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Distribution and dynamics of a tropical waterfalls ecosystem

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ABSTRACT

Key-words: *waterfalls, macro-invertebrates, phytoplankton, zooplankton, vegetation, fish species, physic-chemical properties*

Waterfalls gives the impression of a lifeless zone because researchers have historically focused on the hydrology, ecotourism and geological features. Effective management will require an understanding of changes in species composition and distribution of macro-biota. Monthly samples were taken in wet and dry seasons, over two year period in three regions along the 6817.7 m length of the Agbokum waterfalls. Macro-biota exhibited distinct pattern in respect of seasonal and spatial changes. *Trachelomonas volzii*, the most abundant phytoplankton species reduced from 686 in the dry season to 143 in the wet, and from 455 downstream to 91, midstream (waterfalls region). Zooplankton species *Calanus finmarchicus* decreased from 511 during dry season to 36 in the wet and from 334 downstream to 7, midstream. 71.7 percent of the total macro-invertebrates were recorded from downstream reaches while only 6.3 percent were contributed by midstream. Percentage cover of marginal vegetation by *Bambusasp, Symphonia* and *Elaeis guineesis* displayed progressive increase from upstream reaching a maximum of 38.5 mean percent cover in the relatively undisturbed downstream. In contrast, *Raphia vinifera*, *Havea brasiliensis*, *Grewia* sp. and *Cocos nucifera* shrank in size from 34% to 8% at the midstream stretches of the river while only *nymphia*- rich vegetation becomes more frequent in the middle reaches. The disturbance regimes of the midstream reaches of Agbokum waterfalls combined with its very low faunal and floral diversity has made the environment unstable therefore susceptible to the invasion of disturbance tolerant biota.

RÉSUMÉ

Distribution et dynamique d'un écosystème tropical de cascades

Mots-clés : cascades, macro-invertébrés, phytoplancton, zooplancton, végétation, espèces piscicoles, propriétés physico-chimiques

Les cascades donnent l'impression d'une zone morte parce que les chercheurs ont toujours mis l'accent sur l'hydrologie, l'écotourisme et les caractéristiques géologiques. Une gestion efficace nécessite la compréhension des changements dans la composition des espèces et la distribution des macro-organismes. Des échantillons mensuels ont été pris au cours des saisons humides et sèches, pendant plus de deux ans dans trois régions le long des 6817,7 m des cascades Agbokum. Les macrobiotes présentent des patterns différents selon les changements saisonniers et spatiaux. *Trachelomonas volzii,* l'espèce de phytoplancton la plus abondante, passe de 686 en saison sèche à 143 en saison humide, et de 455 en aval à 91 en zone médiane (région des cascades). L'espèce de zooplancton

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Calanus finmarchicus passe de 511 pendant la saison sèche à 36 en saison humide et de 334 en aval à 7, en zone médiane. 71,7 % du total des macro-invertébrés ont été rencontrés dans les tronçons situés en aval, tandis que seulement 6,3 % sont trouvés dans les tronçons médians. Parmi les trois espèces de poissons dominantes *Tilapia zillii, Clarias gariepinus* et *Labeo coubie,* constituant 45,5 % des captures totales, deux poissons benthiques (*L. coubie* et *C. gariepinus)* présentent des schémas de distribution inverses. Les Clariidés (*C. gariepinus)* se trouvent les plus abondantes en aval et les moins représentées en amont. Les Cyprinidés *(L. coubie),* d'autre part, dominent les tronçons en amont et sont rares en aval. Le pourcentage de couverture de la végétation rivulaire par *Sambusasp, Symphonia* et *Elaeis guineesis* présente une augmentation progressive depuis l'amont pour atteindre un maximum de 38,5 % de couverture moyenne en aval relativement bien préservé. En revanche, *Raphia vinifera, Havea brasiliensis, Grewia* sp. et *Cocos nucifera* diminuent de 34 % à 8 % sur les tronçons médians du fleuve. *Nymphia* est devenue envahissante et présente toute une gamme d'impacts dans un tronçon médian perturbé. Les régimes de perturbation du tronçon médian des cascades Agbokum combinés avec sa très faible diversité faunistique et floristique rend l'environnement instable donc sensible à l'invasion d'espèces tolérantes aux perturbations.

INTRODUCTION

Waterfalls, most of which are formed from stream or river which cascade from a high elevation over a cliff or rock, had very little attention from researchers the world over. In Africa, the reason being that, waterfalls were named after deities and were used as places of traditional and ancestral worships. In other places, the intensity of waterfalls and pressure generated from it due to gravity has given the impression of a lifeless zone (Chernicoff *et al.*, 1997). Knowledge of waterfalls systems in Africa are therefore limited to hydrology and geological features (Chester *et al.*, 1999; Fischer and Harris, 2003), as natural monuments for revenue generation, because of their ecotourism potentials and as source for drinking, irrigation and other domestic purposes. Studies on the fisheries and aquaculture potentials, biodiversity conservation and aquatic ecology of waterfalls are scarce due to traditional and ancestral worship of neighboring communities that had earlier prevented all forms of activities in the study area.

Knowledge of status of the fauna and flora of Agbokum waterfall is important in the development of tourism potentials, management and conservation of the resources. It is also possible that the biodiversity of Cross river fishes is much higher than reported (Teugels *et al*., 1992; Offem *et al.*, 2008) and could yield records of undiscovered and un-described species if the Agbokim Waterfalls and other water bodies such as Crater lakes, flood plains, lakes and mountain streams which link up with the Cross River, are investigated. The fundamental attributes of an aquatic ecosystem are the number of species present and their abundance (Krinitskii, 1972). Both attribute are dynamic and related (Tokeshi and Schmid, 2002). In aquatic ecosystems interaction between the environment and population processes affects the distribution and abundance patterns of species (Brown, 1984; Schlosser, 1987). The resources of the length of the waterfalls are yet to be tapped, more so due to the total neglect by stakeholders. This study presents an analysis of the occurrence, distribution and dynamics in the fauna and flora resources of Agbokim waterfalls to reduce our over- dependence on estuarine and open water body systems.

METHODS

> *STUDY AREA*

The study area is Agbokim Waterfalls in Cross River State, Nigeria, latitude 5° 59' North and longitude 8° 45' East (Figure 1). It is bounded in the West by the Cross River and in the North

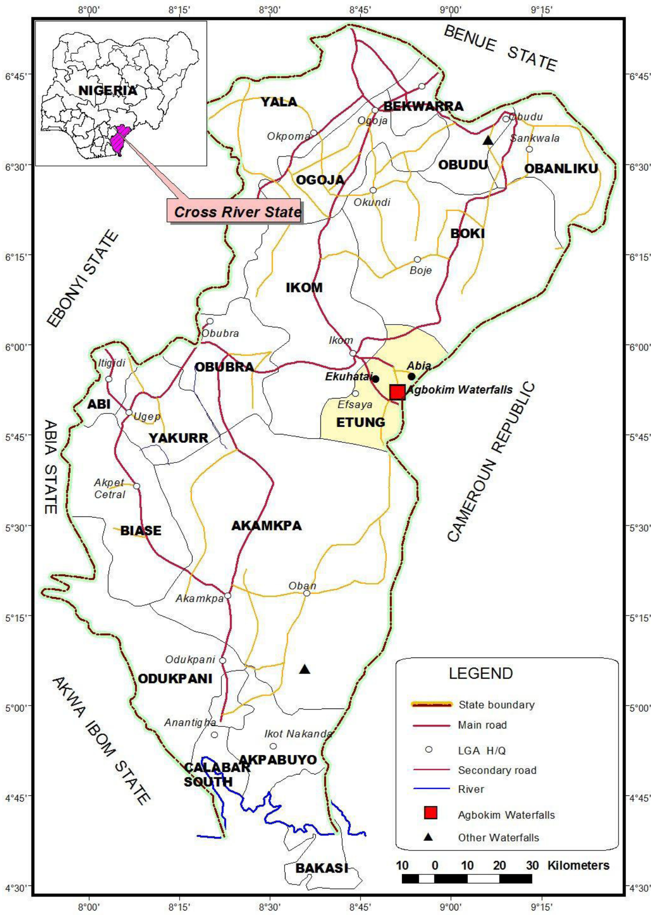

Figure 1
Map of Cross River State showing study area.

by the Cameroon high forests. The climate is the tropical hinter-land type, with wet (May-November) and dry (December-April) seasons. Mean annual temperature ranged between 20° C and 32 °C and annual total average rainfall, from 1450 mm to 3015 mm. The vegetation is the rainforest type with Soil consisting of deep laterite and dark fertile, clayey 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 (Teugels *et al.*, 1992).

> EXPERIMENTAL DESIGN

For the purpose of this study, the 6817.7 m long waterfall is divided into three reaches; upstream, midstream (region of waterfalls) and downstream. upstream is 2003.13 m long with substrate of gravel and rocks under fast water current and shoreline covered with high forest and cocoa farms, midstream 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. one sampling station was located in each of the reaches.

> PLANKTON STUDIES

Phytoplankton samples were collected monthly, from August 2005–July 2007. These were collected in 250 mL bottles (Ajani, 2001). The water samples, for plankton analysis was taken to the Fisheries Laboratory of Cross River University of Technology, Obubra Campus, Cross River State. Fresh sample was mixed gently and pipetted into 5 mL plankton chamber containing 2 drops of Lugol's solution. The Lugol's solution served as the fixative while also enhancing sedimentation of organisms. The chamber was left overnight for complete sedimentation to take place. Plankton was analyzed using Zeiss inverted plankton microscope (UNESCO, 1978) using Plankton determination keys (Edmonton, 1959; Prescott, 1982; Sharma, 1986).

Zooplankton was sampled from a scoop plastic bucket of 10 L capacity. Subsurface water (5 m depth) was vertically collected with a bucket and filtered through plankton net of mesh size 100 µ. Fifty scoop buckets of 10 L capacity were filtered *via* the net. The net samples were washed into the 1 mL sample collecting bottles and fixed immediately in 2% formalin solution. After making up to 100 mL with distilled water, the samples were agitated and homogenized and 1 mL sub-samples placed in counting chamber for observation under 40–100× magnification. Organisms were identified (Durand and Leveque, 1980; Jeje and Fernando, 1985) and enumerated for subsequent statistical computations.

> FAUNAL STUDIES

Macro-invertebrate benthic fauna samples of the waterfalls were collected four times near the margin of the river at each reach by use of a corer 0.004 m^2 already described (Lenat *et al.*, 1981) and modified (Kellogg, 1994). Three replicate samples were taken from each reach and transferred to separately labeled polythene bags for laboratory analysis. Sieves with mesh-sizes 2 mm and 1mm were used to screen the organisms that were later sorted and preserved in 5% buffered formalin. The individual organisms were identified using a stereoscopic microscope and identification guides (APHA, 1987; Hawking, 2000; Theischinger, 2000).

The fish of the river was sampled in all the reaches using gill net (22–76 mm stretched mesh size). Genus and species identifications was carried out for the Cyprinids (Elvira, 1987); for the Bagrids (Erkakan *et al.*, 2007); for the Clariidae (Teugels, 1982) and for the Clupeidae and Mugilidae (Fisher *et al.*, 1987). Fish catch of each reach was presented as a numerical contribution by each species. This was determined by calculating the ratio each species, represented of the total catch for each reach based on the number of species and relative abundance.

> ENVIRONMENTAL PARAMETERS

Water level was determined with a lead sinker attached to a calibrated rope. The sinker was lowered down into water until it reached the substrate. The depth was then read from the calibrated rope. The procedure was repeated in two other locations randomly selected from the edge and middle of water within the sampling site. River width was measured with a long calibrated rope in three places in each sampling sites and the average was taken. Water velocity (flow velocity) was determined to 0.03 $m \cdot s^{-1}$ accuracy with Wagtech current flow meter, model WFM001 with 125 mm diameter impella. Water discharge was determined (Fischer and Harris, 2003) using the formula: WTD = CSA × WD × WV. Where WTD = Water Discharge ($m^3 \cdot s^{-1}$), CSA = Cross Sectional Area (m); WD = Water Dept (m) and WV = Water Velocity $m \cdot s^{-1}$. Temperature values were recorded from a mercury-in glass thermometer graduated in units of °C (50 °C) by immersing the thermometer slightly under the surface of water (2 cm) for 5 min until mercury stood at one place). PyeUnicam Model 7065 electronic metre at 25 °C after standardization with buffer solution at pH 4, 7 and 9 was used for pH. The dissolved oxygen concentration of the water samples was determined with a Fischers digital oxygen analyzer.

> VEGETATION

Study of the vegetation was carried out by selecting three populations from the three reaches to represent different degrees of disturbances. All populations were vigorous and healthy in all sampling sites, when the study began in 2007. In each reach, random stations, 20 × 20 in each were mapped out and labeled markers placed within each quadrat and mapped with the plants. At intervals of 4–6 months, all plants, within a quadrat, were mapped and the following figures recorded for each seedling or established shoot status number damaged, presence or absence of individuals and their zonation patterns were also noted.

> DATA TREATMENT AND ANALYSIS

The mean and standard deviation of each of the physico-chemical parameters were calculated. Statistical comparision of data between and within zones were carried out using analysis of variance (anova) and line graphs using excel statistical package (2007). To calculate mean abundance, numbers in different samples were summed for each species and averaged across all sampling sites. Physico-chemical parameters were correlated with the abundances of most common species using Pearson product moment correlation coefficient analysis. Shannon-Wiener diversity function (*H*) was used to calculate heterogeneity for each site. Richness index was expressed using Margalef's richness index.

$$d = (S - 1) / \log N \qquad \text{(Clarke and Warwick, 1994)}$$

$$H' = -\sum_{i=1}^{S} P_i \operatorname{Ln} P_i \qquad \text{(Krebs, 1978)}$$

$$E = d/S \qquad \text{(Zar, 1996).}$$

E = equitability;

d = Margalef's richness index and H' = Shannon-Wiener diversity function;

S = total species number;

P_i = proportion of each species in each sample;

Relative abundance % = $(n/N) \times 100$;

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

RESULTS

> PLANKTON

A total of 29 phytoplankton species sampled from five taxonomic groups; Chlorophyceae, Cyanophyceae, Bacillariophyceae, Cryptophyceae and Dinophyceae, represented phytoplankton community of the Agbokum waterfalls (Table I). Chlorophyceae was the dominant group and *Trachelomonas volzii* most abundant species within the group. The dry season samples recorded higher values (718) of individual *Trachelomonas volzii* than the wet. Three major taxonomic forms of zooplankton; rotifer, cladocera and copepod, consisting of 13 species were recorded. Copepoda (51) was dominant zooplankton with *Calanus finmarchicus* as most abundant species in the dry season while dominant wet season zooplankton *Moina micrura* (256) represent 65% of total zooplankton. About 78.6% of total phytoplankton and zooplankton was contributed from downstream populations while only 10% from midstream.

> MACRO-FAUNAL COMPOSITION AND DISTRIBUTION

Macro-invertebrates communities collected from the waterfalls consist of nine major taxa and 1878 individuals. Spatial distribution of the taxa and individuals recorded upstream,

Table I

Plankton spatial numerical composition and diversity of Agbokim Waterfalls in wet (W) and dry (D) season for the three sites, upstream, midstream and downstream for 2005–2007.

Reaches	Upstream		Midstream		Downstream	
Seasons	D	W	D	W	D	W
Plankton taxa/species						
Phytoplankton						
Chlorophyceae						
Akinstrodesmus spiralis	46	–	57	4	32	16
Phacus quinquemarginatus	20	18	32	5	13	10
Trachelomonas volvocina	91	55	69	22	318	17
Trachelomonas volzii	163	123	91	–	432	23
Euglena acus	14	3	26	3	2	1
Astasia klebsii	8	2	13	3	3	4
Euglenopsis vorax	5	5	7	5	1	–
Spirogyra varians	9	–	7	3	11	–
Selenastrum gracile	25	5	13	–	88	13
Scenedesmus denticulatus	46	20	44	31	3	6
Zygenma insigne	5	–	7	4	5	–
Dictyosphaerium pulchellum	4	–	4	–	14	8
Tribonema bombycinum	2	–	8	13	2	22
Mougeotia transeaui	2	–	6	–	3	21
Volvox tertius	7	–	11	12	–	8
Ulothrix cylindricum	2	–	4	3	–	3
Eudorina elegans	1	–	2	5	–	7
Chlamydomonas ehrenbergii	2	8	4	2	1	22
Chlorella ellipsoidea	112	18	38	12	212	44
Cyanophyceae						
Anabaena bornetiana	11	–	15	19	27	–
Aphanizomeno holsaticum	22	–	15	11	32	–
Nostochopsis lobatus	12	3	19	2		5
Nostoc lobatus	–		49	10	43	8
Bacillariophyceae		13				
Navicula radiosa	21	12	12	–	27	–
Nitzschia sigmoidea	34	12	12	21		19
Synedra ulna	54	16	12	4	88	10
Chaetoceros elmorei		4	–	4	76	8
Cryptophyceae	23	1	8	–	37	15
Cryptomonas erosa	–	9	11	14	–	3
Dinophyceae					–	
Gymnodinium palustre						
Zooplankton	–		4	10		–
Rotifera		13			5	
Filinia longiseta						
Lecane bulla						
Synchaeta oblonga	4		–	2		16
Bracchionus quadridentatus	12	–	3	2	12	27
Cladocera	3	1	3	1	6	11
Moina micrura	4	6	4	2	13	94
Bosmina longirostris					19	
Daphnia magna	1	138	–	–		151
Diaphanosoma excisum	14	–	8	2	51	–
Copepoda	1	3	4	2	34	25
Calanus finmarchicus	–	–	–	1	17	21
Pseudocalanus elongates	211				–	–
Acartia tonsa	4	35	6	1	334	28
Tisbe holothuriae	22	2	3	1	115	9
Schizopera elatensis	4	–	1	1	47	8
	8	–	8	1	35	23
		4	2	1	30	

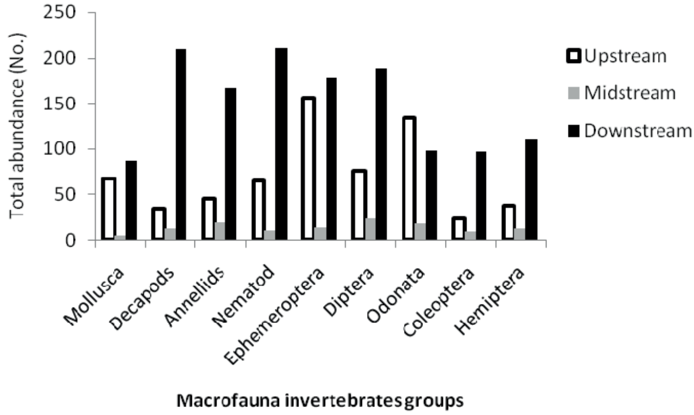

Figure 2
Spatial changes in the total abundance (No.) of the dominant macro-fauna invertebrates.

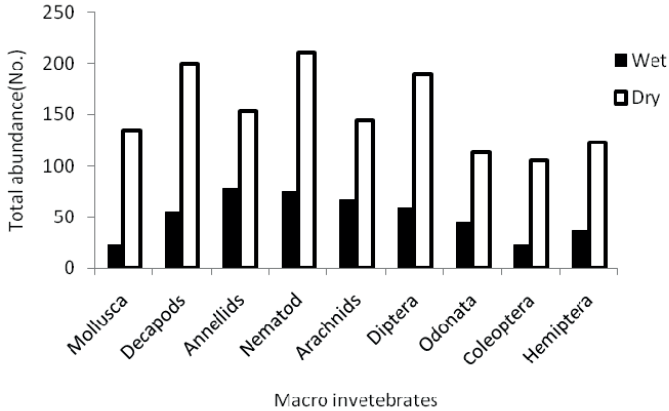

Figure 3
Seasonal changes in the total abundance (No.) of macro-fauna invetebrates.

midstream and downstream reaches were 9 (413), 9 (113) and 9 (1346) respectively (Figure 2). Dipterans and nematodes were dominant groups representing 15.4 and 15.2 percent respectively; decapods and annelids represent 14.7 and 13.5 percent respectively. Coleoptera was the least group (6.5%). About 71.7 percent of the total macro-invertebrates were recorded from downstream reaches while only 6.3 percent were contributed by midstream. Seasonal variation of the invertebrates in the different reaches showed that the dry season samples were significantly higher (1416) ($p < 0.05$) than the wet (462) (Figure 3).

> *FISH FAUNA*

A total of 548 fish representing 13 species from 5 families were sampled during the dry and wet seasons, with only one family being restricted to the wet season, which was of very rare taxa (Figure 4). The number of taxa, and relative proportion of each species present, upstream, midstream and downstream reaches are shown in Table II. Cichlidae, Clariidae and Cyprinidae were the most abundant families accounting for 56.7% of the total catch. *Tilapia zillii*, *Clarias gariepinus* and *Labeo coubie* dominated overall catch constituting 45.5%. Among the three dominant species, two benthic fishes (*L. coubie* and *C. gariepinus*) showed inverse distributional patterns. Clariid fish (*C. gariepinus*) was most abundant downstream and least represented, upstream. Cyprinid (*L. coubie*), on the other hand, dominated the upstream reaches and scarce downstream. Five species were site specific because of the association

Table II
Relative proportions of fish species for the three reaches (January 2006 to December, 2007).

Reaches	Up-river	Mid-river	Down-river
Family/species	P_i	P_i	P_i
Cichlidae			
Oreochromis niloticus	0.042	0.038	0.004
Tilapia zilli	0.110	0.238	0.098
Hemichromis fasciatus	0.000	0.000	0.011
Pelmatochromis guntheri	0.010	0.006	0.024
Clariidae			
Clarias anguillaris	0.031	0.005	0.057
Clarias gariepinus	0.023	0.014	0.315
Heterobranchus longifilis	0.000	0.000	0.111
Bagridae			
Chrysichthys nigrodigitatus	0.000	0.000	0.013
Auchenoglanis occidentalis	0.000	0.000	0.003
Mochokidae:			
Synodontis clarias	0.015	0.004	0.018
Cyprinidae			
Labeo coubie	0.388	0.121	0.003
Labeo senegalensis	0.000	0.044	0.000
Barbus occidentalis	0.034	0.003	0.001

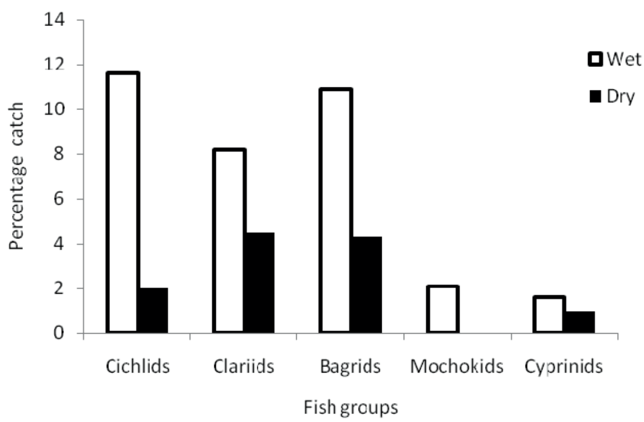

Figure 4
Seasonal changes in the percentage fish catch.

with the midstream portion of the river (*L. senegalensis*) and downstream reaches (*A. occidentalis*, *H. longifilis*, *H. fasciatus* and *C. nigrodigitatus*).

> VEGETATION

The dominant vegetation at the bank are of freshwater swamp type; *Azolla africana*, *Nymphia lotus*, *Commelina* sp., *Bambusa vulgaris*, *Dryopteris* sp. and *Salvia nymphellula*. The fringing trees are principally *Raphia vinifera*, *Symphonia* sp., *Elaeis guinneesis*, *Havea brasiliensis, Bambusasp, Grewiasp* and *Cocos nucifera.* The vegetation showed a distinct pattern in respect of percentage cover of species present. Total numbers of species varied significantly between reaches, but all reaches displayed similar change. *Bambusa sp., Symphonia* and *Elaeis guineesis* displayed progressive increase from upstream reaching a maximum of

Table III
Diversity of macro and micro fauna and flora of Agbokum waterfalls during dry (D) and wet (W) seasons in the three sampling sites. r = *richness index,* d = *Shannon weaner diversity index.*

Reaches		Upstream		Midstream		Downstream	
Seasons		D	W	D	W	D	W
Items	Diversity indices						
Phytoplankton	*r*	52	12	12	9	153	17
	d	0.55	0.28	0.03	0.03	0.69	0.28
Zooplankton	*r*	29	16	7	12	79	49
	d	0.12	0.28	0.16	0.05	0.63	0.16
Macro-invertebrates	*r*	33	12	18	10	89	45
	d	0.34	0.12	0.08	0.02	1.56	0.89
Fish species	*r*	14	28	7	7	11	38
	d	0.23	0.42	0.02	0.06	0.34	1.76
Vegetation	*r*	26	49	8	12	45	78
	d	0.12	0.42	0.02	0.04	0.54	1.55

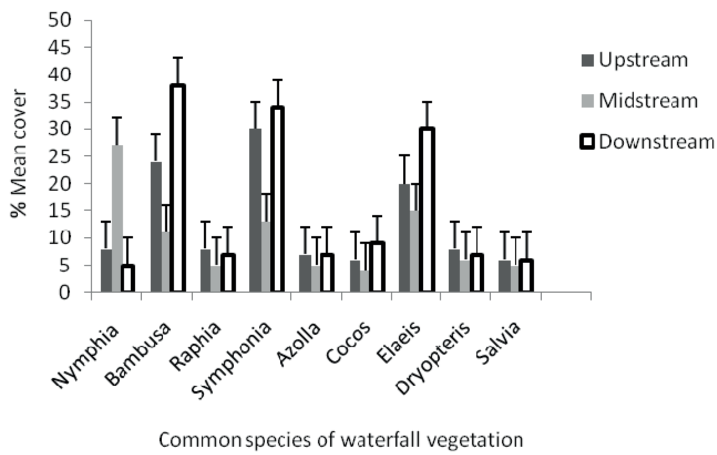

Figure 5
Percentage cover of the most common vegetation types in the three reaches of Agbokum water falls.

38.5 mean percent cover over the other species in the relatively undisturbed downstream. In contrast, the population in the highly disturbed midstream showed much smaller percentage cover values (Figure 5).

> RICHNESS AND DIVERSITY INDICES

Changes in the plankton, flora and fauna assemblages of the Agbokum waterfalls ecosystems were reflected in species richness and diversity. The Shannon-Weiner diversity index for the biodata investigated showed significant difference between reaches, with downstream reaches having highest values while midstream were least (Table III). Seasonal differentiation

Table IV
Mean variation and F*-values of the analysis of variance (ANOVA) of physico-chemical parameters of water measured at three sampling sites. I: Upriver, II: Mid-river, III: Downriver.*

Properties	Upriver	Midriver	Downriver	*F*-value	ANOVA
Physical conductivity (uS·cm^{-1})	36.6 ± 11.0	38.1 ± 11.5	25.3–58.2	0.77	$p > 0.05$
Water temperature (ºC)	28.0 ± 1.1	26.6 ± 1.2	27.2 ± 0.8	3.36	$p > 0.05$
Water depth (m)	1.4 ± 0.7	2.2 ± 0.5	4.8 ± 0.6	4.32	$p > 0.05$
Water discharge (m^3·s^{-1})	156.71 ± 12	1496.46 ± 82	189.8 ± 13	5.8	$p > 0.05$
Water velocity (m·s^{-1})	1.94 ± 0.25	1.01 ± 0.3	0.5 ± 0.14	4.32	$p > 0.05$
Transparency (cm)	26.6 ± 13.9	29.5 ± 14	28.8 ± 13.4	1.56	$p > 0.05$
Chemical					
Dissolved oxygen (mg·L^{-1})	6.6 ± 0.3	9.61 ± 0.2	4.34 ± 0.5	3.98	$p > 0.05$
pH	7.0 ± 0.2	7.0 ± 0.2	7.1 ± 0.2	1.43	$p > 0.05$

Table V
Results of Pearson correlation analysis using physico-chemcal and biological parameters from Agbokum waterfalls.

Item	Water depth	Water discharge	Water velocity	Dissolved O_2
Chlorophytes	–0.675	–0.564	–0.654	0.654
Cyanophyceae	–0.766	–0.843	–0.321	0.435
Rotifers	–0.492	–0.477	–0.765	0.755
Cladocerans	–0.566	–0.777	–0.465	0.665
Cichlids	0.586	–0.345	–0.234	0.788
Clariids	0.897	–0.657	–0.654	0.234
Cyprinids	0.675	0.768	0.876	0.888
Decapods	0.456	–0.543	–0.287	0.654
Annelids	0.654	–0.254	–0.432	–0.765
Azolla	–0.564	–0.671	–0.654	–0.234
Nympha	–0.444	–0.876	–0.324	–0.564
Commelina	0.398	–0.432	–0.487	–0.675

in the diversity indices and species richness revealed higher values for the wet season samples of plankton, fish and vegetation than dry. On the other hand, dry season invertebrate samples showed higher richness index and diversity values. Throughout the year, samples from the waterfalls region of the stream (midstream) exhibited very diversity and richness values.

> PHYSICO-CHEMICAL CHARACTERISTICS

Water depth, water discharge, water velocity and dissolved oxygen vary significantly between reaches ($p > 0.05$) (Table IV). All biological species studied correlated negatively with water discharge and water velocity except the Cyprinids (Table V). On the other hand, all the species correlated positively with dissolved oxygen apart from annelids and the marginal vegetation.

DISCUSSION

> PHYTOPLANKTON

The phytoplankton composition in this study agreed with reports of Adebisi (1981) and Ayodele and Ajani (1999) that blue-green algae and green algae dominate most tropical African waters. The dominance of *Chlorophyceae* in respect of species number and population density in this study had also been observed elsewhere (Tressler *et al.*, 1940; Willen, 1959; Vyverman, 1996, Silva, 2005) and the overwhelming presence in the dry season, attributed to the presence of bright sunshine and extensive catchment area, draining calcium rich agriculture land (Pennack, 1949; Kurasawa and Shiraishi, 1954; Lewis, 1996). Physiological and behavioural flexibility of Chlorophyceae can accommodate environmental stresses better than most fast growing species (Silva, 2004). Second in prominence was Cyanophyceae, which had also been found to be prominent in Bulgaria (Stoyneva, 2003), Hungary (Padisak and Reynolds, 1998) and Sanabria Lake (Spain) (Hoyos and Comin, 1999). Cyanophyta dominance, and sometimes bloom are amongst the most visible symptoms of ORGANIC pollution (Moss *et al.*, 1997), Toxic to living organisms and accelerated natural euthrophication (Stoyneva, 2003; Silva, 2005). The observation in the waterfalls is similar to findings by Adeniyi (1978) that the abundance of phytoplankton increases with increase in transparency, which normally associated with black flood (dry season), while the high turbidity associated with the white flood (wet season) results in a decrease in its abundance. The waterfalls region of the study area recorded least density of phytoplankton due to high level of disturbance caused by the impact of high water discharge on the environment. Re-suspension of particles often observed in this region leads to high water turbidity and therefore low light penetration, low degree of algal sedimentation, and therefore reduced phytoplankton production. Benthic algal production is also hampered by the turbulence effect of water in this region constantly bringing to the top all materials at the bottom (Ewa-Oboho and Oladimeji, 2004). Planktons were moved swiftly from upstream with high flow velocity and water turbulence to downstream with stable ecology, resulting in higher plankton diversity and abundance downstream.

> ZOOPLANKTON

The zooplankton population dominated by copepods and cladocerans had also been documented (Egborge, 1981). There may be alternation in abundance between crustaceans and rotifers as reflected in the distribution and abundance of zooplankton in the sampled parts of the river and seasons. The zooplankton forms respond similarly to disturbance in water environment as phytoplankton. Low densities of all zooplankton species observed in the middle reaches (waterfalls) could be due to high water discharge. Discharge rate is important both directly or indirectly, as it influence the environment by creating turbulence and high turbidity in this region (Nelson and Lieberman, 2002). Suspended particles have been found to hinder metabolism in copepods (Sharp *et al.*, 1979) and turbulence prevent larval forms from settling and developing to adult stages and hence die shortly before metamorphosis (Edung, 2001).

This study showed that the seasonal variation in zooplankton concentration could largely be due to the rotifers which normally constitute major diet items of larger zooplankton during the dry season (Ewa-Oboho and Oladimeji, 2004). Species of rotifers and crustaceans considered good indicators of the trophic state of the water bodies were identified in the zooplankton community. Dominant rotifers species of *Filinia longiseta, Bracchionus quadridentatus* and *Synchaeta oblonga* and crustacean zooplankton community populated mainly by copepods and cladocerans, as a result of increase in cyclopoid copepodids and mesocyclops, are indicative of good water quality (Sendacz *et al.*, 1985). This showed that the organic pollution in the waterfalls, as reflected in cynophyceae dominance, had not reached toxic level. Temperature and the availability of food are about the most important factors controlling the abundance of zooplankton in water (Imoobe and Adeyinka, 2010). In this study, with higher temperature regimes during the dry season coupled with high level of food in the water as a result of high primary productivity (phytoplankton), can be responsible for the high populations of zooplankton. In the dry season the zooplankton population appeared to have great stability and in the rainy season the population is suspected to lack stability. This may depend on the residence time of water and on the abrupt water change which occur frequently during the rainy season (Schoener, 1988). The increased turbidity of the flood (wet season) destroys the periphytic algae and causes a decline in the amount of phytoplankton (Adeniji, 1975; Bidwell, 1979b) which in turn reduces the standing crop of the herbivorous zooplankton fish food (Bidwell, 1979a).

> *MACRO-INVERTEBRATES*

The gradual decrease of current velocity was evident from upstream to the middle reaches, then decrease abruptly to the downstream reaches where the velocity was least during the period of study. According to findings (Nelson and Lieberman, 2002), flow velocity influences the type of river bed, amount of silt deposition, which in turn affects macro-invertebrate abundance. The spatial changes in population densities of macro-faunal species between reaches of the waterfalls may therefore be due, in part, to differences in composition of the substratum which was muddy and silt downstream with sandy and rocky upstream and midstream reaches. The larval forms of most deposit-feeding macro-benthic fauna require fine sediments in which to burrow. The greater quantity of organic matter present in downstream reaches (Ikpi and Offem, 2011), is probably instrumental to decreasing the compartment of the sediments, thereby facilitating the burrowing of larval forms of decapods and polychaetes which formed dominant macro-fauna downstream. Another reason for higher density of macro-invertebrates downstream could be due to large surface area of the reaches which expose the site to air and sunlight as well as abundance of organic debris which favor the photosynthetic activity of aquatic plants (Ewa-Oboho, 1999). The macro-invertebrate COMMUNITY downstream, is striking in the fact that the decapods crustaceans dominated and were present in high numbers. Research findings had earlier implicated the presence of decapods to relatively unpolluted segment of the river since they are not tolerant of polluted water (Ogbeibu and Oribhabor, 2002). On the other hand upstream reaches where the velocity was rather high, the macro-invertebrate community was dominated by Odonata and Ephemeroptera (*Baetise* sp.) which according to findings (Rader and Ward, 1988; Charpenter and Morin, 1994; Nelson and Lieberman, 2001), may be high flow adopted invertebrates. Midstream reaches had consistently lower density of invertebrates than other reaches due to higher water discharge rate which permanently suspended particles in water and in turn reduced to minimum invertebrate density in the region. The higher density of macro- invertebrates during the dry season could be as a result of the unstable nature of the substrate during the wet season arising from inputs of storm water (Victor and Ogbeibu, 1991; Edokpayi *et al.*, 2000; Tumwesigye *et al.*, 2000).

> *FISH SPECIES*

Seasonal differentiation evident in higher number of species and individuals caught during wet months of the study period, agree with other results which described larger ichthyofaunal densities in water bodies in Grahamstown in the rainy season (Harrison and Whitefield, 1995; Cowley and Whitefield, 2001; Vorwerk *et al.*, 2001). Reasons for the variation were ascribed to the connection of the water bodies to the sea which allows free movement of species across the two habitats during flood and these species being able to recruit during flood condition. Agbokim Waterfalls being drained by two small rivers, Ekue and Bakue, which are tributaries of the Cross River system with linkage to Cross River estuary from the lower reaches, could have exhibited the same variation. Also because of the considerable seasonal differences in dissolved oxygen concentration in the system, both at low water and during the floods, this factor appears to have played an essential role in determining the distribution of fish within the system. In general the more active the species the more it tends to avoid de-oxygenated areas (Welcome, 2003). Most species encountered downstream during dry season have adaptation for survival in low dissolved oxygen conditions like presence of external gills (*Clarias*, *Heterobranchus*). These species form a group that is well adapted to swamps life and tend to concentrate in the more de-oxygenated small pools and swamps of the floodplain during low water, when other more active species like Tilapia and carp are to be found in the mid-stream (WATERFALL) and upstream respectively.

Although on a community basis the three reaches did not separate out, some species when analysed individually revealed specific range preferences. Two heterologous species between two genera, *C. gariepinus* and *L. coubie*, the two most common and economically viable benthic fishes found in this study, demonstrated opposite habitat preference, with *C. gariepinus* dominating the lower reach and *L. coubie* more abundant in the upper reach. This opposing habitat preference and the attendant ecological and trophic heterogeneity reduce competition, and may be responsible for the overwhelming success of the two species in the Agbokum waterfalls. The relatively higher number of *C. gariepinus* in the lower reach during this study may be due to the fact that being mud-dwelling species, most individuals found their natural habitat downstream. The common carp, *L. coubie* adapted to live in shallow rocky bottom, assemble in the rocky upstream. Another dominant freshwater species (*T. zilli)* demonstrated great preference to the turbulent well aerated midstream reaches. This distributional trend, in a similar study (Whitfield and Blaber, 1979) was attributed to several factors including fast water current, suitable breeding area, marginal vegetation and the absence of competitors and piscivorous predators.

> VEGETATION

Quantitative difference in numerical abundance of vegetation types between reaches, in this study, implies variation in control on a very local scale (Faroque, 1989). In the present study, experimental field study had been used to assess the impact of waterfall disturbance on marginal vegetation population in the different reaches of the waterfalls. The assessment of the plant size was difficult because individuals vary greatly in the proportion of their stem. Although there was general deterioration in the numerical abundance in the middle reaches of the waterfalls, *Azolla africana*, and probably *Nymphia lotus* and *Commelina* sp. were endemic forming permanent marginal vegetation along all stretches of the midstream. The distribution pattern and composition of the vegetation change in a non-random way during the study period with *Raphia vinifera*, *Havea brasiliensis*, *Grewia* sp. and *Cocos nucifera* shrinking in size from 34% to 8% at the midstream stretches of the river while the *nymphia*- rich vegetation becomes more frequent than expected. *Nymphia* has become a biological invader and has exhibited a full range of impact and abundance in this disturbed midstream reaches.

> DIVERSITY

Shannon Weaner diversity function for samples of phytoplankton, zooplankton and macro-invertebrates studied, reveal that dry season samples of these species were more diversified and stable. On the other hand fish and vegetation appear to be more stable during the wet season considering the higher richness and diversity during this period. However, communities in the waterfall region (midstream) of the river may be unstable throughout the year as reflected in their low values of richness and diversity during both seasons. If the integrity of such waterfalls in the tropics are protected, they will support growth and survival of organisms, throughout the year.

> PHYSICO-CHEMICAL PROPERTIES

The distribution and abundance of macro-invertebrates, as the results show, were affected by the physico-chemistry of the waterfalls, such as dissolved oxygen, water velocity, water discharge and water depth. Pearson's correlation analysis showed that some of these parameters correlated positively with species of Chlorophytes, Cyanophyceae, rotifers, cladocerans, cichlids, clariids, cyprinids, decapods and negatively with annelids, *azolla, Nympha* and *Commelina.* The high correlation that occurred between these groups of organisms and dissolved oxygen suggest that oxygen is the most influencial factor that controls the distribution and abundance of organisms as reported by Barnett (1983) and Oke (1990).

CONCLUSION

The watfalls reaches are not completely lifeless as assumed by many researchers in Africa, but harbor some turbulent tolerant macro-biota. Among the plankton community, waterfalls contributed significant percentage of *Trachelomonas* sp., *Scenedesmus denticulatus*, *Chlorella ellipsoidea* and *Nostoc lobatus*. *Labeo coubie* and *Tilapia zilli* were the fish species that were most abundant in the waterfall region. *Nymphia* vegetation has become a biological invader and has exhibited a full range of impact and abundance in this disturbed midstream reaches. Waterfalls can also be important for fisheries and biodiversity conservation, as rich biome for indigenous and exotic species which are swept upstream and over the waterfalls, settle downstream in a more stable environment. The disturbance regimes of the midstream reaches of Agbokum waterfalls combined with its very low faunal and floral diversity has made the environment unstable therefore susceptible to the invasion of disturbance tolerant biota.

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