dumping of wastes, majorly from domestic sources into the lagoon.

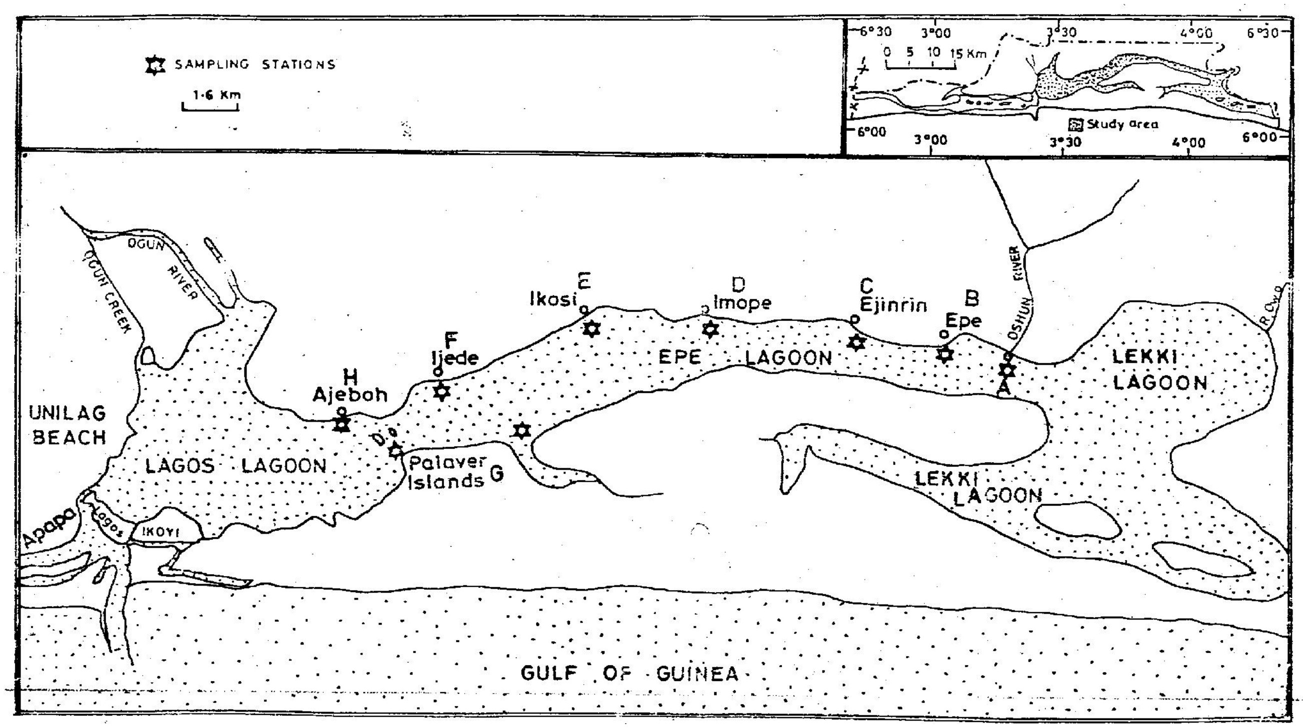

Figure 1. Map Showing Lagos, Epe and Lekki Lagoons as well as the sampling stations

2.2 Collection and Processing of Samples

Collection and analysis of water and sediment samples were carried out according to methods used in Uwadiae *et al*. (2009). Benthic macroinvertebrates were collected from eight sites. Sampling of benthic macroinvertebrates was carried out during the dry and wet seasons. For each study site and sampling occasion, three quantitative samples were taken using van Veen grab. The samples were fixed in 10% formalin solution. In the laboratory, the samples were washed and all macroinvertebrates were sorted under a dissecting microscope. Specimens of macroinvertebrate samples were identified to the lowest possible taxonomic level (mostly family), since previous studies of Dole´ dec *et al*. (2000) and Gayraud *et al*. (2003) showed that the identification to species level was not necessary for studies on functional diversity and therefore, the family level was considered as sufficient. Identification used include; Edmunds (1978), Yankson and Kendal (2001) and Bouchard (2004).

The allocation of each taxon to the FFG depended mainly on the mouthpart morphology (e.g. presence of brushes of scrapers, fine hair fringes of filterers, or dagger-like teeth on the maxillae of predators. Previous FFG allocations from literature were also consulted (Merritt and Cummins, 1996; Graca *et al*., 2001; Polegatto and Froehlich, 2003; Molina, 2004) and included in the final results.

2.3 Statistical Analysis

I applied cluster analysis in order to determine the FFGs with similar density in the study area. Pearson's correlation test was used to determine the relationship between environmental parameters and density of FFGs at the study sites. Graphical and statistical analyses were performed using Excel 2003 and SPSS 10 for windows.

3. Results

3.1. Environmental parameters

The results of physico-chemical parameters studied are summarized in Table 1. The values of dissolved solids (TDS) recorded in this study ranged between 18 and 15,200mg/L. The values were higher in the dry season and was significantly different ($P<0.05$) at the study sites. The total dissolved solids at stations 1 to 3 were similar and significantly lower ($P<0.05$) than those at stations 4 to 8.

The study area was predominantly sandy intermixed with varying proportions of mud. The highest value of sand fraction (93.6%) recorded occurred in station 5, while the least (54.4%) fraction of sand was recorded in station 3. The highest value (44.6%) of mud in sediment was recorded at station 3. A comparatively higher proportion of mud in sediment was recorded in station 3 throughout the period of sampling.

Total organic content (TOC) values ranged between 1.01 and 10.45%. The highest value recorded occurred at station 3 while the least value occurred in stations 4 and 6 respectively. A seasonal pattern in which higher values of TOC were observed in the wet season than in the dry months was evident in the overall values of TOC recorded.

3.2. Functional Feeding Groups

In a total of 17, 444 specimens (density = 174, 440), belonging to 27 taxa (Table 2), aquatic molluscs represented the dominant component of the benthic population and accounted for 98.43% of the total organisms recorded. Annelids constituted 1.16%, while other phyla recorded less than 1% each of the total benthic population. Melaniidae (filter feeders), were the most represented mollusc family in the study area, and within this group the most abundant genus was *Pachymelania*.

Four major FFGs were recognized in this study, these include; Predators (P), Shredders (S), collector gatherers (CG), and collector filterers (CF). Analysing the functional composition of the assemblage, it was found that collector filterers were the most abundant FFG (Figure 2) with a total density of 133, 690 accounting for 76.64% of the animals recorded. Shredders ranked second in total density (25, 740) of individuals contributed, and constituted 14.76% of the total population observed. A total density of 14, 590 was recorded for the collector gatherers, while the predators had a density representation of 420, both groups accounted for 8.36% and 0.24% of the total population respectively.

There was great variations in terms of density distribution of the FFGs at the spatial scales (study sites) (Figure 3). Greater densities of CF occurred at stations 2 and 5, while that of S were recorded at stations 1 and 6. The population of CG was highest in stations 3 and 6. The highest density of P was recorded in stations 4 and 6, but no predator was recorded in stations 6 and 8 during this study.

The cluster analysis presented in Figure 4 shows clearer separation of the FFGs. Group I is composed of FFGs (S, CF, CG) with relatively higher density representations at the study stations, while group II has only the predators as its component, indicating their relatively low densities at the study stations.

The relationship between density of FFGs and environmental parameters (Table 3) using Pearson's correlation test indicates that TOC correlated negatively with the density of all the FFGs except P (r = 0.31). Total dissolve solids affected the density of P negatively (r = -0.37, P > 0.01), but correlated positively with those of S (r = 0.81, P>0.01), CG (R = 0.34, P> 0.01) and CF (r = 0.5, P < 0.01). The percentage of sand in sediment also affected the density of FFGs; the densities of S (r = -0.32, P > 0.01) and CG (r = -0.15, P > 0.01) correlated negatively with the content of sand in sediment at the study sites, but related positively with densities of P (r = 0.38, P > 0.01) and CF (r = 0.51, P > 0.01).

Table 1: Summary of environmental characteristics of the study stations in Epe lagoon.

Station	GPS Location	TDS (mg/L)		Sand (%)		Mud (%)		TOC (%)	
		Max	Min	Max	Min	Max	Min	Max	Min
1	06^{O}34.729'N 004^{O}03.710'E	350	70	92.2	79	21	7.8	8.61	2.11
2	06^{O}34.658'N 003^{O}58. 719'E	340	80	87.4	61.4	28.6	11.4	8.22	2.10
3	06^{O}36.564'N 003^{O}58.799'E	1860	30	89.4	54.4	44.6	9.4	10.45	3.51
4	06^{O}36.929'N 003^{O}44.800'E	1270	70	85.4	65.4	27.6	14.6	7.50	1.01
5	06^{O}36.799'N 003^{O}42. 568'E	1400	71	93.6	1400	6.5	26	1.02	7.50
6	06^{o}33.592'N 003^{0}30^{o}36.102'E	6852	82	71	73.6	26	7.8	7.50	1.01
7	06^{O}31.754'N 003^{O}33.365'E	10932	77	89	65.8	29	11	6.00	1.01
8	06^{o}31.893'N 003^{o}31.912`E	15200	75	92.4	73.5	26.5	7.6	6.30	1.01

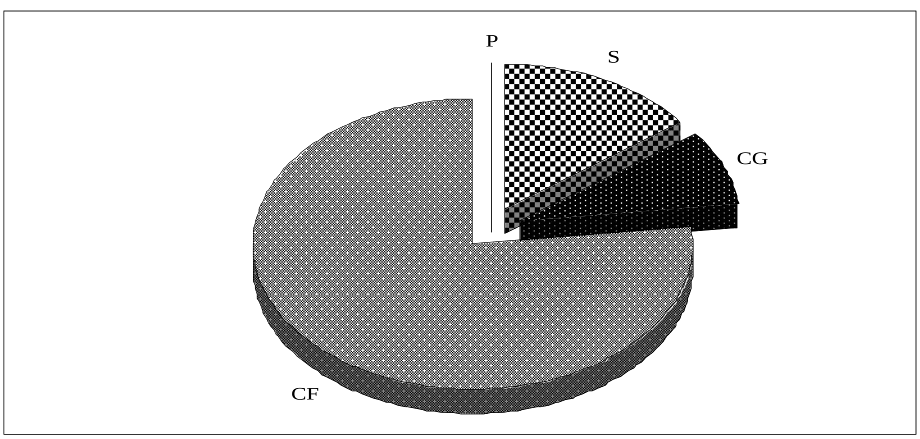

Figure 2. Overall percentage representation of the different functional feeding groups in the study area.

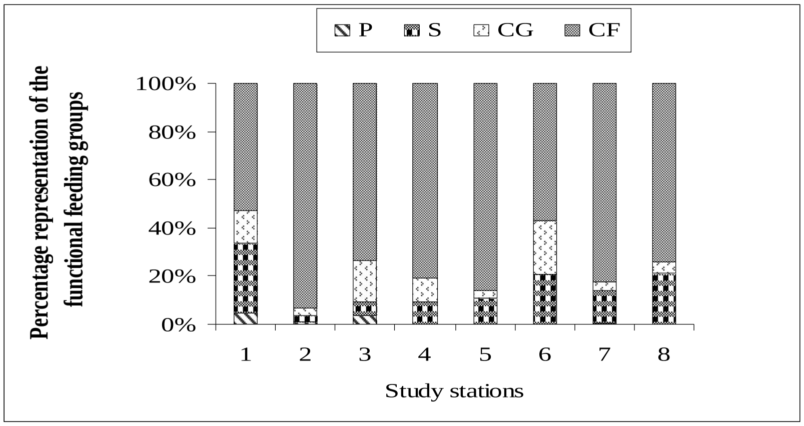

Figure 3. Percentages of benthic macroinvertebrate functional feeding groups (FFG) sampled from the study stations.

Table 2. List of taxa and their functional feeding groups in the study area. P = Predator; S = Shredder; CF = Collector - Filterer; CG = Collector – Gatherer.

Taxa	FFG
Annelida	
Capitellidae	CG
Lumbrineridae	P
Nereidae	S
Lumbriculidae	CG
Naididae	CG
Arthropoda	
Gammaridae	CG
Corophidae	CF
Penaeidae	CF
Ocypodidae	CF
Sesarmidae	CF
Clibanaridae	CF
Chironomidae	P
Gomphidae	P
Libellulidae	P
Baetoidae	CG
Tenthredinidae	CG
Echinodermata	
Cucumariidae	CG
Mollusca	
Neritidae	S
Melaniidae	CF
Potamididae	CG
Tellinidae	CF

Avcidae	CF
Ostreidae	CF
Aloididae	CF
Nemertina	
Otonemeridae	P
Porifera	
Chalinidae	CF

Table 3. Relationships between density of functional feeding groups (FFGs) and environmental parameters at the study stations (Pearson's correlation test). * Statistically Significant $p<0.01$.

	P	S	CG	CF
TOC	0.31	-0.79	-0.58	-0.96
TDS	-0.37	0.81	0.34	0.50*
Sand	0.38	-0.32	-0.15	0.51

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Dendrogram using Average Linkage (Between Groups)

                         Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
  Label     Num  +---------+---------+---------+---------+---------+

  S           2   òûòòòòòòòø
  CF          4   ò÷       ùòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòø
  CG          3   òòòòòòòòò÷                                       ó
  P           1   òòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòòò÷
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Figure 4. Cluster analysis of FFGs based on density at the study station

4. Discussion

This is the first major study in Epe lagoon and about one of the formost in south-west Nigeria examining benthos functional structure as a bioassessment tool. In terms of functional feeding groups' distribution, the benthic community showed few changes across the study stretch, collectors (filterers) being the dominant functional group in all the study sites.

The representation of collector filterers in all the study sites across the lagoon indicates the importance of seston transport in the water column (Minshall *et al*. 1992; Palmer *et al.* 1993b). As all the sites were open and a great part of the lagoon basin drains cultivated land and secondary forests where particulate organic matter tends to be high providing enough filterable materials. This study indicates a positive and significant relationship between density of filterers and the TDS in the water column. The significance of fine detritus as food resources for macroinvertebrates has been highlighted by Tomanova *et al*. (2006) in other lotic ecosystems. The fact that the collector filterers (Melaniidae) were abundant in most of the sites responded to a significant habitat complexity that possibly enhanced organic matter retentions and availability of suspended organic matter. The poor representation of collector-filterers at station 3 could be related with the discontinuities in seston supply and poor water circulation in the muddy sediment (Uwadiae, 2009).

Nature of sediment is an important factor in shaping benthic communities, both in structural and functional composition. Sediments with high percentage of sand fractions have well distributed interstitial spaces which favour oxygenation of sediment. Aquatic areas with sandy sediments are likely to be associated with high water current or velocity which influences water oxygenation and also plays a key role in the feeding process of some groups, such as filterers. Filterers feed on suspended fine particulate organic matter, which is transported by the current, and thus these organisms usually select areas of fast current, which provides more organic matter in a shorter period of time (Bus *et al*., 2002).

Moreover, it is well established that micro-flow dynamics play a key role in the small-scale distribution of benthic communities (Merritt *et al*., 2002; Minshal *et al*., 1992). Considering the substratum composition, our results agree with previous findings in temperate streams where mud was reported as a poor substrate, probably for its anoxic condition resulting from the decomposition of high organic matter load. The hydrogen sulphide released during organic matter decomposition in muddy sediment is poisonous to macrobenthic invertebrates and limits the number and diversity of functional feeding groups. The clogging of the filtering devices of most benthic invertebrates by mud has also been observed (Hart and Robinson, 1990).

The relatively high numbers of collector gatherers, collector filterers and shredders in our samples underscores the roles of these groups in organic matter processing in an environment like Epe lagoon. This supports an emerging hypothesis about allochtonous coarse particulate organic matter processing in tropics: in tropical lotic systems, the decomposition of plant material in fine particulate organic matter is operated either by macroconsumers or by enhanced microbial activity (Graca *et al*., 2001; Dobson *et al*., 2003). The number of predators recorded in this study was low, they were completely absent in stations 6 and 8. This is expected since specialized feeders are more sensitive and thought to be well represented in healthy streams. Generalists, such as collectors-filterers which were well represented in this study, have a broader range of acceptable food materials than specialists (Meritt *et al*., 2002) and thus are more tolerant to pollution that might alter availability of certain food. Their wide spread distribution in the study stretch indicates the perturbed status of the study area.

Understanding community structure and ecosystem functioning and their determinants is one of the main objectives of ecology. The variation of the different FFGs at different sampling stations can be explained by their mode of search for their food resources, together with the environmental variability at these sites. For example, the occurrence of the four FFGs observed in this study at station 3 was low. This can be related to the inability of the animals to carry out active search for food resources (leaf patches, deposited fine detritus patches, and prey items, respectively) due to the muddy nature of the substrate. In the search for food, these animals are constantly moving, and the distances traveled depend on how sparse are their food sources distributed (Covich, 1988; Merritt *et al*., 2002). When food sources are more heterogeneous, individuals can travel long distances until they find a suitable patch (Graca *et al*., 2001).

The present study illustrates that studies at multiple spatial scales are also essential for relating patterns and processes, given that the functional composition of macroinvertebrate communities is directly related to aquatic processes. The relative abundances of the different FFGs are major characteristics of macroinvertebrate communities with important implications at ecosystem level (Ramírez and Pringle, 1998), and thus directly relate community structure with ecosystem functioning. Results recorded in this study corroborates the River Continuum Concept (RCC) which predicts that community functional composition changes with habitat size, with shredders and gatherers being dominant in low-size forested streams, scrapers and gatherers in medium-sized streams, and gatherers and filterers in larger streams (Vannote *et al*., 1980), as observed in Epe lagoon.

The relative flexibility in trophic levels could reduce niche overlap among and within species and therefore, decrease the inter- and intra-specific competition (Callisto *et al*., 2001). Moreover, in unpredictably disturbed aquatic systems the supply and persistence of a particular food item is very variable. Hence the ability to exploit changing resources may potentially maintain population stability against natural fluctuations (Hart and Robinson, 1990). Indeed, the generalist feeding habit in the tropics is not surprising because it is considered as common strategy among lotic macroinvertebrates (Mihuc, 1997). Probably, this diet flexibility might contribute to an increase in the survival ability, and may have facilitated the spatial colonization of generalist feeders in the study area.

Royer and Minshall (2003) showed that leaf processing and supply of food materials is scale-dependent and that factors controlling processing rates largely depend on the spatial scale of study. They presented a hierarchical framework relating constraints on leaf processing to specific spatial scales, which allowed the development of scale-specific predictions of how environmental changes could affect leaf processing. It would be desirable to develop similar multi-scale frameworks to study the different ecosystem processes, and the distribution patterns of the organisms involved in those processes, in order to understand the relationships (Mathuriau and Chauvet, 2002).

The use of surrogate measures for ecosystem attributes shows promise as indicated in this and other studies (Palmer, *et al*., 1993a, 1993b; Merritt *et al.,* 2002; Tomanova *et al*., 2006). Selected ecosystem attributes can be the most sensitive measures of the state of ecosystems. Using various macroinvertebrate functional-group ratios as surrogates for these attributes can provide critical data with much less effort.

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