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Original article

Assessment of the impact of Abiotic factors on the fish assemblages in a tropical estuary creek

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Fish assemblage structures of Badagry creek, Nigeria in relation to abiotic (physical and chemical) variables were studied for 2 years period (November, 2011 – September, 2013). Environmental parameters were monitored in sampling stations randomly selected in each of the three zones established in the creek (3 stations per zone). Fishermen catches were monitored in three major landing sites around the creek (one site per zone). The physico-chemical parameters investigated were within the tolerance limits for aquatic life. Conductance, Salinity and Water depth data showed significant differences ($p < 0.05$) across zones whereas with an exception of pH and Phosphate, there were no significant variations ($p > 0.05$) in physicochemical parameters measured seasonally. The survey of fish in the Badagry creek recorded more estuarine and near-shore marine species with a total of 4,045 fish individuals comprising 36 species from 22 families. Dominant fishes included Tilapia zillii (15.2%), Chrysichthys nigrodigitatus (11.3%) and Ethmalosa fimbriata (11.2%). Fish diversity indices in dry season were higher than wet season. Water depth was found to be the most important abiotic factor determining the abundance of species ecological categories. The other abiotic factors tested also showed some influence on the species (ecological categories) abundance, suggesting the importance of environmental parameters in determining fish distribution and abundance.

1. Introduction

The fundamental goal of ecology is to understand the distribution and abundance of organisms. In achieving this, ecology explores relationships between organisms and biotic (living) factors or abiotic (non-living) factors in the environment. The key abiotic factors in aquatic ecosystems are salt concentration, availability of sunlight, oxygen, and nutrients.

Identification of significant associations between fish species and habitat conditions is the first step towards incorporating environmental information into fish abundance (Perry et al., 1994). Furthermore, fish occupy the highest trophic levels of food chains in aquatic ecosystems, thus their composition in a location reflects both the summation of conditions of lower biological forms and the overall water quality. Research on fish assemblages in estuaries has shown that the main estuarine water quality parameters such as salinity, temperature, turbidity, pH, and dissolved oxygen are known to affect fish distribution (Blaber and Blaber, 1980).

Badagry creek where the study was carried out is situated within the Barrier Lagoon complex in Nigeria, between longitude 2°42¹ and 3°23¹E and latitude 6°23¹ and 6°28¹N (Figure 1). The creek is fed mainly by River Ajara in the Republic of Benin and the Yewa River in Nigeria while it also links Ologe Lagoon. It is bounded in the north by the Egbado plateau and in the west by River Yewa via Ologe lagoon. In the southern boundary is Atlantic Ocean and in the east by the expanse of the mangrove swamp (Abegunde, 2002). The creek with estimated size of 1875ha (Lagos State Fisheries Department, 1998) supports the artisanal fisheries, water ways and cultural values in the area. Badagry creek provides the communities with numerous benefits. In addition to direct use, the creek replenishes the ground water table and influencing the climate of the city. The creek shore is lined with fishing communities whose livelihood depends on the creek resources.

Barrier Lagoon complex is one of the most ecologically important lagoon system in Nigeria (Solarin and Kusemiju, 1991). It stretches from Benin Republic-Nigeria border to Ajumo east of Lekki town (Lagos Lagoon complex) in Nigeria. Studies of the Barrier Lagoon complex are concentrated in Lagos Lagoon. Apart from the fact that there have been few ecological studies in the western most part of this complex (i.e. Badagry Creek) despite its ecological importance, a lack of knowledge exists regarding fish abundance as related to abiotic factors in the creek system. This present study therefore assesses the influence of abiotic factors on fish abundance in Badagry creek.

2. Materials and methods

2.1. Sampling design

Nine stations positioned randomly in the creek (Upper, middle and lower zones) were sampled for two years (Bi-monthly) on relevant environmental variables. Fish sampling was done by monitoring and recording fishermen catches in a selected landing site in each zone.

Sampling was conducted between November 2011 and September 2013 covering 2 Dry and 2 Wet seasons to give a detailed description of the environmental factors and fish diversity of the creek as well as capturing the spatial and seasonal fluctuations.

2.2. Water sampling and analysis techniques

Water samples for environmental factors were collected just below the surface at each sampling site with a 5litre Teflon coated Niskin samplers into 1 litre high-density screw- capped polyethylene containers from the knob of the Niskin sampler, labelled according to the sampling station and kept in a refrigerator until analyses. Separate water samples were collected in 250ml dissolved oxygen bottles at each station and fixed according to Winkler's method using Manganese Sulphate solution and Alkaline Potassium iodide reagents for dissolved oxygen determination.

The various physical and chemical parameters that were analyzed in the present study were: Water Temperature, pH, Electrical conductivity, Turbidity, Salinity, Dissolved oxygen, Water depth and Phosphate.

Mercury in glass thermometer was used to determine the water temperature in situ at each sampling station. A Multi-meter water checker (Horiba U-10) was used to determine the pH, Electrical conductivity and Salinity of the water samples. Turbidity was measured directly in a smart – spectrophotometer at turbidity wavelength against MilliQ water as reference. Dissolved oxygen in the water samples were estimated using Modified iodometric Winkler's method (Stirling, 1999). The depth (m) of the water column was determined by means of a cylindrical rod calibrated along its length in centimetres while Phosphate was determined using the molybdenum-blue method (Parsons et al., 1984).

Monthly rainfall data measured in mm of the study area for the study periods were provided by the Nigerian Meteorological (NIMET) marine office at the Nigerian Institute for Oceanography and Marine Research, Victoria- Island Lagos.

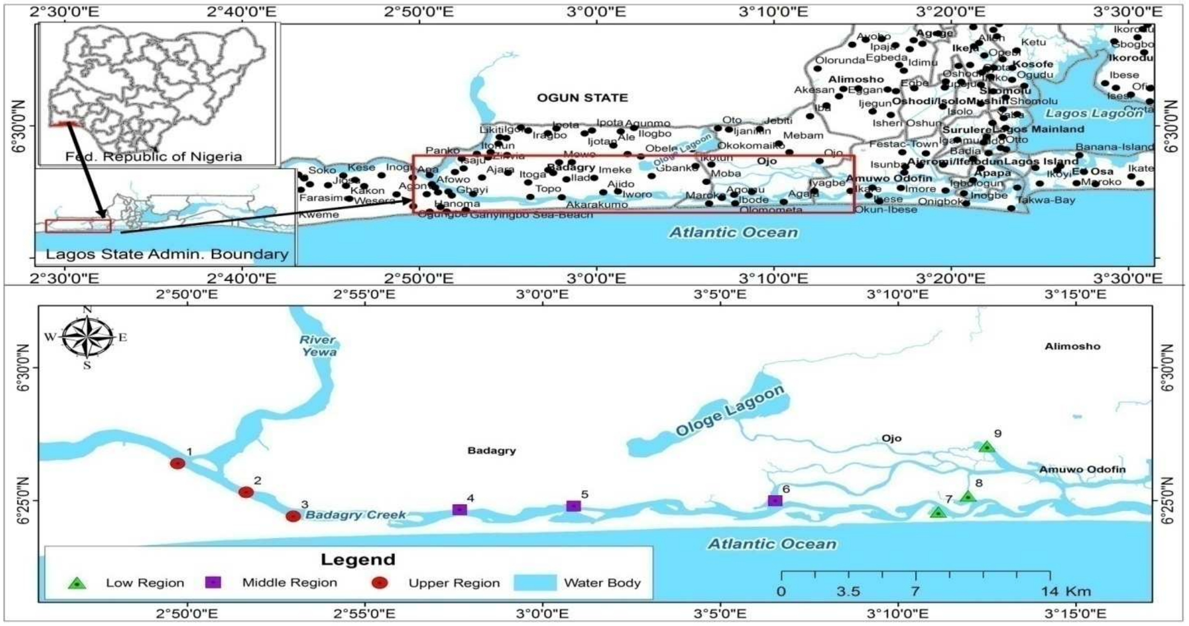

Fig. 1. Map of Badagry Creek and environs with sampling stations.

Upper zone: 1 – Apa; 2 – Igbaji; 3 – Badagry*

Middle zone: 4 – Akarakumo; 5 – Ajido*; 6 – Irewe

Lower zone: 7 – Igbolobi; 8 – Iyagbe; 9 – Ojo*

*Selected Fishermen landing site in each of the zone

2.3. Fish sampling and analysis techniques

Artisanal fishermen in this creek use Plank canoes and deploy surface and bottom-set gillnets, cast-nets, ring-nets, drift-nets, and beach-seines for their fishing operations. Basically, samplings of finfish in this study were carried out by monitoring and recording catches from fishermen at an established major fishing landing site in each of the eco-zone (Upper zone: Badagry; Middle zone: Ajido; Lower zone: Ojo).

Fishermen catches were sorted out; the number of individuals for each species were counted and recorded. Identifications were made with the aid of relevant texts (Tobor and Ajayi, 1979; Fischer et al., 1981; Powell, 1982; Schneider, 1990; Holden and Reed, 1991).

Fish identified in fishermen catches in various selected landing sites were grouped into ecological categories following Day et al. 1989 and Whitfield 1999. Estuarine resident (ER) fish, estuarine residents refer to species of marine origin that reside in estuaries and can complete their life cycle within these systems (Whitfield 1999). Estuarine dependent marine (EDM) fish: the marine species which are predominantly found in estuaries at some stages of their life cycle. Estuarine dependent freshwater (EDF) fish: freshwater species which are predominantly found in estuaries at some stages of their life cycle. Estuarine non-dependent marine (ENDM) fish: species commonly found in both estuarine and coastal inshore areas and do not depend on estuarine environment to complete their life cycles. Occasional marine visitor (OMV) fish: marine species which are regularly caught in estuarine but not abundant in the catch. Freshwater (FW) fish: Freshwater species are those that are restricted to rivers but occasionally enter estuaries when the conditions are favourable (Day et al., 1989).

2.4. Data/Statistical analysis

Based on the rainfall pattern of the study area, November to April was designated as dry season period while May to October as wet season period.

The abundance (number of individuals) of species was established.

The relative abundance (Ra) of fish species was calculated using the equation:

Ra = Qi / N

Where: Qi = Quantity of the given fish species i

N = Total number of all fish sampled.

The diversity indices, viz., Dominance index (D), Shannon – Weiner index (H), Margalef, Evenness index (E), and Equitability J index were computed for fish community structure using 'PAST' software. Data generated from this study were subjected to both descriptive (mean and standard deviation) and inferential statistics (one-way ANOVA and correlations) using Microsoft excel (2010) and SPSS 15.0 for windows evaluation version.

Data were pooled and presented as spatial and seasonal mean variance. Data were subjected to Analysis of variance (ANOVA) to examine differences at $p < 0.05$ with regards to zones and season. Mean values were separated with Tukey's HSD multiple range test.

Canonical Correspondence Analysis (CCA) ordination method was used to detect patterns of species association directly related to environmental variables (ter Braak & Verdonschot, 1995). The CCA was performed with "PAST" software. The implementation in PAST is according to the eigenanalysis algorithm given in Legendre & Legendre (1998). The ordination axes are linear combinations of the environmental variables. The analysis employed fish ecological categories abundance and abiotic factors square root transformed data. The importance of environmental factors is indicated by the relative length of vectors. The length of the vector is a measure of the strength of correlation and hence the importance of that environmental variable in structuring the assemblages: the longer the vector, the greater their influence on species (ecological categories) abundance. In addition, the closer the species to the vector or to another species, the greater their relationship will be with the environmental parameters (ter Braak 1986). A Monte Carlo randomization test (1000 permutations) was run using PAST software to assess the probability of the observed pattern being due to chance (Crowley 1992).

3. Results

3.1. Abiotic factors (physical and chemical parameters)

Rainfall values recorded throughout this study was between 1.1mm and 476.7mm (Figure 2). The total rainfall received was 3342.8mm throughout the study period, with 1827.8mm of rainfall during the first year and 1515mm in the second year (Figure 2). The month of June in each year produced the peak value of rainfall.

Water temperature fluctuated from 220C to 330C. The water temperature mean values were 29.35 ± 2.16 0C, 29.57 ± 1.740C and 29.43 ± 1.270C respectively for upper, middle and lower zones (Figure 3). Season-wise (Figure 3), mean water temperature was slightly higher in the dry season (29.71 ± 0.48 0C) than in the wet season (29.19 ± 2.430C). Results of ANOVA showed that there was no significant difference ($p > 0.05$) in water temperature among the zones and seasons.

The pH values were slightly acidic to alkaline in nature (6.2 - 8.52). The mean pH of zones (Figure 3) decreased slightly from upper zone (7.66 ± 0.50) to lower zone (7.58 ± 0.41). Seasonally (Figure 3), mean pH of wet season (7.75 ± 0.20) was higher than the dry season (7.47 ± 0.55). The seasonal variations in pH were significantly different ($p < 0.05$).

The electrical conductivity values varied between 121µS/cm to 23000µS/cm throughout the study periods. The mean conductivity (Figure 3) increased drastically from upper zone (2596.22 ± 4442.55µS/cm) to lower zone (11462.86 ± 7135.20 µS/cm). Seasonally, mean of pooled electrical conductivity data (Figure 3) was higher in the dry season (7155.43 ± 6166.64µS/cm) than in the wet season (5165.87 ± 3590.17µS/cm). Electrical conductivity values differed significantly across zones ($p < 0.05$), but the difference was not seasonally significant ($p > 0.05$).

Turbidity in the creek throughout the study duration was between 6 and 85NTU. The maximum mean turbidity value of 29.44 ± 11.21NTU was recorded at the middle zone while the minimum (26.61 ± 10.72 NTU) was at lower zone (Figure 3). Mean turbidity value (Figure 3) was higher in the dry season (30.15 ± 12.21NTU) than in the wet season (26.83 ± 7.86NTU). However, turbidity values between the zones and seasons were not significantly different ($p > 0.05$).

The salinity values obtained in this present study ranged from zero to 14.5PSU. The salinity mean values were 1.33 ± 2.48, 2.24 ± 3.21 and 6.41 ± 4.18 PSU respectively for upper zone, middle zone and lower zone (Figure 4). Therefore Banditry creek was classified as oligohaline (0.5 to 5.0PSU) in the upper and middle zone and mesohaline (5.0 to < 18.0PSU) in the lower zone. Season-wise (Figure 4), the dry season salinity average value (3.81 ± 3.72 PSU) was higher than wet season (2.84 ± 2.11PSU). Salinity values differed significantly across zones ($p < 0.05$), but the difference was not seasonally significant ($p > 0.05$).

The Dissolved Oxygen values in the creek in this present study varied between 1.2mg/l and 7.6mg/l. The Dissolved Oxygen average values (Figure 4) increased slightly from lower zone (4.69 ± 0.88mg/l) to upper zone (4.84 ± 1.15mg/l). Seasonally, dissolved oxygen mean seasonal value (Figure 4) was slightly higher during dry season (4.91 ± 0.65mg/l) than in wet season (4.66 ± 1.34mg/l). However, Dissolved oxygen means values between the zones and seasons did not differ significantly ($p > 0.05$).

The water depth of the study area throughout the study period ranged between 0.45 and 8.84m. Mean water depth (Figure 4) increased from lower zone (1.78 ± 0.35m) to upper zone (5.41 ± 1.01m). Season-wise, water depth mean value (Figure 4) was higher in wet season (3.57 ± 0.38m) than dry season (3.39 ± 0.41m). The water depth values differed significantly across zones ($p < 0.05$), but the difference was not seasonally significant ($p > 0.05$).

The concentration of phosphate in this study was from 0.11µM to 15.27µM. The highest average inorganic phosphate concentration (Figure 4) was obtained at lower zone (6.75 ± 4.08 µM) and the least concentration (5.02 ± 3.05 µM) was at middle zone. Seasonally, inorganic phosphate was higher in dry season than wet season with mean concentration of 6.54 ± 3.48 and 4.80 ± 3.10µM in dry and wet season respectively (Figure 4). Seasonal variations in Phosphate values were significantly different ($p < 0.05$), but the differences in zones were not significant ($p > 0.05$).

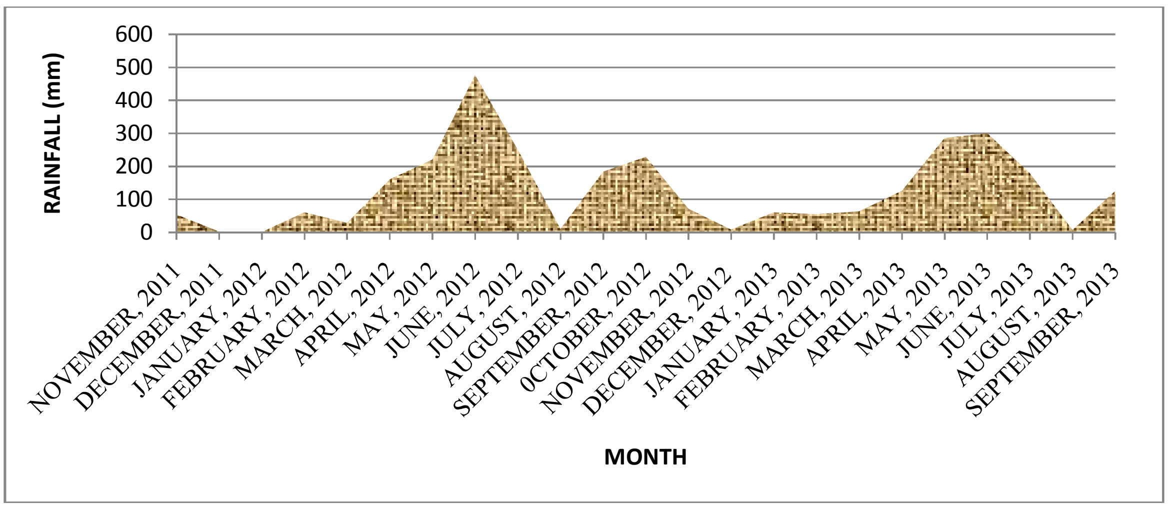

Fig. 2. Monthly Rainfall (mm) pattern in Badagry Creek (November, 2011 – September, 2013).

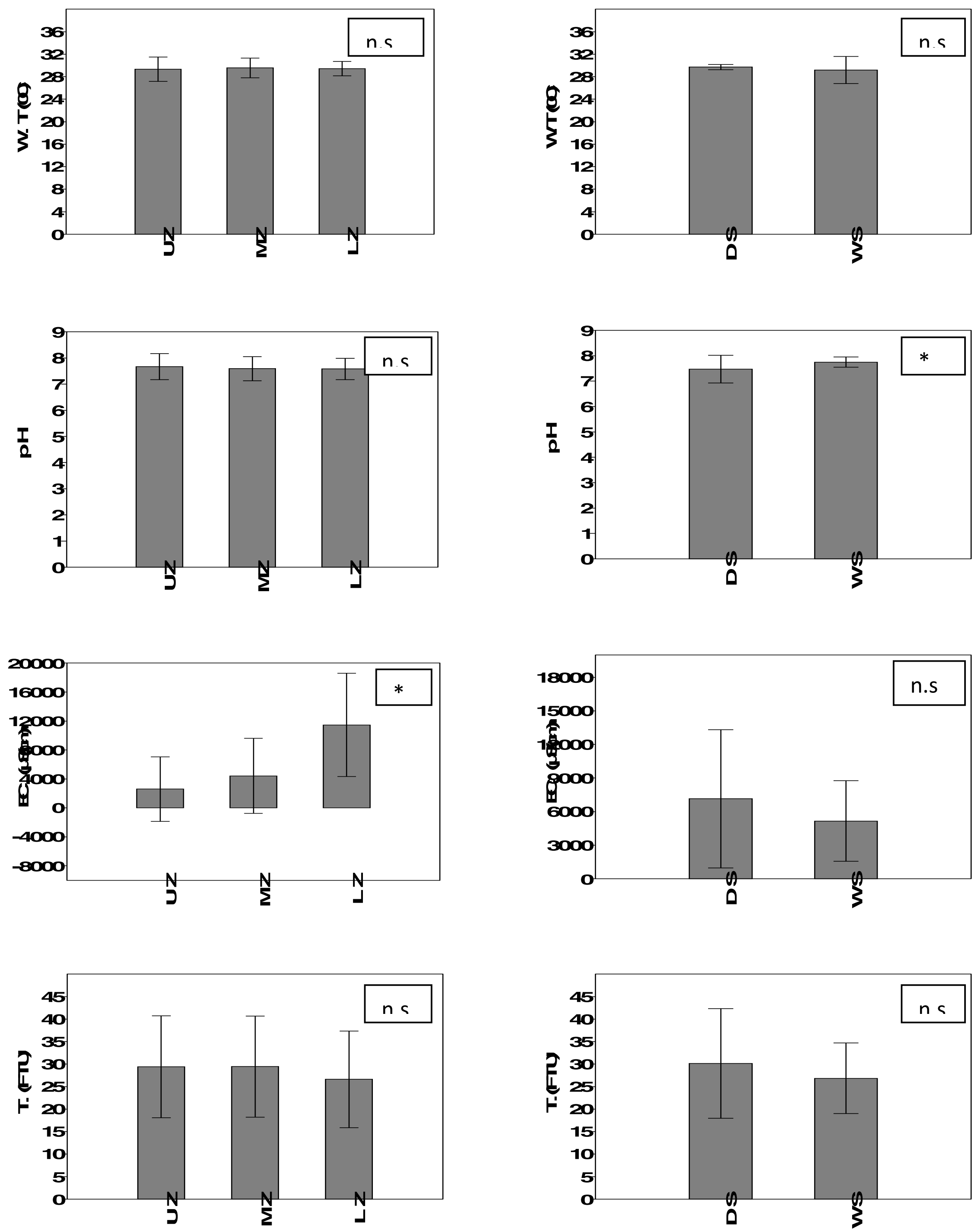

Fig. 3. Spatial and seasonal variations in Abiotic factors (W.T: Water Temperature; pH; EC: Conductivity and T: Turbidity) in the Badagry creek with mean ± SD. UZ: Upper Zone; MZ: Middle Zone; LZ: Lower Zone, DS: Dry season; WS: Wet season; n.s: not significant ($p > 0.05$); *: significant **(**$p < 0.05$**).**

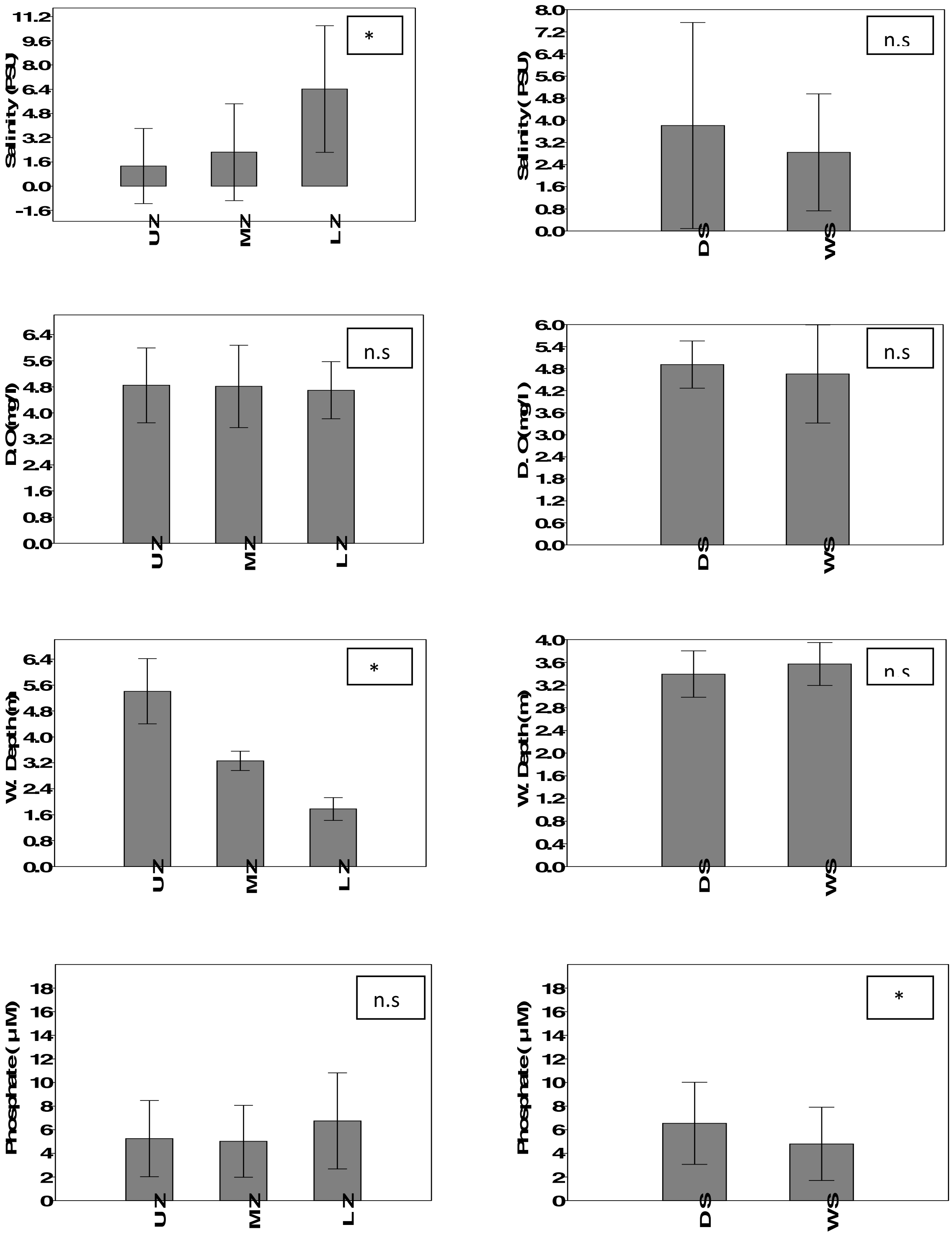
Salinity (PSU)
*
UZ
MZ
LZ
Salinity (PSU)
n.s
DS
WS
D.O(mg/l)
n.s
D. O(mg/l)
n.s
W. Depth(m)
*
W. Depth(m)
n.s
Phosphate(µM)
n.s
Phosphate(µM)
*

Figure 4: Spatial and seasonal variations in Abiotic factors (Salinity; D.O: Dissolved Oxygen; W.Depth: Water Depth and Phosphate) in the Badagry Creek with mean ± SD. UZ: Upper Zone; MZ: Middle Zone; LZ: Lower Zone, DS: Dry season; WS: Wet season; n.s: not significant ($p > 0.05$); *: significant **(**$p < 0.05$**).**

3.2. Fish Assemblage structure

The checklist of finfish catches in the Badagry creek is shown in Table 1. The survey of fin-fish catches yielded a total number of 4,045 individuals comprising 36 species from 22 families (Table 2). The prominent fish families in order of dominance were Cichlidae (25.07%), Claroteidae (16.84%), Clupeidae (15.40%), Carangidae (4.85%), and Cynoglossidae (4.75%). The least family abundance were Citharinidae (0.44%) and Ophichthidae (0.44%). The most dominant fish species in this study (Table 2) was *Tilapia zillii* (15.23%). Other prominent fish species in order of dominance were *Chrysichthys nigrodigitatus* (11.27%), *Ethmalosa fimbriata* (11.17%), *Cynoglossus senegalensis* (4.75%), *Sarotherodon melanotheron* (4.28%), and *Sardinella maderensis* (4.23%). The least relative abundance was *Citharus linguatula* (0.30%) and *Distichodus engycephalus* (0.15%).

Regarding the ecological categories (Table 2), 4 estuarine resident (12.21%), 4 estuarine dependent freshwater (19.5%), 11 estuarine dependent marine (29.28%), 9 estuarine non-dependent marine (16.42%), 2 occasional marine visitors (3.66%) and 6 freshwater species (18.94%) occurred in the fishermen catches from the studied creek.

Seasonal variation of fish species composition and abundance (Table 3) showed that dry season species composition and abundance was higher than the wet season, with a total of 36 species (2,040 individuals) and 34 species (2,005 individuals) fish recorded during the dry and wet season respectively.

The prominent species in the dry season of this study in order of dominance included *Tilapia zillii* (18.68%), *Ethmalosa fimbriata* (6.03%) and *Chrysichthys nigrodigitatus* (5.00%) whereas the notable species in order of dominance in the wet months of this study were *Chrysichthys nigrodigitatus* (17.66%), *Ethmalosa fimbriata* (16.41%) and *Tilapia zillii* (11.72%). *Citharus linguatula* (Citharinidae) and *Ophichthus rufus* (Ophichthidae) were not found during the wet months of this study.

Seasonally, 4 (14.8%) estuarine resident fish, 4 (10.48%) estuarine dependent freshwater fish, 11 (27.99%) estuarine dependent marine fish, 9 (18.34%) estuarine non-dependent marine fish, 2 (5.49%) occasional marine visitors and 6 (22.9%) freshwater fish were found in dry (months) season whereas 4 (9.58%) estuarine resident fish, 4 (28.68%) estuarine dependent freshwater fish, 10 (30.58%) estuarine dependent marine fish, 8 (14.47%) estuarine non-dependent marine fish, 2 (1.8%) occasional marine visitors and 6 (14.92%) freshwater fish were recorded in wet (months) season (Table 3).

The overall fish diversity indices of Badagry creek as presented in Table 2 revealed Dominance, Shannon, Evenness, Margalef and Equitability J indexes with 0.06, 3.13, 0.64, 4.21 and 0.87 values respectively. The seasonal variation in the fish diversity indices of Badagry creek as presented in Table 3 showed that the dominance index varied from 0.06 (dry season) to 0.09 (wet season), Shannon H index was higher (3.19) in the dry season and lower (2.82) in the wet season. Evenness, Margalef and Equitability J indexes were greater in the dry season with 0.68, 4.59 and 0.89 indices values respectively while their corresponding lower values 0.49, 4.34 and 0.80 were obtained in the wet season.

Table 1
Checklist of fish family and species in Badagry creek, (November, 2011 – September, 2013).

FAMILY	SPECIES
CLAROTEIDAE	*Chrysichthys auratus* **(**Geoffroy Saint-Hilaire, 1809)
	Chrysichthys nigrodigitatus. (Lacepède, 1803)
	Chrysichthys walkeri (Günther, 1899)
CARANGIDAE	*Caranx carangus* (Bloch, 1793)
	Caranx hippos (Linnaeus, 1766)
	Trachinotus teraia (Cuvier, 1832)
CICHLIDAE	*Hemichromis fasciatus* (Peters, 1857)
	Sarotherodon melanotheron (Rüppell, 1852)
	Tilapia guineensis (Bleeker, 1862)
	Tilapia zillii (Gervais, 1848)
CITHARINIDAE	*Citharus linguatula* (Linnaeus, 1758)
	Distichodus engycephalus (Günther, 1864)
CLARIIDAE	*Clarias sp.* (Burchell, 1882)
CLUPEIDAE	*Ethmalosa fimbriata* (Bowdich, 1825)
	Sardinella maderensis (Lowe, 1838)
CYNOGLOSSIDAE	*Cynoglossus senegalensis* (Kaup, 1858)
CYPRINODONTIDAE	*Parachanna obscura* (Gunther, 1861)
DREPANIDAE	*Drepane africana* (Osório, 1892)
ELOPIDAE	*Elops lacerta* (Valenciennes, 1847)
GOBIIDAE	*Gobioides africanus* (Giltay, 1935)
MONODACTYLIDAE	*Monodactylus sebae* (Cuvier, 1829)
MORMYRIDAE	*Marcusenius senegalensis* (Steindachner, 1870)
MUGILIDAE	*Mugil cephalus* (Linnaeus, 1758)
OPHICHTHIDAE	*Ophichthus rufus* (Rafinesque, 1810*)*
OSTEOGLOSSIDAE	*Heterotis niloticus* (Cuvier, 1829)
POLYNEMIDAE	*Galeoides decadactylus* (Bloch, 1795)
	Pentanemus quinquarius (Linnaeus, 1758)
HAEMULIDAE	*Brachydeuterus auritus* (Valenciennes, 1832)
	Pomadasys incisus (Bowdich, 1825)
	Pomadasys jubelini (Cuvier, 1830)
SCIAENIDAE	*Pseudotolithus typus* (Bleeker, 1863)
	Pseudotolithus elongates (Bowdich, 1825)
SPHYRAENIDAE	*Sphyraena afra* (Peters, 1844)
LUTJANIDAE	*Lutjanus agennes* (Bleeker, 1863)
	Apsilus fuscus (Valenciennes, 1830)
URANOSCOPIDAE	*Uranoscopus polli* (Cadenat, 1951)

Table 2
Fish composition in terms of ecological categories, abundance and diversity of Badagry creek (Nov., 2011 – Sept., 2013). UZ: Upper zone; MZ: Middle zone; LZ: Lower zone; T_{ab}: Total abundance (Number of individual); R_a: Relative abundance (%); SD: Standard Deviation

Ecological categories	Species	UZ	MZ	LZ	T_{ab}	R_a	Mean ± SD
Estuarine Resident (ER)	*Sarotherodon melanotheron*	29	36	108	**173**	**4.28**	14.42 ± 12.35
	Tilapia guineensis	41	37	39	**117**	**2.89**	9.75 ± 10.98
	Monodactylus sebae	18	24	26	**68**	**1.68**	5.67 ± 6.34
	Uranoscopus polli	49	45	42	**136**	**3.36**	11.33 ± 11.96
Estuarine Dependent freshwater fish (EDF)	*Chrysichthys auratus*	68	48	41	**157**	**3.88**	13.08 ± 18.42
	Chrysichthys nigrodigitatus	197	91	168	**456**	**11.27**	38.00 ± 41.90
	Chrysichthys walkeri	33	11	24	**68**	**1.68**	5.67 ± 10.47
	Hemichromis fasciatus	26	30	52	**108**	**2.67**	9.00 ± 8.91
Estuarine Dependent marine fish (EDM)	*Trachinotus teraia*	21	22	41	**84**	**2.08**	7.00 ± 7.05
	Citharus linguatula	0	4	8	**12**	**0.3**	1.0 ± 2.37
	Ethmalosa fimbriata	193	87	172	**452**	**11.17**	37.67 ± 37.02
	Cynoglossus senegalensis	60	56	76	**192**	**4.75**	16.00 ± 12.09
	Drepane africana	38	30	36	**104**	**2.57**	8.67 ± 8.64
	Gobioides africanus	14	12	22	**48**	**1.19**	4.00 ± 4.84
	Galeoides decadactylus	29	19	36	**84**	**2.08**	7.00 ± 8.92
	Pentanemus quinquarius	12	16	16	**44**	**1.09**	3.67 ± 6.65
	Brachydeuterus auritus	13	10	18	**41**	**1.01**	3.42 ± 4.81
	Pomadasys incisus	18	17	20	**55**	**1.36**	4.58 ± 5.45
	Pomadasys jubelini	22	25	21	**68**	**1.68**	5.67 ± 6.68
Estuarine Non-dependent marine fish (ENDM)	*Caranx carangus*	31	28	20	**79**	**1.95**	6.58 ± 9.54
	Caranx hippos	10	0	23	**33**	**0.82**	2.75 ± 4.69
	Sardinella maderensis	63	53	55	**171**	**4.23**	14.25 ± 15.27
	Elops lacerta	31	17	39	**87**	**2.15**	7.25 ± 7.68
	Mugil cephalus	44	33	42	**119**	**2.94**	9.92 ± 11.76
	Ophichthus rufus	0	6	12	**18**	**0.44**	1.50 ± 3.53
	Pseudotolithus typus	19	15	25	**59**	**1.46**	4.92 ± 7.49
	Pseudotolithus elongatus	19	25	19	**63**	**1.56**	5.25 ± 9.24
	Sphyraena afra	14	6	15	**35**	**0.87**	2.92 ± 4.93
Occasional marine visitors (OMV)	*Lutjanus agennes*	31	27	35	**93**	**2.3**	7.75 ± 11.73
	Apsilus fuscus	15	17	23	**55**	**1.36**	4.58 ± 6.11
Freshwater fish (FWF)	*Tilapia zillii*	218	144	254	**616**	**15.23**	51.33± 43.36
	Distichodus engycephalus	0	0	6	**6**	**0.15**	0.50 ± 1.24
	Clarias sp.	19	15	8	**42**	**1.04**	3.50 ± 4.81
	Parachanna obscura	16	7	6	**29**	**0.72**	2.42 ± 4.08
	Marcusenius senegalensis	0	25	3	**28**	**0.69**	2.33 ± 3.77
	Heterotis niloticus	13	11	21	**45**	**1.11**	3.75 ± 5.22
	Diversity Indices						
	Taxa (S)	32	34	36	36		
	Individuals	1424	1049	1572	4045		
	Dominance (D)	0.08	0.05	0.07	0.06		
	Shannon (H)	3.00	3.21	3.11	3.13		
	Evenness (e^H/S)	0.63	0.73	0.62	0.64		
	Margalef	4.27	4.74	4.76	4.21		
	Equitability (J)	0.87	0.91	0.87	0.87		

Table 3
Seasonal variation of fish composition in terms of ecological categories, abundance and diversity of Badagry creek (Nov., 2011 – Sept., 2013) T_{ab}: Total abundance (Number of individual); R_a: Relative Abundance (%); SD: Standard Deviation

	Species	DRY SEASON			WET SEASON		
		T_{ab}	R_a	Mean ± SD	T_{ab}	R_a	Mean ± SD
Estuarine Resident (ER)	***Sarotherodon melanotheron***	86	4.22	14.33 ± 12.93	87	4.34	14.50 ± 12.97
	Tilapia guineensis	68	3.33	11.33 ± 15.63	49	2.44	8.17 ± 3.87
	Monodactylus sebae	49	2.40	8.17 ± 6.43	19	0.95	3.17 ± 5.67
	Uranoscopus polli	99	4.85	16.50 ± 14.08	37	1.85	6.17 ± 7.22
Estuarine Dependent freshwater fish (EDF)	***Chrysichthys auratus***	26	1.27	4.33 ± 6.53	131	6.53	21.83 ± 22.80
	Chrysichthys nigrodigitatus	102	5.00	17.00 ± 12.99	354	17.66	59.00 ± 51.34
	Chrysichthys walkeri	6	0.29	1.00 ± 2.00	62	3.09	10.33 ± 13.60
	Hemichromis fasciatus	80	3.92	13.33 ± 10.71	28	1.40	4.67 ± 3.88
Estuarine Dependent marine fish (EDM)	***Trachinotus teraia***	37	1.81	6.17 ± 6.88	47	2.34	7.83 ± 7.76
	Citharus linguatula	12	0.59	2.00 ± 3.16	0	0.00	0.00 ± 0.00
	Ethmalosa fimbriata	123	6.03	20.50 ± 25.28	329	16.41	54.83 ± 40.84
	Cynoglossus senegalensis	75	3.68	12.50 ± 11.10	117	5.84	19.50 ± 13.00
	Drepane africana	39	1.91	6.50 ± 7.18	65	3.24	10.83 ± 10.07
	Gobioides africanus	36	1.76	6.00 ± 5.55	12	0.60	2.00 ± 3.35
	Galeoides decadactylus	78	3.82	13.00 ± 9.10	6	0.30	1.00 ± 2.45
	Pentanemus quinquarius	43	2.11	7.17 ± 8.23	1	0.05	0.17 ± 0.41
	Brachydeuterus auritus	39	1.91	6.50 ± 5.24	2	0.10	0.33 ± 0.82
	Pomadasys incisus	35	1.72	5.83 ± 5.00	20	1.00	3.33 ± 6.06
	Pomadasys jubelini	54	2.65	9.00 ± 7.54	14	0.70	2.33 ± 3.83
Estuarine Non-dependent marine fish (ENDM)	***Caranx carangus***	34	1.67	5.67 ± 9.83	45	2.24	7.50 ± 10.07
	Caranx hippos	2	0.10	0.33 ± 0.82	31	1.55	5.17 ± 5.81
	Sardinella maderensis	63	3.09	10.50 ± 18.09	108	5.39	18.00 ± 12.35
	Elops lacerta	40	1.96	6.67 ± 8.94	47	2.34	7.83 ± 7.00
	Mugil cephalus	92	4.51	15.33 ± 13.66	27	1.35	4.50 ± 6.86
	Ophichthus rufus	18	0.88	3.00 ± 4.69	0	0.00	0.00 ± 0.00
	Pseudotolithus typus	42	2.06	7.00 ± 9.63	17	0.85	2.83 ± 4.49
	Pseudotolithus elongatus	60	2.94	10.00 ± 11.52	3	0.15	0.50 ± 0.84
	Sphyraena afra	23	1.13	3.83 ± 6.34	12	0.60	2.00 ± 3.35
Occasional marine visitors(OMV)	***Lutjanus agennes***	69	3.38	11.50 ± 14.52	24	1.20	4.00 ± 7.62
	Apsilus fuscus	43	2.11	7.17 ± 7.49	12	0.60	2.00 ± 3.16
Freshwater fish (FWF)	***Tilapia zillii***	381	18.68	63.50 ± 59.53	235	11.72	39.17 ± 15.41
	Distichodus engycephalus	2	0.10	0.33 ± 0.82	4	0.20	0.67 ± 1.63
	Clarias sp.	27	1.32	4.50 ± 6.53	15	0.75	2.50 ± 2.43
	Parachanna obscura	3	0.15	0.50 ± 1.22	26	1.30	4.33 ± 5.13
	Marcusenius senegalensis	21	1.03	3.50 ± 4.46	7	0.35	1.17 ± 2.86
	Heterotis niloticus	33	1.62	5.50 ± 5.36	12	0.60	2.00 ± 4.90
	Diversity Indices						
	Taxa (S)	36			34		
	Individuals	2040			2005		
	Dominance (D)	0.06			0.09		
	Shannon (H)	3.19			2.82		
	Evenness (e^H/S)	0.68			0.49		
	Margalef	4.59			4.34		
	Equitability_J	0.89			0.80		

3.3. Abiotic factors and fish assemblage (Ecological categories)

Table 4 shows specifically correlation (Spearman) between independent variables and fish species abundance (ecological categories). Water temperature inversely correlated with abundance of estuarine dependent freshwater fish ($P < 0.01$) and estuarine dependent marine fish ($P < 0.05$). Electrical conductivity and Salinity inversely correlated with the abundance of estuarine dependent freshwater fish ($P < 0.05$) and estuarine dependent marine fish ($P < 0.01$). Dissolved oxygen was positively correlated with the abundance of estuarine non dependent marine fish ($P < 0.05$). Water depth and Phosphate showed positive correlation with the abundance of freshwater fish ($P < 0.05$).

Table 4

Correlation (Spearman) coefficients for variables examined in Badagry Creek (Nov, 2011 – Sept., 2013) EDF – Estuarine dependent freshwater fish; EDM – Estuarine dependent marine fish; ENDM – Estuarine non-dependent marine fish; ER – Estuarine resident fish; OMV – Occasional marine visitor fish; FW – Freshwater fish (*P < 0.05, **P < 0.01)

	ER	EDF	EDM	ENDM	OMV	FW
Water Temperature	0.427	-.823**	-.629*	-0.547	0.474	0.350
pH	0.179	-0.368	-0.27	-0.446	0.196	0.165
Conductivity	0.189	-.616*	-.755**	-0.572	0.422	0.315
Turbidity	0.049	0.112	-0.165	0.032	0.093	0.322
Salinity	0.189	-.616*	-.755**	-0.572	0.422	0.315
Dissolved Oxygen	0.091	-0.357	-0.316	.599*	0.247	0.291
Water depth	0.544	-0.23	-0.305	0.48	0.538	.690*
Phosphate	0.333	-0.042	0.091	0.336	0.407	.664*
Rainfall	-0.249	0.119	-0.217	-0.375	-0.299	-0.406

The relative importance of the measured abiotic factors to the ecological (species) categories abundance as determined by Canonical correspondence analysis is shown in Figure 5. Result of CCA showed that the first and second axes accounted respectively for 80.44% and 13.99% of the total variance for the environmental - fish ecological categories relationship. The CCA diagram in Figure 5 indicates the longer the vector, the greater the influence of variables on species abundance. The relative length of the vectors indicates that water depth was the most important environmental variable in the abundance of species ecological categories, thus proving to be the best predictor of species (ecological categories) abundance. Water depth positively influenced abundance of estuarine resident fish, occasional marine visitor and freshwater fish, and negatively influenced the abundance of estuarine dependent freshwater fish and estuarine dependent marine fish. Temperature was positively correlated to the abundance of occasional marine visitor fish, estuarine resident fish and freshwater fish and negatively correlated to abundance of estuarine dependent freshwater fish, estuarine dependent marine fish and estuarine non-dependent marine fish.

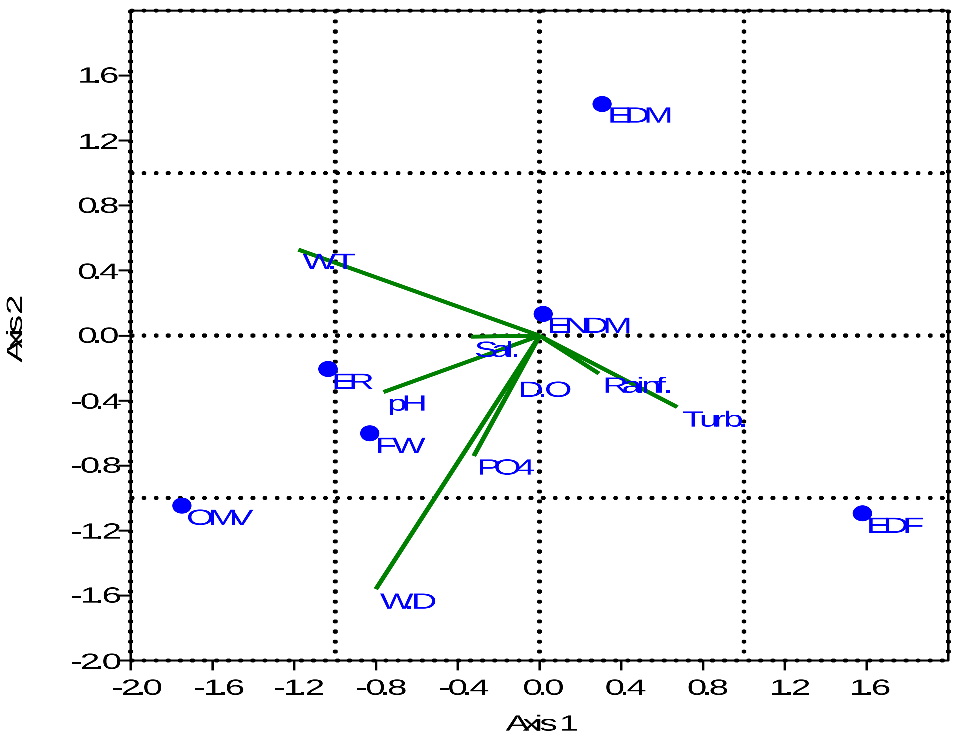

Fig. 5. Ordination diagram from the canonical correspondence analysis applied to the environmental (Abiotic) variables and species ecological categories in Badagry Creek. W.T: Water Temperature; pH; Sal: Salinity; W.D: Water depth; Turb.: Turbidity; D.O: Dissolved Oxygen; PO4: Phosphate; Rainf: Rainfall. Ecological categories code: EDM – Estuarine dependent marine fish; ENDM – Estuarine non-dependent marine fish; OMV – Occasional marine visitor fish; EDF – Estuarine dependent freshwater fish; ER – estuarine resident fish and FW – freshwater fish species. Eigenvalues: axis 1, 0.34; axis 2, 0.06; axis 3, 0.02. First 2 axes accounted for 94.4% of the variance. Monte Carlo test of canonical axes significant ($p < 0.01$) at 1000 permutations.

4. Discussion

The thirty-six fish species and 22 families recorded in Badagry creek during the period of this study compared favourably with Sikoki et al., (1998) who documented 37 species and 15 families in Lower Nun River and Agboola et al., 2008 who reported thirty-seven fish species from 28 families in Badagry creek. However, the reported species figure in this study falls below the reports of some earlier scientists that worked on Nigeria inland and coastal waters (Fagade and Olaniyan, 1974; Ayoola and Kuton, (2009); Solarin and Kusemiju, 1991, Abowei, 2000). This decline could be as a result of environmental degradation. The variation may also be due to selling of fish by fishermen on board without bringing them to the landing station (Ayoola and Kuton, 2009).

The diverse finfish species observed and reported in this study had been reported by Fagade and Olaniyan (1974), Agboola et al., (2008) and Ayoola and Kuton (2009).

The predominant finfish family in this study was Cichlidae which was reported by Ayoola and Kuton, (2009) as the highest abundant in the Lagos lagoon. Agboola et al. also documented Tilapia zillii as one of the prominent species and next to Chrysichthys nigrodigitatus in order of dominance in earlier study in the Badagry creek.

Higher fish species diversity and abundance was recorded in this study in the dry season than in the wet season. A similar observation had been reported (Fagade and Olaniyan, 1974; Solarin and Kusemiju, 2003) for Lagos lagoon. A number of factors could be responsible for higher finfish in the dry season. Tobor, (1992) reported that most of these artisanal fisheries are dry season fishery; this invariably makes fishes more abundant during the dry season. Low water level in the dry season could cause an increase in catch in the season and generally increases abundance of fish species more than that of wet season (Ayoola and Kuton, 2009). Fagade and Olaniyan (1974) opined that higher fish species of marine origin during the dry season may be linked with the fact that the juvenile stages of many marine species are known to live in water of reduced salinity and therefore many of these inhabit Lagos lagoon. This is in agreement with this present study.

Families Mugilidae, Cichlidae, Clupeidae, Claroteidae, Sphyraenidae, pomadasydae and Lutijanidae were recorded in both seasons. Fagade and Olaniyan (1974) recorded these families as being among the fishes caught in the lagoon throughout the year.

The occurrence of more marine species recorded in this study was an indication that these species live and reproduce from nearly freshwater to hyperhaline waters or conditions. These species are also known to be true migratory fish species.

It is commonly agreed that the higher the fish diversity, the more stable the fish community (Leveque, 1995). The species diversity and richness values reported in this study were relatively higher than values reported for many water bodies in south western coastal waters where the present study area is also located. The higher diversity indices in this study were due to the higher number of species and individuals recorded. The low species equitability values in both seasons imply that the two seasons had a dominant fish species abundant. The higher dry season equitability is an indication that there are many dominant fish species in the dry than wet seasons.

The occurrence of some species throughout the study such as Tilapia zillii, Chrysichthys nigrodigitatus and Cynoglossus senegalensis however, are typical of resident species, irrespective of salinity.

Grouping species into ecological categories helps improve our understanding and management of aquatic ecosystems. Predicting responses of individual species to environmental change can be difficult, because fish diversity often times can be quite high. Grouping fishes based on biological or ecological similarities can help reduce that complexity because species in the same group often respond similarly to same threats or exploit the same resources typically in similar ways.

The abundance of a fish species is predicted to be largely regulated by abiotic habitat characteristics when densities of predators or competitors are low. However, when predator or competitor densities are high, the abundance of the fish species is suppressed by biotic interactions regardless of environmental conditions.

Canonical correspondence analysis (CCA) carried out in this study showed that creek characteristics explain the variation in fish abundance. The relative importance of the measured abiotic factor to the ecological categories as determined by CCA revealed water depth as the most important environmental variable in the species ecological categories, proving to be the best predictor of species ecological categories abundance. Similar result was reported (Keskin 2007). The positive effect of water depth on species ecological categories suggests the preference of fish species particularly estuarine resident, estuarine non-dependent marine, occasional marine visitors and freshwater fishes for moderately deep waters. However, the negative influence of water depth on estuarine dependent freshwater and estuarine dependent marine fishes could be attributed to preference of these species for shallow waters. Water depth significantly varied spatially, increasing from the lower zone to the upper zone of the creek.

Studies in other estuaries have highlighted the importance of temperature in fish species abundance. Temperature is often cited as a major factor affecting seasonal abundance of fish species in estuaries (Rakocinski et al. 1992, Arceo-Carranza & Vega-Cendejas 2009). The negligible influence of this factor on the fish community structure in Badagry creek is probably related to the warm conditions of this system and its predominately tropical ichthyofauna. The positive influence of water temperature on estuarine resident, occasional marine visitor and freshwater fishes suggests preference of warmer temperatures for these species ecological categories.

The negative effect of pH on estuarine dependent freshwater, estuarine dependent marine and estuarine non-dependent marine fishes in Badagry creek was an indication that these ecological categories fishes thrives better in moderately low pH waters.

Phosphate is one of the most important nutrient and a limiting factor in the maintenance of aquatic ecosystem fertility. With an exception of estuarine dependent freshwater fish, phosphate positively correlated with the abundance of ecological categories, showing a direct influence on the abundance of these ecological categories.

Turbidity in natural waters restricts light penetration thus limiting photosynthesis, which consequently leads to depletion of oxygen content. Turbidity in water is caused by a wide variety of suspended matter, which range in size from colloidal to coarse dispersions and also ranges from pure organic substances to those that are highly organic in nature. Clay, silt, organic matter, phytoplankton and other microscopic organisms cause turbidity in natural waters. Pate (2001) reported that the dissolved solids influence the turbidity of waters and in turn affect light penetration.

The periods of low Dissolved Oxygen concentrations during the rainy months could possibly be that the creek might have received polluted run-off from the various sewage treatment plant, oil wastes, domestic and sewage dumping sites, waste disposal sites and farming locations along the basin.

Most water bodies in tropical regions show two differentiable seasons (dry and wet), and the majority of these water bodies depend on seasonal changes to activate and deactivate environmental parameters (Fialho et al. 2007). Freshwater runoff increases during the rainy season, leading to a decrease in salinity. The dilution effect of water in the estuary creek is conducive for freshwater and brackish water species which thrive in this environment. However, during the dry season, high salinity incursion triggers the entry of some marine species (Carangidae) into the estuary due to the availability of food and shelter from predators (Blaber 1997, Marshall & Elliot 1998). A negative association of rainfall with estuarine resident, estuarine dependent marine, estuarine non-dependent marine, occasional marine visitor and freshwater fishes suggests preference of low rainfall for these species ecological categories. The abundance of these ecological categories was higher during the dry season months. Salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone (Gibson, 1982). This factor was not totally supported in the CCA plot, where salinity was the weakest variable to influence Badagry creek species ecological categories abundance. However, the negative effect of salinity on estuarine dependent freshwater, estuarine dependent marine and estuarine non-dependent marine fishes suggests their preference for low salinity. Salinity showed direct relationship with conductivity in this study. Conductivity and salinity have been reported as associated factors (Balogun and Ladigbolu, 2010). Salinity significantly varied spatially and drastically reducing from the lower end (zone) having communication with the sea water via Lagos harbour to the upper zone of the creek where there is freshwater inflow.

5. Conclussion

Understanding the factors that influence fish community structure is important not only for accumulating basic information, but also to predict the effects of environmental change on the integrity of these communities.

The present study represents a preliminary exploration of the relationship of fish assemblages with the environmental variables in the creek. However, based on this study, water depth had greater influence on species (ecological categories) abundance. The anthropogenic activities in the creek needs thorough monitoring because this area is an important nursery ground for fishes, plankton, and molluscs, and local communities depend on it for their livelihood.

Generally, the study of Badagry creek has revealed a good ecological system that could support the well-being of biota especially fish. However, the unregulated uses of Badagry creek should be controlled through the enforcement of various regulations and laws by the various implementing agencies involved as there will be serious biodiversity loss if these persist.

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