Re-evaluation Survey of Fish Composition, Abundance and Distribution in Agbokim Waterfalls, Nigeria

Abstract

Alterations in the diversity of the ichthyofauna of a tropical waterfalls system can be affected by unsustainable utilisation of the fisheries resources, anthropogenic activities, runoff from faulty agricultural practices and environmental perturbation. To re-establish the status of the fish composition and diversity of Agbokim Waterfalls, monthly fish samples obtained from the fishery and physico-chemical properties were investigated in rainy and dry seasons, for~~in~~ six months along the length of the three reaches of the waterfalls. The results revealed a total of 833 fish specimens representing 18 species belonging to 15 genera from 9 families which is in deficit of four fish species, in the previous study which are *Alestes nurse* (Characidae), *Aphyosemion gardneri* (Cyprinodontidae), *Pelmatochromis guntheri* and *Hemichromis fasciatus* (Cichlidae). Cichlidae, Clariidae and Bagridae were the most abundant families accounting for 54.4% of the total catch with Cichlidae (23.17%) as the most dominant family and Mockokidae (1.68%) as the least with *Tilapia zillii* (15.4%), *Clarias gariepinus* (10.9%) and *Chrysichthys nigrodigitatus* (9.5%) as the most dominant species accounting for 35.8% and *Synodontis clarias* (1.7%) with the least abundance. Fish species distribution in the d~~D~~ownstream reach was dominant with 15 taxa and 607 (72.9%) individuals and in the m~~M~~idstream reach with 11 taxa but least (12.6%) number of individuals. Shannon Wiener diversity index for the six months was 2.7101 with Evenness value of 0.9376. The Richness index of Margalef's was 2.5279 and Menhinick's 0.6237. Seasonal variations in physico-chemical properties showed that, d~~D~~issolved o~~O~~xygen and c~~C~~onductivity were significantly ($P< 0.05$) higher in the raining season while pH showed no significant difference ($P > 0.05$). Temperature was significantly higher ($p < 0.05$) in the dry season than in the raining season. The hydrological properties showed a significantly higher mean values of r~~R~~ainfall (364.67± 0.00 mm) in the rainy and transparency (45.55± 1.58) in the dry season at ($P < 0.05$). In order to determine the cause of decline in fish species composition and abundance, further research on the heavy metals profile of the waterfalls is suggested.

Keywords: Waterfalls, Shannon Wiener index, Menhinick's index, Fish species, Physico-chemical properties, Distribution.

1. I~~ntroduction~~NTRODUCTION

The diversity of aquatic life particularly that of freshwater fish in a waterfalls ecosystem can be affected by fishery operations, other anthropogenic activities, organic pollution, chemical pollution (example heavy metals, pesticides and fertilizers) [1] and eutrophication, which in turn affect water quality, reduction in fish species composition, abundance and distribution, and the structure of other aquatic biota [2]. The effects of these changes on aquatic systems are severe especially where there is increasing demand for freshwater resources generated by continued growth in human population, urbanization, industrialization, irrigation and agricultural development, which cause serious alterations of the aquatic communities [3]. For example, in aquatic systems, it is well known that pesticides generally reduce the abundance and diversity of fish [4] and aquatic invertebrates and cause changes in community composition in rivers that receive polluted runoff [5] [6]. In extreme cases, pesticide runoff from agriculture can result in large fish kills[7]. Ecosystem threats include: climate change, pollution, habitat destruction, overexploitation and introduction of invasive species [3]. There are several reasons why the aquatic environments are so vulnerable to degradation, these include the complex properties of water itself, the interactions between the aquatic and the terrestrial environments and the proximity of human populations to aquatic systems [8] [3]. The productivity of various aquatic environments is driven largely by the capacity of- water as a solvent and its tendency to ionize dissolved substances. As a result, inland and near shore aquatic environments are affected not only by internal biogeochemical processes, but also by processes in adjacent terrestrial environments [9] [10]. Diversity can be viewed in terms of the number of species in an area (species richness) or in terms of the number of higher taxa, such as families, orders or phyla [10].The main reason for using fish to monitor biodiversity is that we know more about them than about other aquatic organisms, and are relatively easy to collect and identify[3].

Waterfalls are described as inland wetlands based on the Ramsar Classification system for 'Wetland Type' as approved by recommendation 4.7 of the Convention on Wetlands of International importance [11]. They are significant considering their economic importance in fisheries, ecotourism, ~~economic, hydrology~~ and agriculture. In the tropics, they serve the local communities with domestic water supply, bathing, swimming, transportation, fishing, as a source of food and sinks for waste products [9] [3] [1] and are also important in biodiversity and biodiversity conservation. A waterfalls faunal community is ~~an equivalent of any biological community and~~ one of ~~the~~ greatest diversity of aquatic life ~~is distributed in freshwater~~ [9] [12]. Fishes are good indicators in the determination of aquatic biodiversity because their variety reflects a wide range of environmental conditions [3].

Agbokim Waterfalls had previously been investigated [12] [13] [9] and showed that 22 fish species belonging to 16 genera and nine families were identified, with Cichlidae (22.0%), Clariidae (17.7%) and Cyprinidae (17.0%) as the dominant families and with *Tilapia zillii*, *Clarias gariepinus* and *Labeo coubie* respectively as the dominant fish species.The objectives of the present study is to re-evaluate the fish species composition, abundance, distribution and diversity and also physico-chemical and –hydrological properties of the Agbokim Waterfalls.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Agbokim Waterfalls in Cross River State, Nigeria, latitude 5°59' North and longitude 8°45' East. It is bounded in the West by the Cross River and in the North by the Cameroon high forests. The climate is the tropical hinterland type, with wet (May-November) and dry (December-April) seasons. Mean annual temperature ranged between 20℃ and 32℃ and annual total average rainfall, from 1450mm to 3015mm. The vegetation is the rainforest type with s~~S~~oil consisting of deep laterite and dark fertile, clay~~ey~~ and loamy soils. The Agbokim waterfall~~ as most others~~ is a product of two rivers, River Ekim and River Bakue, which are tributaries of the Cross River system. River Ekim is divided into three streams, while River Bakue has four streams. These seven streams flow into a floodplain, from where they independently cascade over steep cliff which provides seven-faced falls into the casket or waterfalls. Of ecological importance are numerous small pools and swamps which are found along the length of the waterfalls. The high annual discharge and rainfall of the area provide excellent buffers against natural ecological stresses such as drought [14]. For the purpose of this study, the 6817.7m long waterfall is divided into three reaches; upstream, midstream (region of waterfalls) and downstream. Upstream is EXPLANATION NEEDED TO CLARIFY THE LENGTH~~2003.13~~ 2003 m long with substrate of gravel and rocks under fast water current and shoreline covered with high forest and cocoa farms, m~~M~~idstream length of 807~~.42~~ m has substrates of sand and rocks under heavy water turbulence with shoreline sparsely shaded with vegetation while downstream length, 4007~~.15~~ m has fine sand and clay under slow water current with an extensive wide area.

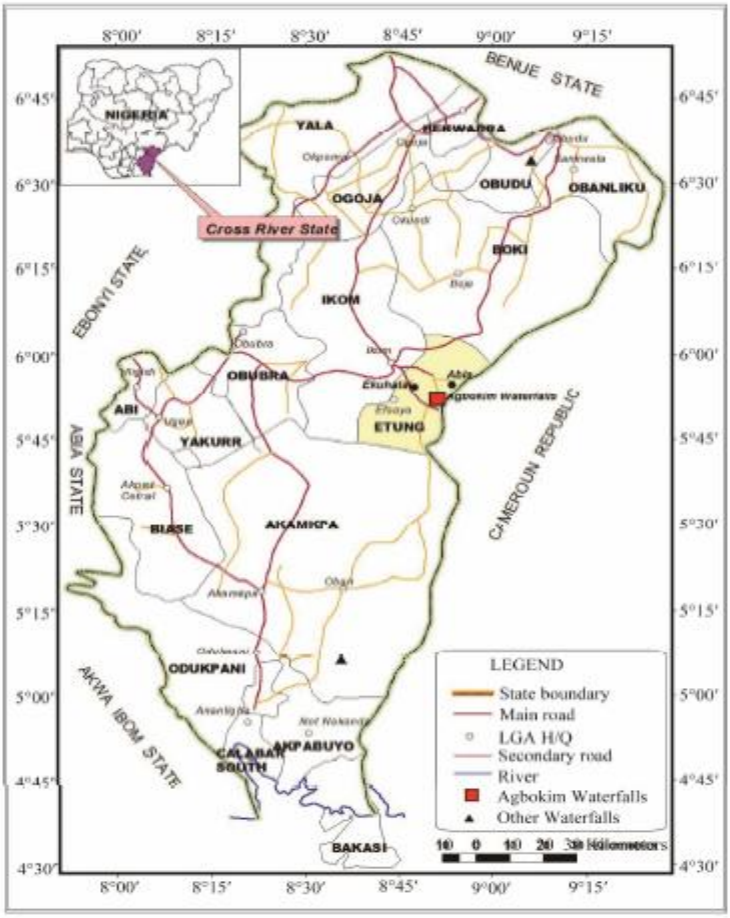

Figure 1: Map of Cross River State, Nigeria, showing Agbokim Waterfalls

~~2.2 Methodology~~

~~The study area was stratified into three study sites, these are Upstream, Midstream and Downstream. The stratification was based on high forest cover and moderately fast water currents during the dry season and very fast water current during the rainy season and nearness to cocoa farms in upstream. Very heavy water turbulence during the wet season and moderate water turbulence during the dry season with small vegetation in midstream, low water currents, stable ecological system with an extensive wide area in downstream.~~

THIS IS A REPEAT OF 2.1. SUGGEST DELETION

2.3 Fish sampling

Fish samples were randomally obtained from the fishery from~~ all~~ the three sites upstream, midstream and downstream ~~were randomly selected from each sampling point~~ at monthly intervals for six months between September, 2021 and February, 2022. As the fishers landed on return from fishing trips with the fish caught with variety of fishing gears~~, which included~~; (gill net with 22-76 mm stretched mesh size, seine net with 10 mm stretched mesh size and cast net 10 mm stretched mesh size, hooks and lines, cutlasses and traps), catches were~~ was~~ examined and sorted according to species. The fishing gears used by the fishers were identified with reference to FAO [15]. The fish weights to the nearest 0.1 g were recorded ~~measured with a balance~~ (Loading Melter model DM 2000~~)~~ for small fish and Salter model 180 for larger species)~~, after removing adhered water from body surface with blotting paper and number of species of fish landed were recorded~~. Sampling was done between 8.00am and 12noon. Fish samples were identified using Idodo-Umeh [16], Olaosebikan and Raji [17] and Holden and Reed [18]. Total fish landings were estimated in each reach.

2.4 Species abundance and diversity

Species abundance of each sampling reach was presented as a numerical contribution by~~ each~~ species. This was determined by calculating the percentage each species represented of the total catch for each site, based on the number of species and relative abundance.

2.5 Physico-chemical and hydrological sampling

Physico-chemical and hydrological parameters were determined monthly between September, 2021 and February, 2022. Standard methods for the examination of water and waste water [19] were used for all measurements. Monthly rainfall data for the study sites was obtained from weather meteorological stations, located in each of the three reaches. Habitat variables, ~~like~~ length and width of the waterfalls system wereas measured on site. Water velocity (flow velocity) was determined by recording~~ water~~ velocity readings using Wagtech current flow meter model WFM001 with 125mm diameter impella.

2.6 Data analysis

To calculate mean abundance, numbers in different samples were summed for each species and averaged across all sampling reaches. Shannon-Wiener diversity function (H’) was used to calculate heterogeneity for each site. Richness index was expressed using Margalef’s richness index and Menhinick’s richness index. The mean and standard deviation of each of the physico-chemical parameters were calculated. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the sampling reaches.

$$d = (S - 1) / \log N$$ [20]

$$H' = -\sum_{i=1}^{S} P_i \ln P_i$$ [21]

$$D_{Mn} = S/\sqrt{N}$$ [22] [23]

H´ = Shannon-Wiener Diversity Function [21]

$$E = H'/H_{max} = H'/\ln S$$ [21] [24]

E = Equitability/Evenness is the ratio of observed diversity to maximum diversity

d = Margalef's richness index

D_{Mn} = Menhinick's richness index where S = total species number and √N = square root of the total number of individuals summed over all S species.

S = total species number

p_i = proportion of each species in each sample

Relative abundance % = (n/N) × 100,

n refers to the number of individuals of the species in the samples and N to the total number of individuals of fish caught.

3. RESULTS

3.1 Fish species composition, abundance and distribution

NEED TO REFER TO ALL TABLES IN NUMERICAL SEQUENCE, FROM TABLE 1 TO TABLE 5. I N THIS SECTION TABLES 2-4 ARE OMITTED. The results revealed a total of 833 fish specimens representing 18 species belonging to 15 genera from 9 families in rainy and dry seasons (Table 1), which is in deficit of four fish species, in the previous study which are *Alestes nurse* (Characidae), *Aphyosemion gardneri* (Cyprinodontidae) and *Pelmatochromis guntheri* and *Hemichromis fasciatus* (Cichlidae). Cichlidae, Clariidae and Bagridae were the most abundant families accounting for 54.4% of the total catch with Cichlidae (23.17%) as the most dominant family and Mockokidae (1.68%) as the least with *Tilapia zillii* (15.4%), *Clarias gariepinus* (10.9%) and *Chrysichthys nigrodigitatus* (9.5%) were the most dominant species accounting for 35.8% and *Synodontis clarias* (1.7%) with the least abundance. Fish species distribution along reaches, revealed dDownstream reach as dominant with 15 taxa and 607 (72.9%) individuals followed by uUpstream with 11 taxa 121 (14.4%) individuals with mMidstream also with 11 taxa but least (12.6%) number of individuals (Table 5). During sampling *Aphyosemion filamentosum* and *Epiplatys sexfasciatus* in the family Cyprinodontidae; *Distichodus rostratus* and *Distichodus engycephalus* in the family Distichodontidae and *Clarias anguillaris* in the family Clariidae where not in the distribution in uUpstream and mMidstream while *Auchenoglanis occidentalis* in the family Bagridae were not represented in the distribution but only in uUpstream and *Hepsetus odoe* in the family Hepsetidae were also not represented except in mMidstream Table 5. The dominant fish species in uUpstream were *Tilapia zillii* (24.8%) followed by *Clarias gariepinus* (20.7%) and *Chrysichthys nigrodigitatus* (13.2%); mMidstream had *Clarias gariepinus* (15.2%) as dominant, *Chrysicthys nigrodigitatus* (13.2%) and *Tilapia zillii* (11.4%) as the least.

3.2 Richness and Diversity indices

The Shannon Wiener diversity index for the six months was 2.7101 with Equitability or Evenness value of 0.9376. The Richness index value of Margalef's was 2.5279 while the Menhinick's richness index value was 0.6237 Table 2. The seasonal variation showed a rainy season Shannon Wiener value of 2.7363 with Equitability value of 0.9467 and with 2.7536 Margalef's richness value and 0.8215 Menhinick's richness index value. The rainy season Richness and Diversity index values were all higher than the dry season's with Shannon Wiener 2.6618, Equitability 0.9209, Margalef's index 2.8978 and Menhinick's index 0.9580 Table 3. The results for the reaches showed a higher Shannon Wiener index value of 2.7329 for dDownstream followed by mMidstream 2.1756 and uUpstream with the lowest value of 2.1695. It followed the same pattern with Evenness, Margalef's and Menhinick's index with dDownstream values of 0.9455, 2.6527 and 0.7306 respectively; mMidstream 0.8755, 2.3635 and 1.1711 respectively with uUpstream values of 0.8731, 2.2937 and 1.0909 respectively Table 4.

3.3 Physico-chemical and Hydrological Properties

The results of the pPhysico-chemical properties of the study area areis shown in Figures 2 – 4. Upstream Temperature values ranged from 24.2 – 29.0^{o}C, dDissolved oxygen 6.0 - 8.7mg/l and cConductivity 14.0 – 72.10µS/cm (Figure 2). The lowest value of tTemperature and the highest of cConductivity were recorded in September while February had the least values of dDissolved oxygen and highest pH. At the mMidstream the tTemperature ranged from 24.2 – 29.2^{o}C, DO 5.0 – 6.6mg/l and cConductivity 70.2 – 12.1 µS/cm (Figure 3). The months of September recorded the highest value of cConductivity and lowest tTemperature while that of January had the highest of tTemperature and lowest of cConductivity. The pH was almost constant with a lower range of 6.7 – 7.1 with the highest value recorded in February. Similar trend in the values of physico-chemical properties was also recorded at the dDownstream with tTemperature and cConductivity. However February had the least cConductivity value and the highest temperature. The range in the values of cConductivity were lower at the dDownstream than mMidstream and uUpstream respectively.

Seasonal variations in physico-chemical properties showed that, dissolved oxygenDO and cConductivity were significantly (P< 0.05) higher in the raining season. While pH was not (P > 0.05) significant, tTemperature was higher (p < 0.05) in dry season than in the raining season.

The overall mean values of the hydrological properties showed a significantly higher mean values of rRainfall (364.67± 0.00 mm) in the rainy and transparency (45.55± 1.58) in the dry season at (P < 0.05) but with wWater velocity that showed no significant difference (P > 0.05) with values that ranged from 0.76±0.04 – 1.37±0.05 with the least value in October and highest in January (Table 7).

4. DISCUSSION

Fish communities are described, identified and classified in various ways reflecting the goals of the present? study and the attributes to be emphasized. In some cases fish communities or species- assemblages have been named on the basis of ecology and numerical dominance.

The ichthyofauna diversity of Agbokim Waterfalls had previously been investigated [9] [12] with a total of 5484 fish representing 22 fish species belonging to 16 genera from 9 families with *Tilapia zilii* (Cichlidae 22.0%), *Clarias gariepinus* (Clariidae 17.7%) and *Labeo coubie* (Cyprinidae 175.0%) as dominant fish species and families. A re-evaluation study was conducted following concerns from stakeholders and some non-governmental organizations on the abuse of the system arising from anthropogenic activities and environmental perturbation. This investigation revealed a total number of 833 fish specimens representing 18 species belonging to 15 genera from 9 families which is in deficit of four fish species, in the previous study Ikpi [9] and Offem, [12], which are *Alestes nurse* (Characidae), *Aphyosemion gardneri* (Cyprinodontidae) and *Pelmatochromis guntheri* and *Hemichromis fasciatus* (Cichlidae) and with *Tilapia zillii* (Cichlidae), *Clarias gariepinus* (Clariidae) and *Chrysichthys nigrodigitatus* (Bagridae) as dominant fish species and families which is not in agreement with the previous study Ikpi and Offem, [12] where the third dominant species was *Labeo coubie*. This findings revealed a lower fish abundance and richness in the present study than the previous study, and followed the~~same~~ trend of the previous study, where d~~D~~ownstream revealed a higher abundance with 607 individuals followed by u~~U~~pstream with 121 and m~~M~~idstream 105.~~ with the least~~. Similar studies Olele *et al*. [25] followed the same pattern on the composition, abundance and distribution of fishes in Onah Lake, Asaba, Nigeria, showed that site~~tation~~ C was~~-~~ the most abundant with 1009 fish species followed by site~~tation~~ A with 880 individuals and site~~tation~~ B with the least abundance. The number of individuals in the present~~is~~ study, is far lower than that of the previous study Ikpi, [9] which has supports the possibility~~increased the suspicion~~ of a~~the~~ negative impact of anthropogenic activities, faulty agricultural practices leading to soil erosion and runoff of chemicals such as pesticides and fertilizers into the waterfalls, which is similar to the findings of Betts *et al.* [4] that pesticides generally reduce the abundance and diversity of fish and aquatic invertebrates in rivers and streams that receive polluted runoffs [5] [6]. ~~This~~ ? WHICH STUDY study is also higher than Ndome *et al*. [26] on the ichthyofauna of the upstream and downstream reaches of the Kwa Falls, Oban, Cross River State, Nigeria with a total of 562 fish representing 12 species belonging to 11 genera from 10 families and 6 orders; a~~. A~~nd also higher than Ikenna *et al*.,[27] in the~~his~~ investigation of Otamiri River, with a total of 129 benthic fish fauna belonging to 5 species and 4 families with *Chrysichthys nigrodigitatus* (32.65%) as the most dominant fish species and *Synodontis soloni* (2.18%) as less dominant. Ikenna *et al*.[27] reported that anthropogenic activities at Otamiri River (a tributary of Imo River) in Imo State, Nigeria affected the faunal diversity of the system.

4.1 Fish richness and diversity indices

The overall Margalef's richness index September, 2021 to February, 2022 was 2.5279 which was higher than 1.932 reported by Ndome *et al*. [26] in their downstream. The Menhinick's richness index value 0.6237 of the AGAIN BE CLEAR ON WHICH STUDYstudy was however lower than the Margalef's richness value of Ndome *et al*. [26]. The Shannon Wiener Index during rainy and dry seasons of the study was 2.7101 which was higher than Emmanuel [28] with 2.015, 1.899 and 1.896 of the three stations in the three tributaries of

River Ore, South West, Nigeria. Equitability 0.9376 in the AGAINstudy was also higher than Emmanuel [28] with value 0.740. The difference can be attributed to disparity in ecological zones, hence the values for H' obtained for both monthly and across reaches in the present?his study indicates a good spread of species diversity but with low abundance. Seasonal variation in the diversity indices revealed higher values for the rainy season fish samples over dry season's for Shannon Wiener and Equitability but with higher richness index values of Margalef's and Menhinick's for dry season over rainy season.

4.2 Physico-chemical and Hydrological properties

Seasonal variations in physicochemical properties showed that, dissolved oxygenDO, and cConductivity were significantly ($P < 0.05$) higher in the raining season which was in agreement with Ikpi, [9]; -Ikpi and Offem [12]. -While pH was not significant ($P > 0.05$) and also in agreement with Ikpi [9]; Ikpi and Offem [12]. Temperature was higher ($p < 0.05$) in dry season than in the raining season. There was no significant difference in pH across seasons. Water Temperature, Dissolved Oxygen and pH recorded in this study were within the values recommended by Boyd [29].

The overall mean values of the hydrological properties showed a significantly higher mean values of Rainfall (364.67± 0.00 mm) in the rainy and transparency (45.55± 1.58) in the dry season at $P < 0.05$. Water velocity showed no significant difference which was not in agreement with Ikpi and Offem [12] that showed significant differences.

Table 1**:** Composition and relative abundance of fish families and species

S/N	**FISH FAMILY**	**FISH SPECIES**	**SAMPLE CATCH (RAINY SEASON)**	**PERCENTAGE TOTAL**	**SAMPLE CATCH (DRY SEASON)**	**PERCENTAGE TOTAL**	**SAMPLE CATCH (RAINY AND DRY SEASON)**	**PERCENTAGE TOTAL**
1.	**Hepsetidae**	*Hepsetus odoe*	19	3.96	11	3.12	30	3.60
			19	**3.96**	**11**	**3.12**	**30**	**3.60**
2.	**Characidae**	*Hydrocynus vitatus*	13	2.71	8	2.27	21	2.52
		Alestes macrolepidotus	27	5.63	20	5.67	47	5.64
			40	**8.33**	**28**	**7.94**	**68**	**8.16**
3.	**Bagridae**	*Auchenoglanis occidentalis*	29	6.04	21	5.95	50	6.00
		Chrysichthys nigrodigitatus	42	8.75	37	10.48	79	9.48
			71	**14.79**	**58**	**16.43**	**129**	**15.48**
4.	**Claridae**	*Heterobranchus bidorsalis*	13	2.71	9	2.55	22	2.64
		Clarias gariepinus	48	10.00	43	12.18	91	10.92
		Clarias anguillaris	11	2.29	7	1.98	18	2.16
			72	**15.00**	**59**	**16.71**	**131**	**15.72**
5.	**Mockokidae**	*Synodontis clarias*	8	1.67	6	1.70	14	1.68
			8	**1.67**	**6**	**1.70**	**14**	**1.68**
6.	**Distichodontidae**	*Distichodus rostratus*	25	5.21	18	5.10	43	5.16
		Distichodus engycephalus	11	2.99	7	1.98	18	2.16
			36	**7.50**	**25**	**7.08**	**61**	**7.32**
7.	**Cyprinidae**	*Labeo coubie*	38	7.92	33	9.35	71	8.52
		Barbus occidentalis	17	3.54	12	3.40	29	3.43
			55	**11.46**	**45**	**12.75**	**100**	**11.95**
8.	**Cyrinodontidae**	*Aphyosemion filamentosum*	41	8.54	20	5.67	61	7.32
		Epiplatys sexfasciatus	28	5.83	18	5.10	46	5.52
			69	**14.38**	**38**	**10.77**	**107**	**12.84**
9.	**Cichlidae**	*Tilapia zillii*	68	14.17	60	11.00	128	15.37
		Tilapia melanopleura	16	3.33	10	2.83	26	3.12
		Oreochromis niloticus	26	5.42	13	3.68	39	4.68
			110	**22.93**	**83**	**17.51**	**193**	**23.17**
			480	**100**	**353**	**100**	**833**	**100**

Table 2**:** Fish Abundance during Rainy and Dry Seasons Using Diversity Indices

S/N	FISH SPECIES	Abundance	Pi	(ln) Pi	Pi (ln) Pi
1)	*Hepsetus odoe*	30	0.0360	-3.3242	-0.1197
2)	*Hydrocynus vittatus*	21	0.0252	-3.6809	-0.0928
3)	*Alestes macrolepidotus*	47	0.0564	-2.8753	-0.1622
4)	*Auchenoglanis occidentalis*	50	0.0600	-2.8134	-0.1689
5)	*Chrysichthys nigrodigitatus*	79	0.0948	-2.3560	-0.2234
6)	*Heterobranchus bidorsalis*	22	0.0264	-3.6344	-0.0960
7)	*Clarias gariepinus*	91	0.1092	-2.2146	-0.2419
8)	*Clarias anguillaris*	18	0.0216	-3.8351	-0.0829
9)	*Synodontis clarias*	14	0.0168	-4.0864	-0.0687
10)	*Distichodus rostratus*	43	0.0516	-2.9642	-0.1530
11)	*Distichodus engycephalus*	18	0.0216	-3.8351	-0.0829
12)	*Labeo coubie*	71	0.0852	-2.4628	-02099
13)	*Barbus occidentalis*	29	0.0348	-3.3581	-0.1169
14)	*Aphyosemion filamentosum*	61	0.0732	-2.6146	-0.1915
15)	*Epiplatys sexfasciatus*	46	0.0552	-2.8968	-0.1600
16)	*Tilapia zillii*	128	0.1537	-1.8728	-0.2878
17)	*Tilapia melanopleura*	26	0.0312	-3.4673	-0.1082
18)	*Oreochromis niloticus*	39	0.0468	-3.0619	-0.1434
	Total	**833**			**-2.7101**
	Shannon Wiener Index				**2.7101**

Shannon Wiener Index H' = -∑ = 2.7101
Margalef's Index d = (S – 1)/lnN = 2.5279

Menhinick's Index $D_{Mn} = S/\sqrt{N}$ = 0.6237

Evenness (E) = H'/lnS = $\frac{2.7101}{\ln 18}$

Evenness (E)/Equitability = 0.9376

Table 3: Seasonal variation of diversity indices by species

S/N		RAINY SEASON (SEPTEMBER TO NOVEMBER, (2021)				DRY SEASON (DECEMBER, 2021 TO FEBRUARY, (2022)			
	FISH SPECIES	ABUNDANCE	PI	(LN)PI	PI(LN)PI	ABUNDANCE	PI	(LN)PI	PI(LN)PIL
1)	*Hepsetus odoe*	19	0.0396	-3.2289	-0.1278	11	0.0312	-3.4673	-0.1080
2)	*Hydrocynus vittatus*	13	0.0271	-3.6082	-0.0977	8	0.0227	-3.7854	-0.0858
3)	*Alestes macrolepidotus*	27	0.0563	-2.8771	-0.1618	20	0.0567	-2.8700	-0.1626
4)	*Auchenoglanis occidentalis*	29	0.0604	-2.8068	-0.1696	21	0.0595	-2.8218	-0.1679
5)	*Chrysichthys nigrodigitatus*	42	0.0875	-2.4361	-02132	37	0.1048	-2.2557	-0.2364
6)	*Heterobranchus bidorsalis*	13	0.0271	-3.6082	-0.0977	9	0.0255	-3.6691	-0.0935
7)	*Clarias gariepinus*	48	0.1000	-2.3026	-0.2303	43	0.1218	-2.1054	-0.2565
8)	*Clarias anguillaris*	11	0.0229	-3.7766	-0.0865	7	0.0198	-3.9221	-0.0778
9)	*Synodontis clarias*	8	0.0167	-4.0923	-0.0682	6	0.0170	-4.0745	-0.0693
10)	*Distichodus rostratus*	25	0.0521	-2.9546	-0.1539	18	0.0510	-2.9759	-0.1517
11)	*Distichodus engycephalus*	11	0.0229	-37766	-0.0865	7	0.0198	-3.9221	-0.0778
12)	*Labeo coubie*	38	0.0792	-2.5358	-0.2007	33	0.0935	-2.3698	-0.2215
13)	*Barbus occidentalis*	17	0.0354	-3.3410	-0.1183	12	0.0340	-3.3814	-0.1149
14)	*Aphyosemion filamentosum*	41	0.0854	-2.4604	-0.2102	20	0.0567	-2.8700	-0.1626
15)	*Epiplatys sexfasciatus*	28	0.0583	-2.8422	-0.1658	18	0.0510	-2.9759	-0.1517
16)	*Tilapia zillii*	68	0.1417	-1.9540	-0.2768	60	0.1700	-1.7720	-0.3012
17)	*Tilapia melanopleura*	16	0.0333	-3.4022	-0.1134	10	0.0283	-3.5649	-0.1010
18)	*Oreochromis niloticus*	480	0.0542	-2.9151	-0.1579	13	0.0368	-3.3.23	-0.1216
					-2.7363	**353**			**-2.6618**
					H' = 2.7363				**H' = 2.6618**

Shannon Wiener Index H' = -∑

Shannon Wiener index value for Rainy season = H' = 2.7363

Shannon Wiener Index value Dry season = H' = 2.6618

Margelef's Index (d) (Rainy season) = 2.7536

Margelef's Index (d) (Dry season) = 2.8978

Menhinick's Index (D_{Mn}) (Rainy season) = 0.8215

Menhinick's Index (D_{Mn}) (Dry season) = 0.9580

Evenness € / Equitability (Rainy season) = 0.9467

Evenness € / Equitability (Dry season) = 0.9209

Evenness Index (Rainy Season) = 0.9467

Evenness Index (Dry Season) = 0.9209

Table 4: Diversity indices in Upstream, Midstream and Downstream

S/N	FISH SPECIES	UPSTREAM				MIDSTREAM				DOWNSTREAM			
		ABUNDANCE	**PI**	**(LN)PI**	**PI(LN)PI**	**ABUNDANCE**	**PI**	**(LN)PI**	**PI(LN)PI**	**ABUNDANCE**	**PI**	**(LN)PI**	**PI(LN)PI**
1)	*Hepsetus odoe*	3	0.0360	-3.3242	-0.1197	-	-	-	-	27	0.0445	-3.1127	-0.1385
2)	*Hydrocynus vittatus*	2	0.0165	-4.1044	-0.0677	3	0.0286	-3.5543	-0.1017	16	0.0264	-3.6359	-0.090
3)	*Alestes macrolepidotus*	5	0.0413	-3.1869	-0.1316	9	0.0857	-2.4567	-0.2105	33	0.0544	-2.9120	-0.1584
4)	*Auchenoglanis occidentalis*	-	-	-	-	11	0.1048	-2.2561	-0.2364	39	0.0643	-2.7450	-0.1765
5)	*Chrysichthys nigrodigitatus*	16	0.1322	-2.0234	-0.2675	14	0.1333	-2.0149	-0.2686	49	0.0807	-2.5167	-0.2031
6)	*Heterobranchus bidorsalis*	6	0.0496	-3.0040	-0.1490	-	-	-	-	16	0.0264	-3.6359	-0.0960
7)	*Clarias gariepinus*	25	0.2066	-1.5770	-0.3258	16	0.1524	-1.8814	-0.2867	50	0.0824	-2.4965	-0.2057
8)	*Clarias anguillaris*	-	-	-	-	-	-	-	-	18	0.0297	-3.5182	-0.1045
9)	*Synodontis clarias*	2	0.0165	-4.1044	-0.0677	3	0.0286	-3.5543	-0.1017	9	0.0148	-4.2113	-0.0623
10)	*Distichodus rostratus*	-	-	-	-	6	0.0571	-2.8622	-0.1634	37	0.0610	-2.7976	-0.1707
11)	*Distichodus engycephalus*	-	-	-	-	3	0.0286	-3.5543	-0.1017	15	0.0247	-3.7005	-0.0914
12)	*Labeo coubie*	13	0.1074	-2.2308	-0.2396	11	0.1048	-2.2561	-0.2364	47	0.0774	-2.5584	-0.1980
13)	*Barbus occidentalis*	6	0.0496	-3.0040	0.1490	4	0.0381	-3.2677	-0.1245	19	0.0313	-3.4641	-0.1084
14)	*Aphyosemion filamentosum*	-	-	-	-	-	-	-	-	61	0.1005	-2.2977	-0.2309
15)	*Epiplatys sexfasciatus*	-	-	-	-	-	-	-	-	46	0.0758	-2.5799	-0.1956
16)	*Tilapia zillii*	30	0.2479	-1.3946	-0.3457	12				86	0.1417	-1.9542	-0.2769
17)	*Tilapia melanopleura*	4	0.0331	-3.4095	-0.1129	6	0.0571	-2.8622	-0.1634	16	0.0264	-3.6359	-0.0960
18)	*Oreochromis niloticus*	9	0.0744	-25986	-0.1933	7	0.0667	-2.7081	-0.1806	23	0.0379	-3.2730	-0.1240
		121			**2.1695**	**105**			**2.1756**	**607**			**2.7329**

Upstream: Shannon Wiener index 2.1695; Evennes 0.8731; Margalef's index 2.2937; Menhinick's index 1.0909

Midstream: Shannon Wiener index 2.1756; Evenness 0.8755; Margalef's index 2.3635; Menhinick's index 1.1711

Downstream: Shannon Wiener index 2.7329; Evenness 0.9455; Margalef's index 2.6527; Menhinick's index 0.7306

Table 5: Fish distribution in sampling Reaches during rainy and dry seasons

			UPSTREAM		MIDSTREAM		DOWNSTREAM	
S/N	Family	Fish Species	Abundance&(%)		Abundance & (%)		Abundance & (%)	
1)	Hepsetidae	*Hepsetus odoe*	3	(2.48)	-		27	(4.45)
2)	Characidae	*Hydrocynus vittatus*	2	(1.65)	3	2.86	16	(2.64)
		Alestes macrolepidotus	5	(4.13)	9	8.57	33	(5.44)
3)	Bagridae	*Auchenoglanis occidentalis*	-	-	11	10.48	39	(6.43)
		Chrysichthys nigrodigitatus	16	(13.22)	14	13.33	49	(8.07)
4)	Claridae	*Heterobranchus bidorsalis*	6	(4.96)	-	-	16	(2.64)
		Clarias gariepinus	25	(20.66)	16	(15.24)	50	(8.24)
		Clarias anguillaris	-	-	-	-	18	(2.97)
5)	Mockokidae	*Synodontis clarias*	2	(1.65)	3	(2.86)	9	(1.48)
6)	Distichodontidae	*Distichodus rostratus*	-	-	6	(5.71)	37	(6.10)
		Districhodus engycephalus	-	-	3	(2.86)	15	(2.47)
7)	Cyprinidae	*Labeo coubie*	13	(10.74)	11	(10.48)	47	(7.74)
		Barbus occidentalis	6	(4.96)	4	(3.81)	19	(3.13)
8)	Cyprinodontidae	*Aphyosemion filamentosum*	-	-	-	-	61	(10.05)
		Epiplatys sexfasciatus	-	-	-	-	46	(7.58)
9)	Cichlidae	*Tilapia zilli*	30	(24.79)	12	(11.43)	86	(14.17)
		Tilapia melanopleura	4	(3.31)	6	(5.71)	16	(2.64)
		Oreochromis niloticus	9	(7.44)	7	(6.67)	23	(3.79)
	Total		**121**	**100**	**105**	**100**	**607**	**100**

Values in parenthesis = percentage abundance (%).

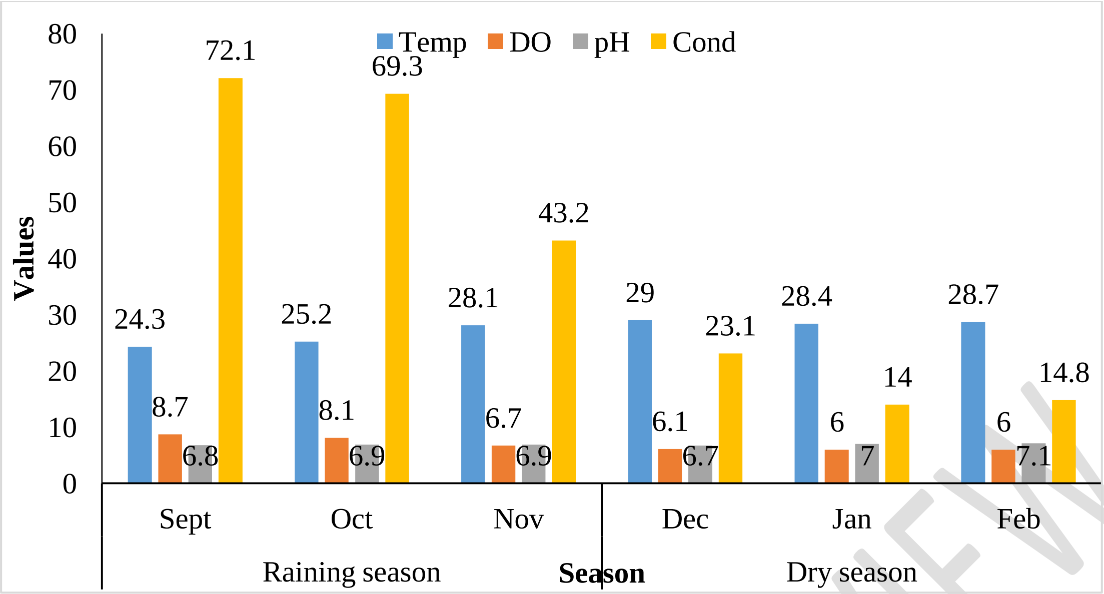

Figure 2: Monthly variation of the physico-chemical parameters in u~~U~~pstream.

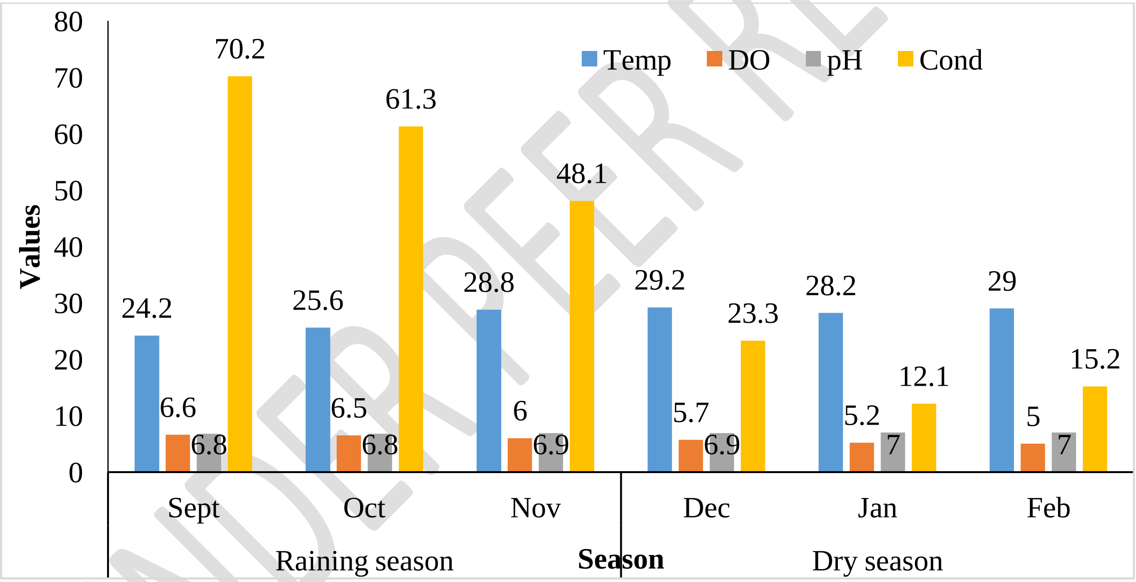

Figure 3: Monthly variation of the physico-chemical parameters in m~~M~~idstream.

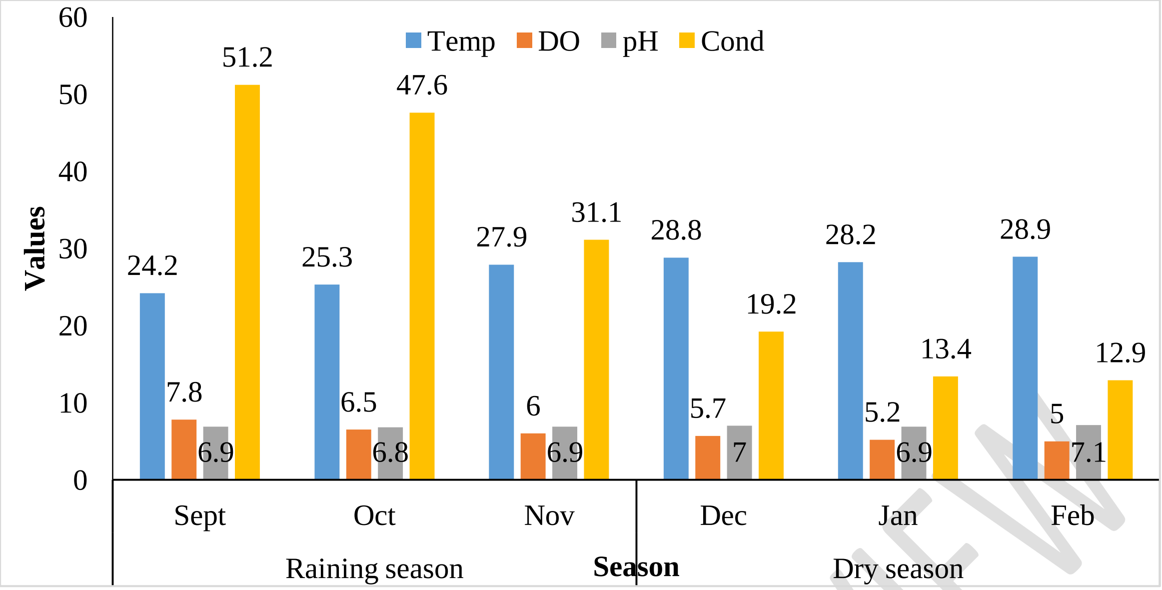

Figure 4: Monthly variation of the physico-chemical parameters in dDownstream.

Table -6:- Seasonal and monthly changes in the mean values of the physicochemical properties

Season	Month	Physicochemical Properties			
		Temperature (C^0)	**Dissolved Oxygen (DO) (mgl^{-1})**	**pH**	**Conductivity (μScm^{-1})**
Raining Season	September	24.23± 0.06	7.70 ±1.05	6.83± 0.06	64.50 ±11.55
	October	25.34 ±0.21	7.03 ±0.93	6.83± 0.06	59.40 ±10.97
	November	28.27± 0.47	6.23± 0.40	6.87 ±0.15	21.87 ±2.31
	Total	25.95 ± 0.74^b	6.99 ±2.38^a	6.84 ±0.27^a	48.60 ± 24.83^a
Dry Season	December	29.00 ±0.20	5.83± 0.23	6.87 ±0.15	21.87 ±2.31
	January	28.27 ±0.12	5.47± 0.46	6,.97± 0.06	13.17 ±0.97
	February	28.87± 0.15	5.33 ±0.57	7.07 ±0.06	14.30 ±1.23
	Total	28.71 ± 0.47^a	5.54 ± 1.26^b	6.79 ±0.27^a	16.45 ±4.51^b

Mean with the same alphabet in the same parameter for the respective seasons are not significant at ($p < 0.05$).

Table 7: Seasonal and monthly changes in the mean values of the hydrological properties

Season	Month	Rainfall (mm)	Transparency (cm)	Water velocity (ms^{-1})
Raining Season	September	582.50 ± 0.00	23.33 ± 1.53	0.79 ± 0.05
	October	379.0 ± 0.00	25.67 ± 1.53	0.76 ±0.04
	November	132.50± 0.00	32.17 ± 1.04	1.18 ± 0.06
	Total	364.67 ±0.00[b]	27.06 ± 1.53[b]	1.18 ± 0.06[a]
Dry Season	December	81.00±0.00	42.00 ± 1.00	1.28 ± 0.12
	January	52.00 ±0.00	47.33 ± 0.29	1.37± 0.05
	February	40.00± 0.00	47.33 ± 0.29	1.37 ±0.01
	Total	57.67 ± 0.00[a]	45.55 ± 1.58[a]	1.34 ± 0.02[a]

Mean with the same alphabet in the same parameter for the respective seasons are not significant at ($p < 0.05$).

5 CONCLUSIONonclusion

The present study showed a total number of 833 fish specimens representing 18 species belonging to 15 genera from 9 families which is in deficit of four fish species, which are *Alestes nurse* (Characidae), *Aphyosemion gardneri* (Cyprinodontidae) and *Pelmatochromis guntheri* and *Hemichromis fasciatus* (Cichlidae) which is in difference of the previous studyGIVE THE REFERENCE with a total of 5484 fish representing 22 fish species belonging to 16 genera from 9 families. Whereas *Chrysichthys nigrodigitatus* (Bagridae) is the third dominant fish species in this study, *Labeo coubie* (Cyprinidae) was the third dominant fish species. Water velocity was influenced by rainfall intensity and steep gradient. In order to determine the cause of decline in fish species composition and abundance, further research on the the heavy metals profile of the waterfalls is suggested.

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