Assessment of the macro-invertebrate fauna of rivers in southern Nigeria

J.O. Olomukoro* & L.I.N. Ezemonye

Department of Animal and Environmental Biology, University of Benin, P.M.B. 1154, Benin City, Nigeria

Received 28 July 2005. Accepted 6 April 2006

This study evaluated the macro-invertebrate fauna in water bodies of southern Nigeria spanning the rainforest and derived savanna ecozones. The benthic macro-invertebrate fauna of Edo Ecozone comprises 55 taxa, belonging to 13 major groups. The abundance of major taxonomic groups varied considerably among the surveyed aquatic ecosystems. Chironomidae (Diptera) were well represented and dominant in 11 of the 20 water bodies surveyed. Most rare and restricted species were gastropods (Mollusca), one such species, *Mutela* cf. *dibia*, being endemic to the catchment. The overall abundance was maximal (97) at Okomu River in the lowland forest and minimal (5) at Avielle River in derived savanna, respectively. The human impact on macro-invertebrate biodiversity is documented, including changes in benthic fauna distribution patterns.

Key words: macro-invertebrates, biodiversity, survey, Nigeria.

INTRODUCTION

In the past two decades, there has been a tremendous fear of a possible global biodiversity crisis arising out of a rapidly accelerating loss of species, populations and natural habitats such as tropical rainforests and wetlands. It has been estimated that more than half the habitable surface of the planet has already been altered by human activity (Hengeveld 1990). Also suggested is that we are on the verge of mass extinctions of species (McCarthy 2002). These concerns stem from the realization that our knowledge of the diversity and variability of plants, animals, microorganisms and the ecosystems in which they occur is woefully incomplete.

The global biodiversity crisis arising from overexploitation and pollution of water bodies is of great concern. Consequently, the degradation of water bodies necessitates regular assessment and management of Nigeria's aquatic resources. The sediments of all water bodies, either lentic or lotic, contain vast numbers of invertebrate macrofauna (species visible to the unaided eye) which are used to assess water quality in rivers (Elliot & Drake 1981). Not only are they numerically abundant, they are also taxonomically diverse. Hynes (1972) observed that the aquatic animals, which live on, in or near the substratum of running waters, include the nematodes, annelids, insects, crustaceans and molluscs. The few notable studies documenting the freshwater fauna in this region are those of Olomukoro & Victor (1999) and Olomukoro & Ezemonye (2000), who worked on the macrobenthic fauna of a first order stream, a tributary of Ikpoba River, Benin City; while Ogbeibu & Egborge (1995) worked on the macro-invertebrates of some water bodies in Okomu Forest Reserve, Benin City.

The impacts of river impoundments through the building of barriers (Cambray 1991; Ogbeibu & Oribhator 2000), road and bridge construction (Ogbeibu & Victor 1989), and river flow modification (Kleynhans 1996) on the water quality and fauna of downstream lotic reaches have been addressed (Egborge 1991). However, the impacts of human activities on water bodies in the Edo State Ecozone have not been studied, which prompted this survey.

The objectives of this ecological assessment were to analyse the composition, abundance, diversity and distribution of macrobenthic fauna in the water bodies of rainforest and savanna areas, and to document changes in distribution patterns associated with ecological alteration due to human activity, with a view to making recommendations for the effective management of these ecosystems

STUDY AREA

Edo State Ecozone lies between 5°05′ and 6°40′E, and 5°15′ and 7°34′N. It has a total land area of 19 794 km^2, most of which consists of low plains with great networks of water bodies (Fig. 1). The climate is tropical, and primarily regulated by rainfall. The wet season covers the period May–

*Author for correspondence: E-mail: olomsjo@yahoo.com

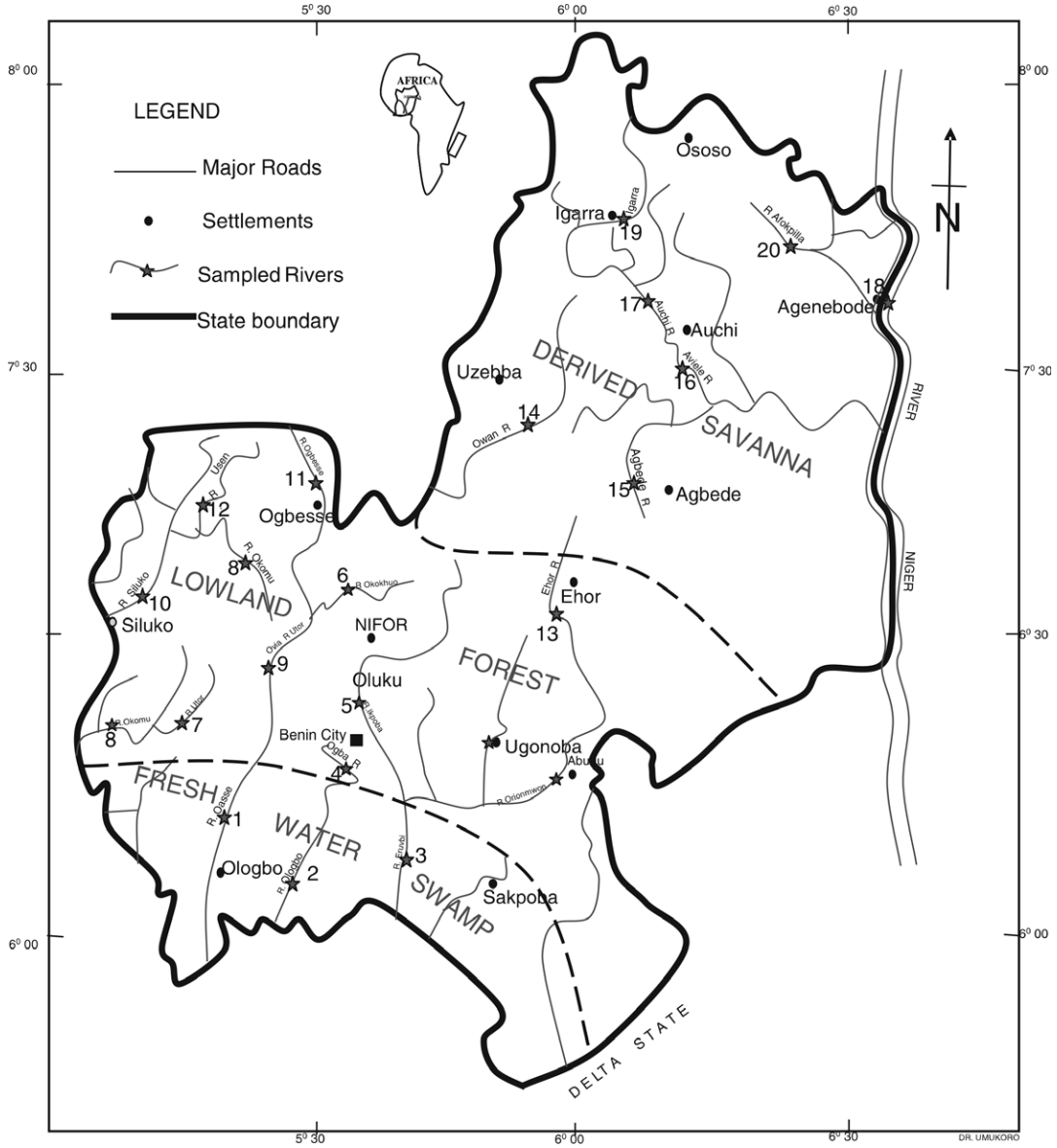

Fig. 1. Map of Edo State showing the study area and sampling sites.

October while the dry season is usually November–April. The average annual rainfall is 312 mm, while the mean minimum rainfall is 15 mm (Olomukoro & Victor 1999). The minimum air temperature recorded is 22°C, and the maximum 34°C.

The zone has no fewer than 25 rivers and their tributaries, each with a separate drainage region. The rivers run in an East–West direction. The water bodies had low conductivity, ranging from 14.6–149.6 μS/cm (with mean value of 57.9 ± 10.7), and pH was slightly acidic to circumneutral with pH 5.05–7.76 with a mean of 6.0 ± 0.14. The dissolved oxygen ranged from 5.5–8.0 mg/l (with a mean of 6.7 ± 0.1 mg/l). The salinity was zero.

The upper reaches of most of the rivers, particularly in the northern part, are mountainous, originating in small springs and characterized by shallow, fast flowing water and rocky beds with sandy pockets. Some of these are intermittent streams observed to overflow their banks during

Table 1. Potential impacts to river basins in various ecozones.

Impactable river basins	Impacts											
	Settlement	Farming	Sewage/ solid	Industrial effluent	Impoundment	Dredging	Construction	Suburban development	Mining	Runoff/ siltation	Erosion (stream banks)	Flooding
Freshwater swamp												
1. Osse	+	+							+	+		
2. Ologbo	+								+	+		
3. Eruvbi	+	+								+		
Lowland forest												
4. Ogba	+		+	+			+	+		+	+	+
5. Ikpoba	+		+	+	+	+	+			+	+	+
6. Okhuo	+	+					+			+		
7. Utor												
8. Okomu	+	+								+	+	+
9. Ovia	+	+								+	+	+
10. Siluko	+	+								+	+	+
11. Ogbese	+	+								+	+	
12. Usen	+	+								+	+	+
13. Ehor	+	+										
Derived savanna												
14. Owan	+	+								+	+	+
15. Agbede	+									+	+	+
16. Avielle		+								+	+	+
17. Auchi		+								+	+	+
18. Agenebode	+	+	+		+					+	+	+
19. Igarra		+								+	+	+
20. Okpilla											+	+

the rainy season. The lower regions of the rivers run through the coastal plain, and the river beds comprise fine, sandy, muddy sediment with submerged vegetation.

Edo Ecozone is divided in this study into three areas as follows:

i. Freshwater swamp, from Osse River to Ovia River, covering three sampling sites.
ii. Lowland forest rivers, from Ogbese River to Ehor River, with ten sampling sites.
iii. Derived savanna, from Owan River to Okpilla River, with seven sampling sites.

Egborge (2002) was used as a guideline in the identification of 12 environmental impacts monitored in the various study areas (Table 1). The effects of farming activities runoff/siltation, erosion and flooding impact on more than 70% of the rivers.

MATERIALS & METHODS

Two sampling methods were used for the collection of benthic organisms. First, benthic samples were collected with an Ekwan grab (15 × 15 cm) as recommended for sand and silt (Hynes 1961; Elliot 1977). Contents trapped by the grab were processed as described by Olomukoro & Victor (1999). Second, the aquatic macrophytes were sampled by the 'kick' sampling method used by Hynes (1961). Samples collected were sieved with a set of Tyler sieves of 20 cm diameter and mesh sizes of 2 mm, 1 mm, 150 μm and 100 μm, respectively. The contents retained in the sieves were washed into polypropylene sampling bottles containing 10% formalin. A dissecting microscope was used to sort out the macrobenthic organisms in the laboratory. The organisms collected were stored in labelled specimen bottles containing 4% formalin for later examination.

For quantitative analysis, up to 12 samples per site may be required, but this restricts the number of sites that can be sampled (Hynes 1961). In this study, we followed Towns (1979) in taking three replicate samples per site in each trip. These were pooled to avoid the effects of selectivity by the sample and species aggregations.

Benthic organisms were identified by reference to appropriate keys and works of Ward & Whipple (1959), Pennak (1953), Powell (1983) Mellanby (1963), Hynes (1972), Needham & Needham (1982), Olomukoro (1996) and Brinkhurst (1966). Owing to limited taxonomic knowledge of the benthic fauna of Nigeria, some specimens were assigned to generic level only.

Data analysis

In characterizing the different biotic communities, Margalef's index of species diversity (Clifford & Stephenson 1975), Shannon-Wiener (Shannon & Weaver 1949) and evenness indices were used to assess components of species diversity in streams systems.

The modified form of Simpson's index (developed by unbiased eliminator for sampling from an infinite natural population) referred to as measures of dominance was also used (Ogbeibu 2004).

RESULTS

Status of benthic macrofauna

Fifty-five taxa were recorded from the widely surveyed aquatic ecosystem in Edo State Ecozone. These comprised Nematoda (two species), Annelida (Oligochaeta, 5 spp.; Hirudinea, 2 spp.), Decapoda (5 spp.), Ephemeroptera (6 spp.), Odonata (Anisoptera, 4 spp.; Zygoptera, 4 spp.), Hemiptera (1 sp.), Coleoptera (4 spp.), Trichoptera (6 spp.), Plecoptera (1 sp.) and Arachnida (1 sp.), Diptera (Ceratopogonidae, 3 spp.; Chironomidae, 7 spp.) and Mollusca (4 spp.) (Table 2).

Diptera constituted the dominant group with 32.54% density occurrence. Ephemeroptera and Oligochaeta were next with 18.85 and 15.02% density, respectively. The rare groups were Nematoda (1.1%), Hemiptera (2.50%), Coleoptera (3.53%), Trichoptera (3.53%) and Mollusca (1.49%). Among the taxa recorded, *Baetis* sp., *Cloeon* sp. (Ephemeroptera), and *Chironomus* sp. (Diptera) were most prevalent with 5.89, 7.21 and 9.13% density occurrence. Few taxa had low densities of between 0.14 and 0.30%. These were *Stylaria fossularis* (Oligochaeta), *Macrobrachium dux* (Decapoda), *Hydropsyche* sp., *Polycentropus* sp. and *Stenophylax* sp. (Trichoptera). Others included *Neoperla* sp. (Plecoptera), *Argyroneta aquatica* (Arachnida), *Forcipomyia* (Ceratopogonidae), *Lanistes* sp. and *Hydrobia* sp. (Mollusca).

Eruvbi and Okomu rivers had the highest numbers of individuals representing 14.28 and 12.81% population density of all collections, while Igarra and Okpilla rivers had the least organisms with 1.17 and 1.47%, respectively.

The overall maximum abundance was at Okomu River followed by Eruvbi stream both located in the lowland forest, while the lowest abundance was recorded at Avielle and Igarra rivers, respectively (Fig. 2). Gradual increase of macrofauna

Table 2. Composition and diversity of benthic macrofauna in Edo ecozone water bodies.

Taxa	Freshwater zone			Lowland forest rivers										Derived savanna						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
NEMATODA																				
Rhabdolaimus sp.	■			■				■								■			■	
Other nematodes	■							■												
OLI GOCHAETA																				
Nais sp.	■		■	■	■	■	■	■	■	■										
Tubifex sp.													■		■	■	■			
Aulophorus furcatus Muller			■	■				■												
A. vagus Leidy			■					■		■										
Stylaria fossularis Leidy			■																	
HIRUDINEA																				
Haemopsis sp.		■						■				■								
Haemopsis marmorata Say		■						■												
DECAPODA																				
Caridina africana Kingsley	■		■	■	■	■	■	■	■		■									
C. gabonensis, Roux			■	■	■	■	■	■		■										
Desmocaris trispinosa Aurivillius	■	■	■	■	■	■	■	■	■		■									
Macrobrachium dux Lenz					■															
Potamalpheops monodi Sollaud	■	■	■																	
EPHEMEROPTERA																				
Baetis sp.	■		■	■	■	■	■		■	■		■								
Centroptilum sp.	■	■	■		■	■	■		■	■	■		■							
Cloeon sp.	■	■	■	■		■	■		■	■	■	■					■			■
Heptagenia sp.	■	■		■			■		■				■	■			■			■
Dicercomyzon sp.	■		■				■		■							■	■			■
Adenophlebiodes sp.							■		■					■						
ODONATA – ANISOPTERA																				
Libellula sp.	■		■	■	■		■	■	■		■									
Cordulia sp.							■	■												
Epicrodulia sp.							■	■												
Plathemis sp.							■	■												
ZYGOPTERA																				
Coenagrion sp.	■		■				■	■			■		■	■						
Enallagma sp.	■		■	■	■	■	■	■	■			■		■						
Hetaerina sp.					■			■												
Ischnura sp.								■												

Continued on p. 6

Table 2 (*continued*)

Taxa	Freshwater zone			Lowland forest rivers										Derived savanna						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
HEMIPTERA	■	■	■			■	■		■						■		■			
COLEOPTERA																				
Dytiscus marginalis Mellanby	■	■					■	■		■		■								
Hydrophilus sp.			■	■	■	■		■			■									
Gyrinus sp.		■	■	■			■													
Deronectes sp.								■												
TRICHOPTERA																				
Leptocella sp.							■	■												
Other Trichoptera				■		■		■	■			■								
Limnophilus sp.	■				■		■	■		■										
Hydropsyche sp.			■		■															
Polycentropis sp.							■													
Stenophylax sp.								■												
PLECOPTERA																				
Neoperla sp.				■	■															
ARACHNIDA			■																	
DIPTERA																				
Ceratopogonidae																				
Alluaudomyia sp.	■						■	■		■	■									
Forcipomyia sp.																				
Palpomyia sp.							■					■					■			
CHIRONOMIDAE																				
Chironomus fractilobus Kieffer	■		■	■	■			■	■		■							■		
C. travalensis Kieffer	■		■	■	■		■	■	■									■		
Clironomus sp.	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		■		
Pentaneura sp.		■	■	■	■			■						■			■	■	■	
Tanypus sp.			■	■				■		■	■	■		■				■	■	
Clinotanypus maculates Miegen			■			■	■	■						■	■		■	■		■
Pseudochironomus sp.			■			■								■						
MOLLUSCA																				
Lanistes sp.				■															■	
Mutela cf. *dibia*																				
Hydrobia sp.		■													■					
Potadoma sp.																				

Key: Sampled rivers: 1) Osse, 2) Ologbo, 3) Ogba, 4) Ikpoba, 5) Eruvbi, 6) Okhuo, 7) Utor, 8) Okomu, 9) Ovia, 10) Siluko, 11) Ogbese, 12) Usen, 13) Ehor, 14) Owan, 15) Agbede, 16) Avielle, 17) Auchi, 18) Agenebode (Niger), 19) Igarra and 20) Okpilla.

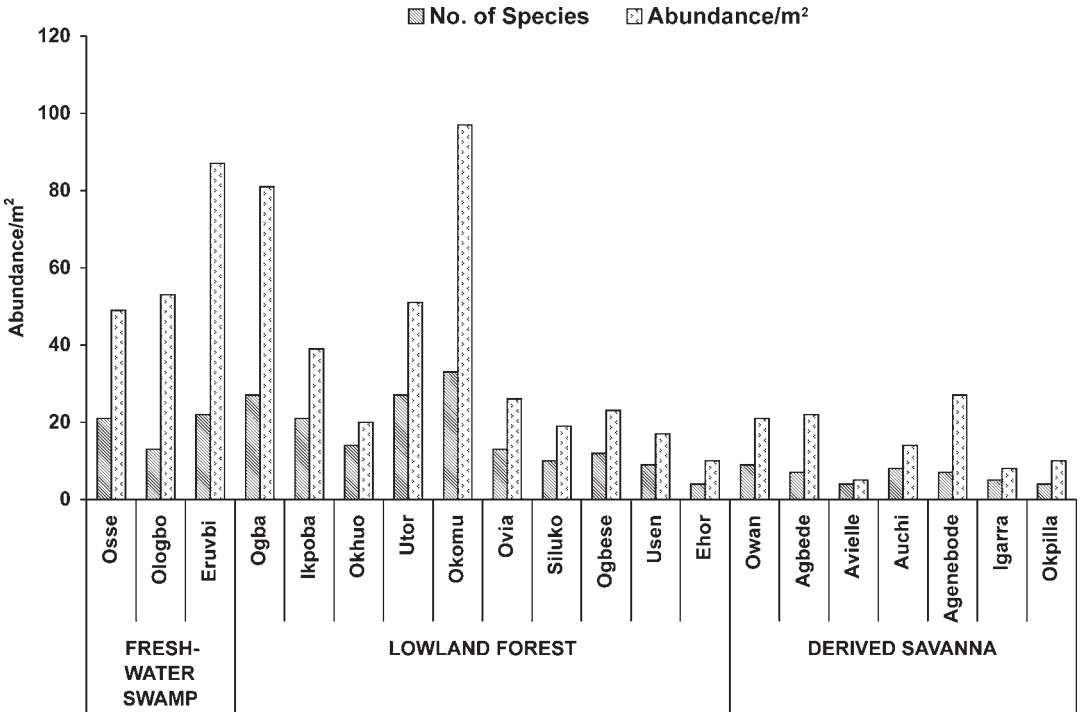

Fig. 2. Macro-invertebrate abundance and species number in Edo Ecozone water bodies.

diversity in the freshwater swamp was observed until a peak was obtained at Okomu River in the lowland forest. A decrease occurred thereafter at Ovia River with a downward trend in both species richness and abundance until very low density was obtained at Ehor, which is the last of the rivers in the lowland forest. Fluctuation in species abundance was minimal, with low density of occurrence in the water bodies within the derived savanna area. The abundance of major taxonomic groups varied considerably among the aquatic ecosystems. The family Chironomidae (Diptera) was well represented and dominant in 11 of the 20 sites, while Ephemeroptera (particularly *Baetis* sp.) dominated eight of the aquatic ecosystems. The rare species are the gastropods (Mollusca).

In terms of distribution, some taxa were cosmopolitan, occurring in over 60% of the study area. These were among the Oligochaeta, *Nais* sp.; Ephemeropteran larvae, *Baetis* sp., *Centroptilum* sp. and *Cloeon* sp. and 71.43% of the taxa in the family Chironomidae, which comprised *Chironomus* sp., *Chironomus fractilobus, C. travalensis, Pentaneura* sp. and *Tanypus* sp. and Zygopteran (Odonata) larvae, *Coenagrion* sp. and *Enallagma* sp. Few species with single record were *Macrobrachium dux* (Decapoda) found in Eruvbi stream, a tributary of Ikpoba river, *Ischnura* sp. (Zygoptera: Odonata) found in Okomu river, *Argyronnecta aquatica* (Arachnida) found in Ogba river and among the Mollusca *Lanistes* sp., *Mutela* cf. *dibia, Hydrobia* sp. and *Potadoma* sp. found in Ikpoba, Igarra, Ologbo and Owan rivers, respectively.

Restricted species include those of the benthic groups [Decapoda, Anisoptera (Odonata), Trichoptera and Plecoptera] found in rivers within the freshwater and lowland forests.

Faunal diversity

Table 3 and Figure 2 show the heterogeneity indices of water bodies in Edo State. Margalef's species richness (*D*) was highest in Okomu River, closely followed by River Utor and lowest in the Ehor and Okpilla rivers. Shannon-Wiener diversity indices ranged from 0.48 to 2.37. The rivers in the derived savanna had low diversities, ranging from 0.054 to 0.202, while the highest diversity value of 2.37 was recorded in Ikpoba River. Rivers in freshwater swamp and lowland forest, Osse, Ologbo, Eruvbi, Ogba, Okhuo, Utor, Okomu and Usen had diversity values >1.00 while for all others the values were <1.00.

All the rivers except Owan, Avielle and Auchi located in the derived savanna had low species

Table 3. Diversity indices of macro-invertebrate fauna of Edo State.

Waterbody	No. of species	Abundance	Diversity (*D*)	Shannon-Wiener (*H*)	Evenness (*E*)	Dominance
Freshwater swamp						
1. Osse	21	49	5.14	1.25	0.41	0.045
2. Ologbo	13	53	3.02	1.07	0.42	0.067
3. Eruvbi	22	87	4.07	1.23	0.40	0.057
Lowland forest						
4. Ogba	27	81	5.92	1.33	0.40	0.031
5. Ikpoba	21	39	5.46	2.37	0.78	0.050
6. Okhuo	14	20	4.32	1.09	0.41	0.060
7. Utor	27	51	6.52	1.37	0.42	0.030
8. Okomu	33	97	7.00	1.51	0.43	0.061
9. Ovia	13	26	3.68	0.80	0.31	0.122
10. Siluko	10	19	3.06	0.96	0.42	0.092
11. Ogbese	12	23	3.50	0.48	0.19	0.360
12. Usen	9	17	2.83	1.15	0.13	0.020
13. Ehor	4	10	1.30	0.47	0.34	0.350
Derived savanna						
14. Owan	9	21	2.63	0.94	0.43	0.054
15. Agbede	7	22	1.94	0.78	0.40	0.056
16. Avielle	4	5	2.65	0.58	0.42	0.100
17. Auchi	8	14	2.65	0.87	0.42	0.200
18. Agenebode	7	27	1.82	0.71	0.37	0.202
19. Igarra	5	8	1.92	0.65	0.40	0.090
20. Okpilla	4	10	1.30	0.70	0.50	0.130

diversities compared to the rivers located in the fresh/lowland forest area of Edo State.

Benthic macro-invertebrate equitability or evenness indices for all water bodies were <0.50, apart from Ikpoba with the highest value (0.78), followed by Okpilla (0.50). The lowest values were recorded for Usen (0.13) and Ogbese (0.19). Usually, the index varies from zero to one. When equitability is one, it implies that all the species present are all evenly distributed.

DISCUSSION

Changes arising from anthropogenic activities have taken place in the aquatic ecosystem especially in the last two decades. This has affected the aquatic habitat, and consequently, the macro-invertebrates biodiversity. In the Nigerian lowland rainforest, these changes have affected the entire aquatic systems, particularly of two principal rivers in Benin metropolis, namely Ikpoba and Ogba Rivers. They have witnessed pollution and drastic reduction in benthic fauna (Ezemonye & Kadiri 1998). Only the dipteran larvae *Chironomus fractilobus* and *C. travalensis,* occurred at high population densities among other benthos in these rivers. Some other Lowland rivers (e.g. Okhuo, Utor and Ogbese) had the least anthropogenic impact and sustained their original species diversity.

A total of 55 taxa were recorded in the assessment studies. Ecologically important bottom fauna were primarily from the major groups such as Diptera, Ephemeroptera, Plecoptera, and Trichoptera, which serve as bio-indicators of pollution in the aquatic ecosystem. The dominance of dipteran species in many tropical assemblages has been acknowledged. This significance as indicators of trophic status of freshwater ecosystem have been stressed (Paterson & Fernando 1970; Ogbeibu 2001). The qualitative presence of Ephemeroptera in almost all the water bodies in Edo State is spectacular. They are also used as indicators of environmental conditions (Olomukoro 1996). They tend to live mostly in unpolluted lakes, ponds, streams and rivers, where they contribute substantially to secondary production. However, very small amounts of organic pollution can sometimes, initially, increase the number and production of certain species, while others are exterminated (Williams & Feltmate 1992). Like Ephemeroptera, Plecoptera and Trichoptera are restricted to cool, clean streams and rivers with high dissolved oxygen content. The former was found in two

rivers, Eruvbi and Ogba, while Tricoptera were restricted to 80% the rivers in freshwater swamp and lowland forest of the study area.

The benthic macro-invertebrates recorded were those commonly found in tropical African freshwater ecosystems. The total number of taxa from this survey was very low compared to records from various lacustrine ecosystems in Nigeria (Ogbeibu & Egborge 1995; Olomukoro 1996; Ajao & Fagade 2002) where over 60 species have been documented. O'Keefe & Uys (1998) reported high numbers of taxa in separate studies conducted in four South African rivers, namely the Sabie, Mutale, Luvuvhu and Letaba, with 134, 104, 150 and 60 taxa, respectively. The Letaba River had the most modified flow regime and the lowest number of taxa, but survey methods differed between rivers, so results were not directly comparable.

High fluctuations in benthic organisms' abundance occurred in all the water bodies within the ecozones particularly in the freshwater swamp and lowland forest. The paucity of benthic macroinvertebrate in the derived savanna water bodies could be attributed to the season of sample collection. Samples were collected during the rainy season when the water bodies are characterized by high levels of turbidity, and serve as a collecting point for urban run-off water. Consequently, the rivers overflow their banks during this period, and benthic organisms, which are sessile in nature, become susceptible to high current velocity in the receiving water bodies. Benthic organisms, being sessile, are easily swept away at high velocity in streams. The rivers in the derived savanna experience much less water pollution than those in the lowland rainforest and freshwater swamps. However, some dramatic environmental and structural changes such as: 1) a sharp decrease in water level in the rivers during the dry season; 2) changes in water-flow regime as a result of flood occurrence in the wet season; and 3) intensive inland subsistence agricultural activities, which adds a high nutrient load to the river watercourses, are common features. Rivers in the savanna ecozone are prone to flooding during the wet season, thus altering the flow regime of the rivers and the consequent alteration of the benthic community. Neckles *et al. (*1990), Castella *et al.* (1995) and Growns & Growns (2001) observed that the alteration of community composition was the most common response of macro- and microinvertebrates to modification of flow regimes in river catchment areas.

This investigation agrees with previous reports on the impact of road construction (Ogbeibu & Victor 1989), industrial effluents (Egborge 1991) and river impoundment through construction of dams (Egborge 1979c; Ogbeibu & Oribhator 2002) on the benthic invertebrates, plankton and fish communities of Nigerian water bodies. Deterioration of water quality has been a major concern within the last two decades. Some of the river basins are sometimes subjected to deforestation and other anthropogenic activities.

One exceptional river in this zone that has received so much of anthropogenic pollutants is River Niger (at Agenebode). This is because its drainage system cuts across seven states in Nigeria, resulting in drastic variation in benthic macrofauna density.

The key reasons for the loss of benthic macrofauna were identified during the survey. These are:

i) Habitats/niches loss due to human activities,
ii) Intense flooding and over flowing of the banks during the rainy season,
iii) Sand mining prevailing at some of the locations,
iv) Biochemical changes of the water bodies, and
v) Introduction of anthropogenic pollutants from domestic and industrial activities.

Observed economically important benthic species utilized at the local level, which are highly valued by man as a source of food were: *Caridina africana, Desmocaris trispinosa, Macrobrachium dux and Mutela* cf. *dibia (Bivalvia).* All benthic macrofauna also serve as source of food for fish. Thus they occupy a significant position in the aquatic food web (William & Feltmate 1992; Mackie 1998). They are prevalent in freshwater streams and swamps, especially in clear water forest area. The Decapoda are generally unexploited except in special situations where they are easily captured in huge numbers with fine-meshed nets or baskets (C.B. Powell, pers. comm.). They are harvested annually from vegetation in water bodies and sold in other areas during the dry season in the central part of the Niger Delta.

Species diversity is known to be highly variable in streams in response to disturbance, resource availability and the presence of suitable habitat (Fowler 2002). Higher diversity also results when many species have equal or near-equal opportunity of co-existence. Mckintosh (2000), in support of this, observed that in the absence of disturbance, community composition may be strongly influenced by biotic interactions such as competition

and predation. A decrease in diversity and corresponding increase in abundance of a limited number of species is a common community response to environmental disturbance. That is, low diversity is an indication of environmental stress while high diversity is a reflection of stress-free environment. The rivers in derived savanna recorded low diversity compared to the rivers in freshwater swamp and lowland forest.

Absence of proper implementation of existing environmental policies, conservation strategy of biodiversity in different biogeographical areas has suffered a major set back (Giuseppe & Ancarani 2002). Both flora and fauna in the aquatic environment in Edo State Ecozone could be conserved if relevant policies are stringently enforced. Certain categories of renewable resources require deliberate and crucial intervention (preservation and out-right protection) in order not to become irretrievable lost to present and future generations. One key strategy that needs to be explored among others for the effective water resource management is the establishment of adequate controls and enforcement procedures to prevent contamination and depletion of aquatic environment. Control of diversity of untreated wastewaters into the rivers should be enforced.

ACKNOWLEDGEMENTS

We are very grateful to Ben Miller Ltd and Niger-Delta Development Commission (NDDC), Nigeria for providing the opportunity to carry out the Biodiversity Study of Edo State Ecozone from which this report is part.

REFERENCES

AJAO, E.A. & FAGADE, S.O. 2002. The benthic macrofauna of Lagos Lagoon. *The Zoologist* **1**(2): 1–15.

BRINKHURST, R.O. 1966. A contribution towards a revision of aquatic Oligochaeta of Africa. *Zoologica africana* **2**(2): 131–166.

CAMBRAY, J.A. 1991. The effects of fish spawning and management implications of impoundment water releases in an intermittent South African River. *Regulated Rivers: Research and Management* **6**: 39–52.

CASTELLA, E., BICKERTON, M., ARMITAGE, P.D. & BETTS, G.E. 1995.The effects of water abstractions on invertebrate communities in U.K. streams. *Hydrobiologia* **308**: 167–182.

CLIFFORD, H.T. & STEPHENSON, W. 1975. *An Introduction to Numerical Classification.* London, Academic Press.

EGBORGE, A.B.M. 1979c. The effect of impoundment on the phytoplankton of River Oshun. *Nova. Hedwigia* **31**(1&2): 407–417.

EGBORGE, A.B.M. 1991. Industrialization and heavy metal pollution in Warri River, 32nd Inaugural Lecture, University of Benin, Benin City. Nigeria.

EGBORGE, A.B.M. 2002. Environmental impact assessment (EIA) of the Escravos-Warri/Aladja Capital Dredging Project, Nigerian Ports Authority, Nigeria.

ELLIOT, J.M. 1977. *Some Methods for the Statistical Analysis of Benthic Invertebrates.* Scientific Publication No. 25, Freshwater Biological Association, Windermere, U.K.

ELLIOT, J.M. & DRAKE, C.M. 1981. A comparative study of four dredges used for sampling macro-invertebrates in rivers. *Freshwater Biology* **11**: 245–261.

EZEMONYE, L.I.N. & KADIRI, M.O. 1998. Edo State Environmental Protection Agency. United Nations Development Programme. Final Report on Ikpoba and Ogba River in Benin City.

FOWLER, R.T. 2002. Relative importance of surface and sub-surface movement on benthic community recovery in the Makarerie River, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Resources* **36**: 459–469.

GIUSEPPE, R. & ANCARANI, A. 2002. Innovation in water legislation in Italy: ecosystem protection and stakeholders participation. *International Journal of Water* **2**(1): 17–34.

GROWNS, I.O. & GROWNS, J.E. 2001. Ecological effects of flow regulation on macro-invertebrate and periphytic diatom assemblages in the Hawkesbury-Nepean River, Australia. *Regulated Rivers: Research and Management* **17**: 275–293.

HENGEVELD, R. 1990. *Dynamic Biogeography.* Cambridge University Press, Cambridge.

HYNES, H.B.N. 1961. *The Ecology of Running Waters.* Toronto University Toronto Press.

HYNES, H.B.N. 1972. The ecology of stream insects. *Annual Review of Entomology* **15**: 25–42.

KLEYNHANS, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). *Journal of Aquatic Ecosystem Health* **5**, 41–54.

MACKIE, G.L. 1998. *Applied Aquatic Ecosystem Concepts.* Course Pack, University of Guelph, Guelph.

McCARTHY M.P. 2002. Freshwater ecosystem management from theory to application. *International Journal of Water* **2**(1): 1–16.

McINTOSH, A.B. 2000: Aquatic predator–prey interactions In: *New Zealand Stream Invertebrates: Ecology and Implications for Management,* (eds) K.J. Collier & M.J. Winterbourn, pp. 125–156. New Zealand Limnological Society, Christchurch.

MELLANBY, H. 1963. *Animal Life in Freshwater.* Chapman and Hall, London.

NECKLES, H.A., MURKIN, H.R. & COOPER, J.A. 1990. Influences of seasonal flooding on macro-invertebrate abundance in wetlands habitats. *Freshwater Biology* **23**, 311–322.

NEEDHAM, J.G. & NEEDHAM, P.R. 1982. *A Guide to the Study of Freshwater Biology.* Holden-Day, San Francisco.

OGBEIBU, A.E. 2004. *Biostatistics: A Practical Approach to Research and Data Handling.* Mindex Publishing, Benin-City, Nigeria.

OGBEIBU, A.E. & VICTOR, R. 1989. The effects of road and bridge construction on the bankroot macrobenthic invertebrates of a southern Nigeria stream. *Environmental Pollution* **56**: 85–100.

OGBEIBU, A.E. & EGBORGE, A.B.M. 1995. Hydrobiological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in Southern Nigeria. 1. Distribution and diversity of the Invertebrate fauna. *Tropical Freshwater Biology* **4**: 1–27.

OGBEIBU, A.E. & ORIBHATOR, B.J. 2002. Ecological impact of river impoundment using benthic macroinvertebrates as indicators. *Water Research* **36**: 2427–2436.

O'KEEFE, J. & UYS, M. 1998. Invertebrate diversity in natural and modified perennial and temporary flow regimes. In: *Wetlands for the Future, Proceedings of the Fifth International Wetland Conference,* (eds) A.J. McComb & J.A. Davis, pp. 173–192. Gleneagles Publishing, Adelaide, Perth, WA.

OLOMUKORO, J.O. & EZEMONYE, L.I.N. 2000. Studies of the macrobenthic fauna of Eruvbi stream, Benin-City, Nigeria. *Tropical Environmental Research* **2**(1&2): 125–136.

OLOMUKORO J.O. & VICTOR, R. 1999. The distributional relationship between the macrobenthic invertebrate fauna and particulate organic matter in a small tropical stream. *Tropical Journal of Environment, Science and Health* **2**(1): 58–64.

OLOMUKORO, J.O. 1996. Macrobenthic fauna of Warri River in Delta State. Nigeria. Ph.D. thesis, University of Benin, Nigeria.

PENNAK, R.W. 1953. *Freshwater Invertebrates of the United States.* Ronald Press, New York.

POWELL, C.B. 1983. Fresh and brackish water shrimps of economic importance in the Niger Delta. In: *Proceedings of the 2nd Annual Conference of the Fisheries Society of Nigeria (FISON),* Calabar, 25–27 January 1982, (ed.) E.O. Ita. Kainji Lake Research Institute, New Bussa.

SHANNON, C.E. & WEAVER, W. 1949. *The Mathematical Theory of Communication. Urban.* University of lllinois Press, Chicago.

TOWNS, D.R. 1979. Composition and zonation of benthic invertebrate communicaties in a New Zealand Kuari forest stream. *Freshwater Biology* **9**(3): 251–260.

VICTOR, R. & OGBEIBU, A.E. 1985. Macrobenthic invertebrates of stream flowing through farmland in southern Nigeria. *Environmental Pollution* (Series A) **39**: 337–349.

WARD, H.B. & WHIPPLE, G.C. 1959. *Freshwater Biology* (ed.) W.T. Edmondson, 2nd edn. John Wiley and Sons, U.S.A.

WILLIAMS, D.D. & FELTMATE, B.W. 1992. *Aquatic Insects.* CAB International, Wallingford.

Responsible Editor: C.L. Griffiths