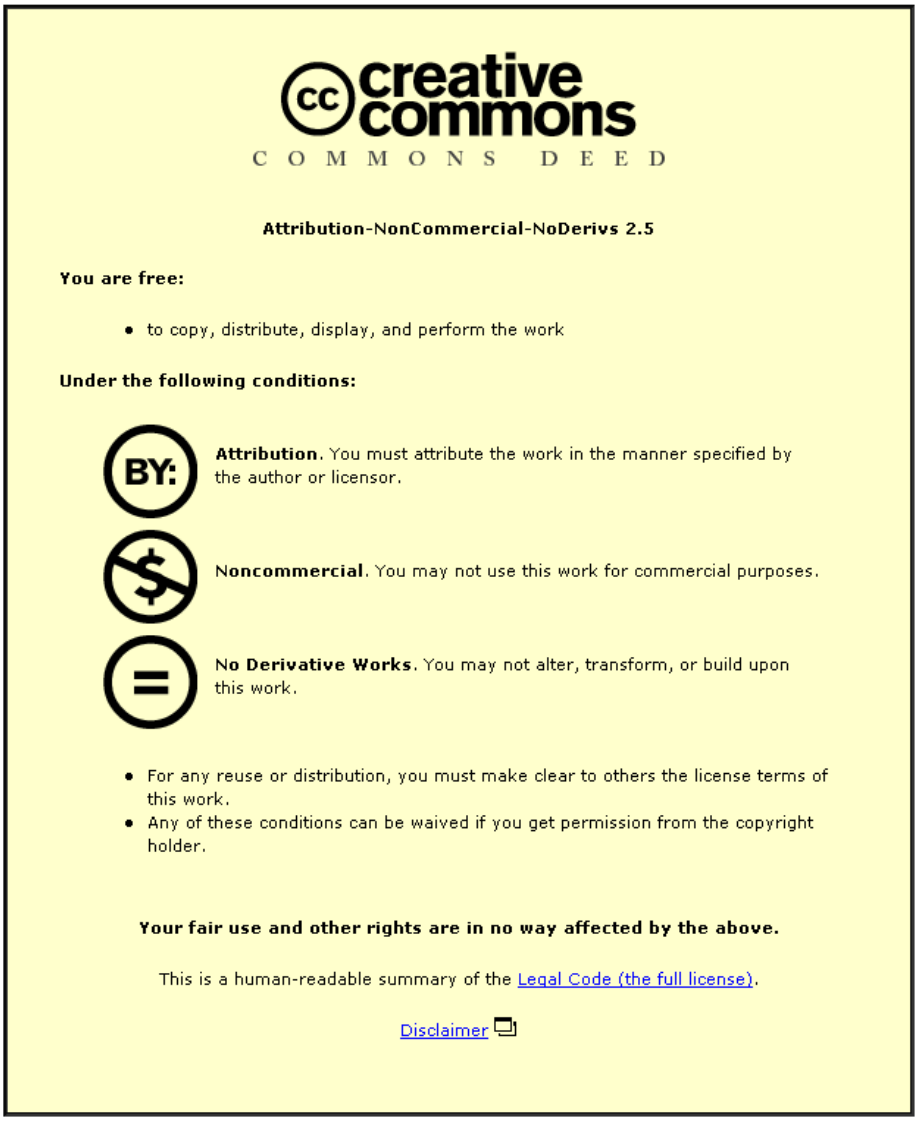

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Fish Species as Eco-indicators in the Comparative Ecological Characterisation of two Creeks in the Central Niger Delta, Nigeria

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Abstract

Fish species have been used to compare the ecological characteristics of two surface waters in the same geo-ecological zones Central Niger Delta. The authors carried out twenty four ecological expeditions along the Kolo and Otuoke Creeks in the Central Niger Delta for the purpose of comparing the ecological characteristics of these two surface waters that are in the same geo-ecological zone. Duplicate ecological surveys were conducted across three fishing seasons in the Study Area, and the traditional eco-livelihoods knowledge of experienced fishermen was explored during the survey to ensure that the surveys captured the spatial and temporal variation of fish species distribution in these creeks. The result of our study shows that there are no significant statistical ecological differences between the Kolo and Otuoke Creeks based on the following ecological indices: relative species percentage abundance; species richness; species diversity index; Shannon diversity index; and Simpson diversity index. Furthermore, the Bray-Curtis similarity index has been used to demonstrate that the two surface waters were ecologically significantly similar. The implication of the findings is that the ecological attributes of surface water in the same geo-ecological zone are not significantly different in the absence of major environmental noise or human induced stress.

Key words: Eco-indicator; Fish species; Kolo Creek; Otuoke Creek; Ecological survey; Shannon diversity index; Simpson diversity index; Bray-Curtis similarity Index.

1 Introduction

Ecosystems are characteristically complex, dynamic and extremely variable systems (Folke, 2004; Karr and Chu, 2002; Pavlikakis and Tsihrintzis, 2000), but ecological attributes and structures have been successfully used as indicators of ecological status (De Groot, *et al.* 2003; Liu, *et al.* 2012). Generally, ecological status is linked to

ecosystem functions and services (De Groot, *et al.* 2003; McGregor, 1993; Liu, *et al.* 2012). Hence, the knowledge of the relationship between the ecological attributes of surface fresh waters in the same geo-ecological zones could constitute the basis for understanding the services these systems provide. In the context of this study, the authors used fish species as eco-indicator of ecological status for the Central Niger Delta. Fish species have been used for this study because fish species occupy a wide trophic spectrum, and fishing represents a significant livelihood source in rural communities of the Central Niger Delta.

Living organisms, in addition to providing clear signals about river health, also attract the attention of various stakeholder groups, often reaching more diverse groups emotionally. For example, for generations, in the areas surrounding Lake Biwa (Japan) aquatic organisms have been central to the peoples' lives. Although the residents around Lake Biwa are currently less connected with aquatic organisms than in earlier generations, ecological indicators are more relevant and appealing to them than other water status indicators. Signals from biota are more easily grasped intuitively than are physico-chemical water quality data. Photographs of massive fish deaths, for instance, have far greater impact on members of the public than water chemistry data indicating pollution (Karr and Rossano, 2001).

The use of biological communities as bio-indicators in the assessment of ecological status has been widely investigated and documented (OrFandis, *et al.* 2003; Nikolic, *et al.* 2013). According to Schiller, *et al.* (2001), ecological indicators have been successfully used for the assessment of the ecological status of streams and rivers. However, no single ecological indicator group is preferred by environmental professionals for all situations, but fish and invertebrates have received the most attention in environmental monitoring and assessment.

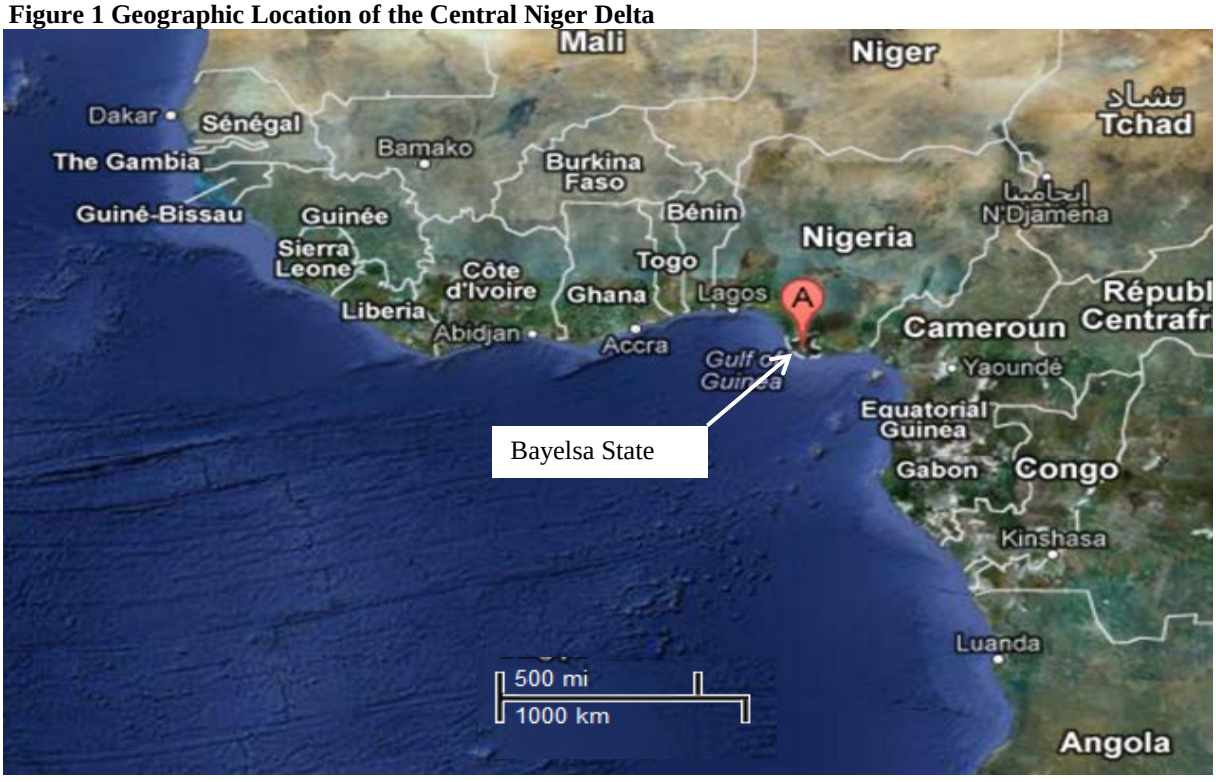
The major advantages of fish species as eco-indicators of surface waters is that fish species are the best known inhabitants of freshwater systems, are good indicators of a wide variety of aquatic habitat, and have food, livelihood and commercial value (Giller and Malmqvist, 2001; Whitfield and Elliot, 2002). Different fish species are tolerant of different levels of water quality, and fish survival therefore provides an indication of water quality, and of variations in water quality over time. Therefore, significant alteration in fish abundance or distribution will be easily identified in areas where fishing plays a role in local livelihoods and where there is high interest in water resources. Generally, fisheries have livelihood significance in most rural fishing

communities in developing countries. This makes fish species even more ecologically relevant, and appropriate socially sensitive indicators for environmental management, policy-making and biological conservation than other aquatic biota in areas such as the Central Niger Delta.

2. Study Area

The Niger Delta is located in the southernmost part of Nigeria and it is characterised by a network of rivers, creeks and swamps (Abam, 2001). Bayelsa State is located at Longitude 6 degrees east, and Latitude 4 degrees 30 minutes north, in the Central Niger Delta region of Nigeria, and the ecological characteristics of Bayelsa State are dependent on the annual flood pattern (Alagoa, 1999). The rainy season of the Central Niger Delta lasts for approximately ten months, and the average annual rainfall ranges between 2,000 and 4,000 mm. The dry season extends from December to February, although occasional rainfall and storms may occur during this period. The four major ecological zones of the Niger Delta are: coastal barrier islands; mangroves; fresh water swamp forests; and lowland rainforest and the Central Niger Delta (Bayelsa State) typically represent the ecological characteristics of the Niger Delta (Figure 1 shows the geographic locations of the Central Niger Delta).

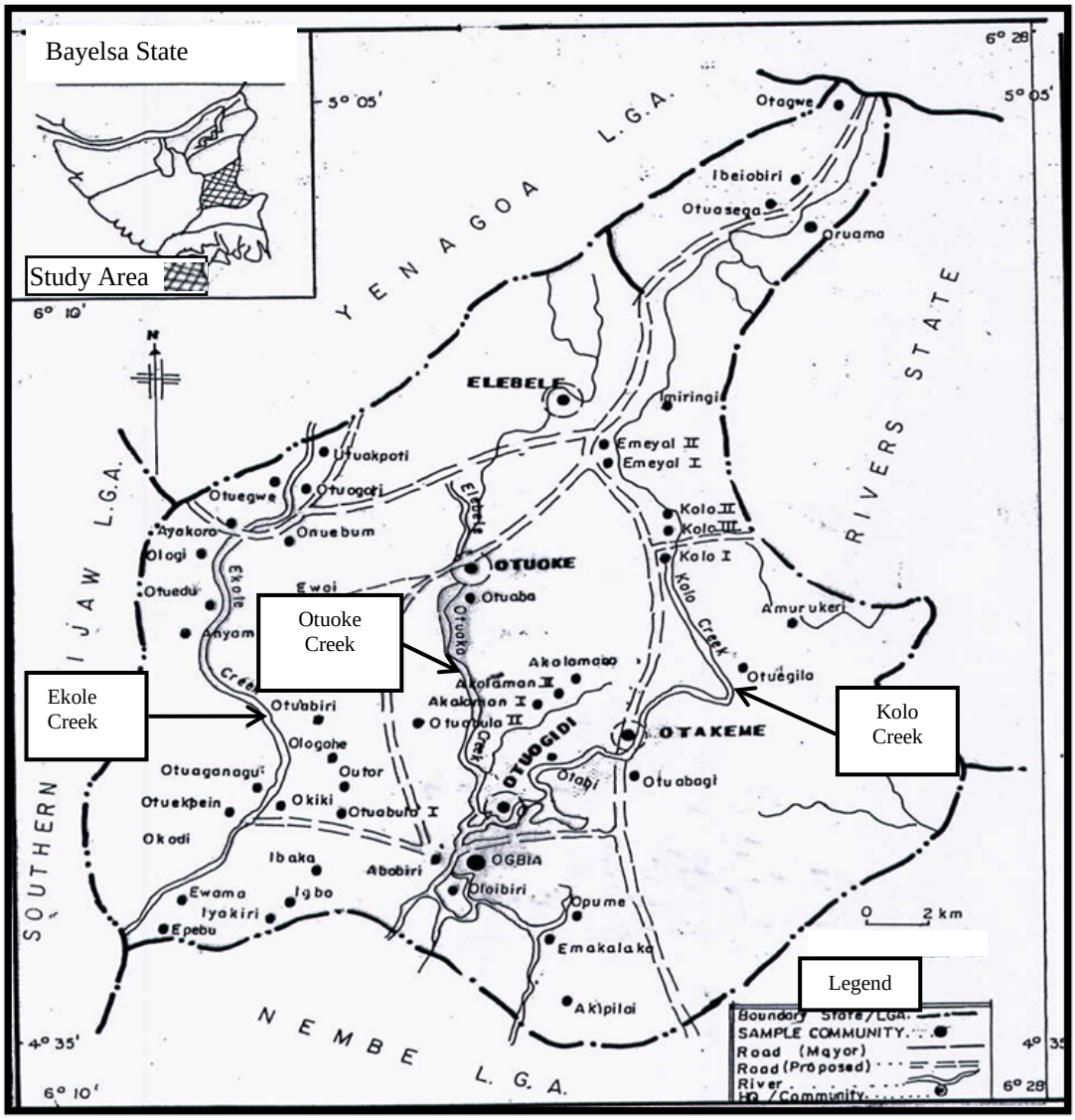
Figure 1 Geographic Location of the Central Niger Delta



Source: Google Map

Bayelsa State is geo-politically divided into: the Bayelsa Central, Bayelsa West and Bayelsa East Senatorial Zones. Figure 2 shows the three surface waters (Ekole, Otuoke and the Kolo Creeks) in the Ogbia Local Government Area, and two of these waters (the Kolo and Otuoke Creeks) represent the study catchment. The Kolo and Otuoke Creeks are two of the 23 major surface waters in the Central Niger Delta and the average length of these study Creeks is 59 km, which is 7 km longer than the average length of the 23 major surface waters in the Central Niger Delta. The Kolo and Otuoke Creeks, like many other surface waters, play a significant role in the socio-economic development of the Central Niger Delta. Furthermore, Tamuno, *et al.* (2009), reported that the river use and environmental pressure of the Kolo and Otuoke Creeks are statistically not significantly different. Hence, this study has been carried out on the premise that both fresh waters were under similar human-induced stress at the time of this study.

Figure 2 Map of the Study Area



The distribution and abundance of tropical fresh water fisheries is affected by, and dependent on, the height and duration of annual flood regime (Hoggarth, 1999; Sikoki, and Otobotekere, 1999; Van Zalinge, *et al.* 1998). Therefore, the ecological survey of this research was carried out to capture, as much as possible, the seasonal variation in ecological characteristics of the Kolo and Otuoke Creeks as represented by fish species community. The benefit of such a survey protocol is the reduction of the likelihood of the occurrence of false negative or false positive errors (Type 1 and Type 2 errors) that may arise as a result of natural ecological variation.

3. Methodology

Twenty four ecological expeditions were carried out along two-thirds of the length of the Kolo and Otuoke Creeks across three fishing seasons in 2004. These surveys were embarked upon for the purpose of testing whether there are any statistically significant differences in the ecological characteristics of the surface water in the Lower Niger Floodplain, which lies in the Central Niger Delta geographical region. The ecological surveys were conducted along the Kolo and Otuoke Creeks between 06:00 hours and 19:00 hours in February, April, and June - July using cast nets.

The three survey periods in February, April and June/July were used to capture fish abundance and variation across the dry, early rainy and rainy fishing seasons in the Central Niger Delta. Furthermore, multiple surveys and sampling across different times of the year could enhance the statistical validity of the results from this study, by capturing the range of ecological attributes of surface fresh water in the Central Niger Delta. Similarly, Whitefield and Paterson (2003) reported that duplicate sampling of fish in the Eastern Cape estuaries of South Africa was effective in determining the distribution of freshwater fish species.

Our choice of cast nets as the sampling tool was based on the premise that cast net is the single most cost-effective gear that captures a wide range of freshwater fish species compared to other fishing equipment. In addition, the use of consistent sampling gear and protocols implies that the results from the survey are fairly unbiased, and representative of the ecological characteristics of the Kolo and Otuoke Creek. The average mesh size of the cast nets used for our study was about 20 mm, and these nets were on the average thrown to a depth of approximately 5 meters.

To achieve the research objectives, the sampling was carried out across all river habitats and fishing grounds along the sampling sections of the Kolo and Otuoke Creeks. Four local fishermen actively participated in the ecological survey. The involvement of these fishermen enabled the authors to explore the local knowledge and experience of the fishermen in identifying appropriate fishing grounds and fish habitats.

The fish captured during the ecological expeditions were photographically recorded and identified by their local names by the fishermen involved in the survey. In addition, Community level triangulation of the names of these fish species was achieved with the help of other fishers in the respective sample communities. The book titled "Fish and fishes of Northern Nigeria" by Reed, *et al.* (1967) and two fisheries scientists were consulted for the confirmatory identification of the fish species from the ecological survey. Similarly, key informants have been involved in sampling and identification using native names of plants in Mexico (Potvin, *et al.* 2005), and Karr and Chu (1999), reported that the use of local knowledge in ecological surveys enhances sampling efficiency.

Excel Spread Sheets and the Statistical Package for Social Scientists Version 17 (SPSS 17) have been used to analyse the results from this study. Independent Sample t-test has been used for the statistical comparison of the duration of the 24 (12 from each Creek) ecological surveys carried out along the Otuoke and Kolo Creeks. In addition the Bray Curtis dissimilarity index was used to quantify the ecological structural dissimilarities between the Kolo and Otuoke Creeks. Bray-Curtis dissimilarity index lies between 0 and 1, where 0 means the two sites have the same species composition (that is they share all the species), and 1 implies that the compared sites are ecologically diverse. Bloom (1981) proposed an ecological variation interval and the graduation scale ranges from: 0.0 to 0.2 very low; 0.2 to 0.4 low; 0.4 to 0.6 intermediate; 0.6 to 0.8 high; 0.8 to 1 very high (difference). The formula for calculating the Bray Curtis index is as follows.

$$d_{ij} = \frac{\sum_{k=1}^{n} \left| x_{ik} - x_{jk} \right|}{\sum_{k=1}^{n} \left(x_{ik} + x_{jk} \right)}$$

d_{ij} = Dissimilarity index

x_{ik} - x_{jk} = Total number of unique species (unique to one of the two sites);

x_{ik} + x_{jk} = Total number of species across both sites

4 Results and discussions

Appendix 1 contains a summary of the fish species from the twenty four ecological expeditions carried out along the Kolo and Otuoke Creeks. The total survey durations were 3,795 minutes and 4,295 minutes along the Otuoke and Kolo Creeks respectively. Generally, catch per expedition (survey day) ranged from 1 to 146 fish; 665 and 505 fish were captured from the Otuoke and Kolo Creeks respectively.

In addition, 25 different fish species were identified from the surveys; of these 20 species were from the Kolo Creek and 15 were from the Otuoke Creek. Ten of these species were common to both creeks, these common species are: *Aletes spp; Distichodus spp; Citharinus spp; Tilapia spp; Petrocephalus spp; Marcusenius spp; Pareutropius spp; Synodontis spp; Chrysichthys nigrodigitatus;* and *Hydrocynus linaetus.* The result of our research compares favourably with the study by Sikoki and Otobotekere, (1999) that characterised the commonly occurring fish species in the Central Niger Delta. Seven of the twelve species identified by Sikoki and Otobotekere, (Ibid) were also identified from our study. These species are: *Aletes spp; Tilapia spp; Heterotis niloticus; Citharinus citharus; Labeo spp; Distichodus spp;* and *Synodontis spp*. The implication of the above is that the dominant species in the Kolo and Otuoke Creeks are the same.

The result of the t-test of the duration of the ecological surveys shows that there is no significant statistical difference between the sampling duration for the Kolo and Otuoke Creeks ($p = 0.450$). This implies that any statistical comparison between the results from the ecological survey can be appropriately described as statistically valid, and have not been unduly affected by the respective sampling durations.

Further quantitative comparative of the results of the ecological surveys was done using the Bray Curtis index and the outcome of this result is shown in Table 1. Generally, a Bray Curtis dissimilarity index of 0.1 implies that the Kolo and Otuoke Creeks are ecologically significantly similar, with a 10% compositional dissimilarity between these freshwaters. The recorded 10% difference between the Kolo and Otuoke Creeks could be attributed to natural spatial ecological variation.

Table 1 Bray-Curtis Distance (Dissimilarity Index)

Species	Otuoke Creek	Kolo Creek	Common (C)	Total (S)
Aletes spp	178	108	286	286
Distichodus spp	6	11	17	17
Heterotis niloticus	2	0	0	2
Citharinus spp	153	236	389	389
Tilapia spp	5	20	25	25
Bagrus spp	0	6	0	6
Mugil cephalus	0	3	0	3
Micralestes spp	85	0	0	85
Petrocephalus spp.	111	24	135	135
Marcusenius spp	53	25	78	78
Pareutropius sp	39	14	53	53
Phago loricatus	0	1	0	1
Synodontis spp	8	11	19	19
Chrysichthys nigrodigitatus	16	33	49	49
Hydrocynus linaetus	0	2	0	2
Pantodon bucholzi	3	0	0	3
Notopterus chitala	5	0	0	5
Bagrus spp	0	3	0	3
Acestrorhynchus sp.	0	1	0	1
Labeo sp	1	0	0	1
Ichthyborus monody.	0	1	0	1
Xenomystus nigri (Pez cuchillo Africano)	0	3	0	3
Raiamas senegalensis	0	1	0	1
Hepsetus odoe	0	1	0	1
Polycentropsis abbreviate	0	1	0	1
Bray-Curtis (D)			0.10	

Generally, species richness, species diversity and trophic structure are among the ecological metrics that have been used to appropriately define the status of ecological systems (Dale and Beyeler, 2001; Karr and Chu, 1999; Welcomme, 2001). Therefore, further comparison of the ecological characteristics of the Kolo and Otuoke Creeks has been carried out using: Species Richness; Species Diversity Index; Shannon Weaver Diversity Index; and Simpson Diversity Index. These indices provide more information about the quantitative biodiversity and ecological structure of the Otuoke and Kolo Creeks. A summary of the above ecological indices based on the ecological survey across the Kolo and Otuoke Creek is shown in Table 2.

Figure 3 shows the qualitative comparison of the average: Species Richness; Species Diversity Index; Shannon Diversity Index; and Simpson Diversity Index of the fish species communities of the Kolo and Otuoke Creeks that has been used to compare the ecological characteristics of these surface waters. Figure 3 shows that these ecological indices are qualitatively very similar for the two creeks and further statistical analysis (independent sample t-test) of these indices shows that there is no significant statistical difference ($p > 0.05$) in fish species

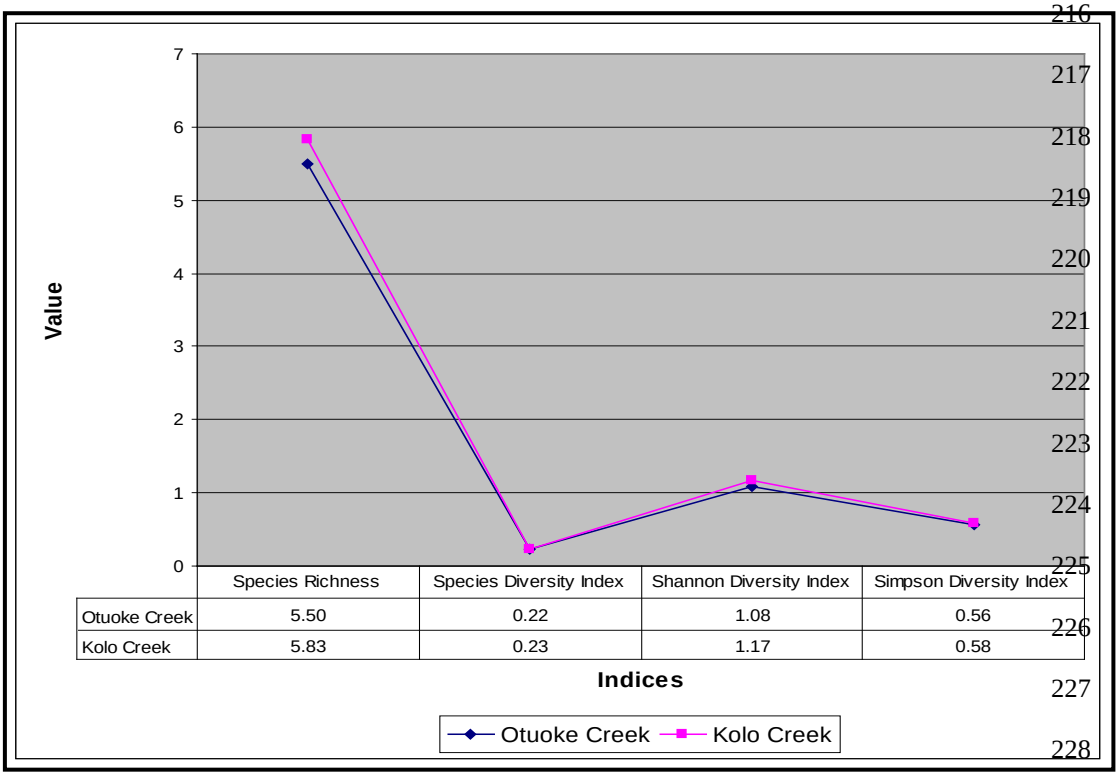
distribution and composition between the Otuoke and Kolo Creeks, as shown below: Species Richness (p = 0.823); Species Diversity Index (p = 0.823); Shannon Diversity Index (p = 0.668); and Simpson Diversity Index (p = 0.804).

Table 2 Summary of the Ecological Indices

Creek	Sampling Day	Species Richness	Species Diversity Index	Shannon Diversity Index	Simpson Diversity Index
Otuoke Creek	1	9	0.36	1.90	0.84
	2	8	0.32	1.45	0.68
	3	1	0.04	0.00	0.00
	4	11	0.44	1.57	0.71
	5	8	0.32	1.76	0.79
	6	9	0.36	1.76	0.78
	7	5	0.20	1.17	0.65
	8	5	0.20	1.01	0.53
	9	2	0.08	0.64	0.67
	10	1	0.04	0.00	0.00
	11	4	0.16	0.89	0.49
	12	3	0.12	0.80	0.53
Average		**5.5**	**0.22**	**1.08**	**0.56**
Kolo Creek	1	8	0.32	1.56	0.73
	2	4	0.16	0.64	0.31
	3	7	0.28	1.70	0.78
	4	7	0.32	1.69	0.78
	5	7	0.28	1.52	0.76
	6	5	0.20	1.45	0.80
	7	5	0.20	0.54	0.24
	8	3	0.12	0.66	0.38
	9	5	0.20	1.09	0.58
	10	5	0.20	1.29	0.71
	11	7	0.28	0.64	0.26
	12	7	0.28	1.30	0.64
Average		**5.83**	**0.23**	**1.17**	**0.58**

Average species richness is the easiest and easily comprehensible index of ecological attributes. From our study the average species richness of Kolo Creek (5.50) compares favourable with that of the Otuoke Creek (5.83). Generally, a t-test result of the species richness of the Kolo and Otuoke Creeks (p = 0.823) confirms that these freshwaters have similar ecological attributes. Furthermore, the comparison of the Simpson and Shannon diversity indices of the Kolo and Otuoke Creeks using the t-test gives results of p = 0.804 and p = 0.668 respectively. These results indicate that the taxonomic diversity and species distribution of the two surface waters are statistically significantly similar.

Figure 2 Comparison of the Ecological Characteristics



5 Conclusions

In summary, the ecological attributes of the Kolo and Otuoke Creeks are characteristically similar statistically, which means that, despite natural variation and spatial differences between these two surface waters, they are ecologically not significantly different based on their individual properties represented by: Bray Curtis Dissimilarity index; Species richness; Species diversity index; Shannon diversity index; and Simpson diversity index.

Our comparisons of the Kolo and Otuoke Creeks have been made based on the premise that both surface waters were undergoing similar environmental stressors at the time of our study. Hence, the ecological functions and services of surface freshwater in the same geo-ecological zone are similar within the limits of natural ecological variation.

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306 **Appendix 1 Summary of result of the ecological survey**

Creek	Sampling Day / Fish Species	*Aletes spp*	*Distichodus spp*	*Heterotis niloticus*	*Citharinus spp*	*Tilapia spp*	*Bagrus spp*	*Mugil cephalus*	*Micralestes spp*	*Petrocephalus spp.*	*Marcusenius spp*	*Pareutropius sp*	*Phago loricatus*	*Synodontis spp*	*Chrysichthys nigrodigitatus*	*Hydrocynus linaetus*	*Pantodon bucholzi*	*Notopterus chitala*	*Bagrus spp*	*Acestrorhynchus sp.*	*Labeo sp*	*Ichthyborus monodi.*	*Xenomystus nigri (Pez cuchillo Africano)*	*Raiamas senegalensis*	*Hepsetus odoe*	*Polycentropsis abbreviata*	Total Fish Catch	Total Attempt	Sampling Duration
Otuoke Creek	1	24	0	0	21	0	0	0	31	34	14	14	0	0	2	0	1	5	0	0	0	0	0	0	0	0	146	46	416
	2	25	1	0	2	1	0	0	3	0	13	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	50	29	286
	3	17	0	0	20	0	0	0	0	0	0	2	0	4	1	0	0	0	0	0	0	0	0	0	0	0	44	47	427
	4	7	2	0	24	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	36	32	374
	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	213
	6	25	1	1	10	1	0	0	24	70	4	5	0	0	2	0	2	0	0	0	0	0	0	0	0	0	145	45	233
	7	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	29	271
	8	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	41	321
	9	23	0	0	7	0	0	0	8	3	10	5	0	3	1	0	0	0	0	0	0	0	0	0	0	0	60	34	288
	10	41	1	0	10	1	0	0	19	4	11	9	0	0	8	0	0	0	0	0	0	0	0	0	0	0	104	51	331
	11	3	0	0	12	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	36	379
	12	13	0	0	18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	32	30	256
Kolo Creek	1	11	1	0	26	9	2	0	0	0	0	2	0	2	3	0	0	0	0	0	0	0	0	0	0	0	56	26	215
	2	5	2	0	53	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	47	340
	3	47	0	0	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	44	240
	4	0	0	0	11	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	14	81	626
	5	12	0	0	32	6	0	0	0	8	9	4	0	0	7	0	0	0	0	0	0	0	0	0	0	0	78	49	363
	6	9	4	0	27	0	0	0	0	0	11	8	0	7	2	0	0	0	0	0	0	0	0	0	0	0	68	37	276
	7	1	0	0	0	0	1	0	0	2	0	0	0	0	13	0	0	0	3	0	0	0	0	0	0	0	20	16	235
	8	6	1	0	8	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	18	39	115
	9	8	1	0	12	0	0	0	0	14	1	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	40	48	607
	10	1	0	0	2	0	0	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	12	51	508
	11	1	1	0	44	0	1	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	51	51	309
	12	7	1	0	17	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	30	36	425

307