Environmental Quality Assessment of Anthropogenically Impacted Estuary using Fish Genera Composition, Tissue Analysis, and Condition Factor.

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ABSTRACT

This study assessed the environmental quality of Calabar estuary using fish genera composition, condition factor, and tissue analysis for heavy metals. Twenty-seven fish families in 52 genera were collected. The Condition factor (k) values ranged from 0.788 to 0.902 and were outside the recommended range. Tissue analysis for Cadmiun (Cd), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn), showed that the concentration levels approached critical levels except for Mn. The findings indicated existence of some level of stressors and perturbation in the estuary. High pollution level will affect the sustainable development of the resources of the Calabar River estuary, and must be stopped.

(Keywords: environment quality, tissue analysis, fish, genera composition, estuary, condition factor)

INTRODUCTION

There are many methods available for the assessment of environmental and water quality. Historically, the monitoring of aquatic ecosystems has been based on chemical measures of water quality (Metcalfe-Smith, 1994). However, current views are that chemical monitoring does not provide sufficient information to enable meaningful conclusions to be drawn on the status of environment quality (Metcalfe-Smith, 1994, Wright *et al*., 1994). Consequently, the use of biological protocols provide invaluable alternative to water quality assessment (Karr, 1993). It is the use of any group of organisms to examine the biological condition of a river, and many attempts have been made using both flora and fauna in this regard (Armitage *et al*., 1983). The use of fish communities constitutes a prominent option among biological protocols, and is often used as an indicator of water quality. For instance salmonids (trout and salmon) are associated with high water quality, and similarly, individual fish species have extremely specific water quality requirements (Bauer and Ralph, 2001).

Fish populations provide useful indication of environmental and pollution stress. It has been reported that mean annual diversity of fish is inversely related to the amount of toxic materials in waste water (Bechtel and Copeland, 1970). The effect of pollution on fish behavior has been reported (Little *et al*., 1993). Streams polluted by heavy metals results in extreme environment with relatively low species diversity (Brock, 1969). Those organisms remaining in the aquatic system may be affected in many ways, such as reduced growth rate or inability to complete a particular stage in their developmental cycle. Furthermore, the organisms may accumulate large amounts of the heavy metal, which are passed on to animals which feed on them (Whitton and Say, 1975). By definition, heavy metals are those metals having a density greater than five (Passow *et al*., 1961). Heavy metals cause absence of fish in some aquatic systems, and these include dissolved lead (Carpenter, 1924), zinc (Jones, 1964), and Copper (Butcher, 1955). However, toxicity observed in the field could be greater than predicted by the likely contributions of heavy metals and harmful agents known to be present (Dethlefsen, 1986).

The employment of fish diversity as a veritable tool for environmental impact assessment is predicated on the principle that increased diversity leads to an increase in response diversity (range of traits related to how species within the same functional group respond to environmental drivers) resulting in less variability in functioning over time as environment changes. Secondly, idiosyncratic effects due to keystone species properties and unique trait-combinations which may result in a disproportional effect of losing one particular species compared to the effect of losing individual species at random (Elmqvist *et al*., 2010). Species diversity and number of individuals in space and time can be understood as qualitative and quantitative aspects of the biotic processes in an ecosystem (Ball and Bahr, 1975), and have been used to analyze community structure of organisms (Bass, 1995).

An environmental impact assessment of the Calabar estuary hosting a jetty operated by an oil exploratory multinational company in Calabar, and other communal and industrial entities was carried out. The assessment was carried out using biological protocols. This study was aimed at assessing the environmental impact of the jetty and other industrial and communal entities on the Calabar estuary fish. The specific objectives of the study were to assess the fish genera composition, to calculate fish condition factor for few selected fish species, and to carry out fish tissue analysis for some selected heavy metals.

MATERIALS AND METHODS

Background Information on the Study Area

The jetty facility, which is by Calabar estuary, had been in use for many years but the new oil exploratory company acquired it 9 years preceding the study. Activities that were carried out in the base included general corporate administrative activities, aircraft landing operation and maintenance with a hanger, aviation fuel dump and a busy helipad. Importantly, many hazardous chemicals including biocides were stored at the base. There were serious evidences of major leakages and possibly minor spillages of these hazardous chemicals. All these ran atop cemented floor through channels to the Calabar Estuary. There were three main drainage channels serving the entire facility. The jetty served large vessels that conveyed and brought cargo. There were two fuel dumps: one was a 22,000-litre capacity PMS dump, while the other was a 7,000-litre capacity diesel dump.

There were several uncoordinated but ongoing waste disposal activities observed along the Calabar estuary by several communal and industrial entities, including sewage facilities.

Collection of Fish and Condition Factor

Adult specimens of fish species were collected upstream and downstream of the jetty with the help of local fishermen using a combination of trap and gill nets. Fish were kept in coolers packed with ice and transported to the laboratory where the wet weight and total length of individual fish was measured with an electronic weighing balance and a meter rule. The condition factor (k) of fish was calculated from the relationship:

Condition factor (k) = 100 x W/L3

where W= wet weight of fish and L= total length (Fulton, 1902).

Fish tissue analysis for heavy metals was carried out using Perkin-Elmer flame and graphite furnace atomic absorption spectrophotometry (Perkin-Elmer, 4100 ZL) by Professor V. Uzoukwu of Department of Applied Chemistry, University of Port Harcourt. Results were expressed in micrograms per gram.

RESULTS AND DISCUSSION

Fish Genera Composition

Twenty-seven families of fish were caught in the estuary, which were comprised of fifty-two fish genera (Table 1). The composition of the fish genera collected from the study area did not show any indication of significant community dislocations, as it is congruent with reports from similar aquatic systems in the region (Kumolu-Johnson and Ndimele, 2010). The interactions within communities of organisms at population and community level play a key role in determining the stability and resilience of the ecosystem as a whole. Communities are structured by multiple biotic processes, and external conditions may strongly influence the outcome (Elmqvist *et al*., 2010). There was no indication from the fish genera composition of any significant perturbation beyond the carrying capacity of the aquatic system.

Table 1: Checklist of the Fish Genera Readily Found in the Study Area.

Family	Genera
Mormyridae	*Mormyrus, Mormyrops, Hyperopistus, Marcusenius, Gnathonemus.*
Clupeidae	*Cynothrissa*
Osteoglossidae	*Heterotis*
Polypteridae	*Calamichthys, Polypterus*
Pantodontidae	*Pantodon*
Notopteridae	*Papycranus, Xenomystus*
Gymnarchidae	*Gymnarchus*
Kneridae	*Cromeria*
Bagridae	*Bagrus, Chrysichthys, Clarotes, Auchenoglanis*
Citharinidae	*Nannaethiops, Distichodus, Nannocharax, Nannocharaxloticus, Citharinus, Citharidium.*
Hepsetidae	*Hepsetus*
Characidae	*Hydrocynus, Microalestes, Alestes*
Icthyboridae	*Icthyoborus, Phago*
Cyprinidae	*Garra, Labeo, Barilius*
Clariidae	*Clarias, Heterobranchus*
Mochokidae	*Synodontis*
Schilbeidae	*Siluranodon, Physailia, Eutropus, Schilbe*
Malapteruridae	*Malapterurus*
Lutjanidae	*Lutjanus*
Pomadasyidae	*Pomadasys*
Cichlidae	*Tilapia*
Scienidae	*Plectorhynchus, Pseudotolithus*
Sphyraenidae	*Sphyraena*
Serranidae	*Epinephelus*
Elopidae	*Elops*
Drepanidae	*Drepane*
Polydactylidae	*Polydactylus (=Polynemus), Galeoides*

Fish Condition Factor (k)

Four finfish species caught in the Calabar Estuary were selected to be used for the determination of the condition factor. They were *Synodontis batensoda* (Mochokidae), *Chrysichthys nigrodigitatus* (Bagridae), *Macrobrachium macrobrachion,* and *Aphiosemion gardneri*. Condition factor is a vital tool for assessing the well-being of a species population in different localities (Bolger and Conolly, 1989; Patrakis and Stergion, 1995), and for monitoring of feeding intensity, age, and growth rates in fish (Oni *et al*., 1983). Since it is greatly influenced by both biotic and abiotic environmental conditions, it is useful in assessing the status of the aquatic ecosystem in which fish live (Anene, 2005).

Analyzing the results of the condition factors in this study revealed a range of k value from 0.788 to 0.902 (see Table 2). This indicates that all the fish species (100%) had their K values outside the range (2.9-4.8) recommended as suitable for matured fresh water fish (Bagenal and Tesch, 1978). This could be a resultant effect of adverse environmental factors (Anene, 2005), and is suggestive of the fact that the condition of the area of Calabar estuary under investigation when compared with fresh water bodies may be unfavorable to fishes. This agrees with the recent observations of a study in Lagos lagoon, which is in the same region where 86% of k values of fish samples were outside the recommended range (Kumolu-Johnson and Ndimele, 2010). However, more studies are needed to establish the ecological suitability of Calabar estuary for fish survival.

Table 2: Condition Factor (k) of Finfish Species caught in the Calabar River Estuary during the Study.

Fish species	Condition Factor (k)
Synodontis batensoda	0.902
Chrysichthys nigrodigitatus	0.874
Macrobrachium macrobrachion	0.805
Aphiosemion gardneri	0.788

Tissue Analysis for Heavy Metals

Tissue analysis for the levels of seven heavy metals levels: Cadmiun (Cd), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb), and Zinc (Zn), was carried out on five species, namely, *Synodontis batensoda*, *Chrysichthys nigrodigitatus, Macrobrachium macrobrachion, Aphiosemion gardneri* and on the mangrove oyster *Crassostrea gasar*. Fish are ideal indicators of heavy metal contamination in aquatic systems because they occupy different trophic levels and are of different sizes and ages (Burger *et al*., 2002).

The result of the tissue analysis (Figure 1) showed that the concentration levels of most the heavy metals in the tissues of most fish samples were approaching critical levels except for manganese. However, it was only in the case of level of iron in *Chrysichthys nigrodigitatus* that was actually beyond the permissible limit of both WHO and the European Union benchmarks.

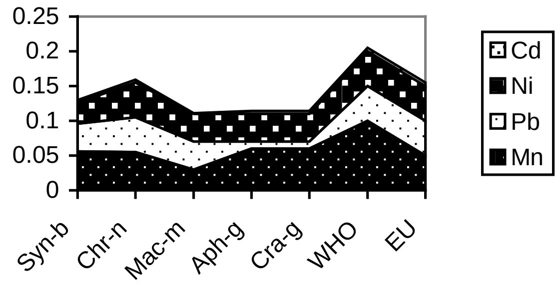

Figure 1: Results of Tissue Analysis on the Five Species (*Synodontis batensoda*, Syn-b; *Chrysichthys nigrodigitatus, Chr-n; Macrobrachium macrobrachion, Mac-m;* and *Aphiosemion gardneri, Aph-g;* and *Crassostrea gasar, Cra-g*) compared with World Health Organization (WHO) and European Union (EU) benchmarks for Maximum Permissible Levels of the Respective Heavy Metals.

This indicates existence of some level of heavy-metal stressors and perturbation in the estuary. Major heavy metal inputs into aquatic systems are traceable to a variety of increasing anthropogenic activities, atmospheric deposition, erosion of geological matrix or due to industrial effluents, domestic sewage and mining wastes (Anderson *et al.,* 1981; Gumgum *et al*, 1994; Alam *et al*, 2002).

Calabar River estuary receives domestic and industrial effluents in significant quantities as a result of extensive industrial activities and urbanization. For example, the large store of industrial chemicals observed in the jetty, some of which leaked and streamed into the estuary through four waste pipes, showed uncoordinated handling of industrial and communal wastes in the area without regard to environmental policies. Indeed industrial chemicals, heavy metals, petroleum hydrocarbons and other floating organics are some of the common contaminants which affect the quality of the aquatic environment. The geo-characteristics of the Calabar estuary made these contaminants usually undergo slower dilution and dispersion than would occur in open marine systems. Consequently, seafood, particularly fishes and crabs which had great local consumption and export value, was considerably affected negatively.

In addition, the observation along the Calabar River estuary of some outlets of sewage disposals directly into the estuary could explain the near-critical levels of heavy metals. An example was one prominent communal toilet facility by a commercial public jetty probably built for those who patronized one of the jetties along the estuary. This exemplified the level of recklessness and ignorance of social responsibility to preserve the integrity of the environment exhibited by private and corporate (industrial) citizens carrying out their trade on the estuary.

Heavy metals top the list of most frequently occurring, and toxic contaminations (Pliesovska *et al*., 1997). Accumulation of heavy metals in aquatic ecosystems is of global importance. The progressive and irreversible accumulation of these metals in various organs of marine creatures ultimately leads to metal-related diseases in the long run because of their toxicity, thereby endangering the aquatic biota and other organisms (Watling, 1983; Hart, 1982; Lee and Cundy, 2001; Melville, and Burchett, 2002). Fishes being one of the main aquatic organisms in the food chain may often accumulate large amounts of certain metals (Mansour and Sidky, 2002; Hadson, 1988). Essentially, fishes assimilate these heavy metals through ingestion of suspended particulates, food materials and/or by constant ion-exchange process of dissolved metals across lipophilic membranes like the gills/adsorption of dissolved metals on tissue and membrane surfaces.

CONCLUSIONS

Protecting diverse fish communities will require more thorough understanding of long-term functional relationships among these species in an ecosystem context. To this end, enlightenment campaigns by Government and corporate bodies assume urgent *desiderata*.

High pollution levels will affect the sustainable development of the resources of the Calabar River estuary. There should be a regular monitoring of activities of individual and corporate users of our aquatic systems to ensure sustainability of the integrity of the environment. This should be done in such a way that offenders are brought to book.

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SUGGESTED CITATION

Uttah, C., E. Uttah, and I. Ayanda. 2012. "Environmental Quality Assessment of Anthropogenically Impacted Estuary using Fish Genera Composition, Tissue Analysis, and condition Factor". *Pacific Journal of Science and Technology*. 13(2):537-542.

Pacific Journal of Science and Technology