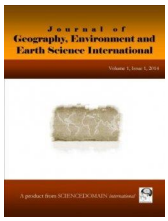

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# Impacts of Industrialization on Fish Species Composition and Diversity in Warri River, Niger Delta, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors OAA and OAO designed the study, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Author EIO finalized the manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

Changes in water quality caused by industrialization and technological advancement, affect fishery resources. The Warri River like many other water bodies in the Niger Delta are experiencing side effects in terms of pollutant build up and destruction of fishes resources. Samples were collected from 9 sampling points namely, stations (A, B, C, D, E, F G, H and I along the Warri River. The fish species were obtained over 24 months from landings of local fisherfolks every forth night with prior arrangement. Fish species found in the respective sampling stations were recorded. Fish species diversity indices were carried out using Margalef, Shannon Wiener and Simpson indices. Condition factors (KF) were also computed. Result show that 34 fish species were recorded in this study,

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which was lower than the 91 spcies reported previously in 1994. A total of 20 – 29 fish species were recorded and the total number of species recorded during the study period ranged from 2905 – 6789 with the areas of highest industrial activities (stations B, C, and D) having the least diversity. Industrial activities that are linked to the declining fisheries include oil and gas exploration, dredging, waste disposal (solid wastes and effluents), jetty and port activities. Hence, sustainability of the fisheries is threatened by industrial activities. The continuous monitoring of the quality of river and enforcement of strict water pollution prevention measures is therefore suggested.

*Keywords: Anthropogenic influences; dredging; fisheries resources; Niger Delta; oil and gas exploration; pollutants; species diversity; Warri River.*

## 1. INTRODUCTION

Environmental baseline studies of Warri River started in 1981 and therefore predates most baseline and impact assessment investigations of oil companies operation in Western Niger Delta. The proliferation of urban, domestic and industrial establishment along the shores of Warri River, may have introduce many synthetic and organic wastes into the environment. Rapid industrialization growth, while poor development planning, chronic unhygienic habits and lack of regulation enforcement, have provided opportunities for discharge of untreated effluents into the Warri River and its Creeks [1,2]. Warri River is located in a rapidly urbanizing and industrializing area in Nigeria. The people of the area depend on the river for the supply of drinking water and fish protein. But lots of anthropogenic activities including dredging, reclamation and sand winning, wastes and waste water disposal are common activities carried out in Warri River.

The major industrial activity in Warri River is oil exploration. Oil exploration activities are many including seismic exploration, drilling and completion. It also includes the construction, installation and operation of production facilities such as flow stations, compressor stations and gas plants, refinery and petrochemical plants, pipeline and flowlines. Oil spill occurs and the production facilities routinely discharge effluents into Warri River, while gas flaring has continued unabated. Oil servicing firms also discharge effluent into the river [3,4]. A steel production company and seaport are also located in Warri River [5]. Solid wastes from domestic and many small and medium scale artisanal activities also discharged effluent into Warri River. Urbanization, sand mining and reclamation are also taking place within Warri River.

Oil exploration related dredging activities is quite extensive in Warri River causing the death of vegetation, plankton and fisheries [6-11]. The abandonment of dredged spoils results in the acidification [12-14], which destroys water quality, fisheries and vegetation. Because of the presence of oil and gas infrastructure, oil spills are now increasing in the Niger Delta due to illegal oil bunkering and artisanal refineries [15,16]. Moffat and Linden [3] linked the decline in fisheries of the Niger Delta to oil and gas exploration and other anthropogenic influences in the Niger Delta.

A comparison of the fish fauna of Warri River and some inland river such as Ase, Ogun and Niger/Benue show that these rivers have a greater variety of fish species. In these latter rivers more species were recorded in the rainy season when the rivers overflow their banks and annex hitherto separate water bodies with their fishes [17]. In this regard, it seems justifiable to regard the fishes in the tributaries of Warri River around Warri as fishes, which migrated from the main channel [4]. According to him the responses of aquatic organisms to increasing pollution varies.

There are at least 91 species of fish in 67 genera and 42 families in the Warri River system [18-22]. Egborge [4] state that the fisheries of the Warri river have been diminished besides other negative effects of economic or socio-economic nature. According to him, the oral evidence of fishermen, suggests that apart from low catches, certain species of fish that were commonly seen in the Warri River before industrialization are now hardly seen. This study therefore attempts to determine fish species composition and diversity of the Warri River.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The study area was Warri River in Delta State, Nigeria. Warri River stretches within latitude

5°21[1] – 6°00[1]N and longitude 5°24[1] – 6°2[1]E. Its source is around Utagba Uno and runs in a Southwest direction passing between Oviorie and Ovu-inland and southwards at Odiete through Agbarho to Otokutu and Ugbolokposo [4]. It turns southward to Effurun and forms a 'W' between Effurun and Warri. Important land marks in this River stretch are Enerhen, Igbudu, Ovwian and Aladja (steel town), Warri Ports, main Warri market, NNPC Refinery, and many oil servicing and producing companies.

## 2.2 Materials and Methods

The study was conducted on two rainy seasons and two dry season months (2years) at 9 locations. Sampling was done monthly.

## 2.3 Fish Species Sampling

Fish species were collected from the study area at each location monthly within the period of 24 months. Fish were caught at locations A (Jeddo), B (refinery Jetty), C (Warri Port Jetty), D (main Warri Market), E (steel company Jetty), F (Ramp), G (Udu Bridge/Market), H (Ugbolokposo dredging site) and I (Agbarho), using gill nets of 1.5 inches (38.1 mm) 2 inches (50.8 mm), 3 inches (76.2 mm) and 4 inches (101.6 mm) stretched mesh size at dusk and retrieved at dawn. Baited hooks and lines as well as traditional basket traps, were also used in fishing. Fish were obtained from landing of local fishermen every fortnight with prior arrangement. The nets were sets in different locations in open water, flooded bush patches and shallow bays. Catches from long-lines, fish traps, and hollow cylinders made of bamboo and set hooks were used to obtain/ provide comprehensive picture of fish species in the Warri River. Fishing effort were basically the same at all the locations of the study.

## 2.4 Fish Enumeration

Catches were enumerated at the landing sites down to species level. Record of endemic fish species (fish regularly seen) as well new catches where sited were taken from each location. Records of distribution/population of fish assessed were collected at all the nine sampling locations.

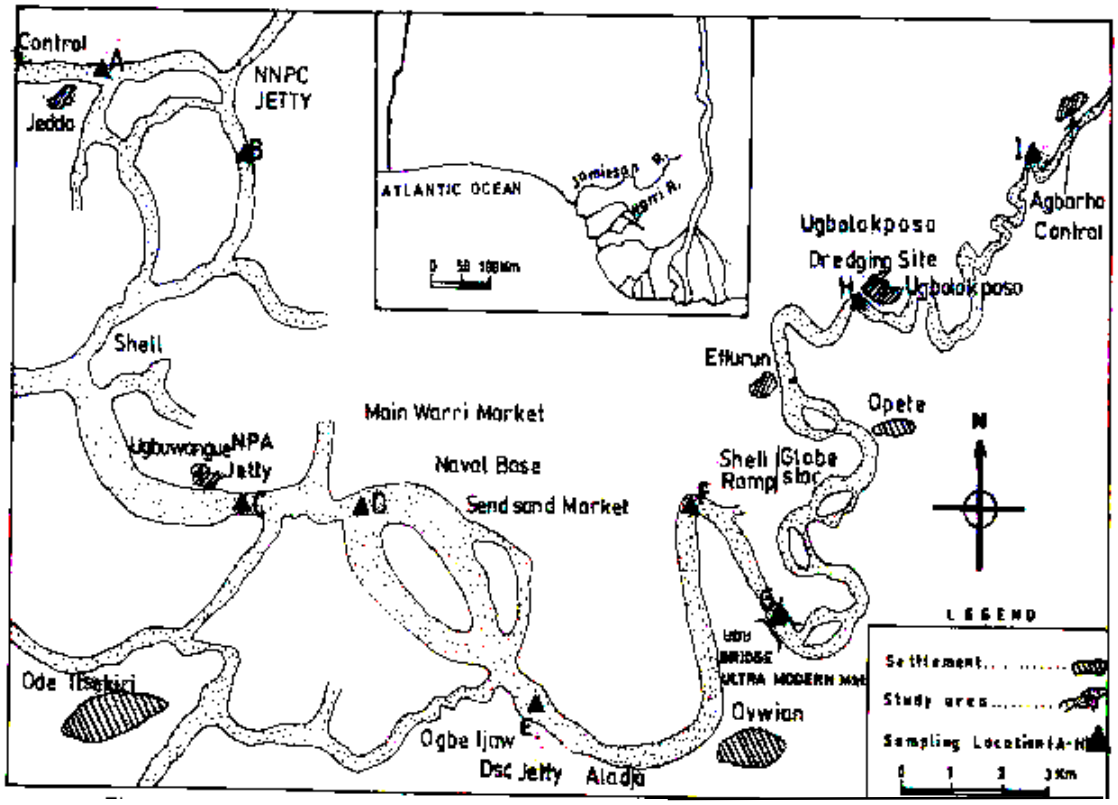


**Fig. 1. Map of Warri River showing settlements and sampling points**

The fish species were identified to species level using the keys and descriptions of [4,23-27].

The weights of the fish were measured to the nearest 0.1 g using a meuler E-200 top loading balances and the standard lengths were measures to the accuracy of 0.1cm using a measuring board.

Data processing involved the calculation of diversity indices such as Margalef' [28], Shannon – Wiener [29] and equitability [30,31].

Margalef's values, is a measure of species richness which is expressed by equation.

$$d = \frac{S - I}{\text{Log}_e N}$$

Where d = Margalef's diversity index
S = Numbers of Species
N = number of individuals

$$\text{Simpson index } D = 1 - \sum_{i=1}^{S} \frac{ni\ (ni - i)}{N\ (N - 1)}$$

where ni = number of individual of species I
N = total number of individuals of all species

Shannon – Weiner index H =

$$\frac{3.321928}{N}\ (N \log_{10} N - \sum_{i=1}^{S} ni \log_{10} ni)$$

Where ni and N are as above

The equitability index of Pielou was used to measure evenness of distribution of individuals among species.

$$\text{Pielou's } J = \frac{H}{\text{Log}_2 S}$$

Where H = Shannon – Weaver Index
S = Number of Species

## 2.5 Condition Factor

Condition factor fish, species caught were computed. Condition factor is an index of the degree of fatness or well being of a species. The condition factor (KF) is described by the evaluation.

$$K(f) = \frac{100W}{L^3}$$

Where

W = weight in grammes(g)
L = standard length (Cm)

## 3. RESULTS

### 3.1 The Fish Abundance/Distribution of Warri River

Thirty-four fish species were identified during the study (Table 1). Out of these, station E and F recorded the highest taxa (30) each comprising 4,503 (10.1%) and 4, 180 (10.3%) fishes respectively. Udu Bridge/market (station G) and Agbarho (station I) ranked next in terms of taxa, recording 29 each, while the numbers of fish caught were 4549 (11.2%) and 6,798 (16.7%) respectively. The least tax (22) with 3456 (8.5%) was recorded in station C whereas the least of them all in terms of individual (number of fish) caught 2905 accounting for just 7.2% of total catch was recorded in station B. The student's t – test showed that the abundance of fish was significantly higher at the two comparative reference points (Jeddo 13.1% and Agbarho 16.7%) and Ugbolokposo dredging site (station H) (13.5%). The families and species found in stations E, F. G, H and I but absent in station B, C and D were Carangidae (*Caranx hippos*; *C. langubris*, and *Chloroscombus chrysurus*), Channidae (*Parachana obscura)* and Cichlidae (*Oreochromis niloticus, Chromodotilapia guentheri, Hemicromis biinaculatus, Hemicromis faciatus* and *Tilapia zillii*). On the other hand, some of the species not found in stations G, H, F and I, yet commonly seen at E, D, C and B include Cynoglossidae (*Cynoglossus browni*), Distichodontidae (*Distichodus brevipinnis, D. rostratus, D. engycephalus*) and *Monodactylidae (Psettias sebae)*.

The families Bagridae (e.g. *Auchenoglanis occidentalis*) and Cichlidae dominated the collections in terms of number of taxa, although Bagridae dominated relative to abundance 12,769 (31%), followed by Clupeidae (e.g. *Ilisha africana*) 7,093 (17.5%) and Cichlidae 4804 (11.8%). In station I, 18 dominant species (relatively highest number of individuals caught) were recorded, while in stations A, E, F and C were dominant in 7,4,3, and 1 species caught respectively among the 9 locations of the study (Table 1).

**Table 1. Species checklist, of abundance and distribution of fishes in the study section of the Warri River**

| Family | Species | Locations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H | I | Total |
| Anabantidae | *Ctenopoma kingsleyae* | 51 | 21 | 37 | 38 | 31 | 31 | 28 | 46 | 75 | 358 |
| Aridae | *Arius gigas* | 112 | 60 | 93 | 96 | 85 | 108 | 119 | 161 | 203 | 1037 |
| Bagridae | *Auchenoglaris occidentalis* | 462 | 360 | 418 | 307 | 323 | 128 | 166 | 221 | 187 | 2572 |
| | *Chrysicthys a longifilis* | 238 | 268 | 246 | 228 | 283 | 160 | 256 | 287 | 286 | 2252 |
| | *Chrysicthys nigrodigitatus* | 386 | 355 | 376 | 380 | 414 | 307 | 250 | 343 | 411 | 3222 |
| | *Chrysicthys furciatus* | 288 | 293 | 282 | 305 | 284 | 219 | 236 | 349 | 402 | 2658 |
| | *Chrysicthys walker* | 260 | 206 | 280 | 290 | 206 | 209 | 155 | 215 | 244 | 2065 |
| Carangidae | *Caranx hippos* | 0 | 0 | 0 | 0 | 32 | 47 | 64 | 94 | 113 | 350 |
| | *Carranx senegalus* | 0 | 0 | 0 | 0 | | 83 | 92 | 108 | 133 | 396 |
| | *Caranx langubris* | 0 | 0 | 0 | 0 | 57 | 73 | 67 | 73 | 126 | 396 |
| | *Chloroscombu chrysuris* | 0 | 0 | 0 | 0 | 85 | 42 | 47 | 73 | 85 | 332 |
| Channidae | *Parachana obscura* | 342 | 0 | 0 | 0 | 0 | 0 | 476 | 654 | 741 | 2213 |
| Cichlidae | *Orecheomis niloticus* | 218 | 0 | 0 | 0 | 0 | 186 | 151 | 180 | 281 | 1016 |
| | *Chromodotilapia guentheri* | 85 | 0 | 0 | 61 | 201 | 284 | 230 | 0 | 272 | 1048 |
| | *Hemicromis binaculatus* | 62 | 0 | 0 | 0 | 32 | 115 | 237 | 237 | 241 | 924 |
| | *Hemicromis faciatus* | 111 | 4 | 0 | 4 | 83 | 74 | 67 | 105 | 110 | 558 |
| | *Tilapia zilli* | 336 | 21 | 0 | 0 | 110 | 102 | 104 | 212 | 373 | 1258 |
| Citharinidae | *Citharinus citharus* | 223 | 155 | 122 | 170 | 202 | 199 | 174 | 237 | 404 | 1886 |
| Clariidae | *Clarias lazera* | 277 | 181 | 182 | 200 | 204 | 144 | 184 | 294 | 385 | 2051 |
| Clupeidae | *Ethmalosa fimbriata* | 444 | 209 | 205 | 274 | 396 | 263 | 330 | 403 | 316 | 2840 |
| | *Ilisha africana* | 240 | 40 | 285 | 234 | 207 | 237 | 210 | 129 | 69 | 1651 |
| | *Sardinella maderensis* | 211 | 79 | 212 | 196 | 234 | 256 | 175 | 97 | 60 | 1520 |
| | *Pellonula afzeliusi* | 165 | 104 | 155 | 189 | 191 | 177 | 32 | 33 | 36 | 1082 |
| Cynoglossidae | *Cynoglosus browni* | 82 | 94 | 107 | 100 | 108 | 110 | 0 | 0 | 0 | 601 |
| Cyrinidae | *Labio coubie* | 0 | 0 | 0 | 0 | 61 | 71 | 118 | 185 | 230 | 665 |
| | *Labio senegalensis* | 0 | 0 | 60 | 57 | 40 | 92 | 96 | 78 | 120 | 543 |
| Distichodontidae | *Dislichodus brevipinnis* | 137 | 83 | 108 | 81 | 85 | 0 | 0 | 0 | 0 | 494 |
| | *Dislichodus rostratus* | 90 | 74 | 88 | 70 | 56 | 47 | 0 | 0 | 0 | 425 |
| | *Distichodus engycephalus* | 94 | 61 | 93 | 50 | 63 | 74 | 0 | 0 | 0 | 435 |
| Gobidae | *Corconogobis schlegelli* | 92 | 88 | 44 | 74 | 34 | 7 | 71 | 87 | 94 | 591 |
| Gymnarchidae | *Gymnarchus niloticus* | 20 | 0 | 0 | 0 | 0 | 0 | 30 | 64 | 78 | 172 |
| Malapteridae | *Malapterus electricus* | 221 | 111 | 0 | 0 | 177 | 203 | 241 | 312 | 447 | 1712 |
| Monodactylidae | *Psettias sebae* | 67 | 38 | 63 | 46 | 67 | 0 | 0 | 0 | 0 | 281 |
| Noptoteridae | *Xenomystus nigri* | 0 | 0 | 0 | 11 | 152 | 112 | 143 | 203 | 276 | 897 |
| total | | 5314 | 2905 | 3456 | 3461 | 4503 | 4180 | 4549 | 5480 | 6798 | |

Stations B, D and G never dominated in any of the species caught during the study. Station H produced 12 subdominant species while stations A and C obtained 6 and 4 subdominant species caught respectively

### 3.2 Fish Species Diversity/Similarity Indices

Species general diversity were richness and relatively higher in stations E (3.48) and DSC (3.45), G (3.33) closely followed by I (3.17), H (3.14) and A (3.03) (Table 2). The two similarity indices computed to compare fish species from the nine locations showed that there was marked dissimilarity between locations of the study. The highly industrialized areas (stations B, C and D except E), which is also around the axis of industrial site, had the lowest species diversity in all cases. This is not unconnected with the uncontrolled discharge of effluent by the aforementioned industries which are toxic and could have been responsible for destruction of the aquatic environment including the fisheries The long period of inactivity of a steel company located at Ovwian Aladja (from 1993 – 2005) may have been responsible for the observed relatively high diversity index recorded at E. Similarly, the locations E and F which had the highest diversity in the study is traceable to the fact that it is located upstream where it receives fresher water from the river source. The location E was at the time of the study was inactive while the F location effluent were of domestic origin which may have improve the nutrient content of the water thus providing feeding ground for the fishes.

### 3.3 Species Diversity of the Warri River

Species richness and general diversity were relatively higher in locations F (3.48) and E (3.45), G (3.33) closely followed by I (3.17), H (3.14), A (3.03) (Table 2).

- The two similarity indices computed to compare fish species from the nine locations showed that there was marked dissimilarity between locations of the study (Table 2). The highly industrialized areas (Locations B, C and D except E), which is also around the axis of industrial site, had the lowest species diversity in all cases (22, 21, 20, 30 respectively). The long period of inactivity at the steel company at Ovwian Aladja (between 1993 and 2005) may have been responsible for the observed relatively high diversity index recorded at location E.

## 4. DISCUSSION

The responses of aquatic organisms to increasing pollution vary [4]. Changes in water quality caused by industrialization and technological development, are known to affect fish and other aquatic communities [32- 34]. The overall number of species (34) recorded in all the 9 study locations during this study is low when compared with 91 species earlier reported by Agada [18], Okumagba [19], Tetsola [20], Dibia [21], Okia-Anie [22]. The number of species was also lower than 58 species documented for flood plain rivers in Africa by Welcome (1979). The reduction in the number of fish species and what appeared to be a local extinction of some fish families in the downstream location; could be attributed to effect of impoundment [28,35], dredging [6,7], urbanization and waste discharge [36].

Location B segment of the river recorded the lowest species diversity in all cases (Table 2). *Auchenoglaris occidentalis* and *Corconogobius schlegeli* earlier recorded by Egborge [4] as rare species in the main channel of the river were commonly caught there, indicating temporary nature of community changes result from habitat alternation. Fish species that are unable to withstand environmental condition may die or migrate to elsewhere, while those that are hardy enough, survives.

### 4.1 Condition Factor

Among fish species, those that are well fed are better conditioned than the same species, which are poorly fed [35]. The condition factor of most fish species found in the study locations were above 1.0 (Fig 2). Comparison of the condition factor of the same fish species in the nine study locations showed more species had higher condition factor in location I. These could be as a result of the fact that this location is at the upstream area where relatively fresher water is received. Besides there are no industries sited there. The general trend in the condition factor was in the order I > H > G > F > E > A > D > C > B. The cat fishes (e.g. Bagridae, Clariidae) out of all the families represented were well conditioned. This could be due to their hardy nature and ability to adapt well to environmental conditions that may be unfavorable to many fish families.

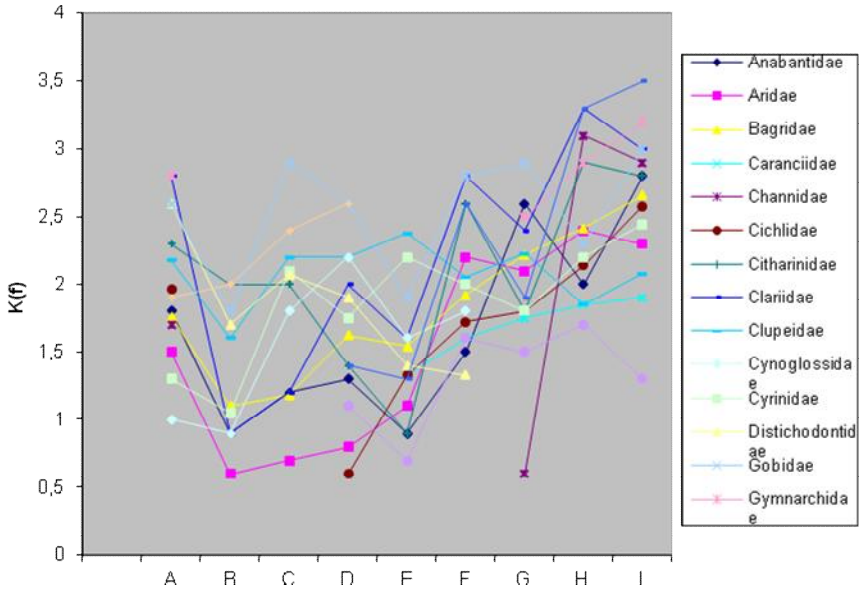


**Fig. 2. Comparison of the condition factor of fish species of the study sections of the Warri river 2005-2007**

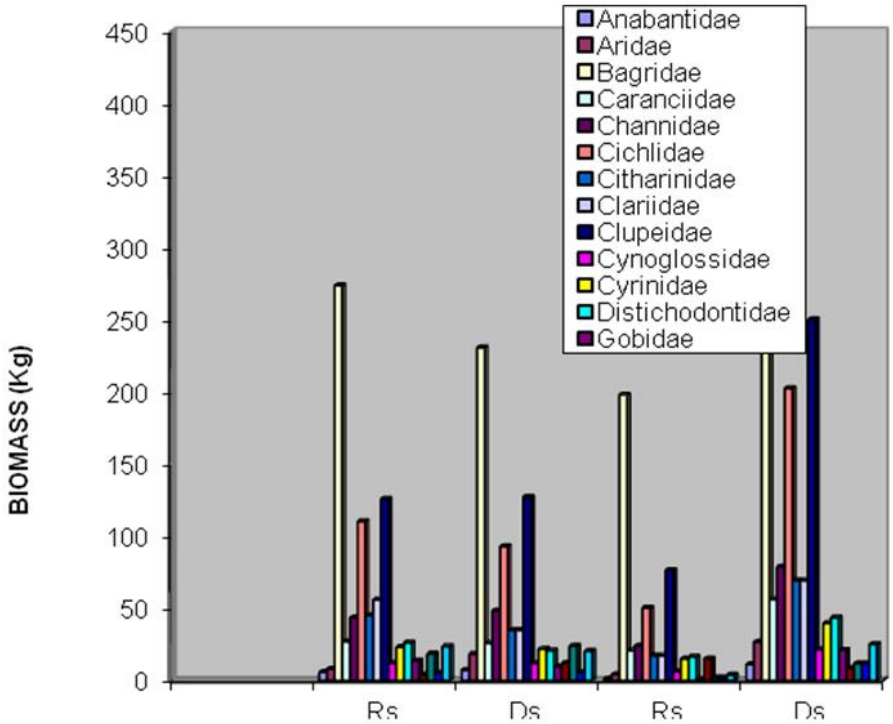


**Fig. 3. Biomass of fish species (Sept. 2005- Aug. 2007)**
**Rs=rainy season, Ds=dry season**

**Table 2. Spatial variation in fish diversity index**

| | Sampling locations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| No of species | 27 | 22 | 20 | 23 | 30 | 30 | 29 | 28 | 29 |
| Total captured | 5314 | 2905 | 3456 | 3461 | 4503 | 4180 | 4549 | 5480 | 6789 |
| Margalef's index | 3.0310 | 2.6335 | 2.3315 | 2.6996 | 3.4473 | 3.4780 | 3.3246 | 3.1363 | 3.1735 |
| Shannon Weiner's index | 4.4760 | 4.0172 | 4.1718 | 4.1252 | 4.5490 | 4.6493 | 4.5791 | 4.5043 | 4.5556 |
| Simpson's index | 0.9491 | 0.9301 | 0.9306 | 0.9343 | 0.9496 | 0.9501 | 0.9519 | 0.9301 | 0.9508 |
| Pielou's Eveness index | 0.9413 | 0.9007 | 0.9652 | 0.9118 | 0.9270 | 0.9474 | 0.9425 | 0.9369 | 0.9377 |

## 5. CONCLUSION

Warri River is located in a rapidly urbanizing and industrializing area of Nigeria. The river is the major source of fish protein for the inhabitants of the area. This study assessed the fisheries of the river and found that it is declining. Anthropogenic activities such as oil and gas exploration, dredging, wastes and wastewater discharge may be responsible for the decline in fish species diversity and number.

An overview of this work shows that the sources of pollution of the Warri River are anthropogenic in nature. The culmination of all these activities may have led to changes in fish biological diversity. This may account for the sharp drop of fish species (from 94 species) in baseline studies to the 34 species obtained in the present study. In the light of the findings above, it is expedient to have an insight of the social, economic and environmental consequences of the impact of pollutants to the aquatic environment. The outcome is certainly not desirable especially to those who leave in the Niger Delta Region. In the light of these it is expedient that there is dire need to control the quantity and quality of effluent that entered the river, in order to forestall continuous pollution. To be able to actualize these set objectives the following are recommended:

1. Regular predictions should be made using past and present data covering Warri River, in order to keep pollutant levels under control.
2. Proper refuse disposal facilities should be provided in the town.
3. A continuous and serious public education should be given to alert the public (through the various media, traditional council at the grass roots) on the imminent danger that could arise from indiscriminate dumping of domestic and industrial effluent, directly or indirectly into the water bodies.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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