Comparative Assessment of the Relative Abundance and Diversity of Near-Shore and Offshore Communities of Benthic Macro-Invertebrates off the Bonny Estuary, Nigeria.

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ABSTRACT

This study was aimed at ascertaining the level of anthropogenic impact on the near-shore area by comparing its relative abundance and diversity indices of benthic macro-invertebrates with that of the adjoining offshore area. The study area lies off Bonny coast between latitudes 4^{o} 23^{i} 37^{ii} N and 4^{o} 24^{i} 54^{ii} N and longitudes 7^{o} 7^{i} 53^{ii} E and 7^{o} 9^{i} 22^{ii} E; was delineated into 45 sampling stations in the near-shore (NRSH), and off-shore areas. The benthos samples were collected aboard a vessel fitted with a grab sampler. The grab-collected sediments were processed and preserved in 10% formalin with Rose Bengal dye. Overall mean of benthos collected was 27.3 (35.5 for offshore, 19.4 for near-shore). In all, 131 species were collected with Phylum Mollusca contributing 50.76% of all species, and Annelids 24.24%. The highest Margalef's diversity indexes were 4.290, 4.096, and 4.006 while the least Margalef's diversity indexes were 1.099, 1.610, and 1.668. Uttah's biotic Ranking indicated better balance of species richness-evenness in the offshore area compared to the near-shore area.

(Keywords: benthic macro-invertebrates, relative abundance, diversity, Uttah's biotic ranking, near-shore, offshore, Atlantic, Nigeria)

INTRODUCTION

Benthic macro-invertebrates are organisms that live on or within sediments at the bottom of a water body (Idowu and Ugwumba, 2005), for all or part of their life cycle (Rosenberg and Resh, 1993). According to Abowei et al., (2012) Several species of organisms which cut across different phyla of annelids, coelenterates, mollusks, arthropods and chordates are found in the brackish water ecosystem, where they play a vital role in the circulation and distribution of nutrients in aquatic ecosystems. Benthic macro-invertebrates represent an extremely diverse group of aquatic animals, and the large number of species represents a wide range of responses to stressors such as organic pollutants, sediments, and toxicants, and enables for indicator organisms for all situations of environmental quality (Buckup et al., 2007). Benthos species are sensitive to environmental perturbations, and consequently, their structure (density, richness and diversity) or the functional organization of the macro-invertebrate community is affected by environmental changes (Miserendiro, 2001; Pereira and De Luca, 2003). Variations in the distribution of macro-benthic organisms could be as a result of differences in the local environmental conditions (APHA/WWA/WEF, 1998; Odiete, 1999; Abowei et al., 2012).

Benthic macro-invertebrates are vital in biological monitoring, which is an effective tool to assess the ecological quality of aquatic sysems (Lorenz et al., 2004; Barbone et al., 2007; Mora et al., 2008). Biological monitoring has advantages over chemical monitoring in that although the latter can also be very important to understand water quality, it is expensive, takes time, and often offers only limited information. Furthermore, biological monitoring can give an indication of past as well as present conditions (Fenoglio, 2002; Mitrofanova, 2008). Benthic macro-invertebrates are useful indicators of sediment quality since they spend most of their lives in direct contact with the sediment (Odiete et al., 2003), and they are long-lived, allowing for detection of past pollution events such as runoffs, pesticide spills and illegal dumping. Macro-invertebrates are good for quick assessment of biological resources both for conservation purposes and for the detection of pollution through differences between predicted and actual faunal assemblages (Ormerod and Edwards, 1987; Abowei et al., 2012). In this study, the near-shore area water health was studied using benthic macro-fauna, since they are good indicators of watershed health and integrators of environmental condition (Sivaramakrishnan, 2000; Davis, 2003; Thompson, 2005; Dinakaran and Anbalagan, 2007). The study was aimed at ascertaining the level of anthropogenic impact on the near-shore area by comparing the relative abundance and diversity indices of benthic macro-invertebrates of the near-shore area with that of the adjoining offshore sampling stations.

MATERIALS AND METHODS

Description of the Study Area

The study area lies off the coast between latitudes 4^{o} 23^{i} 37^{ii} N and 4^{o} 24^{i} 54^{ii} N and longitudes 7^{o} 7^{i} 53^{ii} E and 7^{o} 9^{i} 22^{ii} E. The communities on the shore of Bonny estuary comprise of indigenous dwellers and fishermen settlers who depend on the estuary resources for subsistence. There are global-scale oil and gas exploratory activities in the area. These exploratory activities involve numerous gas flaring activities, liquefied natural gas refining which is in a scale that attracts heavy traffic of sea-going vessels that come to carry liquefied natural gas to many destinations around the world.

The study area was delineated into 45 sampling stations comprising 23 in the near-shore area (NRSH), and 22 in the off-shore transect. The off-shore transect was further divided into those offshore of Bonny river (PLB-S) and those offshore Qua River (PLQ-S).

Sampling Methods

The benthic macro-invertebrates samples were collected on board a vessel fitted with a 300kg grab. The grab-collected sediments were washed using a sieve with a 500µm mesh-size in a basin to extract the benthos. The washed benthos was then preserved in well-labeled plastic containers in 10% formalin with Rose Bengal as vital stain.

Laboratory Analysis

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

Data Analysis

The relative abundance was analyzed by simple proportions in relation to benthos taxa and sampling stations. Benthos diversity was analyzed using Margalef index (Margalef, 1958) and Shannon-Wiener index (Valiela, 1984). These indexes were calculated for each sampling station following standard formulae after Ludwig & Reynolds (1988) and Magurran (1988). The Microsoft Office Excel 2007 edition was used.

RESULTS AND DISCUSSION

Relative Abundance

A total of 1228 benthic macro-invertebrate specimens were collected in the study. Of this, 796 or 64.82% belonged to the Phylum Mollusca, which comprised mainly of the bivalves, gastropods, and scaphopods. A total of 239 or 19.46% belonged to the phylum Annelida, while 108 or 8.79% belonged to Arthropod Crustacea. Other benthos groups observed (see Figure 1) were Echinodermata, which represented 5.1% of all benthos specimens, Sipuncula (1.3%), Nemertea (0.4%); and Hemichordata (0.2%).

The distribution of benthos in the 45 sampling stations is shown in Table 1. One offshore sampling station off the Bonny River was outstanding, contributing 9.8% of all benthos collected. This was followed by another offshore sampling station off the Bonny River, PLB-S8 and PLB-S10, which contributed 6.6% and 4.6% of all benthos collected. The first sampling station PLB-S1 benefitted from fewer benthos species with high opportunistic populations, hence recording relatively low diversity indices.

Table 1: Relative Abundance and Diversity Indexes of Benthic Macro-Invertebrates in Relation to the Sampling Stations.

Station	Abun. Val.[a]	Rel. Abun. (%)	No. of Spp	Marg. Index	S.W.I.
PLB-S1	120	9.77	13	2.506	1.751
PLB-S2	46	3.75	11	2.612	1.926
PLB-S3	19	1.55	8	2.377	1.782
PLB-S4	35	2.85	15	3.938	2.336
PLB-S5	20	1.63	13	4.006	2.484
PLB-S6	17	1.38	7	2.118	1.84
PLB-S7	26	2.12	10	2.762	1.989
PLB-S8	81	6.6	19	4.096	3.122
PLB-S9	22	1.79	11	3.235	2.224
PLQ-S1	43	3.5	16	3.988	3.038
PLQ-S2	49	3.99	13	3.083	2.312
PLQ-S3	30	2.44	9	2.352	1.915
PLQ-S4	31	2.52	10	2.621	2.122
PLB-S10	57	4.64	9	1.979	1.969
PLB-S11	27	2.2	10	2.731	2.044
PLB-S12	23	1.87	13	3.827	2.421
PLB-S13	21	1.71	10	2.956	2.265
PLB-S14	35	2.85	8	1.969	1.881
PLB-S15	10	0.81	8	3.04	2.025
PLB-S16	26	2.12	10	2.762	2.172
PLB-S17	33	2.69	8	2.001	1.739
PLB-S18	10	0.81	6	2.171	1.748
NRSH-1	19	1.54	11	3.396	2.434
NRSH-2	35	2.85	11	2.812	1.776
NRSH-3	24	1.95	7	1.888	1.716
NRSH-4	3	0.24	3	1.82	1.099
NRSH-5	8	0.65	5	1.924	1.56
NRSH-6	25	2.03	10	2.796	2.132
NRSH-7	8	0.65	5	1.924	1.56
NRSH-8	8	0.65	5	1.924	1.56
NRSH-9	38	3.09	5	1.099	1.023
NRSH-10	21	1.71	9	2.628	2.083
NRSH-11	33	2.67	16	4.29	2.619
NRSH-12	39	3.17	14	3.548	2.214
NRSH-13	6	0.48	5	2.232	1.561
NRSH-14	36	2.93	7	1.674	1.628
NRSH-15	25	2.03	7	1.864	1.351
NRSH-16	6	0.49	5	2.232	1.561
NRSH-17	3	0.24	3	1.82	1.099
NRSH-18	11	0.9	6	2.085	1.652
NRSH-19	41	3.34	13	3.231	2.344
NRSH-20	16	1.3	6	1.803	1.667
NRSH-21	12	0.98	5	1.61	1.468
NRSH-22	11	0.9	5	1.668	1.458
NRSH-23	19	1.55	10	3.057	2.26
Total	1228	100	141		

[a]Key: Abun. Val. Stands for Abundance value; Rel. Abun. Stands for Relative abundance; No. of Spp stands for Number of species; Marg. Index stands for Margalef's Index; S.W.I. stands for Shannon-Wiener Index.

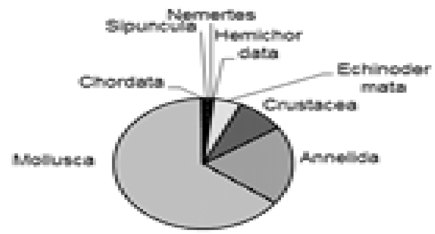

Figure 1: Relative Abundance of Benthos Taxa.

The overall mean of benthos collected was 27.3. The mean for offshore sampling stations was 35.5, while that for the near-shore was 19.4. The mean for the offshore sampling stations was significantly higher than both the overall and that for the near-shore stations (t-test; $p < 0.05$ for both tests).

The relatively high abundance of Mollusks (including bivalves), polychaetes, and crustaceans is reported elsewhere (Barnes et al, 1988); and derives from the fact that they have more species that are better in resilience and resistance to fluctuations in the ecological system. Their prominence in in-faunal samples is well reported (Lopez, 1988).

The species composition indicates that the study area is not within the Critical Salinity Range of 3 - 8%o where marine groups find it difficult to survive, and mollusks are known to be incapable of cell volume regulation at salinities this low (Remane & Schlieper, 1971). The preponderance of Ophuiroids, which are mainly of marine habitat is quite indicative.

Diversity

A total of 131 species of benthic macro-invertebrates were collected. Sixty-seven species belonged to the Phylum Mollusca comprising of gastropods and bivalves, and this represented 50.76% of all species. Annelids were next with 32 species (24.24%), and were followed by Crustaceans with 16 species (12.12%); Echinodermata 9 species (6.82%); Chordata 3 species (2.27%); Sipuncula, 2 species (1.52%); Hemichordata, 2 species (1.52%); and Nemertea, 1 species (0.75%). This is shown in Figure 2.

The number of species ranged from 3 to 19 species, with an average of 9 species per sample station. About 24 sampling stations (53.33%) had

9 or less species each, while 21 sampling stations (46.67%) had 10 or more species each.

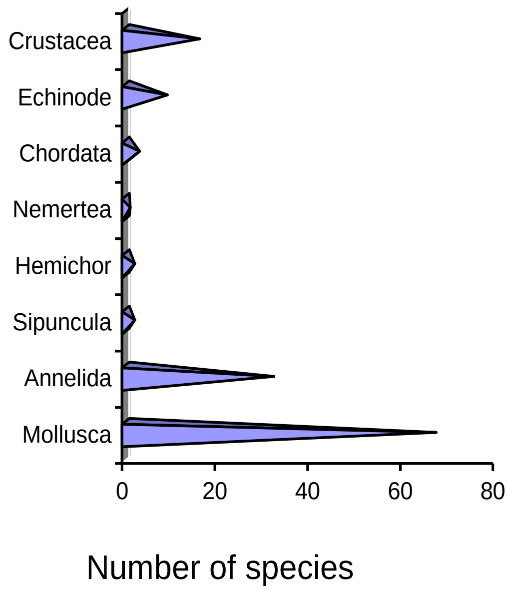

Figure 2: Number of Species of Major Taxonomic Groups of Benthic Macro-Invertebrates Collected in the Study.

The offshore sampling stations had 70.8% of the higher number of species (10 to 19 species) category, whereas the near-shore had 76.19% of the lower number of species (3 to 9 species) category. This suggests that the near-shore sampling stations have considerably lower species richness than the offshore sampling stations.at the time of study. A diversity index increases as both as the number of species increases and as the numerical distribution of species becomes more even.

The Margalef's diversity indexes among the various sampling stations showed that stations NRSH-11, PLB-8, and PLB-5 had the highest Margalef's diversity indexes of 4.290, 4.096, and 4.006 respectively; whereas stations NRSH-9, NRSH-21, NRSH-22 had the least Margalef's diversity indexes of 1.099, 1.61., 1.668 respectively.

Margalef's diversity index gives more weight to Species Richness, which is the number of species in the habitat. However, diversity is more than just the number of species in the ecological system. A community is less diverse in which species are unevenly abundant (Phillips, 1988). So the Shannon-Wiener diversity index (HI) was employed to assess the evenness. Using HI the highest diversity (evenness) was recorded in stations PLB-8, PLQ-1, and NRSH-11, which had figures of 3.122, 3.038, and 2.619 respectively.

Although diversity indexes are useful in assessing and comparing sampling stations, they have limitations, one of which is that many factors other than the disturbance of concern can cause a change in the index. This problem is particularly acute when communities in different areas are compared only once.

Site differences in physical and biological factors such as nutrient availability, presence or absence of key species, climatic differences, among others, that can cause differences in diversity. Furthermore, the species present in a community can change substantially without any significant change in diversity indices. More importantly, some disturbances can increase diversity if they increase habitat heterogeneity, reduce the number of competitively dominant species, or create opportunities for new species to invade (Fernando, 1981).

The number of species in a community (species richness) often changes in response to disturbance that simplify the stream environment thereby reducing the number of available niches and kill off many species outright (Patrick and Palavage, 1994). Disturbance is a key factor regulating the structure and functioning of natural communities (Herkul et al., 2011). A large environmental change often leads to local extinction of many sensitive species and to the predominance of a few "disturbance-tolerant" organisms or organisms capable of using the new conditions for increased growth.

Margalef's Diversity Index and Depth of Sampling Stations

The NGL II area is shallow with depth ranging from 6 meters to 58 meters in offshore stations, and from 1.6 meters to 33 meters in the near-shore stations. Relating the Margalef's diversity index with the depth of the sampling points showed a relationship for benthos in the strikingly deeper sampling stations which had relatively lower diversity indexes (see Figure 3 and Figure 4).

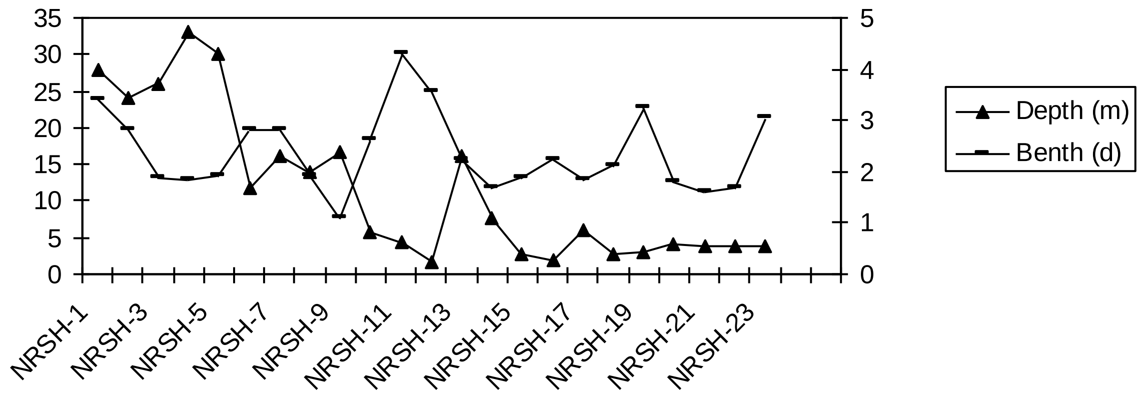

Figure 3: Depth of Near-Shore Sampling Stations in Relation to their Margalef's Diversity Indexes.

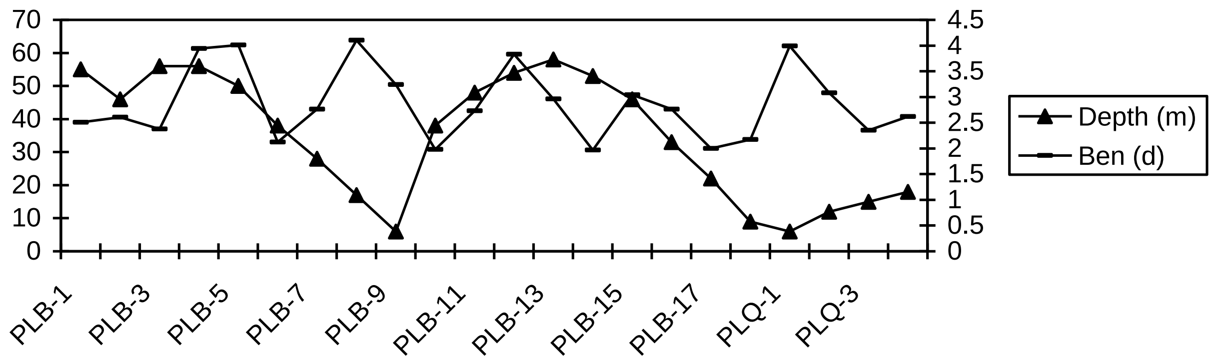

Figure 4: Depth of Offshore Sampling Stations in Relation to their Margalef's Diversity Indexes.

It is generally accepted that to a certain extent, there is a decrease in animal life with increasing depth of water and distance from land. This was corroborated by Wlodarska-Kowalczuk et al., (2004) that species richness (expressed by number of species per sample and species–area accumulation curves) decreased with depth.

Uttah's Biotic Ranking (UBR) of sampling stations

Uttah's Biotic Ranking (UBR) assesses the balance between species richness and evenness in sampling stations by ranking and scoring Margalef's diversity Index and Shannon-Wiener Diversity Index recorded in each sampling station (see Table 2). The offshore sampling station off Bonny estuary PLB-S8 recorded the least total score of 3 representing the best balanced of the highest species richness and evenness among the sampling stations. The lesser the total score for a sampling station, the better the performance in diversity indices. The average total score for the near-shore was 77 compared to 33 recorded in the offshore sampling stations. This is a clear indication of better biodiversity indices in the offshore stations than in the near-shore stations.

Species Composition and Ecological Integrity of the Study Area

Species composition is a product of several interacting factors. The near-shore part of the study area is an estuary. A considerable portion of the sediments was detritus. In estuaries, tidal currents bring in much seaweed, which is broken down into detritus; furthermore considerable detritus is also formed from the decaying of plants growing in the estuaries themselves. Detritus forms the main food of the animals in estuaries (Quasim, 2003). The consistency of the bottom of a mud flat is of great importance to estuarine animals as the distribution of benthos depends on physical nature of the substratum, nutritive content, degree of stability, oxygen content and level of hydrogen sulphide (Anbuchezhian, et. al. 2009).

The sediment type is an important determinant of the kind of benthic community that colonizes it. Sand has the tendency to shift and move, but some clams, burrowing worms, and small crustaceans find sand to be a suitable habitat. Clams filter water for plankton and detritus, or burrow through sand, feeding on other inhabitants.

Muds generally have relatively less oxygen in them but still may be inhabited by a variety of burrowing organisms that feed by filtering water above them or feed on the other animals in the mud. Sediment texture and debris accumulation on the surface of the seabed were the factors responsible for the sparse distribution of crustaceans and bivalve in some of the sampled stations, which had a lot of debris on the surface.

Most stations if not all have been subjected to dredging either to make room for big vessels or during laying of pipelines for oil or gas. Dredging does affect the marine ecosystem and its habitat negatively. It does spoil coastal habitats. Dredged areas take a very long time to recover (Patin, 2004).

Capittelids are identified with pollution indication. When they occur in opportunistic proportions, they indicate evidence of considerable stress beyond the carrying capacity of the ecosystem. In the study transect, however, only three species of Capittelids (Notomastus latericeus Notomastus spp, and Capitella capitata) were collected during the sampling process and in only six sampling stations, five of which are in the near-shore area (NRSH-1, NRSH-12, NRSH-13, NRSH-15, and NRSH-22) and only one sampling station offshore (PLB-15). However, they were not in opportunistic proportions as to suggest any considerable stress beyond the carrying capacity of the stations in question.

It must be stressed that species composition of a station is a product of interplay of factors such as temperature, salinity, dissolved oxygen, and nature of substratum (Levinton, 1995).

An important limitation of these comparative assessments of the near-shore and offshore sampling stations is the confounding effect of salinity. The salinity-level differences between the estuarine near-shore areas and the marine offshore stations could be a major contributing factor for differences in diversity between near-shore and offshore sampling stations.

According to Lopez (1988), naturally, more phyla are well represented in the macro-fauna of marine sediments and there is more diversity within each phylum than in the brackish and freshwater sediments. Salinity is reported to be the major restrictive factor limiting the distribution of marine and lacustrine taxa that causes the glut of species in brackish and freshwater systems (Ramane and Schlieper, 1971).

CONCLUSION

It is inferred that the near-shore sampling stations could have been more impacted anthropogenically than the offshore sampling stations due to their relatively poor performance in relative abundance and in the Uttah's Biotic Ranking. Strict adherence to environmental laws, regulations, bilateral agreements and protocols by individuals and corporate users of near-shore water resources is recommended.

Table 2: Uttah's Biotic Ranking of the Sampling Stations.

Station ID	M.I.S[a].	S.W.S.	Total Score	UBR
PLB-S1	27	27	54	27
PLB-S2	21	21	42	22
PLB-S3	23	25	48	24
PLB-S4	5	7	12	6
PLB-S5	3	3	6	3
PLB-S6	28	24	52	26
PLB-S7	17	19	36	18
PLB-S8	2	1	3	1
PLB-S9	9	11	20	11
PLQ-S1	4	2	6	3
PLQ-S2	11	8	19	10
PLQ-S3	24	22	46	23
PLQ-S4	5	15	20	11
PLB-S10	31	20	51	25
PLB-S11	19	17	36	18
PLB-S12	6	5	11	5
PLB-S13	14	9	23	14
PLB-S14	32	23	55	28
PLB-S15	13	18	31	17
PLB-S16	17	12	29	15
PLB-S17	30	29	59	30
PLB-S18	27	28	55	28
NRSH-1	8	4	12	6
NRSH-2	15	26	41	21
NRSH-3	36	30	66	34
NRSH-4	38	42	80	41
NRSH-5	33	36	69	35
NRSH-6	16	14	30	16
NRSH-7	33	36	69	35
NRSH-8	35	36	71	37
NRSH-9	44	44	88	45
NRSH-10	20	16	36	18
NRSH-11	1	3	4	2
NRSH-12	4	12	16	8
NRSH-13	25	34	59	30
NRSH-14	41	33	74	39
NRSH-15	37	41	78	40
NRSH-16	25	34	59	30
NRSH-17	38	42	80	41
NRSH-18	29	32	61	33
NRSH-19	10	6	16	8
NRSH-20	40	31	71	37
NRSH-21	43	39	82	44
NRSH-22	42	39	81	43
NRSH-23	12	10	22	13

[a]Key: M.I.S. stands for Margalef's Index score; S.W.S. stands for Shannon-Wiener Index score; UBR stands for Uttah's Biotic Ranking.

REFERENCES

1. Abowei, J.F.N., E.N. Ezekiel, and U. Hansen. 2012. "Effects of Water Pollution on Benthic Macro Fauna Species Composition in Koluama Area, Niger Delta Area, Nigeria". *Intl. J. Fish. Aquat. Sc.* 1(2):140-146.

2. Anbuchezhian, R.M., G. Rameshkumar, and S. Ravichandran. 2009. "Macrobenthic Composition and Diversity in the Coastal Belt of Thondi, Southeast Coast of India". *Global J. Environ. Res.* 3(2):68-75.

3. APHA/AWWA/WEF. (1998). Standard Methods for the Examination of Water and Waste Water. Greenberg, A.E., Clesceri, L.S. and Eaton, A.D (Eds.), 18th Edn., America Public Health Association, American Water Works Association, Water Environment Federation.

4. Barbone E., I. Rosati, M. Pinna, and A. Basset. 2007. "Taxonomic and Dimensional Structure of Benthic Macro-Invertebrate Guilds in the Margherita di Savoia Salt Pans (Italy) Transit". *Waters Bull*. 4:21-31. DOI 10.1285/i1825229Xv1n4p1.

5. Barnes, R.S.K. 2010. "Regional and Latitudinal Variation in the Diversity, Dominance and Abundance of Microphagous Microgastropods and other Benthos in Intertidal Beds of Dwarf Eelgrass, *Nanozostera spp*". *Mar Biodiv*. 40:95–106. DOI 10.1007/s12526-010-0036-1

6. Buckup, L., A.A.P. Bueno, G. Bond-Buckup, M. Casagrande, and F. Majolo. 2007. "The Benthic Macroinvertebrate Fauna of Highland Streams in Southern Brazil: Composition, Diversity and Structure". *Revista Brasileira de Zoologia.* 24(2): 294–301.

7. Dinakaran, S. and S. Anbalagan. 2007. "Anthropogenic Impacts on Aquatic Insects in Six Streams of South Western Ghats". *J. Insect Sc.* 7(37):1-9.

8. Davis, S., S.W. Golladay, G. Vellidis, and C.M. Pringle. 2003. "Macroinvertebrate Biomonitoring in Intermittent Coastal Plain Streams Impacted by Animal Agriculture". *J. Environ. Qual*. 32:1036 – 1043.

9. Fenoglio, S., G. Badino, and F. Bona. 2002. "Benthic Macro-Invertebrate Communities as Indicators of River Environment Quality: An Experience in Nicaragua". *Rev. Biol. Trop*. 50(3/4): 1125-1131.

10. Fernando, O.J. 1981. "Ecological Studies in the International Region of the Vellar Estuary (Porto

Novo. S. India)". Ph.D. Thesis, Annamalai University: India. 140.

11. Herkul, K., J. Kotta, and M. Parnoja. 2011. "The Effect of Physical Disturbance on Soft Sediments Benthic Macrophytes and Invertebrate Community in the Northern Baltic Sea". *Boreal Environ. Res.* 16(Suppl. A):209-219.

12. Idowu, E.O. and A.A.A. Ugwumba. 2005. "Physical Chemical and Faunal Characteristics of a Southern Nigeria Reservoir". *Zool*. 3:15-25.

13. Lopez, R.G. 1988. "Comparative Ecology of the Macro-Fauna of Freshwater and Marine Muds". *Limnol. Oceanogr*. 33(4-2):946-962.

14. Lorenz, A., D.H.C.K. Feld, and P. Rolauffs. 2004. "A New Method for Assessing the Impact of Hydromorphological Degradation on the Macro-Invertebrate Fauna of five German Stream Types". *Hydrobiologia*. 516:107-127.

15. Ludwig, J.A. and J.F. Reynolds. 1988. *Statistical Ecology: A Primer on Methods and Computing*. John Wiley & Sons: New York, NY.

16. Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Croom Helm Limited: London, UK.

17. Margalef, R. 1958. "Information Theory in Ecology". *General Systems*. 3:36-71.

18. Miserendiro, M.L. 2001. "Macro-Invertebrate Assemblages in Andean Pentagonian Rivers and Streams: Environment relationships". *Hydrobiol*. 444:14-158.

19. Mitrofanova, E. 2008. "Indicative Significance of Phytoplankton for Estimation of Large River State Near Cities and Settlements (Ob and Tom Rivers as a Case Study, Russia)". *Geophysical Research Abstracts*. 10, EGU2008-A-00166.

20. Móra, A., E. Csépes, M. Tóth, and G.Y. Dévai. 2008. "Spatio-Temporal Variations of Macro-Invertebrate Community in the Tisza River (Ne Hungary)". *Acta Zoologica Academiae Scientiarum Hungaricae*. 54(2):181–190.

21. Odiete, W.O. 1999. *Environmental Physiology of Animals and Pollution*. Diversified Resources: Lagos, Nigeria.

22. Odiete, W.O., R.C. Nwaokoro, and T. Adaramola. 2003. "Biological Assessment of Four Watercourses in Lagos Metropolis Receiving Industrial and Domestic Waste Discharges". *Journal of Nigerian Environmental Society*. 1(1):1-14.

23. Ormerod, S.J. and R.W. Edwards. 1987. "The Ordination and Classification of Macro-Invertebrate Assemblages in the Catchment of Rivers Wye in Relation to Environmental Factors". *Freshwater. Biol*. 17: 533-546.

24. Patrick, R. and D.M. Palavage. 1994. "The Value of Species as Indicators of Water Quality". *Proc. Academy Natl. Scs. Philadel.* 145: 55-92.

25. Pereira, D. and S.J. De Luca. 2003. "Benthic Macro-Invertebrates and the Quality of the Hydric Resources in Maratá Creek Basin (Rio Grande do Sul, Brazil)". *Acta Limnologica Bras.* 15(2):57-68.

26. Phillip, E.A. 1988. *Basic Ideas in Biology. The Macmillan Core Series in Biology.* Norman H. Giles and John G. Torrey (eds.). Macmillan: London, UK.

27. Qasim, S.Z. 2003. *Indian Estuaries*. Allied Publishers: New Delhi, India.

28. Ramane, A. and C. Schlieper. 1971. *Biology of Brackish Water*. Willey: New York, NY. 211.

29. Rosenberg, D.M. and V.H. Resh. 1993. "Introduction to Freshwater Biomonitoring and Benthic Macro-Invertebrates". In: D.M. Rosenberg & V.H. Resh (eds). *Freshwater Biomonitoring and Benthic Macroinvertebrates.* Chapman and Hall: New York, NY. 1-9.

30. Sivaramakrishnan, K.G. 2000. "A Refined Rapid Bio-assessment Protocol for Benthic Macro-Invertebrates for Use in Peninsular Indian Streams and River". *Sustainable Water Resource Management, Policies and Protocols Report*.

31. Thompson, J. 2005. "Using Benthic Macroinvertebrates and GIS to Assess and Manage Watershed Health of the Colorado River Basin". City of Austin, Texas.

32. Valiela, I. 1984. *Marine Ecological Processes.* Springer-Verlag: New York, NY.

33. Wlodarska-Kowalczuka, M., A. Michael, M.A. Kendallb, J.M. Weslawskia, M. Klagesc, and T. Soltwedel. 2004. "Depth Gradients of Benthic Standing Stock and Diversity on the Continental Margin at a High-Latitude Ice-Free Site (off Spitsbergen, 791N)". *Deep-Sea Res*. I 51:1903–1914.

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