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Research Article

Post-impact evaluation of concrete structure on the fish fauna of a running freshwater ecosystem in southeastern nigeria

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Abstract

An evaluation of concrete structure on the fish fauna in Ogbei Stream, Southeastern Nigeria was studied. Fish samples were collected from six stations namely stations 1, 2, 3, 4, 5 and 6 for twelve months between May 2008 and April 2009. A combined total of 694 species of fish belonging to 6 orders, 10 families and 15 species were recorded in the study. Stations 1, 2, 3, 4, 5 and 6 had respective overall percentage abundance of 4.90, 35.30, 10.23, 7.20 9.08 and 33.29. Perciformes, the most abundant order with two families namely Cichlidae and Channidae occurred most in station 2. The least abundant order, Lepidosireniformes with *Protopterus annectens* (Family Protopteridae) as the only representative taxon, occurred most in station 4. Cichlidae, the most abundant family of the order Perciformes, had *Sarotherodon galilaeus* as the most important taxon with the highest and lowest abundance in stations 2 and 1 respectively. The low faunal diversity in station 1 showed strong evidence of impact arising from concrete structure erected in this station. The study showed that concrete structure which is a human perturbational activity that changes aquatic habitats and the water properties affected the fish diversity and abundance in Ogbei Stream.

INTRODUCTION

Although concrete structures are erected to harness water for industrial, agricultural and domestic purposes, it reduces water quality and hence negatively affect fish. It alters fish composition, distribution and abundance. Thus major differences occurred in fish species richness, density and community composition above and below (Winberg and Heath, 2010) concrete structures.

Concrete structures as barriers block migration routes for diadromous species moving between marine and freshwater environments at the different stages of their life cycle. This study investigates the impact of concrete structure on the fish fauna of Ogbei Stream.

MATERIALS AND METHODS

The Study Area

The study area is Ogbei Stream (Fig. 1) in Nkpologwu, Anambra State, southeastern, Nigeria. The study area has been described by Ibemenuga (2017).

Fish sampling and preservation

Fish sampling was done with gill nets of various mesh sizes (such as 25 mm, 30 mm and 40 mm). The gill nets were fixed in position with stakes at strategic positions along banks in each station and were anchored to the stream bottom to enable sample the entire water column.

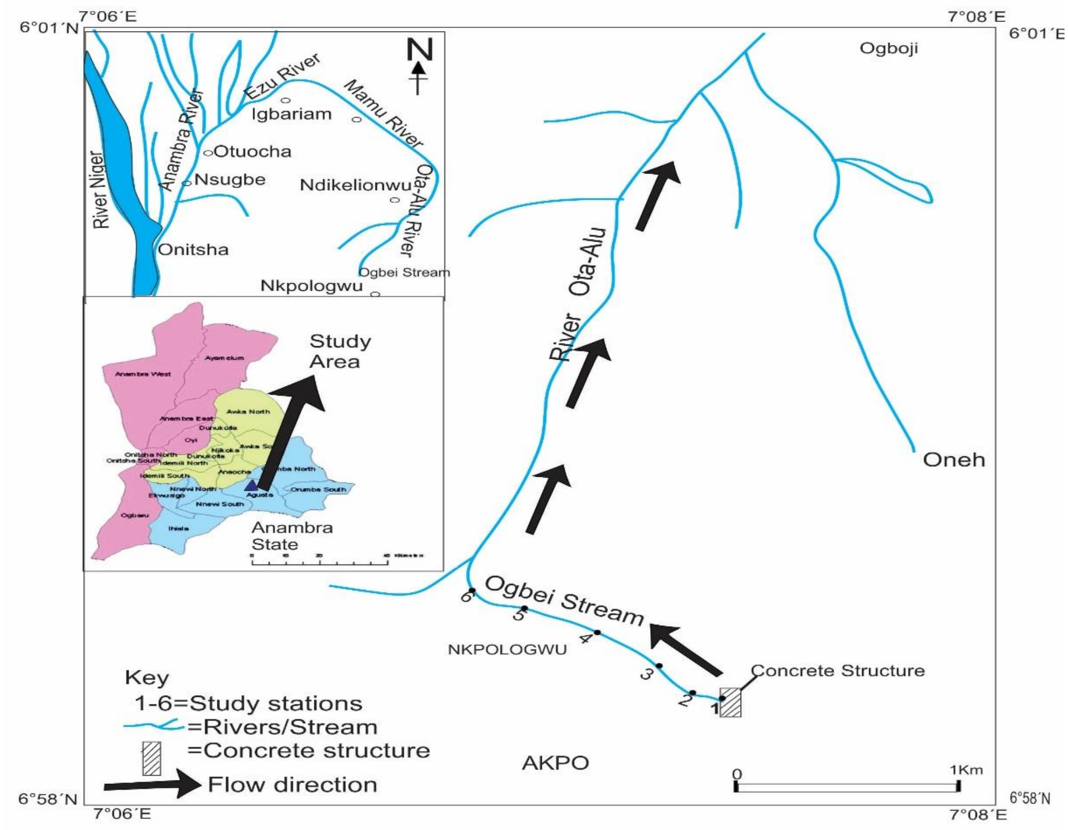

Fig. 1: Map of the Study Area

The nets were set in the evening and checked early in the morning. Fish caught were collected and preserved in 5% formalin in storage bottles labeled according to stations.

Fish identification

The preserved fishes were transported to the laboratory for identification. Keys complied by Holden and Reed (1972), Ugwu and Mgbenka (2006) and Olaosebikan and Raji (1998) were used for identification.

Computational Analysis

Percentage relative abundance

The total number of individuals of each fish group was determined as percentage composition at each study station as follows:

$$Percentage\ relative\ composition = \frac{m}{n} \times \frac{100}{1}$$

Where

m = number of individuals recorded

n = total number of all species in the station

Faunal diversity and dominance

Faunal diversity index for species richness (d) was analyzed using Margalef's diversity index for species (taxa) richness, while Shannon Wiener index (H) was used for general diversity and equitability of evenness (E) of distribution.

Margalef's diversity index for species richness (d) was calculated as follows:

$$D = \frac{S-1}{Log\ N}$$

Where

S = number of species recorded,

N = total number of individuals of all **species recorded (Magurran, 1988).**

Shannon Wiener (H) which is the function devised to determine the amount of information in a code (Southwood, 1978), and Equitability (E) were used to calculate species diversity as follows:

$$H = \sum_{i=1}^{S} (P_i)\ (log_{10}\ Pi)$$

Where

H = information content of sample (bits/individuals) = index of species diversity,

S = number of species,

P*i* = proportion of total sample belonging to i^{th} species (Krebs, 1978).

Equitability or evenness (E) was computed as follows:

$$H_{max} = \log_2 S$$

Where H_{max} = species diversity under conditions of maximal equitability,
S = number of species in the community (Krebs, 1978)

Equitability index (E) $= \frac{H}{H_{max}}$

Where E = Equitability, H = observed species diversity, H_{max} = highest species diversity = Log_2 S (Krebs,1978)

Hutcheson's t-test was carried out to detect the significant difference between general diversity indices (Hutcheson, 1970; Victor and Tetteh, 1988; Victor and Meye, 1994) as follows:

$$t = \frac{Hi - Hj}{(Var\ Hi + Var\ Hj)^{1/2}}$$

Where

H_i = General diversity in the ith station
Hj = General diversity in the j^{th} station
Var H*i* = i^{th} station diversity variance
Var Hj = j^{th} station diversity variance

$$Var\ (H) = \frac{\Sigma Pi(logPi)^2 - (Pi\log Pi)^2}{N} - \frac{S-1}{2N^2}$$

Where

N = total number of taxa in a station
S = Number of species recorded

Dominance was computed using Simpson's index thus:

$$Simpson's\ index = \frac{1}{D}$$

Where, D = Σ pi^2, *pi* = the proportion of individuals in the i^{th} species (Magurran, 1988).

Faunal similarity of study stations

Bellinger's coefficient was computed to evaluate faunal similarity between sampling stations (Walwork, 1970) as follows:

Bellinger's coefficient $= (p - q)^2/p + q$

Where

p = number of occasions in which the taxon occurs in one station than the other

q = number of occasions where reverse is the case.

Statistical Analysis

Data on fish fauna were analyzed using SPSS version 20.0. Data on fish abundance were subjected to two way analysis of variance (ANOVA) to determine differences between stations. Where significant differences existed, Duncan's New Multiple Range Test (DNMRT) was used to separate station means at 0.05%.

RESULTS

A total of 694 individuals belonging to six (6) orders, ten (10) families and fifteen (15) species were collected Table 1.

Stations 1, 2, 3, 4, 5 and 6 had respective overall percentage abundance of 4.90, 35.30, 10.23, 7.20, 9.08 and 33.29 (Fig. 2). The percentage relative abundance was used to express the relative contribution of major fish orders, families and species to the overall fish abundance in the various stations.

A total of 15 fish species was collected in the study. The abundance of major taxonomic groups varied greatly among the study stations. The order Perciformes was widespread. It occurred in all the stations. Its abundance was highest in Station 6, followed by Station 2. Very few individuals were collected in Station 1. *Sarotherodon galilaeus* and *Parachanna obscura* were among the prominent taxa. The order Cypriniformes represented by the genus Labeo was restricted in distribution, occurring in Stations 2, 5, and 6. The dominant taxon was *Hydrocynus vittatus*. Siluriformes was represented in all the stations with the highest abundance in Station 6, followed by Station 2.

It had least abundance in Station 4. *Synodontis robbianus* was the prominent taxon. The order Polypteriformes represented by *Erpetoichthys calabaricus* occurred in Stations 2, 3, 4 and 5. Lepidosireniformes was represented only in Station 4. Its representative taxon, *Protopterus annectens*, occurred only in Station 4. The Cyprinodontiformes was restricted in distribution. It was found only in Station 2. *Epiplatys sexfasciatus* was the only taxon recorded.

The most abundant order was the order Perciformes. It was represented by 4 taxa from two families: Cichlidae (3) and Channidae (1). The most important taxon, *Sarotherodon galilaeus* (Cichlidae), recorded the highest abundance in Station 2.

The order Cypriniformes was not prominent. It was absent in Stations 1, 3 and 4 contributing 0.82%, 7.93% and 0.87% in Stations 2, 5 and 6. Two families Citharinidae and Characidae were represented. *Labeo senegalensis* was the only Citharinidae while *Hydrocynus vittatus* dominated Characidae with percentage contribution of 4.76 in Station 5. It was absent in all other stations. Siluriformes was recorded in all the study stations with percentage contribution of 50.00, 33.06, 43.67, 12.00, 28.57 and 39.39 in Stations 1, 2, 3, 4, 5 and 6 respectively.

Table 1: Fish composition in relation to study stations of Ogbei Stream

Taxa			Stations					
Order	**Family**	**Species**	**1**	**2**	**3**	**4**	**5**	**6**
Perciformes			17(50.00)*	112(45.72)	37(52.11)	34(68.00)	37(58.72)	138(59.68)
	Cichlidae		13(38.24)	79(32.25)	32(45.07)	26(52(.00)	35(55.55)	48(20.78)
		Tilapia zilli	0(0.00)	0(0.00)	2(2.82)	2(4.00)	3(4.76)	0(0.00)
		Sarotherodon galilaeus	13(38.24)	68(27.76)	30(42.25)	24(48.00)	32(50.79)	48(20.78)
		Oreochromis niloticus	0(0.00)	11(4.49)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
	Channidae		4(11.76)	33(13.47)	5(7.04)	8(16.00)	2(3.17)	90(38.90)
		Parachanna obscura	4(11.76)	33(13.47)	5(7.04)	8(16.00)	2(3.17)	90(38.90)
Cypriniformes			0(0.00)	2(0.82)	0(0.00)	0(0.00)	5(7.93)	2(0.87)
	Citharinidae		0(0.00)	0(0.00)	0(0.00)	0(0.00)	2(3.17)	0(0.00)
		Labeo senegalensis	0(0.00)	0(0.00)	0(0.00)	0(0.00)	2(3.17)	0(0.00)
	Characidae		0(0.00)	2(0.82)	0(0.00)	0(0.00)	3(4.76)	2(0.87)
		Alestes macrolepidotus	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	2(0.87)
		Alestes nurse	0(0.00)	2(0.82)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
		Hydrocynus vittatus	0(0.00)	0(0.00)	0(0.00)	0(0.00)	3(4.76)	0(0.00)
Siluriformes			17(50.00)	81(33.06)	31(43.67)	6(12.00)	18(28.57)	91(39.40)
	Clariidae		0(0.00)	13(5.31)	0(0.00)	0(0.00)	0(0.00)	6(2.60)
		Clarias anguillaris	0(0.00)	13(35.31)	0(0.00)	0(0.00)	0(0.00)	6(2.60)
	Mochokidae		12(35.29)	66(26.94)	31(43.67)	4(8.00)	13(28.57)	83(35.93)
		Synodontis robbianus	12(35.29)	64(26.12)	29(40.85)	4(8.00)	18(28.57)	78(33.77)
		Synodontis clarias	0(0.00)	2(0.82)	2(2.82)	0(0.00)	0(0.00)	5(2.16)
	Malapteruridae		5(14.71)	2(0.82)	0(0.00)	2(4.00)	0(0.00)	2(0.87)
		Malapterurus electricus	5(14.71)	2(0.82)	0(0.00)	2(4.00)	0(0.00)	2(0.87)
Polypteriformes			0(0.00)	0(0.00)	0(0.00)	2(4.00)	0(0.00)	0(0.00)
	Polypteridae		0(0.00)	46(18.78)	3(4.23)	8(16.00)	3(4.76)	0(0.00)
		Erpetoichthys calabaricus	0(0.00)	46(18.78)	3(4.23)	8(16.00)	3(4.76)	0(0.00)
Lepidosireniformes			0(0.00)	0(0.00)	0(0.00)	2(4.00)	0(0.00)	0(0.00)
	Protopteridae		0(0.00)	0(0.00)	0(0.00)	2(4.00)	0(0.00)	0(0.00)
		Protopterus annectens	0(0.00)	0(0.00)	0(0.00)	2(4.00)	0(0.00)	0(0.00)
Cyprinodontiformes			0(0.00)	4(1.63)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
	Cyprinodontidae		0(0.00)	4(1.63)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
		Epiplatys sexfasciatus	0(0.00)	4(1.63)	0(0.00)	0(0.00)	0(0.00)	0(0.00)
Total			**34(100)**	**245(100)**	**71(100)**	**50(100)**	**63(100)**	**231(100)**

Three families, Clariidae, Mochokidae and Malapteruridae were encountered. The most important taxon, *Synodontis robbianus* (Mochokidae), present in all the study stations recorded the highest abundance in Station 6 where it contributed 31.77% of all Siluriformes.

The order Polypteriformes represented by one taxon, *Erpetoichthys calabaricus* (Polypteridae) had the highest abundance in Station 2 with percentage contribution of 18.78. Lepidosireniformes represented by *Protopterus annectens* (Protopteridae) occurred only in Station 4 with percentage contribution of 4.00.

Cyprinodontiformes was not prominent; it contributed only 1.63% in Station 2, being absent in all other stations. The representative taxon was *Epiplatys sexfasciatus* of the family Cyprinodontidae.

Taxa richness, Shannon Wiener index, maximum species possible diversity, equitability and dominance indices

Table 2 shows a summary of the taxa richness, general diversity, maximum species possible diversity, equitability and dominance. Station 2 recorded the highest taxa richness, and Shannon Wiener index which were low in station 1. Similarly maximum species possible diversity was highest in station 2 and lowest in station 1. The equitability (evenness) was highest in station 1 and lowest in station 6. The highest and lowest dominance were recorded in stations 3 and 2 respectively.

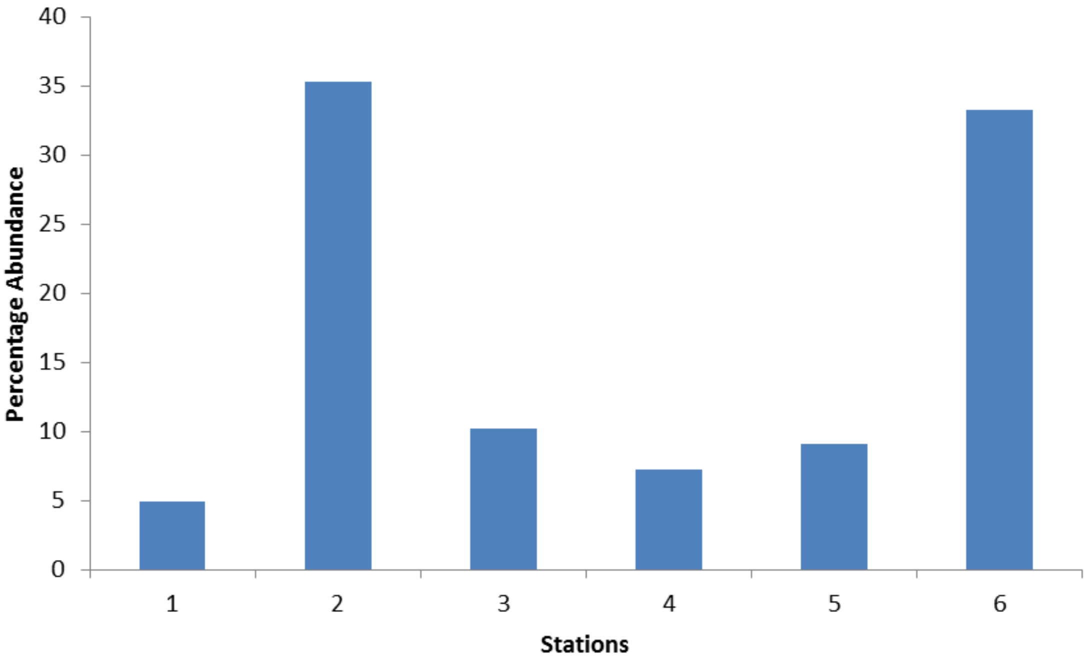

Fig. 2: **Percentage abundance of fish at the study stations**

Hutcheson's test (Table 3) revealed that the faunal diversity in Station 2 was significantly higher ($p < 0.05$) than that of the other stations. In terms of pairs of sampling stations, values for Stations 2 and 3 were significantly higher ($p < 0.05$) than that of other stations. Stations 1 and 3, 1 and 4, 1 and 5, 1 and 6; 2 and 4, 3 and 5, 3 and 6; 4 and 5, 4 and 6; and 5 and 6 were not significantly different ($p > 0.05$). The other pairs of sampling stations were significantly different ($p < 0.05$) from one another.

Fish similarity coefficients of pairs of study stations

Bellinger's coefficient for pairs of study stations is shown in Table 4. Station 2 was significantly different ($p < 0.05$) from the other sampling stations in terms of faunal similarity. Stations 2 and 3, 2 and 4, 2 and 5, and 3 and 6 were significantly different ($p < 0.05$). Other pairs of sampling stations were not significantly different ($p > 0.05$).

Table 2: Diversity of fish in the study stations of Ogbei Stream (May 2008 - April 2009)

	STATIONS					
	1	2	3	4	5	6
No. of Taxa	4	10	6	7	7	7
No. of individuals	34	245	91	50	63	231
Margalef's Index (d)	1.961	3.966	2.703	3.529	3.333	2.597
Shannon Wiener Index (H)	0.552	0.769	0.542	0.663	0.589	0.573
Highest Maximum Possible Species Diversity (H_{max})	0.602	1.000	0.778	0.845	0.845	0.845
Equitability (E)	0.917	0.769	0.697	0.785	0.697	0.678
Dominance (D)	0.307	0.203	0.354	0.294	0.348	0.310

Table 3: Hutcheson test of significance of general diversity index (H) between pairs of study stations

STATIONS	1	2	3	4	5	6
1						
2	S					
3	NS	S**				
4	NS	NS	S			
5	NS	S*	NS	NS		
6	NS	S	NS	NS	NS	

S** indicates highly significant difference ($p < 0.05$)
S* indicates very significant difference ($p < 0.05$)
S indicates significant difference ($p < 0.05$)
NS indicates no significant difference ($p > 0.05$)

Table 4: Fish similarity coefficient of pairs of study stations of Ogbei Stream (May 2008-April 2009)

	BELLINGER'S COEFFICIENT					
STATIONS	1	2	3	4	5	6
1						
2	1.000					
3	3.000	4.000				
4	0.000	4.000	0.000			
5	0.333	4.000	0.000	0.200		
6	1.000	0.200	4.000	3.000	3.000	

DISCUSSION

The results of the study indicated that the 15 species of fish from 10 families recorded for Ogbei Stream was of low diversity. Thus it did not compare favourably with earlier reports by earlier researchers on some Nigerian and West African water bodies: 46 fish species from 20 families sampled in Otamiri River (Okereke, 1990); 40 species representing 24 families in Ikpa Stream (Udoidiong and King, 2000), 44 species from 20 families in Mewd River, Ivory Coast (Kouadio *et al*., 2006). Such low fish diversity and quantity is a good indicator of a possible stressed ecosystem (Leveque, 1995; Emmanuel and Onyema, 2007).

The major taxon in the present study is the order Perciformes. Cichlidae, the dominant family had *Sarotherodon galilaeus* as the dominant taxon. The dominance of cichlids agreed with their high preponderance reported from other Nigerian waters. Udoidiong (1988) reported 6 species in Nung-Oku and Udom Streams ; Udoidiong and King (2000) reported 9 species in Iba-Oku Stream; Odo *et al.* (2009) reported 3 species in Anambra River and Onuoha *et al.* (2010) reported 11 species in Ntak Inyang Stream.

Feeding habit is one of the factors responsible for the abundance of cichlids. Cichlid fish had a euryphagic feeding habit, a strategy that allows for a switch from one diet to another and also disallows inter- and intra-species competition for food (Anene, 2005).

Lagler *et al.* (1977) stated that some African tilapias are called “mouthbrooders” because the young when they are hatched escape at time of danger into the oral cavity of either sex. The absence of large numbers of piscivorous fish species in the stream may have also contributed to their abundance.

Characidae with the highest species diversity was the dominant family in the order Cypriniformes. Araonye (1999) linked their high species diversity to diverse feeding habit and their prolific breeding capabilities. The abundance of the dominant taxon, *Hydrocynus vittatus* in Station 5 may be attributed to adequate living conditions such as temperature, velocity and dissolved oxygen. Odo *et al*. (2009) reported Characidae as the dominant family in Anambra River. Characids and catfishes are especially important and diverse in South American streams (Giller and Malmqist, 2002). Alfred-Ockiya and Otobo (1990) reported the characidae as mainly shallow backwater fish which are predatory along the pelagic zones.

Mochokidae is the most abundant family in the order Siluriformes. Odo *et al*. (2009) recorded Mochokidae as one of the dominant fish families in Anambra River. The abundance of the dominant taxon, *Synodontis robbianus* in Station 6 could be associated with food availability.The occurrence of the polylpterid, *Erpetoichthys calabaricus* (Polypteridae) in Station 4 may be due to low velocity, dissolved oxygen and food availability.

The African lung fish, *Protopterus annectens* (Protopteridae), in the order Lepidosireniformes was more abundant in Station 2. The most peculiar feature of this fish is that it has a pair of lungs which enables it to breathe air (Holden and Reed, 1972). Since they build nests in which eggs are laid, their abundance in this station may be associated with the presence of aquatic weeds growing along the banks where they build nests with plants.

Cyprinodontidae (*Epiplatys sexfasciatus*) of the order Cyprinodontiformes recorded in Station 2 may be attributed to the presence of aquatic plants and food availability. *Epiplatys sexfasciatus* seems to rely more readily on allochthonous food items from the surrounding (ants, beetles and arachnids) which are either blown into the water from the emergent vegetation or washed from the surrounding into the water by rain (Inyang and Anozie, 1987) and dipteran larvae. The absence of this fish in all other stations may be due to alterations through human activities.

The taxa richness (d), Shannon-Wiener index (H), highest species diversity (H_{max}), equitability (evenness) (E) and dominance (D) measures calculated by the Shannon-Wiener function all revealed the decimating impact of concrete structures on the fish communities.

Diversity of fish population was significantly higher ($p < 0.05$) in Station 2 implying a higher ecological stability. The reduced values of taxa richness and general diversity of fauna in Station 1 and the subsequent rise in most of the stations downstream was similar to the report of Ogbeibu and Victor (1989) for fish communities in Nigerian streams . Lenat *et al*. (1981) propounded two theories to explain this response; habitat reduction and habitat change theories. Where habitat reduction was most important, one would expect all groups to be equally affected. In this present study, all groups were not equally affected. Thus, habitat change caused by concrete structure and other human activities are bound to have led to a significant reduction in the density of all the groups except *Malapterurus electricus* which had higher density in Station 1 than in all other stations. The overall change observed has been described by Ogbeibu and Oribhabor (2001) as an increase or decrease in the importance of certain components of the normal community. The community was relatively less diverse and less stable in Station 1, with evidence of slow recovering in Stations 2 - 6 downstream.

The significant higher diversity in Station 2 is a reflection of its ecological heterogeneity and stability. The high evenness and low dominance index justify this situation, since the higher the evenness the higher the diversity (Victor and Ogbeibu, 1985).

The higher variability in diversity and evenness index that was observed in Station 1 is a reflection of community instability. Hutcheson’s test (Table 3) showed that Station 2 was significantly different ($p < 0.05$) from all other stations. Bellingers test showed that the fish fauna of Station 2 was significantly different from those Stations of 1,3, 4, 5 and 6. Ogbeibu (2005) indicated that the coefficient value will increase as the difference between population sizes increase.

CONCLUSION

This study revealed that fish respond to changes in water quality and habitat reduction of water bodies. This was observed in fish species composition, distribution and abundance at the study stations. Concrete structure distorted water proeprties of Ogbei Stream and adversely affected the fish species composition, distribution and abundance at station 1 where the concrete structure is erected. The low abundance and diversity in station 1 was due to habitat change and low microhabitat diversity caused by concrete structure. The higher significantly diversity observed in station 2 is a reflection of its ecological heterogeneity and stability. Generally, the result showed that concrete structure greatly reduces fish fauna, making them less diverse and less stable (as observed in station 1) with gradual recovery (as observed in stations 2, 3, 4, 5 and 6) downstream. An intensive three-year comprehensive post-impact evaluation of concrete structure on the fish fauna of Ogbei Stream is recommended for more relevant information necessary for the management of concrete structured streams.

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