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SPATIAL AND TEMPORAL DISTRIBUTION OF INVERTEBRATES IN ANAMBRA RIVER BASIN, NIGERIA

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Abstract- Invertebrates, physiochemical, wild animals and aquatic vegetation of Anambra River were assessed for the 2010-2011 flooding season using standard methods. A total of 109 taxa belonging to 15 orders and 20 families made up of 1406 individuals were collected from the basin. The dominant organisms were Hemiptera, 386 and Coleopterans, 337. Crustaceans were of 38% (±14) of the assemblage with 18-47% of these crustaceans considered as zooplankton. Insects comprised 51% (±13) of the assemblage. *Gyrinus sp, Hydrophilus sp, Metadiaptomus traavenlsid, Velia sp, Lepesthestheria rubidgei, Nepa sp* and *Macrobranchium sp* were the most abundant invertebrates species. The most abundant animal utilizing the basin was the *Ardea cinerea* with 22.2% occurrence and this was followed by *Caprini* sp., with 13.51%, and *Varanus niloticus* with 10.04%. The cations were dominated by magnesium (40-43%), followed by calcium (22.4%) and Sodium (22.2-22.6%) while potassium was the least cation in the sites. The distribution of invertebrate species could be attributed to invertebrate - plant association and to chemical factors such as ammonia, conductivity, dissolved oxygen and NO_3-N.It is concluded that low in invertebrate diversity at Anambra River may be induced by sewage and other domestic pollutant discharged in it.

Keywords- Invertebrates, Anambra River, distribution, Nigeria, Cation, Anion

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Introduction

The Anambra River channel has a total length of approximately 207.4 km. The River rises from Ankpa hills in the Benue State of Nigeria, from where it flows in a southerly direction through a narrow trough that gradually broadens as it courses down. It crosses the Benue/ Anambra State boundary a bit north of Ogurugu, and then meanders through the Ogurugu station to Otuocha. From there it flows down to its confluence with the Niger at Onitsha. The Anambra river system is known to support a rich and thriving fishery [1]. The area it drains is one of the agriculturally rich areas of the country. Agriculture and fishing thus form the dominant occupations of the local people and these two major economic activities are closely tied up to the two seasons of the year. The basin drained by the Anambra River and its principal tributaries, the Okutu, Adada, Mamur, Oji and Ajalli rivers constitute the area covered by the study. It is roughly 18122.2 square Kilometers in area and includes the western parts of the Udi Hills and the Western parts of Benue State (i.e. The Igalla and Idoma areas), and it supports a population of one million people who are mainly farmers and fishermen. There are also varieties of flora and fauna in the River basin including invertebrates. The aquatic invertebrates are important food items for the young and some adult of many fishes and are extensively used in the rearing of larva and fry of commercially important fishes and other aquatic life. These communities are very important as they have been identified as possible indicators of ecological integrity for Basin [2]. The use of invertebrates in aquatic ecosystems as indicators, including the community structure and species composition, began over a century ago [3-5] and is now well established in many countries around the world [6]. There are two main approaches to using invertebrates as indicators. Firstly, there is the taxonomic approach, with the focus on diversity or taxa richness. The taxonomic approach requires considerable effort to separate organisms into the correct taxonomic groups [7]. The second approach is focused on the ecological functions (traits) of the taxa that makeup a given community and is more useful in determining the ecological condition of system [7]. Although it has been suggested that identification of invertebrates to species level has many benefits [4] the functional approach is more rapid. A functional approach is also relatively independent of factors like natural variation in diversity due to seasonal and geographical patterns [8]. There has been scanty information on invertebrate spatial and distribution in the Anambra river basin.

Apart from that Eyo & Ekwonnye [9] worked on composition and abundance of macro invertebrates of (fadama) flood plain system of

Anambra River basin, no other studies have been carried out on the invertebrates of the River basin. Such scanty information hinders effective management and utilization of the aquatic resources. Proper management of any aquatic system demands base line information not only on the water chemistry but also on the dynamic interactions among the various components of the system hence the studies on the spatial- temporal distribution, and abundance of invertebrate of Anambra River basin. The aim of the present study was to characterize the invertebrate communities of Anambra river basin using both a taxonomic and a functional approach and to determine which of these would be most suitable for identifying the environmental factors responsible for differences in the aquatic invertebrate community structures of the River basin. Also the animal utilizing the basin, chemical variables influencing the invertebrates as well as aquatic vegetation prevailing in spatial and temporal distribution will be characterized.

Materials and Methods

The Study Area

The basin drained by the Anambra River and its principal tributaries - the Okutu, Adada, Mamur, Oji and Ajalli rivers- constitute the area covered by the study [Fig-1].

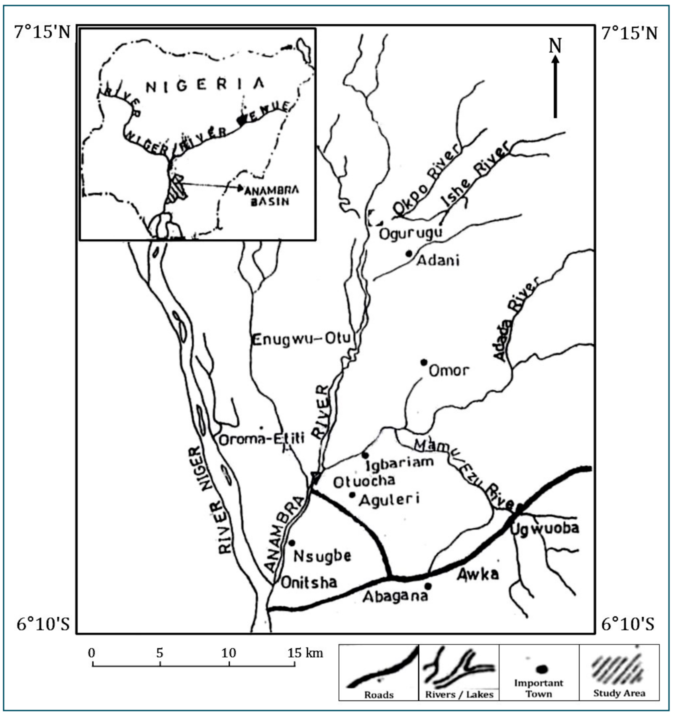

Fig. 1- Map Showing location of study area.

It is roughly 18122.2 square Kilometres in area and includes the western parts of the Udi Hills and the Western parts of Benue State (i.e. the Igalla and Idoma areas), and it supports a population of one million people who are mainly farmers and fishermen. It lies between latitudes 6^0 86^1 N and 7^0 3^1 N and between longitudes 6^0 36^1E and 7^0 41^1E. A map of the area drawn partly from aerial photograph is shown in [Fig-1]. As might be expected from its geographical location, the basin has a rainfall of 150 cm-200 cm annually; and because of its low altitudes of less than 1000 above sea level, temperatures are uniformly high with a small annual range of 5-10 ^{0}C. Parts of this region are rocky and the rocks are of the younger sedimentary types - or the tertiary age- while the vegetation is somewhat transitional between the Equatorial Rain Forest and the Guinea Savannah types. The main Anambra River channel has a total length of approximately 207.4 km. The water emerges from a somewhat inaccessible point near Ankpa in the Benue State of Nigeria, from where it flows in a southerly direction through a narrow trough that gradually broadens as it courses down. It crosses the Benue/Anambra State boundary a bit north of Ogurugu, and then meanders through the Ogurugu station to Otuocha. From there it flows down to its confluence with the Niger at Onitsha. The normal rainy season occur between May and October, with a short break between late July and early August. Variations, however, have been known to occur especially in the timing of the second rains. During the rains, water levels increase in the main river channels. There is also a rise in the levels of the natural depressions, lakes and ponds in the extensive flood plains that lie mainly on the western side of the Anambra River. The rise in the water levels of the river channels is brought about by direct precipitation within the catchments area as well as by inflow from the Niger floodplains. The flooding of the adjacent floodplains results from the joint action of local rainfall and overspill from the river. Also at this season local rainfall inundates depressions in the floodplains independently of any rise in the river level. The width of the Anambra River differs in the various sampling stations. Of the three stations, the river at Ogurugu was fastest and narrowest (about 30 m wide). At Otuocha it widens to about 55 m while its widest portion (ca. 170 m) was recorded in the Onono area under its confluence with the Niger. The deepest area of the three sampling station, (about 11.1 m) was recorded in October. The Anambra river system is known to support a rich and thriving fishery [1]. The area it drains is one of the agriculturally rich areas of the country. Agriculture and fishing thus form the dominant occupations of the local people and these two major economic activities are closely tied up to the two seasons of the year.

Invertebrate Sampling

Invertebrate communities were sampled from a variety of biotopes in each station of the River. These biotopes included stones, gravel, sand and mud, and vegetation. Samples were collected by using a sweep net (500 μm netting mesh size), with the number of sweeps dependent on the extent of a particular biotope. The stone biotope was sampled for an average of 180 seconds, while gravel, sand and mud were each sampled for 60 seconds. When vegetation was present, sampling covered a total of two metres. Zooplankton communities were sampled as well, using plankton net of 60×60 cm with a 63 μm mesh size. The plankton net was swept once through the water for a distance of 10-15 m, depending on the size of the station. Benthic communities were sampled using a Petit Ponar grab (12.5 × 12.5 × 12.5 cm). The content of each grab was emptied into a bucket and a small amount of 10% formalin was added to force invertebrates present to release their hold on any particulate matter. The bucket was filled with water and the mixture thoroughly stirred. The suspended matter was then decanted through a 63 μm mesh and the process repeated 5 times. The remainder of the sample was then transferred into a polyethylene (honey) jar. One sample from each biotope was fixed in 5% neutrally buffered formalin in a polyethylene jar and stained by Rose Bengal. In the laboratory, invertebrates were removed and placed in70% ethanol. They were then identified to species level when possible [10] and counted.

Biological Traits

The traits of each of the identified taxa were determined by using relevant literature [11-13]. Pollution tolerance traits [14] were calculated by taking into account the number of sensitive taxa (number of Ephemeroptera, Odonata and Trichoptera taxa). Traits based on taxon habit [15] and Functional Feeding Groups (FFGs) [16] were expressed both as richness of a given habit or FFGs (i.e. total number of taxa in a given habit or FFGs) and as richness of a given habit or FFGs relative to total assemblage richness (i.e. the proportion of total richness of a given habit or FFGs relative to overall taxa richness of the basin).

Spatial and Temporal Analysis

To determine which environmental variables were possibly responsible for the various groupings based on diversity and biological traits, a Redundancy Analysis (RDA) was completed using Canoco version 4.5. Interpretation of RDA is through tri-plots. These tri-plots produce a map of the samples analyzed on a 2-dimensional basis, where the placements of the samples reflect the (dis)similarities between the samples; in this case the sampling sites. Indices of diversity and evenness were also applied to describe the species abundance relationships among the invertebrate communities. These included the Shannon-Wiener diversity index [17] Simpson's index [18] Margalef's species richness index [19] and Pielou's evenness index [20].

Aquatic and domestic wildlife animals sighted during the periods of data collection were counted and recorded. Droppings of domesticated animals utilizing the flood plain were evaluated and identified.

Physicochemical

Physicochemical parameters of the Anambra River were taken monthly for 12 months. In each station at least five sample collections were taken at different locations. All in situ determinations and collections of water samples were made during mid-morning (10-11am) local time. The water depth was measured using a graduated sounding line. A "HACH" conductivity meter (model 6300) was used for the conductivity measurement. The hydrogen ion concentration was measured using a compensated pH meter Kent Model 6025. Transparency was measured using a secchi disc. Total ions, Hardness, Total alkalinity, Calcium, colour, turbidity, were analysed using 'HACH' portable laboratory test kits. The current (Ms^{-1}) was estimated at the different aforementioned stations by noting the time taken when a piece of lead fixed cork was allowed to drift from one predetermined point to the other. Free $C0_2$ was determined in the field titrimetrically using 0.0027 N NaOH and phenolphthalein indicator. The Chemical Oxygen Demand (COD) was estimated by running blank 70 ml (double distilled water to 50 ml of water. This was heated to boiling point. Then 5 ml of $KMnO_4$ plus 5 ml KI+10 ml 2 M H_2SO_4 +1 ml of starch solution. These combinations were titrated with 0.IM Na_2S_2O until blue colour disappeared which was the end point. Temperature was measured immediately in the field using mercury in -glass bulb thermometer and read to the nearest 0.1^0C. Dissolved oxygen (DO) was also determined in the field using a dissolved oxygen meter. Samples for the measurement of BOD were collected in 250ml opaque (BOD) reagent bottles, and measured with the dissolved oxygen meter after five days of incubation in the dark. Samples for the analysis of other variables were then taken to the laboratory in clean 2.51 polyethylene bottles, and preserved in a deep freezer until analysed. The concentrations of sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}) Magnesium (Mg^{2+}), Zinc (Zn) and Lead (Pb) in the samples were determined using atomic absorption spectrophotometer (Buck 200A mode) at their characteristic wavelengths of 589, 766, 422, 285, 214 and 283p.m respectively. The concentrations of SO^{2-}, NO_3^-, PO_4^{3-} and Cl^- were determined using the colorimetric method (M201 Ccam Spec Visible Spectrophotometer) as described by APHA [21]. Ammonia was determined by phenate method. Total dissolved solids (TDS) was measured by the filtration, evaporation (at 105^0C) and weighing method [21].

Vegetation

At the commencement of study, samples of each aquatic and marginal vegetation types were collected from the River basin and deposited with the Herbarium of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka for identification. The macrophyte species were subsequently monitored in each station for presence, coverage (density) and relative association with macro invertebrates. Coverage in percentage was determined by a rough estimate of the area of a station covered by each plant species during each monthly site visit. These were scored as O for <5%; 2 for 5-25%; 3 for 26-50%; 4 for 51-75% and 5 for >75 coverage.

Statistical Analyses

Data were first tested for normality, and those which did not conform to the assumptions were transformed to logarithms. Since an initial comparison of station means in the various water stations investigated, showed no significant variation, all subsequent analyses were based on the overall mean of stations in each water body, henceforth referred to as sites. One- way analysis of variance (one-way ANOVA) was used to determine the differences in each physical and chemical variable between season, and between sites, while multiple comparisons of sites was performed with the Scheffe test. The least squares regression analysis was used to determine the nature of down- stream changes in each variable (i.e. whether it increased or decreased in value). Unlike the other tests, upstream data were excluded from this analysis and regression was based on individual station distance from the Ogurugu (fixed at 0-point). The importance of the differences in the value of each variable between sites was determined using the discriminate analysis. All analyses were performed on SPSS 10 software. Differences in Invertebrate density between stations were determined using the Friedman two-way analysis of variance. Kendal coefficient of concordance was used to test for agreement in monthly and seasonal fluctuation patterns, while strength of invertebrate-plant association was determined using the Spearman ranked-order correlation coefficient. The total and relative abundance of aquatic and other animals utilizing the basin were calculated.

Results

Invertebrate diversity

A total of 109 taxa belonging to 15 orders and 20 families made up of 1406 individuals were collected from the various stations during the one year survey period [Table-1].

The number of taxa is possibly even higher as many invertebrates could not be identified to species level. The invertebrate fauna in these stations consisted of many "typical" invertebrates, including various large branchiopods like: Anostraca, Conhostraca,and Notostraca. Some of the other crustaceans that were abundant in all of the stations included the Copepods, *Lovenula falcifera*, *Metadiaptomus meridianus* and the Cladoceran *Daphnia sp*.

Table 1- List of aquatic invertebrate taxa recorded in the Anambra River basin

	Ogurugu	Otuocha	Nsugbe	Total		Ogurugu	Otuocha	Nsugbe	Total
	N	N	N	N		N	N	N	N
Crustacean:Anostaca					**Crustacea: Ostracoda**				
Acroperus sp	0	1	0	1	*Cyprideis sp.*	3	0	1	4
Chydrorus sp		0	1	2	*Darwinula sp.*	1	2	0	3
Streptocephalus sp.	1	2	0	3	*Gomphocythere obtusata*	0	1	0	1
Crustacean: Cladocera					*Limnocyther sp.*	0	2	0	2
Alona sp	2	3	2	7	*Oncocypris sp*	1	0	1	2
Ceriodaphnia dubia (Richard, 1895)	0	1	0	1	*Vestalenula sp*	0	1	0	1
Ceriodaphnia quandrangula (Mulluer, 1785)	1	1	2	4	Macrobranchium	2	3	6	11
Ceruidaogbua reticulata (Jurine 1920)	0	2	1	3	**Mollusca:Gastropoda**				
Ceruidaogbua rugyadu (Richard 1985)	2	1	0	3	*Afrogyrus sp*	5	6	2	13
Daphnia barbata (Waltner, 1897)	4	0	0	9	*Bulinus africanus* (Krauss, 1948)	2	1	1	4
Daphnia leavis (Birge, 1874)	1	2	0	3	*Bulinus natalensis* (Kuste, 1841)	1	2	0	3
Daphnia longispina (Muller 1785)	0	3	4	7	*Cyraulus connollyi*	2	0	2	4
Daphnia obtusta (Kurz, 1874)	3	1	2	6	*Lymnea natalensis* (Krauss, 1848)	2	0	2	4
Diaphanosoma excisum (Sara, 1886)	0	1	1	2	**Insecta:Coleoptera Cureulionidae**				
Eurycecus lamellatus (Muller, 1776)	8	2	1	9	*Cyrtobagous sp*	3	0	1	4
Moina micrura (Kurz, 1874)	3	1	2	6	**Dytiscidae**				
Simocephalus ezpinosus (Koch, 1842)	4	6	1	11	Hybius	10	9	0	19
Crustacea: conhostraea					Dytiscus	16	11	3	30
Cyzicus sp	2	1	0	3	*Dytiscidae larvae*	1	0	1	2
Lepthestheria rubidgei (Baird, 1962)	3	1	2	6	*Agabus sp*	3	19	20	42
Lynecus pachydactylus (Barnard, 1929)	1	2	1	4	*Copelatus sp*	1	4	2	7
Crustacea: Copepoda					*Cybister sp*	4	0	7	11
Thermocydops neglect (Sars 1909)	2	1	0	3	*Hydrovatus sp*	1	0	2	3
Cucyclops sp	1	0	0	1	*Laccobius sp*	0	0	1	1
T. emni (Mrazek 1895)	2	1	0	3	*Methles sp*	1	3	0	4
Lovenula excellens (Kiefer 1929)	20	15	16	51	*Peeshetisu sp*	2	0	1	3
T. elecipieus (Kiefer, 1929)	0	1	2	3	*Philaccolus sp*	0	3	3	6
Lovenula falcidera (Loven, 1845)	14	16	4	34	*Philodytes sp*	1	0	1	2
Macrocyclops albidus (Jurine 1820)	2	0	1	3	*Rhantus sp*	1	2	0	3
Metadiaptomus meridianus (van Douwe, 1912)	18	21	26	65	**Cyrinidae**				
Metadiaptomus transvaalensis (Methuen 1919)					Gyrinus	16	18	10	44
Microcyclops Sp	2	1	0	3	*Aulongyrus sp*	2	0	3	5
T. consimilis (Kiefer 1934)	3	1	0	4	*Haliplidae haliplus sp*	1	0	2	3
Mesocyclps ogunnus (Onabanio 1957)	1	2	1	4	**Hydrophilidae**				
M. dusarti (van De Velde, 1957)	1	2	1	4	*Hydrophilidae larvae*	0	3	2	5
Tropodiatomus and banforanus	1	0	1	2	*Berosus sp*	4	3	0	7
Themodiaptomus galebibarrois 1891	0	1	0	1	*Laccophilus sp.*	7	2	3	12
Crustaeea: Notostraca					Hydrophilus	63	59	9	131
Triops granarus (Lucas, 1864)	0	1	0	1	Hydrobius	6	21	0	27
Insect: Ephemeroptera Baetidae					*Paracymus sp*	3	0	3	6
Baetis	3	1	7	11	*Paracymus sp*	3	0	3	6
Cleon sp	1	2	1	4	**Insect: Dipera (all larvae Culicidae)**				
Canidae					*Anopheles sp*	10	7	6	23
Cleons	8	16	7	31	*Malaya sp*	0	1	2	4
Insect: Hemiptera Belostomatidae					**Muscidae**				
Appasus sp	1	0	2	3	*Chironomidae chironominae chironomus*	4	7	0	11
Limnogeton sp	3	1	4	8	**Insect: Trichoptera**				
Corixidae					*Ecomus thomasseti* (Mosley, 1932)	2	0	1	3
Agraptocorixa sp	2	1	0	3	*Oecetis sp*	1	1	0	2
Micronecta sp	0	1	3	4	*Oxyethira Sp*	1	1	0	2
Sigara sp	0	1	3	4	*Oecetis sp*	1	1	0	2
Mesovelidae Mesoovelia sp	0	31	0	31	*Oxyethira Sp*	1	1	0	2
Velidae					**Insect: Odonata**				
Velia	5	87	34	126	*Aeshna sp*	1	0	2	3
Naucoridae					*Anax sp.*	0	3	0	3
Macrocoris sp	7	1	0	8	*Caragrion sp*	4	6	0	10
Nepidae nepa	20	71	58	149	*Pantala sp*	1	0	1	2
Ranatra sp	17	11	16	44	**Annelid: Hirudinea**				
Notonectidae Anisops sp.	0	1	2	3	Hirudo	8	11	12	31
Notonecta sp	1	0	1	2	*Batracobdelloides tricarinata*	1	0	1	2
Nychia sp	0	2	1	3	*Helobdella confier* (Moore, 1933)	1	0	2	3
Pleidae Plead piccanina (Hutchinson 1925)	0	1	0	1	*Helobdella stagnalla stagnalis* (Linnaeus, 1758)	0	1	0	1
Plea pullua (Stal, 1855)	1	0	1	2	Grand total 1488 Families = 20				
Total no of individuals = 1407									

The most common of the plank tonic crustaceans that were encountered belonged to the order Cladocera. This included more than 16 taxa from five families. The most dominant groups of organisms sampled at all study sites were Hemiptera, 386 and Coleoptera, 337. A total of 23 genera from the order Hemiptera were collected. Ten genera from the family Dytiscidae (order Coleoptera) were also recorded. The genus *Cloeon* was the only representative of the mayfly families that occurred on a regular basis and the damselfly *Ceragrion*, also a member of the order Odonata, was often present as well. Also 97 individuals of the order Diptera were recorded while Oligochaeta had only 6 individuals.The seasonal variations in the relative abundance of the major genera of the invertebrates are shown in [Fig-2] (A & B). *Gyrinus* sp, *Ranatra* sp and *Caridina* are more abundant in the dry season months of December and January than in the months of wet season [Fig-2]. The mean abundance and biomass of major invertebrates among the three stations of the River system are shown in [Fig-3] (A,B,C & D). *Gyrinus* sp ranked highest in all the stations and was closely followed by *Decapods* sp and *Ranatra* sp. In Nsugbe *Gyrinus* sp was most abundant and was followed by *Ranatra* sp and *Decapods* sp respectively. The *Velia* sp, *Nepa* sp and *Hydrophilus* sp were the least abundant. In Ogurugu the least abundant species were the *Velia* sp and *Nepa* sp. The negative correlation between *Hydrophilus*, *Agabus*, *Gyrinus* sp, *Nepa* and Depth was not significant as against *Caridina* sp that had significant negative correlation (r = -0.55). There was a significant positive relationship between the temperature and the invertebrates of the River system. The abundance of the fauna was positively related with pH, NO_3-NCO_2, hardness, as against the relationship with current that was negative.

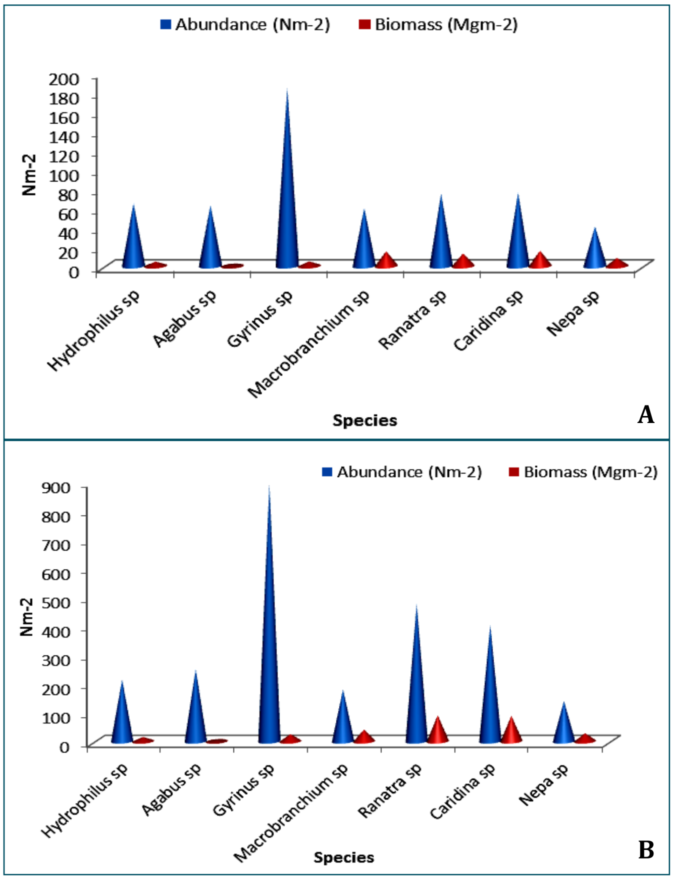

Fig. 2- Seasonal abundance and biomass of the major invertebrate of Anambra river system; **A:** Rainy season; **B:** Dry season.

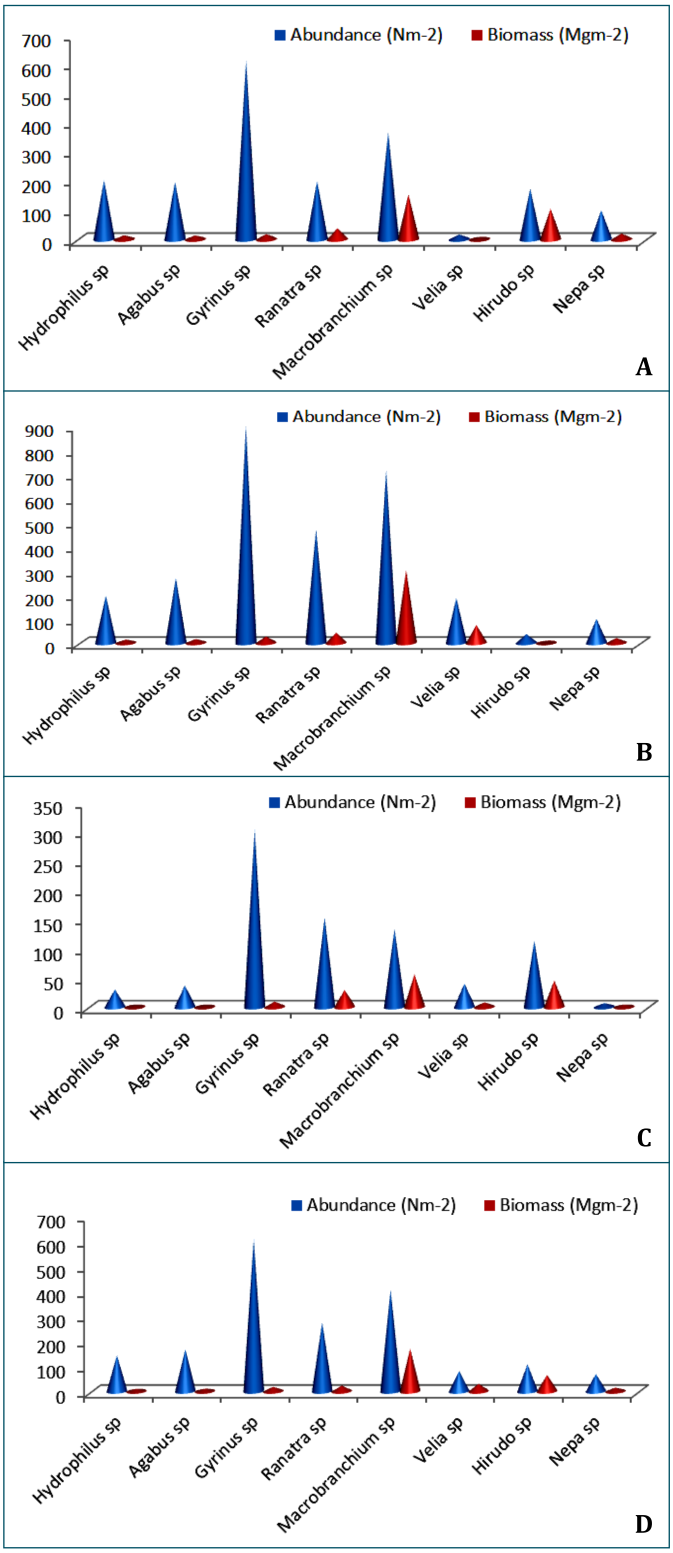

Fig. 3- Abundance and biomass of major invertebrate for 12 months in Anambra river system; **A:** Ogurugu; **B:** Otuocha; **C:** Nsugbe; **D:** Mean Value

Biological Traits

A total of 32 traits were selected and compared between the various stations and seasons [Table-2]. Traits were expressed both as total number within the community and the percentage contribution to the overall community structure.

Table 2- List of biological traits that were included during the study [14,25].

Abundances	Functional Feeding Groups
Number of taxa (families/orders included)	Collectors
Number of individuals	Scrapers
Mean number of individuals	Shredders
Crustacea	Predators
Mollusca	Habits
ETO (Ephemeroptera, Trichoptera, Odonata)	Burrowers
Ephemeroptera	Skaters
Trichoptera	Clingers
Odonata	Climbers
Non-insects (excluding crustaceans & mollusk)	Sprawlers
Non-insects	Swimmers
Insects	Swimmers (excluding zooplankton)
Oligochaeta	Flyers
Coleoptera (larvae and adults)	Breathing Mechanisms
Diptera (excluding Chironomidae)	Air breathers
Diptera (including Chironimidae)	Gills
Zooplankton	Other

All the traits were expressed both as the number of taxa that display a specific trait and the percentage contribution of a trait to the overall assemblage. From the results, it became evident that during all the seasons most of the stations were dominated by crustaceans and insect taxa. Crustaceans made up 38% (± 14) of the total assemblage in certain stations, with 18-47% of these crustacean communities considered as zooplankton species. Insects comprised 51% (± 13) of the overall assemblage. As mentioned above, most of these insects belonged to the orders Hemiptera and Coleoptera. As a result of the percentage contribution of these insects, the FFGs were dominated by predators (66%± 8). Because many of the crustaceans were zooplankton, filter feeders were the other dominant FFG observed in the stations. The majority of the taxa found were air breathers. Most of the invertebrates that were present in the stations were also free-swimming, with swimmers making up 68% (± 13) of the community. In addition, clingers (18% ± 9) made up a large proportion.

Spatial and Temporal Analysis

Results of the of the Shannon diversity index [Fig-4] indicate a loss in diversity at Ogurugu sample1 when compared to Otuocha sample 5, which was similar in physical habitat and trophic state. Results for Simpson's index were also lower at Ogurugu sample 1 as compared to the other stations. Results of Margalef's species richness index show higher species richness at Ogurugu sample 3, Otuocha sample 4 and Otuocha sample 6 in comparison with the other stations.

The mean was obtained from the results of the various sampling surveys and as a result, the standard deviation indicates seasonal variation. (1,2,3 rep samples at Ogurugu; 4,5,6 rep samples at Otuocha; and 7,8,9 rep sample at Nsugbe).

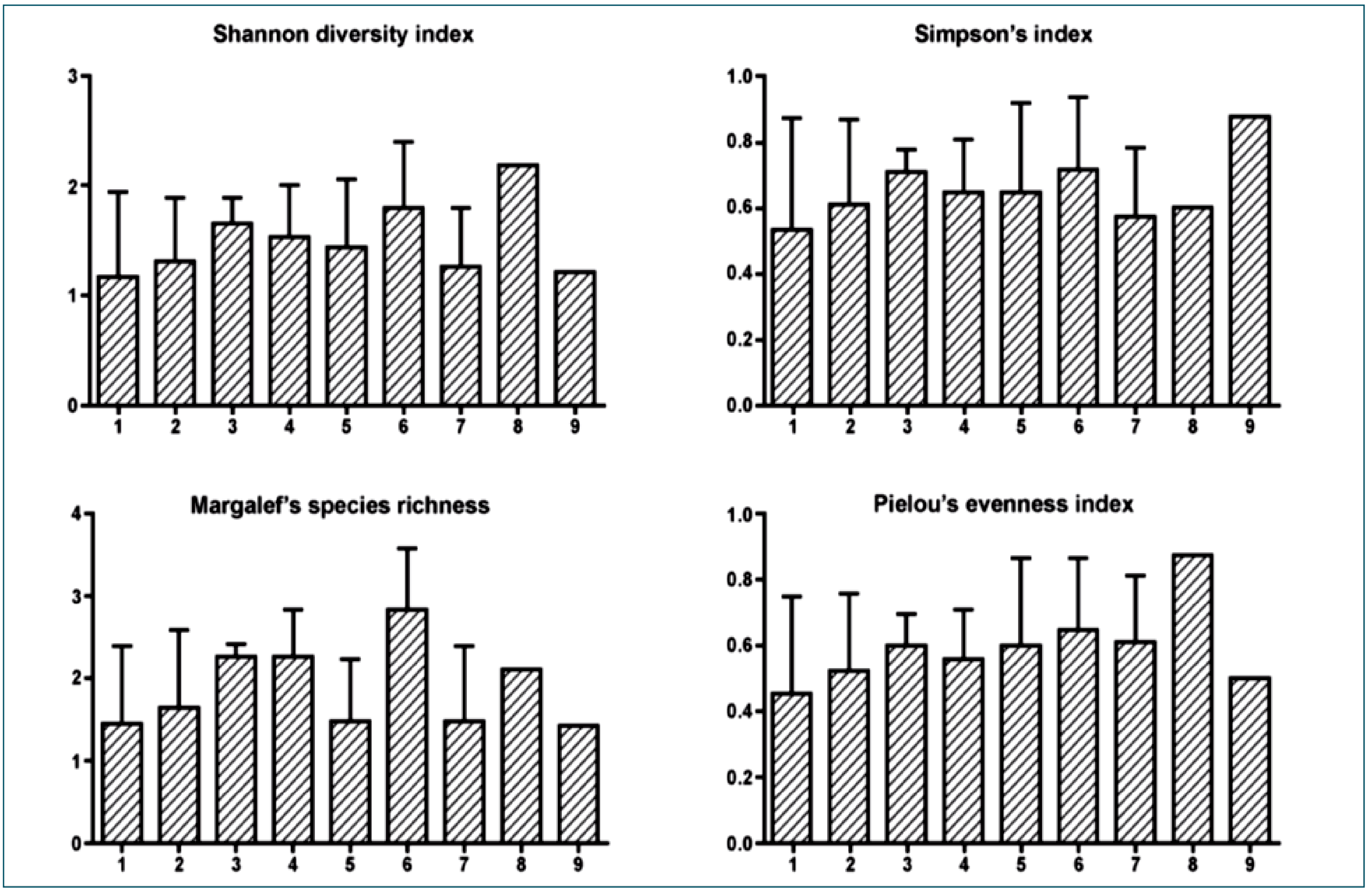

Fig. 4- Mean and standard deviation of the Shannon diversity index, Simpson's index, Margalef's species richness index, and Pielou's evenness index for each of the stations of the River. The mean was obtained from the results of the various sampling surveys and as a result, the standard deviation indicates seasonal variation. (1,2,3 rep samples @ Ogurugu; 4,5,6 rep samples @ Otuocha; and 7,8,9 rep sample @ Nsugbe).

Pielou's evenness index reflected a lack in evenness at Ogurugu subsamples 1-3 and Nsugbe subsample 8. The RDA tri-plot based on diversity [Fig-5] indicates that Ogurugu subsample 3 appears to separate from the other stations in the study area because of a different community structure. Whereas the community structures of most of the pans consist mainly of crustaceans, the invertebrate fauna at Ogurugu sample 3 is made up of aquatic insects (including many Hemiptera, Ephemeroptera and Odonata). From the RDA, it appears that conductivity atOgurugu sample 3 is one of the main physico-chemical variables responsible for the different community structures. The taxa that are responsible for the grouping includ-e*Plea piccanina*, *Plea pullula*, and *Gomphocythere obtusata*. Many of the mayfly *Cloeon*sp. and the damselfly *Ceragrion* sp. were sampled in high abundances at this sample station on a regular basis along with Diptera like *Anopheles* sp., *Malaya* sp., and individualsfromthe family Chironomidae. Otuocha sample 6 appeared to be different from the other sample stations in the study area as many of the taxa that were sampled occurred only in this sample station and are invertebrates that are typically found in fresh water (with low salinity). These included various molluscs(*Afrogyrus* sp., *Bulinus africanus*, *Bulinus natalensis*, *Gyraulus connollyi*, and*Lymnaeanatalensis*), the Trichoptera (*Oxyethira*) and larvae of drophilidae. In thetri-plot based on the various biological traits [Fig-6], it can be seen that on the first axis there is a separation of Ogurugu sample station 3 and Otuocha sample 6 from some of the study sites during some of the surveys. These sites include all the sampling sites apart from Nsugbe sample tations 8 and 9. The dissimilarity between Ogurugu sample 3 and Otuocha sample 6 is brought about by the higher percentage of molluscs and clingers and a higher number of scrapers at Otuocha sample 6. The dissimilarity of Ogurugu sample 3 is largely a result of a higher percentage of Diptera (including Chironomidae) at this site. There is marked similarity between the various sampling surveys of Ogurugu sample 3, indicating limited seasonal variation in the invertebrate community at this site.

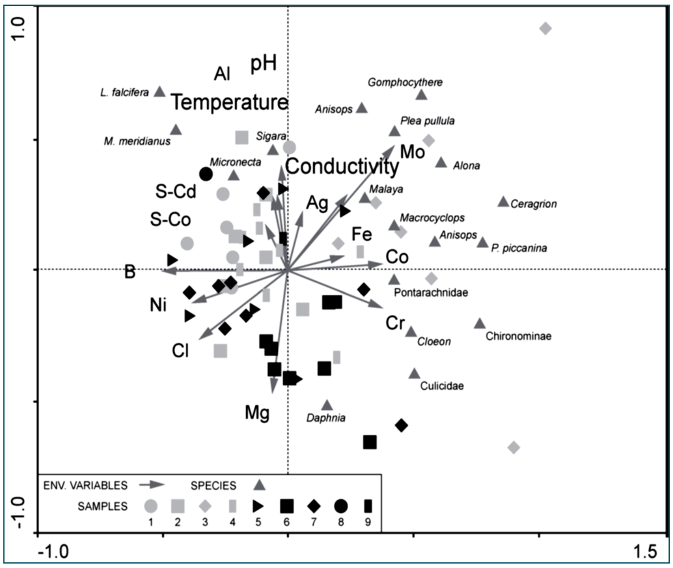

Fig. 5- RDA tri-plot illustrating the similarities between the various sites (and surveys) and the physicochemical variables. The tri-plot describes 45.3% of the variation, with 22.3% being described on the first axis and 23% on the second axis. Only the taxa of which more than 10% is explained by the model and the 15 most significant environmental variables are visualised.

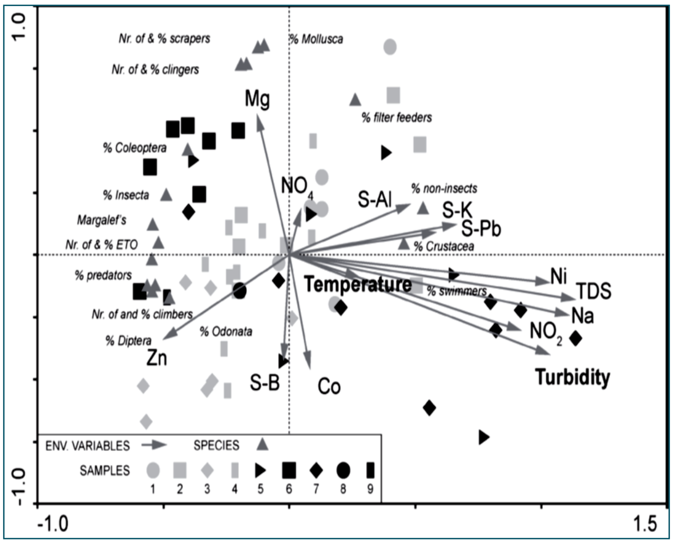

Fig. 6- RDA plot showing the similarity among sites during the different seasons, based on the various community traits (metrics) with physico-chemical variables superimposed. This tri-plot describes56.2% of the variation in the data, where 38.6% is displayed on the first axis and 17.6% on the second axis. Only metrics of which more than 31% is explained by the model and the 14 most significant variables are visualized.

Table 3- The relative abundance of aquatic and other animals utilizing Anambra river basin

	Count of Aquatic and other animals caught per station			
Species	Ogurugu	Otuocha	Nsugbe	Total No (%)
Venellus sneegallus	2(0.39)	6(1.16)	1(0.39)	9(2.32)
Charadrius dubius	0	2(0.39)	3(0.58)	5(0.96)
Ardeola ibis	1(0.19)	0	5(0.96)	6(1.16)
Egretta garzetta	20(3.4)	10(1.9)	8(3.47)	48(9.27)
Ardea cinerea	30(5.8)	35(6.76)	50(965)	115(22.20)
Nettapus auritus	0	3(0.58)	1(0.19)	4(0.77)
Actophilornils africana	5(0.96)	10(1.9)	2(0.39)	17(3.28)
Trigonoceps occipitallis	10(1.9)	17(3.28)	4(0.77)	31(5.98)
Milvus nigrans	12(2.3)	9(1.74)	3(0.58)	24(4.63)
Ciraeceatus gallicus	0	6(1.16)	2(0.4)	8(1.54)
Haliaetus vocites	1(0.19)	0	4(0.77)	5(0.96)
Tragelaphus scriprus	2(0.39)	0	6(1.16)	8(1.5)
Syncerns caffer	1(0.19)	0	2(0.39)	3(0.58)
Chephalophus afilatus	0	3(0.58)	0	3(0.58)
Kobus Kobus	2(0.39)	2(0.39)	0	4(1.16)
Lepus capensis	4(0.77)	7(1.40)	11(2.12)	22(4.25)
Erythrocebus patas	2(0.39)	0	1(0.19)	3(0.58)
Trichechus senegalensis	11(2.120)	8(1.5)	1(0.19)	20(3.86)
Varanus nitoticus	20(3.86)	19(3.67)	13(2.51)	52(10.04)
Bos indicus	5(0.96)	20(2.12)	15(2.90)	40(7.72)
Caprini	26(5.01)	31.5.98	13(5.98)	70(13.51)
Tortoise sp.	1(0.19)	4(0.77)	0	5(0.96)
Total	155	192	169	516
Values in brackets represents Percentage				

The most abundant animal utilizing the basin was the Ardea cinerea with 22.2% occurrence and this was followed by Caprini sp. with 13.51%, and Varanus niloticus with 10.04%. The least abundant animals utilizing the basin were Chephalophus rufilatus and Erythrocebus patas with 0.58% of occurrences each [Table-3].

Physicochemical

There are two main seasons, the dry season, October/November - March and the wet season, April- September/October approximately corresponding to the dry and flood phases respectively of the hydrological regime of the Anambra river basin. The depth started decreasing in November with the recession of the rains/river tributaries and reached its minimum in March. With the onset of heavy rains in May, it began to increase reaching its first peak in October, 10.34 m [Table-4].

Table 4- Physiochemical characteristics of the Anambra basin and optimal levels for fish *production in tropical aquatic ecosystems physiochemical attribute*

	Ogurugu	Otuocha	Nsugbe	Levels in Anambra river basin			Optimal levels for fish production				
				Means	Mini	Max	Mini	Max	Ref	Max	ref
Depth (m)	5.84±2.16	5.07±1.75	7.08±2.02	6.0±1.98	3.2	10.34	-	-		-	
Temp °C	27.90±2.87	29.10 ±1.84	29.70±2.30	28.90 ±2.40	25.3	32.4	25	32	1	32	1
Transparency cm	2.21± 0.76	1.83 ± 0.59	1.33 ± 0.56	1.79 ± 0.64	0.96	3.13	30	60	1	60	1
Coefficient of suspended solid	3.02 ±1.55	3.08 ±1,47	2.93 ± 1.32	3.01 ±1.45	1.1	6.48	-	-		-	
Suspended solid mgl^{-1}	3.30 ± 1.73	2.71 ±1,59	3.07 ± 1.12	3.03 ±1.48	1.32	14.67	25	80	2	80	2
Conductivity μScm^{-1}	31.33 ±8.27	28.96 ± 7.61	29.10 ± 0.07	29.80 ±7.98	22.83	43.2	40.7	61.8	1	61.8	
pH	6.82 ±0.67	6.91 ± 0.64	6.31 ± 0.59	6.68 ±0.63	6.52	7.11	6.5	9	1	9	1
NO_3-N Mgl^{-1}	3.65 ±1.12	3.29 ± 1.09	3.17 ±1.10	3.37 ± 1.10	1.77	5.34	-	-		-	
PO_4-P Mgl^{-1}	9.50 ± 3.70	7.41 ± 2.19	5.68 ± 1.70	7.53 ±2.5	2.97	13.67	12.5	60	1	60	
FCO_2 $MgCO_2l^{=1}$	3.32 ± 0.60	3.35 ± 0.58	3.32 ± 0.60	3.33 ± 0.59	2.1	4.75	-	5	1	5	1
Cgen,0_2 Demand Mgl^{-1}	4.11 ± 0.78	3.30 ± 0.59	3.44 ± 0.62	3.62 ± 0.66	3.73	11.62	-	-		-	
$D0_2$ Mg^{-1}	4.99 ± 1.18	4.97 ± 1.07	5.57 ±1.01	5.18 ± 1.09	3.62	7.04	-	5	1	5	1
THardnesMg $Caco_3L^{-1}$	7.09 ± 3.04	5.96 ± 2.02	6.24 ± 2.09	6.43 ± 2.38	4.79	10.28	-	-		-	
Current Ms^{-1}	2.12 ± 0.26	1.62 ± 0.40	2.14 ± 0.29	1.96 ± 0.32	1.5	2.67	-	-		-	
BOD Mgl^{-1}	4.01 ± 0.70	3.30 ± 0.57	3.04 ± 0.60	3.45 ± 0.61	2.5	5.37	-	-		-	
Alkalinity- $mgCaCO_3^{-1}$	35.86 ± 9.86	32.61 ± 6.91	31.42 ± 6.10	33.30 ± 7.62	22.94	52.4	-	300	1	300	1
NO_3-N/PO_4P	0.43 ±0.32	0.31	0.59 ±0.41	0.50 ± 0.35	0.18	1.77	-4			4	3
CO_2/DO_2	0.88 ± 0.35	0.78 ± 0.29	077 ± 0.31	0.81 ± 0.32	0.42	1.35	-	-		-	

1=Boyd and Lichkroppler(1979),2=FWPCA(1968) and 3=Kutty(1987)

The lowest mean monthly water temperature of 25.30°C was recorded in June while the maximum water temperature of 32.40°C occurred in the dry month of January. Generally the temperature of the dry season was higher than the one of the wet season.

Transparency varied from 0.96 cm in October to 3.30 cm in February [Table-4]. The coefficient of coarseness of suspended solids ranged from 1.10 in February to 6.48 in October the later almost coinciding with the month of maximum suspended solids and minimum value of transparency.. The wet season showed more significant ($P < 0.05$) departure from that of the dry season types. The 1.32 mg^{-1} suspend solids recorded in February showed marked variations from the 14.66 mgl^{-1} observed in October. The current showed marked monthly variations. The current of the wet season significantly varied from that of the dry season. The river recorded 1.50 m/s water current in April as against 2.67 m/s observed in the months of October. Conductivity ranged from 22.83 ($uScm^{-1}$ in January to 43.20 $uscm^{-1}$ in September [Table-4]. There were interring monthly variations. The Anambra River with an average conductivity of 29.80 $uscm^{-1}$ was low in ionic content. The pH fluctuated between 6.52 pH in November and 7.16 pH in February of the dry season while it ranged from pH 7.11 in March to 6.33 in October for the wet season.. The average concentration of NO_3-N was 3.37 mgl^{-1}. The maximum concentration, 5.34 mgl^{-1} was attained n February while in October it was 2.31 mgl^{-1}. Higher mean NO_3-N occurred in the dry season than during the rains. Average concentration of ammonia was much higher at Ogurugu station, 1.85mgL^{-1} than at Otuocha, 1.02mgL^{-1}. Wet season sustained the highest ammonia value at Nsugbe station 3.4mg $L^{-1,}$ while the highest concentration of (3.7 mgL-I) was recorded at Ogurug during wet season. Maximum concentration 13.67 mgl^{-1} of PO_4-P occurred in August and minimum 2.97 mgl^{-1} in January. PO_4-P concentration was significantly ($p < 0.05$) higher in the river during the months of wet season than dry season ones. The mean free CO_2 was 3.33 mgl^{-1} and ranged from 2.54 mgl^{-1} to 4.75 mgl^{-1} in January. Mean concentration of free CO_2 was slightly higher in the dry season than in the wet. The Anambra River with an annual average of 6.43 mgl^{-1} $CaCO_3$ may be considered 'soft'. Total hardness ranged from 4.79 mgl^{-1} in September to 10.28 mgl^{-1} CaCO3 in February [Table-4]. The concentration level of calcium hardness of the river was significantly higher ($p<0.05$) during the dry season than during the rains. The magnitude of intra seasonal variability in total hardness and calcium hardness was higher in the wet season than in the dry season phase. The dissolved oxygen concentration ranged between 3.62mgl^{-1} in January and 7.04lmg^{-1} in April of the dry months as against 5.47l^{-1} in May and 9.1mg^{-1} in October of the rainy season.The phenolphthalein alkalinity was zero throughout the study period. The annual mean alkalinity was 33.30mg $CaCO_3l^{-1}$; it varied from 27.87mgl^{-1} $CaCO_3$ in December to 42.20 mgl^{-1} $CaCO_3$ in July. The levels of the total alkalinity were significantly ($p<0.05$) more pronounced during the rainy season than in the months of dry, one. The levels of NO_3-N/PO_4 ratio were consistently higher than those of PO_4-P with an overall NO_3-N/PO_4-P ratio of 0.50. The monthly variations demonstrated that the predominance of NO_3-N culminated during the onset of the dry season and at the peak of the dry season. The overall level of CO_2/DO ratio was 0.81. The maximum CO_2/DO ratio, 1.35 occurred in January and minimum, 0.42 in July [Table-4].

Major Ion Distribution

In general, the analysis of salts was fairly satisfactory as shown by the TDS ratio although there is a slight over- estimation of the cat ions [Table-5]. Ionic concentration was generally high but both cation and anion sums decreased from the network of Ogurugu to Nsugbe stations [Table-6] & [Table-7].

Table 5- Ion balance at Anambra River basin (annual mean concentration)

	Ogurugu		Otuocha		Nsugbe	
Ion	$Mg1^{-1}$	$mequiv1^{-1}$	$mg1^{-1}$	$mequiv1^{-1}$	$mg1^{-1}$	$mequiv.1^{-1}$
Ca^{2+}	87.5	4. 37	61.2	3.05	54	2.69
Mg^{2+}	97.6	8.03	71.4	5.88	64.2	5.28
K^{+}	107.1	2.74	83.2	2.13	83.8	2.14
Na^{+}	7.3	4.23	75.4	3.26	67.2	2.92
Pb	0.12	0.001	0.13	0.001	0.11	0.001
Zn	3.8	0.12	3.3	0.1	2.5	0.08
Total cations	19.49		14.42		13.11	
SO^{2-}	143.1	2.99	144.9	3.02	169	3.52
PO^{3-}	0.76	0.02	0.28	0.01	0.26	0.01
NO^{-}	0.1	0.002	0.07	0.001	0.1	0.002
Cl^{-}	254.3	7.17	179.8	5.07	121.2	3.42
HCO^{-}	147.5	2.42	98.3	1.61	81.4	1.33
Total anions	2.6		9.71	8.28	7.69	
%Difference	21.47		19.52		22.58	
Estimated TDS	877.4		675.4		610	
Measured TDS	992.7		810		719.4	
TDS ratio	1.13		1.2		1.18	

[a]The F-probability is significant for the differences at the 0.005 level
[b]ns: value not significant at ≤0.0

Table 6- ANOVA and Scheffe multiple comparisons among the physical and chemical variables from the Ogurugu to Nsugbe (Significance of the annual mean difference)

Variables	F-ratio	F-probability	Ogurugu		Otuocha		Nsugbe	
			1	2	3	4	5	6
Temperature	0	8.69	0.002	0.006	0	ns[b]	Ns	Ns
PH	0	47.84	0	0	0	ns	0.028	Ns
Electrical	0	9.78	ns	ns	0.002	0.016	0	Ns
Total alkalinity	0	217	0	0	0	0.004	0	0.003
TDS	0	75.83	0	0	0	ns	0	0.017
DO	0	13.34	0.029	0	0.001	ns	Ns	Ns
BOD	0	9.93	0.029	0	0.001	ns	Ns	Ns
Ca^{2+}	0	14.59	0.001	0	0	ns	Ns	Ns
Mg^{2+}	0	7.6	0.005	0	0	0.029	0.005	Ns
Na^{+}	0	9.08	0.037	0.002	0	ns	Ns	Ns
K^{+}	0	23.92	0.005	0	0	0.029	0.005	Ns
SO_4^{2-}	0.937	0.14	ns	ns	Ns	ns	Ns	Ns
PO_4^{3-}	0	23.55	0	0	0	ns	Ns	Ns
Cl^{-}	0	15.2	0.041	0	0	ns	0.033	Ns
NO_3^{-}	0.46	2.82	ns	ns	ns	ns	Ns	Ns
Pb^{2+}	0	6.73	0.007	0	0	ns	Ns	Ns
Zn^{2+}	0	14.19	ns	0.008	0	ns	0	0.049

The major cat ions, from Otuocha to Nsugbe stations were dominated by magnesium (40-43%), followed by calcium (22.4%) in the basin and while sodium had (22.2 - 22.6%) in the river and potassium was the least important cation in all the sites. In the case of the anions, chloride dominated (about 48% each), while the Nsugbe stations were dominated by sulphate ions (39-43%). Thus, while the Magnesium Chloride dominated Ogurugu and Otuocha the Nsugbe contained magnesium sulphate water.

Table 7- Results of least square regression analysis of the effect of the concentration of different Physical and chemical variables

Variable	Constant (a)	Slope (b)	Significant level
Temperature	8189.1	-239.9	0.033
Electrical conductivity	2721.9	-3.64	0
Ph	-1193.7	343.3	0.049
Do	-500.4	273.96	0
BOD	2203.3	-157.08	0.001
Total alkalinity	4343	-32.52	0
TDS	6622.3	-6.82	0.001
Ca^{2+}	2961.1	27.16	0
Mg^{2+}	2642.6	-18.93	0.002
K^{+}	3619.5	-20.55	0
Na^{+}	2929.5	22.62	0
SO^{2-}	1043.8	0.563	0.593
PO^{3-}	1932.2	18.53	0
CL^{-}	2589.9	-8.23	0
NO^{-}	495.2	7579.36	0.058
Pb	3829.4	-19,833.80	0
Zn	3134.7	-681.93	0

Invertebrate Distribution and Aquatic Vegetation

The aquatic vegetation found in the River basin is dominated by grass species. A total of eleven plant species which included *Sida lorilofolia, Leocus species, Zornia species, Meremia species, Nelsonia caiescens, Anthephra coriescens, Grostia asper, Cassia rofundifolic, Walthenia indica, Spilanthes Africana* and *Scleria species* were found and consisted of grass, herbs and shrubs. The frequency of occurrence and the density of each macrophyte species in the stations investigated are presented in [Table-8]. *Spilanthes africana* and *Sida lorilofolia* were the most frequently encountered vegetation in the River basin respectively. Correspondingly, they were also the least and the most dense each. In terms of site distribution, *Spilanthes africana*, *Scleria* species, and *Walthenia indica* were found only along the Ogurugu station, *Meremia* species only along the Nsugbe station and the rest along both shores of Nsugbe and Otuocha, although, only *Sida lorilofolia* occurred in all stations. The strength of invertebrate- plant association in the River basin is summarized in [Table-9].

Table 8- The density (i.e. % coverage) and frequency of occurrence (i.e. number of times in 12 site visits) of aquatic vegetation in seven stations investigated in Anambra river basin for 12 months (figures in parenthesis represent frequency of occurrence).

	Ogurugu		Otuocha		Nsugbe		Mean	Total
	1	2	3	4	5	6	7	
Sida lorilofolia	47(25)	35(26)	23(23)	42(25)	62(26)	19(19)	28(28)	36.7(28)
Leocus species	63(24)	0(0)	3(3)	55(24)	0(0)	5(5)	0(0)	18.0(24)
Zornia species	61(25)	47(23)	32(20)	42(21)	0(0)	27(24)	0(0)	29.9(25)
Meremia species	0(0)	0(0)	0(0)	45(23)	40(24)	56(25)	23(23)	23.4(25)
Nelsoria cariescens	0(0)	71(26)	0(0)	48(23)	40(24)	23(23)	0(0)	29.4(26)
Anthephra umpulacea	0(0)	53(22)	19(19)	42(24)	52(25)	40(23)	40(28)	35.1(28)
Eragrostia asper	0(0)	0(0)	30(20)	0(0)	41(26)	0(0)	33(26)	14.9(26)
Cassia rofundifolic	0(0)	0(0)	58(25)	0(0)	0(0)	0(0)	5(5)	9.0.(25)
Walthenia indica	8(4)	6(4)	25(16)	0(0)	0(0)	0(0)	0(0)	5.6(16)
Spilanthes Africana	5(5)	0(0)	36(22)	0(0)	0(0)	0(0)	0(0)	5.9(22)
Scleria species								
Total	18.4(25)	21.3(26)	22.6(25)	27.4(25)	23.9(26)	19.0(28)	12.9(28)	20.8(28)

Table 9- The correlation coefficient for Invertebrate density and environmental factors (climatic, vegetation, biological, physical and chemical) in Anambra River basin for 12 months.

Factor	Hydrophilus	Agabus	Gyrinus	Macrobranchium	Ranatra	Lovenlaveia sp	Nepa
Climatic factors Rain episode	0.58a	0.4	0.45	0.21	-0.04	0.20	-0.1
Rain fall	0.62 a	0.43	0.46	-0.16	-0.3	0.1	0.26
Temperature	-0.19	0.14	-0.26	-0.16	-0.1	-0.25	0.43
Aquatic vegetation							
Sida lorilofolia	0.42b	0.49b	0.47b	0.45b	0.45b	0.014	0.032
Leocus species	0.25a	0.32b	0.38b	0.26a	0.27a	0.211	-0.066
Zornia species	0.26a	0.0.34b	0.0.37b	0.13	0.43b	-0.033	0.1
Meremia species	0.45a	0.19b	0.06b	0.32	0.21	0.09	0.19
Nelsonia carescens	0.45b	0.25a	0.24	0.41b	0.14	0.211	0.29
Anthephra coriescens	0.30b	0.30b	0.27a	0.18	0.18	0.078	0.01
Eragrostia asper	0.29b	0.23	0.19	0.30b	0.1 5	0.141	0.33
Cassia rofundifolic	0.12	0.05	0.01	0.21	-0.02	-0.17	0.07
Walthenia indica	0.13	0	0.04	0.01	0.03	-0.21	0.35
Spilanthes Africana	0.16	0.08	0.09	0.06	0.24	0.02	0.024
Scleria species	0.19	0.04	0.08	0.02	0.07	0.71	-0.072
Physical and chemical factors							
Water level	0.2	0.30a	0.31a	0.49a	0.41a	-0.021	-0.06
Cond	0.09	-0.07	-0.06	-0.05	-0.05	0.029	0.2
Biochemical Oxy demand	0.30b	0.26 a	0.22	-0.07	-0.04	0.011	0.29
Dissolved oxygen	0.03	0.19	0.19	-0.23	0 -1.2	0.225	0.303
Ph	-0.13	-0.13	-0.07	-.0.06	0 -.17	0.23	0.15
Sodium	0.22a	-0.27a	-.28a	-0.34a	-0.15	-0.79	0.089
Calcium	-0.09	-0.18	-0.22	-0.13	-0.05	0.12	0.19
Magnesium	-0.02	-0.03	-0.06	-0.03	-0.11	0.14	0.09
Significant levels: a <0.01; b p<0.001							

A total of twenty two positive and significant correlations were recorded. Out of these, *Sida lorilofolia* and *Leocus* species accounted for five correlations each, i.e. each correlated positively and significantly with all invertebrate species, *Zornia* species account for four, *Meremia* species and *Anthephra umpulacea*, for three each and *Eragrostia asper*, for two only. Similarly, *Hydrophilus* significantly associated with six plant species, *Agabus* with five, *Gyrinus* and *Macrobranchium*, with four each and *Nepa* species with three. On the other hand, the association between other invertebrate species and aquatic plant species was very pronounced in the field, especially between *Macrobranchium* and *Sida lorilofolia*.The association was so strong that the plant species served as a positive indicator for the presence of the invertebrates in all parts of the River basin throughout the study period.

Discussion

Invertebrate Diversity

The branchiopod taxa that were found during the study have become suited to environments through various physiological, behavioural, life-history and structural adaptations [22]. Most of the branchiopod taxa sampled during the study are usually allopathic (i.e. do not normally occur together). The reason is that their eggs are dependent on different environmental conditions for hatching [10]. Apart from the branchiopod crustaceans, many of the crustaceans were free-swimming zooplankton taxa.. Also the community structure was often dominated by Hemiptera. Individuals from the genus *Anisops*, *Micronecta*, *Sigara*, Agraptocorixa and *Notonecta* were all encountered during the one-year period and have often been found in similar aquatic environments around the world [23]. The occurrence of the recorded mayfly genus in basin is also not unusual. *Cloeon* species are known to be tolerant to salinity changes and are able to survive anoxic conditions [24]. There were large differences in assemblages on a spatial and temporal level. The Anambra River ecosystems are dynamic, with a variety of factors contributing to the invertebrate community structure. Apart from the physical variations (habitat, temperature, hydroperiod, etc.) it appears that chemical variations in the form of different trophic states also have a major influence on the community structure within the basin.

Biological Traits

Based on the diversity observed, the dominance of predatory insects and crustaceans within the species assemblages was expected. Although many of the traits used in the current study have also been included in similar studies [25] the most commonly used of the biological traits still remains the different Functional Feeding Groups (FFGs). Functional Feeding Groups refer to different feeding mechanisms and not specifically to the food being eaten [26]. The reason for this is that FFGs emphasize the various linkages between food source and the ability of a specific invertebrate group to use this resource. The FFG approach is thus more directly related to ecosystem processes than the taxonomic approach [27]. Therefore, changes in food sources can lead to a change in the feeding strategy that is being applied. Changes in food sources are often brought about by human activities and the FFG approach can thus be used to assess impacts on a given ecosystem [25]. The numerically dominant FFG throughout this study was the predators. In a system where predators dominate, the system is known as a top down control system [13]. Filter feeders were also abundant at all of the sampling sites. This is perhaps to be expected because of the abundance of zooplankton taxa in these ecosystems. Shredders, for example, may occur in different abundances in a system depending on the diversity and quality of vegetation sources [28].

Furthermore, the presence of inorganic nutrient and sunlight can stimulate the growth of periphyton, which serves as a food source for shredders and scrapers [29]. Although the reduction in the number of scrapers and shredders can in most ecosystems be a sign of environmental stress, these groups simply do not occur in high numbers in basin due to a lack of suitable habitat and food sources. Only in those stations where suitable conditions were present did representatives of these groups occur. Because individual FFGs react differently to human impacts, ratios between various FFGs have been suggested as possible indicators of ecological integrity [13]. Very few of the other FFGs (like scrapers and shredders) were present during the different sampling surveys. It is clear that the presence of certain FFGs is driven by the availability of food sources and quality of the biotope. It became apparent that the biological traits reflected the available biotopes and not necessarily the impacts of human activities. The habitat available to the various invertebrates can thus be seen as one of the most important driving variables of biological traits displayed by the community [30]. This explains the occurrence of so many free-swimming and air-breathing taxa, aquatic macrophytes in these systems also contributes to the presence of certain traits [31].

Spatial and Temporal Analysis

The Shannon diversity index [17] incorporates both the species richness and equitability components and has long been used as an index of diversity together with the Simpson index [18], which is an index of concentration or dominance. Simpson's index measures the probability that two individuals selected at random from a sample will belong to the same species. The results for both these indices show that there have been definite changes in the invertebrate community at Otuocha. It should be noted that a very low number of taxa was sampled at this site and as diversity indices take into account species richness (number of taxa) and evenness (number of individuals per taxa) [32], the lower abundances clearly had an influence on the results for this site. Margalef's species richness index [19] measures the number of individuals present for a given number of species, incorporating both the total number of species and the total number of individuals. Pielou's evenness index [20] is an indication of how the individuals in a sample are distributed over the various species that make up a community and gives an indication of dominance. It became evident that the invertebrate community structure might become altered as a result of the agricultural activities at the representative sites. A lack of evenness is often considered a sign of dominance within a given biotic community. The community at Nsugbe was dominated by zooplankton and oligochaetes, while zooplankton (*Lovenula falcifera*, *Metadiaptomus meridianus*and *Daphnia sp*) dominated at Ogurug and Otuocha.The invertebrate community at Ogurugu (in the vicinity of agricultural activity) showed several alterations, with *Gomphocythereobtusata*, *Lovenula falcifera* and *Plea piccanina* dominating the community structure. Dominance is often seen as a sign of pollution, although zooplankton communities are expected to dominate in lotic environment. The habitat is dominated by Sida lorilofolia and Anthreohra umpidacea and various submerged macrophytes. The changes in the diversity and biological traits displayed by the taxa in Nsubge appeared to be the result of a change in habitat. The occurrence of many of these taxa (*Cloeon* sp. and *Plea* sp.) may thus be related to the presence of aquatic macrophytes as a habitat in an ecosystem where vegetation is usually restricted. The change in habitat may be a direct result of anthropogenic inputs from the agricultural activities. This includes eutrophication and a change in substrate caused by siltation. In addition to the fish species found in the river, there are some other forms of aquatic fauna. The crab Sudanonantes Africa occurs in large quantity, as well as snails, crocodiles, and snakes. Both the numbers and distribution of large mammals on the River basin have been greatly reduced due increased human influence such as hunting, burning. Fish eating birds, always the most abundant species, were confined largely only to the vicinity of River Anambra and shoreline. Domestic animal populations are on the increase. The moist and easily saturated soil condition for some months of the year might favor growth of herbaceous grasses and forbs which could serve as fodder to the livestock. In fact more than 300 domestic animals were counted during the dry season utilizing the plain. The availability of forage species coupled with perennial fodder shortage for the Nigeria livestock population indicate the River basin might serve a good dry season grazing areas for both resident animals. This confirms that natural aquatic environment houses a variety of aquatic lives. The surface temperature undergoes relatively small fluctuations, there was a fairly consistent thermal regime of about 29.5°C and the pH range was between 6.8 and 7.7. This range fell within the recommended range that supports aquatic life including fishes [33]. The water quality of the river can be improved further by controlling and / or prohibiting the discharge of municipal effluents and domestic garbage into the river as well as the use of the riparian zone for crop agriculture. The maintenance of 50 -60 m thick riparian vegetation can act as a buffer strip to check erosion by acting as sediment break/filter.

Physiochemical

The density diversity indices vary both spatially and temporally. The pattern of temporal dynamics in the density of fauna was affected by the variability of the physicochemical parameters of the river. The long-term monitoring of anthropogenic pollution in aquatic ecosystem is of environmental and human health concern even nowadays, when numerous effective measures were undertaken to reduce the pollution impact of natural water bodies. In these aquatic organisms are used for biological monitoring of variations in the environmental levels of anthropogenic pollutants [16]. Both ecological and toxicological factors influenced invertebrate assemblages at the studied area. Among ecological factors, DO, $N0_3$-N, ammonia, conductivities, were the most significant variables to explain variations in invertebrates. The concentration of dissolved oxygen is one of the most important key factors in controlling aquatic life.The low O_2 levels was an important factor in limiting species distribution. In response to decrease O_2 concentration, species richness and diversity both decrease, and the species composition is largely determined by the tolerance to O_2 deficiency [25]. The Otuocha station was more oxygenated as compared to Ogurugu and Nsugbe stations. This may be one major factor responsible for increasing diversity with invertebrates in these stations. Total ammonia nitrogen (TAN) is composed of toxic (un-ionized) ammonia (NH_3) and non-toxic ionized ammonia NH_4. Only a fraction of the TAN exists as toxic (un-ionized) ammonia, and a balance exists between it and the non-toxic ionized ammonia: The proportion of TAN in the toxic form increases as the temp and the pH of the water increases. For every pH increase of one unit, the amount of toxic un-ionized ammonia increases about 10 times [6]. Anambra River is characterized by high concentration of ammonia which may result from the large amount of domestic, agric input and sewage input. Result of present study was substantiated by the findings of Beketov, et al [8]. They stated that ammonia is toxic not only to fish but to all aquatic animals. The invertebrates prefer pH range of 6.5 to 8.5.In this study pH ranged from 6.52 in November to 7.16 in February of the dry season while pH 6.33 in March to 7.11 in October was registered for the wet season which fall closes the recorded preference. The pH showed negative correlation (Pearson) in relation to the population dynamics (density and diversity), of invertebrates in all the three study stations. Conductivity is considered to be an important indicator of trophic states. Conductivity ranged from 22.83 (uScm^{-1} in January to 43.20 uscm^{-1} in September. There were interring monthly variations. The Anambra River with an average conductivity of 29.80 uscm^{-1} was low in ionic content and positively correlated with invertebrate density and diversity in all the three study stations. It conforms to the studies of Haase & Nolte [3] who observed the seasonal samples of invertebrate in the Salado River basin (Argentina). He found that there were differences in number and diversity of species in relation to conductivity, and species which might tolerate high conductivity. According to the most recent literature, nitrogen compounds which are included in artificial fertilizer are one major factor responsible for accelerating the eutrophication of surface waters [31]. This influences the quality of inland waters, which are endangered by the increase of trophic condition as a result of enrichment from the catchments area [5]. The Anambra River showed high, enrichment with nutrients and the dominant invertebrate's species in this river, *Gyrinus, Ranatra*, and *Caridina* are abundant in their basin. The abundance and biomass of the invertebrates' communities suggest a high trophy in this river.

Conclusion

The study revealed a large degree of variation when the invertebrate communities of different stations of the basin were compared taxonomicallyThe strong invertebrate-plant association recorded in this study agrees with similar reports from many parts of Africa [11,34,35]. However, while in Lake Volta *Ceratophyllum dermersum* was the most important vegetation found in association with invertebrate [35] and in Egypt, *Potamogeton crispus* and *Eichhornia crassipes* were commonly associated with invertebrate fauna [36] in Anambra River basin, *Sida lorilofolia* which significantly associated with all invertebrates fauna is the most important vegetation. These results highlight the importance of aquatic plants in invertebrate distribution, although the importance of each species may vary between regions and even between water bodies within a give region. The above considerations suggest that local distribution of invertebrate species in Anambra River basin could be attributed to invertebrate - plant association and to chemical factors such as conductivity, dissolved oxygen and biochemical oxygen demand, while seasonal trends depended mainly on rainfall and water level patterns. Although the study may not have exhausted all factors which influence local distribution of invertebrate in River basins, it has provided the necessary baseline data for planning future research programmes. Finally, according to the criteria adopted by the European Union, the United States of America's Environmental Protection Agency (EPA), the United Nations Food and Agricultural Organization (FAO) and the Inland Waters Directorate of Canada (IWD) the quality of Anambra River basin water all seasons is low and less than the least recommended standard for raw water supply [Table-10]. The need for remedial action to improve the quality of Anambra River water cannot be over-emphasized. At the present quality of the water, treatment to minimum international limitation standards for drinking water would be both intensive and expensive, while lack of proper treatment due to cost constraints will give rise to some health problems, the socio-economic implication of which is better imagined.

Table 10- Comparison of the chemical quality of Anambra River water with International limitation standards for untreated drinking water supply

Variable	Class A	Class B	Class C	Anambra River
DO (mg1^{-1})	50%>9	50%>9	50%>8	7.4 (4.7-10.5)
BOD (mg1-1)	<3	<5	<7	4.8(3.3-5.9)
SO^{2-} (mg1^{-1})	<150	<150	<150	176.7(5.0-512)
PO^{3-} (mg1^{-1})	<10	<20	<50	240(50-740)
Cl- (mg1-1)	<150	<150	<150	103.2(28.4-262.7)
NO^{-} (ng1^{-1})	<5	<10	<10	100(50-200)
Pb (ng1^{-1})	<5	<10	<25	1500(100-3100)
Zn (ng1-1)		<50	<100	7.2(6.3-7.8)
PH	6.5-8.5	6.5-8.5	41888	262.6(90-500)
Conductivity (p.Scm^{-1})	<1000	<100	<100	

Conflicts of Interest: None declared.

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