

Diversity and Spatial Structure of Benthic Macro-Invertebrates Community of Calabar River, Nigeria: Implications for Bio-Monitoring of River Environmental Quality.

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ABSTRACT

The study was carried out to ascertain benthic macro-invertebrates checklist in the Cross River, Nigeria and using it for bio-indication of the river quality. A total of 186 benthos specimens were collected. The phylum Insecta was most abundant (96) representing 51.61% of total benthos abundance; followed by Oligochaeta 60 (32.25%), Nemertea 10 (5.37%), Hirudiae 8 (4.3%), Cladocera 6 (3.22%), Asteroidea 4 (2.15%), and Gastropoda 2 (1.07%). At the species level, *Chironomus* was the most abundant (64) representing 34.4% of the total benthos abundance, and this was followed by *Limnodrilus* sp (11.82%), *Tubifex* (10.75%), and *Eristalis* (9.67%). The least abundant species were *Myxas glutinosa* (1.07%), *Hirudo* sp (1.07%), and the unidentified Asteroid (2.15%).

Overall abundance in sampling stations ranged from 34 (Station 4) to 64 (Station 3) and comprised of 15 species, with the taxon Oligochaeta contributing the highest percentage of species (33.33%). This was followed by Insecta (26.66%), Nemertea (6.66%), Asteroidea (6.66%), Cladocera (6.66%), Gastropoda (6.66%) and Hirudea (3.33%). Only two species *Limnodrilus* and *Chironomus* sp, were found in all the sampling stations. The range of diversity indexes were as follows: Margalef's index (1,412 in Station 4 to 3.174 in Station 3), Shannon-Weiner Index (1.565 in Station 4 to 2.202 in Station 3), Pielou's evenness index (0.8 in Station 2 to 0.97 in Station 4), Simpson's Diversity Index (0.137 in Station 3 to 0.463 in Station 1).

The comparative theoretical ranking of unhealthiness (CTRU) ranks station 4 as the best in environmental quality followed by stations 3, 2, and 1 in that order. Data from this study suggests

that although Calabar River exhibited fragmentations in benthos species composition, abundance and diversity, the river generally is of satisfactory environmental quality and devoid of any evidence of significant pollution-triggered perturbation that is beyond its carrying capacity.

(Keywords: benthic macro-invertebrates, bio-indicators, river quality)

INTRODUCTION

Text Benthic macro-invertebrates or benthos occupy the benthic, or bottom, layer of a body of water for all or part of their life cycle (Rosenberg and Resh, 1993). Generally, they are visible to the naked eye and play an important role in the metabolism of aquatic ecosystems (Allan, 1995). Benthos species are sensitive to environmental perturbations, and consequently, their structure (density, richness and diversity) or the functional organization of the macro-invertebrate community is affected by environmental changes (Pereira and De Luca, 2003). Because of their abundance and position as "middlemen" in the aquatic food chain, benthos species play critical role in the natural flow of energy and nutrients (www.dnr.state.md.us/streams/pubs/freshwater.html).

They are vital in biological monitoring, which is an effective tool to assess the ecological quality of rivers (Lorenz *et al.*, 2004; Barbone *et al.*, 2007; Mora *et al.*, 2008). Apart from benthos, other groups of organisms used in biological monitoring include planktons (Uttah *et al.*, 2008), parasites (Sures, 2004) and fisheries (Smolders *et al.*, 2003). However, the use of benthic macro-invertebrates appears more preferred due to availability of better knowledge of their taxonomy and autoecology than those of other aquatic

groups, and due to the fact that their sensitivity varies according to numerous environmental factors (both biotic and abiotic) that could depict the general conditions of an aquatic environment (Fenoglio *et al.*, 2002). Furthermore, benthic communities are studied because they spend most of their lives in direct contact with the sediment, and therefore are useful indicators of sediment quality (Odieta *et al.*, 2003).

Their usefulness in environment quality indication is predicated on three principal factors: their "immobility," long lifecycles, and their diversity. Benthos' inability to move around so much ensures that they are less able to escape the effects of sediment and other pollutants that diminish water quality. This translates to mean that benthos can give reliable information on stream and lake water quality. Benthic macro-invertebrates represent an extremely diverse group of aquatic animals, and the large number of species represents a wide range of responses to stressors such as organic pollutants, sediments, and toxicants, and enables for indicator organisms for all situations of environmental quality (Buckup *et al.*, 2007). Benthos species are long-lived, allowing for detection of past pollution events such as pesticide spills and illegal dumping.

Every species has particular optimal environmental requirements for it to be healthy and reproduce successfully. The presence or absence of healthy populations of organisms within their habitats is a sign of particular environmental condition. The presence of living organisms inherently provides information about water quality over time unlike chemical and physical tests which give information that is accurate only at that moment the sample is taken. For example, the presence of a mixed population of healthy aquatic insects, mussels or fish usually indicates that the water quality has been good for some time (Odieta *et al.*, 2003). Biological monitoring has advantages over chemical monitoring in that although the latter can also be very important to understand water quality, it is expensive, takes time, and often offers only limited information. Furthermore, biological monitoring can give an indication of past as well as present conditions (Fenoglio, 2002; Mitrofanova, 2008).

In studying benthos, especially their relationship with environmental quality, certain indexes are employed. An Index is a means devised to reduce a large quantity of data down to its simplest form,

retaining essential meaning for the questions that are being asked of the data (Ott, 1978). Detailed reviews on most utilized indexes have been published (Peláez-Rodríguez *et al.* (2000; Bollman and Marques, 2000; 2001; Pereira and De Luca, 2007). The usefulness of diversity and species richness of benthic communities in assessment of environmental quality has been demonstrated in Europe, Asia and the Americas (Afonso, 1992; Kulinska *et al.*, 1992; Sinha and Das, 1993; Barbone *et al.*, 2007). Similarly, the successful utilization an aggregate of indicator species to come to an informed conclusion on the state of an aquatic system (Pollution index) was reported in Lagos (Odieta *et al.*, 2003). Some of the popular indexes among biodiversity experts in this part of the world include Margalef's diversity index, Shannon Weiner index (H'), Simpson's Diversity Index, and Pielou Evenness Index.

This study was aimed at determining the checklist, diversity and relative abundance of benthic macro-invertebrates of Calabar River, Nigeria, and also at employing the benthos species composition to ascertain the river water quality.

MATERIALS AND METHODS

Description of Sampling Stations

Calabar River is the major river that drains Calabar city. It is a center of major economic activities such as fishing, and transportation of goods and personnel in the area, among others. Some manufacturing companies are located on the banks of the river which increases the possibilities of effluent discharge into the river systems. These were taken into consideration during project design and while choosing sampling stations. Four sampling stations were chosen for the study (Stations 1 to 4). The stations were located at various points within the metropolis representative of the entire river stretch.

Sampling Methods

The benthic macro-invertebrates samples were collected with Day grab and washed using a sieve with a 500 μ m mesh-size; then preserved in plastic containers in 10% formalin with Rose Bengal as vital stain.

Laboratory Analysis

Sorting and counting of the benthic macro-invertebrates were carried out on the standard white panel in the laboratory using a hand lens. As much as possible, identification of both plankton and benthos specimens was made up to species level or genus levels using the keys of WRC (2001).

Grouping of Benthos Species According to Pollution Sensitive Characteristics

The benthos species collected were separated into five groups based on their pollution sensitivity characteristics (see Table 1). This key was adapted from Odiete *et al.* (2003).

Table 1: Bio-Indication of River Quality using Macro-Invertebrates (adapted from Odiete *et al.*, 2003).

Group	Description
I	Animals found in water of very high quality, that is, relatively clean, example May fly larvae, stonefly larvae, caddis fly larvae, flatworms.
II	Animals tolerating water of moderate quality, example mussels, dragonfly and damselfly larvae, water boatmen, beetles and beetle larvae, mites.
III	Animals tolerating water of poor quality or ones recovering from pollution, example pond snails, <i>Ascellus</i> , <i>Corixa</i> , Water fleas, leeches, pond cricket (<i>Velia</i>), pond skater (<i>Gerris</i>).
IV	Animals found in water of very poor quality (polluted), example sludge worms (<i>Tubifex</i> , <i>Nais</i>), fly larvae (<i>Chironomus</i> , <i>Chaoborus</i> , <i>Tipula</i>).
V	Animals in heavily, organically polluted water, example rat tail, <i>Eristalis</i>

Data Analysis

The benthic macro-invertebrate community structure was analyzed using different diversity indexes. Species diversity was analyzed using Margalef index (Margalef, 1958) and Shannon-Weaver index (Valiela, 1984). Evenness and dominance were analyzed using Pielou's

evenness index (Pielou, 1966) and Simpson's Dominance index respectively. These indexes were calculated for each sampling station following standard formulae after Ludwig and Reynolds (1988) and Magurran (1988). The Microsoft Office Excel 2007 edition was used.

RESULTS AND DISCUSSION

Abundance

A total of 186 benthic macro-invertebrate specimens were collected in the survey. Of this, the phylum Insecta was most abundant with 96 specimens representing 51.61% of total benthos abundance. The relative abundance of other benthic macro-invertebrates represented were: Oligochaeta 60 (32.25%), Nemertea 10 (5.37%), Hirudiae 8 (4.3%), Cladocera 6 (3.22%), Asteroidea 4 (2.15%), and Gastropoda 2 (1.07%).

At the species level, *Chironomus* were the most abundant (64) representing 34.4% of the total benthos abundance. This was followed by *Limnodrilus* sp (11.82%), *Tubifex* (10.75%), and *Eristalis* (9.67%). The least abundant species were *Myxas glutinosa* (1.07%), *Hirudo* sp (1.07%), and the unidentified Asteroid (2.15%). A breakdown of abundance in relation to sample stations shows that overall abundance ranged from 34 in Station 4 to 64 in Station 3 (Table 2).

Species Diversity

Overall Species Richness: A total of 15 species of benthic macro-invertebrates was counted during the survey. The Oligochaeta contributed 33.33% of Species Richness which was the highest. This was followed by Insecta with 26.66%, Hirudea 3.33%, Nemertea 6.66%, Asteroidea 6.66%, Cladocera 6.66% and Gastropoda 6.66% of total Species Richness. Most of these taxa are found in other Nigerian lotic systems (Edokpayi *et al.*, 2000; Omudu and Odeh, 2006; Adeyemi *et al.*, 2009; Uttah and Uttah, 2009). It is known that species composition is affected by environmental and biological characteristics (Salgado-Maldonado and Kennedy 1997; Valtonen *et al.* 2001; Vidal-Martínez and Poulin 2003; Poulin 2003; Violante-González *et al.* 2008; Tavares and Luque 2008).

In the same vein, the local differentials in Table 2.

Table 2: Abundance of Benthic Macro-Invertebrates in Relation to the Sampling Stations of Calabar River, Nigeria.

Species	St.1	St.2	St.3	St.4
<i>Tubifex</i> sp.	0	6	4	6
<i>Limnodrilus</i> sp.	6	2	10	4
<i>Nais</i> sp.	0	4	2	0
<i>Paranais</i> sp.	0	0	8	0
<i>Aulodrilus</i> sp.	0	2	2	0
Nemertean	2	2	6	0
<i>Eropbdella</i>	0	4	2	0
<i>Hirudo</i> sp.	0	0	2	0
<i>Chironomus</i>	18	22	16	8
<i>Eristalis</i>	0	4	4	10
<i>Telmatoscopus</i>	0	0	0	6
Chrysomelidae	4	2	2	0
Ephippian	4	0	2	0
<i>Myxas glutinosa</i>	2	0	0	0
Asteroidea	4	0	0	0

Environmental and biological indices in the four stations in this study must have influenced the species composition of each component community. This agrees with indications from some earlier studies that local environmental conditions can substantially and critically define community structure (Machado *et al.* 1995; Salgado-Maldonado and Kennedy 1997; Valtonen *et al.* 2001; Vidal-Martinez and Poulin 2003; Aguirre-Macedo *et al.* 2007).

Station 3 presented the greatest Species Richness (12) (see Table 3), followed by station 2 (9), while Station 4 recorded the least Species Richness (5). Factors such as area, altitude, productivity, landscape heterogeneity, succession status and disturbance have been reported to play roles in determining species richness (Kohn and Walsh, 1994; Pys̆ek *et al.*, 2002a; Barnes, 2010). Generally, greater Species Richness indicates better water quality (www.dnr.state.md.us/streams/pubs/freshwater.html).

Diversity Indices of the Sampled Stations: The results of species diversity analyzed using Margalef's Index and Shannon-Wiener Index, as

well as evenness and dominance analyzed using Pielou's evenness index, and Simpson's Dominance index respectively after Sharma (2009) are presented in Table 3.

Table 3: Abundance and Diversity of Benthic Macro-Invertebrates in Relation to Sample Stations of Calabar River, Nigeria.

Parameter	Sampled Stations			
	1	2	3	4
Taxa Richness	7	9	12	5
^a Ab. per sample	40	48	64	34
^b Margalef's	2.003	2.517	3.174	1.412
^c H ⁱ	1.634	1.768	2.202	1.565
^d Simpson's	0.463	0.253	0.137	0.218
^e Pielou	0.84	0.8	0.89	0.97

(Note: ^aAb. per sample = Abundance per sample; ^bMargalef's = Margalef's Diversity Index; ^cHⁱ = Shannon Weiner index; ^dSimpson's = Simpson's Diversity Index; ^ePielou = Pielou Evenness Index)

Margalef's index ranged from 1,412 in Station 4 to 3.174 in Station 3 which showed that there were significant differences between some sections of the river as represented by the sampled stations (t-test; p > 0.05), and could indicate some degree of heterogeneity as a result of mosaics introduced by anthropogenic activities (Pys̆ek *et al.*, 2002b).

Shannon-Weiner Index ranged from 1.565 in Station 4 to 2.202 in Station 3. The differences in the Shannon Weiner index values in the sections of the river were not significant (χ^2 -test; p < 0.05). The index is widely used, consistent, relatively independent of sample size and employs both abundance and species richness (Gray *et al.*, 1990). It is the most suitable expression of biotic diversity known to be strongly correlated to Pielou's Evenness index (Gray *et al.*, 1990), but the latter is a preferred tool (Valiela, 1984). Pielou's Evenness Index ranged from 0.8 in Station 2 to 0.97 in Station 4. It is common knowledge that a community is less diverse in which species are unevenly abundant (Phillips, 1988; Gray *et al.*, 1992).

Simpson's Diversity Index ranged from 0.137 in Station 3 to 0.463 in Station 1. This result indicates absence of marked and significant

dominance by any taxonomic group in the sampled stations at the time of study. Simpson's Diversity Index was used to measure dominance among species in the community (Simpson, 1949). This is based on the principle that marked dominance of one species results in low diversity, while co-dominance of several species presents high diversity. High diversity indicates a balanced, stable, responsive community, and low diversity occurs in an area where the community is dominated by a few species, such as in a stressed area of high pollution, large and frequent disturbances, or anoxic sediments. However, diversity indices are criticized because they cannot detect community changes due to one environmental factor especially when considered individually (Cao *et al.*, 1996; Buckup *et al.*, 2007).

Spatial Distribution of Benthos Species

The geo-spatial distribution of species, in terms of percentage number of species, in relation to percentage number of sampling stations were analyzed (Figure 1). The results indicated that many species had limited distribution, and exhibited high fidelity, while few species had very wide distribution. Spatial distribution is a factor in determining the importance of a taxonomic entity in an ecosystem (Philip, 1988). This factor accords a place of importance to *Chironomus* in Calabar River in this study. This species is found in both aquatic systems of poor water quality (Odieta *et al.*, 2003), as well as in those not presenting organic enrichment (Gray and Pearson, 1982). Calabar River belongs to the latter category as has been indicated in an earlier study (Uttah *et al.*, 2008).

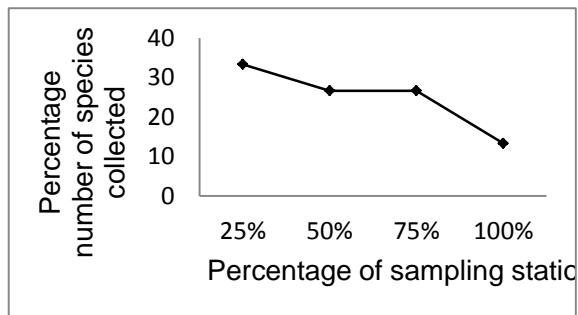


Figure 1: Relationship between Number of Species and the Frequency of Sampling.

The most abundant species were the most spatially distributed (Figure 2), In other words, spatial distribution of species increased as their relative abundance increased. It was observed that the chance of encountering species with very low abundance during surveys was relatively less than the chance of encountering species with relatively higher abundance. This strengthens the philosophy of an earlier finding that the chances of collecting species with low abundance during sampling are improved with repeated sampling (Uttah *et al.*, 2008).

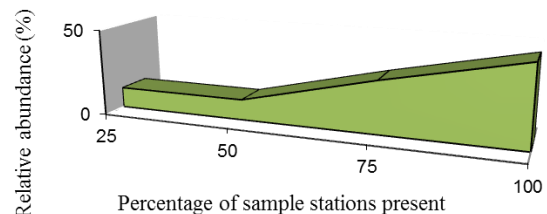


Figure 2: Relationship between Species Distribution and Relative Abundance of Benthos of Cross River, Nigeria.

Bio-Indication of Calabar River Quality using Benthic Macro-Invertebrates

Grouping of benthos species collected according to their pollution sensitivity characteristics was carried out after Odieta *et al.* (2003). This was based on the principle that macro-invertebrates are bio-indicators whose presence, absence or condition provides information about environmental quality of aquatic systems. In Sample Station 1, both pollution-sensitive pond snail (*Myxas glutinosa*) and pollution-tolerant species: *Chironomus*, *Nais* and *Tubifex* were present. This was not unusual as a clean watercourse may contain benthos from all the five groups although in small numbers (Odieta *et al.*, 2003). However, the presence of *Myxas glutinosa*, which was recorded only in Station 1 and in small numbers (low abundance), might indicate that, relatively, Station 1 was perhaps, the poorest in environmental quality of all the sampled stations.

Table 4: Relative Percentage Abundance, Relative Percentage Species Richness, and the Theoretical Ranking of Unhealthiness of the Sampled Stations of Calabar River, Nigeria.

Sample station	Relative species Richness of Pollutant-tolerant species (%)	Relative abundance of Pollutant-tolerant species (%)	Theoretical rank of unhealthiness
1	14.29	45.0	4th
2	44.44	75.0	2nd
3	33.33	46.88	3rd
4	60.0	70.59	1 st

The grouping of benthic macro-invertebrates according to their response to quality of the water has also been carried out in different regions of the world (Pereira and de Luca, 2003; Buckup *et al.*, 2007).

The above conclusion was strengthened by another assessment tool we refer to as the Comparative Theoretical Ranking of Unhealthiness (CTRU) of all the sampling stations (Table 3). The CTRU method ranked Station 4 as the best in environmental quality followed by Stations 3 and 2 in that order, while Station 1 was adjudged the least healthy station in terms of environmental quality. These were done by comparing, and ranking the relative percentage abundance and the relative percentage of species richness of pollution-tolerant species collected in each sampling station. The underlying principle was that as a station got more and more polluted, the pollution-sensitive species became eliminated. Species tend to disappear in the order from group I to group V as the degree of pollution increases (Odiete *et al.*, 2003).

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