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Environmental correlates of some selected fish species in the Jebba Dam, North-Central Nigeria

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Research Article

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Abstract

There is a lack of comprehensive understanding of environmental factors influencing fish species' abundance and distribution in some Nigerian freshwater ecosystems. Our study investigated the environmental factors that drive the abundance and distribution of three economically important fishes – *Lates niloticus, Citharinus citharus*, and *Distichondus rostratus* – in Jebba Hydroelectric power dam in Northcentral Nigeria. The species catch abundance was determined using gillnets of different mesh sizes, each measuring 50 m length and 20 m deep. The physicochemical parameters were also assessed following standard methods. A total relative abundance of 47.49%, 27.74%, 24.77% were observed for *C. citharus*, *L. niloticus*, and *D. rostratus*, respectively. The canonical correspondence analysis showed that the catch abundance of *L. niloticus* associates with water volume, turbidity, phosphate, and hydrogen carbonate. Analysis showed that water hardness, biological oxygen demand (BOD), dissolved oxygen (DO), and chloride levels drive the catch abundance of *D. rostratus*, while *C. citharus* associates with temperature and depth. The linear Pearson correlation showed a strong positive relationship of the abundance of *L. niloticus* with turbidity, phosphate, total suspended solids, hydrogen carbonate, water depth, temperature, and water volume. Our result showed a strong positive association of the abundance of *C. citharus* with water volume, total dissolved solids, temperature, and water depth. A strong positive relationship of the abundance of *D. rostratus* with conductivity, water depth, and total dissolved solids was reported. Our study improved knowledge on the environmental factors affecting the abundance of three economically important freshwater fishes in Jebba Hydroelectric dam. Further study is needed to investigate the impact of global climate change on the future distribution of these freshwater fish species.

Introduction

Nigerian freshwater ecosystem is home to diverse fish fauna (Idodo-Umeh 2003; Iyiola *et al.* 2018; Oladipo *et al.* 2018a; 2020; Olaosebikan and Raji 1998). The varied fish species have become significant protein sources and income (Mustapha 2010). Over time, tremendous growth in the human population has increased pressure on fish resources (Olalekan and Ojebiyi 2018). Anthropogenic activities have led to unsustainable fishing practices (Raji *et al.* 2012). Also, the pollution of the aquatic ecosystem is evident, which often destroys the fish habitat and its breeding sites (Dawodu *et al.* 2015). These threats have brought a decline in the fish catch. Despite this, there is a lack of adequate information on how environmental changes affect fish species availability and abundance.

Within the context of the loss in freshwater biodiversity in Nigeria, it is imperative to identify critical environmental factors that contribute to the patterns of distribution and abundance of freshwater fishes. Studies have shown that fluctuations in environmental conditions can lead to changes in stock diversity, composition, and catch abundance of fish (Ita and Balogun 1982; Mensah *et al.* 2018; Ogutu-Ohwayo 1993). For instance, turbidity and dissolved oxygen have been reported to affect fish species abundance and distribution (Daget *et al.* 1986; Goudswaard *et al.* 2011; Njiru *et al.* 2011; Paterson and Chapman 2009; Taabu-Munyaho *et al.* 2013). Abiotic and biotic factors such as water depth, temperature, nutrients, predator–prey interaction, etc., have been reported to determine the distribution and abundance of pelagic fishes (Brosse *et al.* 2007; Taabu-Munyaho *et al.* 2013). These factors could vary with the season, which may or may not affect fish abundance. For instance, earlier studies (e.g., Eby and Crowder 2002; Taabu-Munyaho *et al.* 2013) have revealed that fish catch abundance and distribution vary with season. On the contrary, Mensah *et al.* (2018) argued that these seasonal differences in distribution, abundance, and diversity of the fish species might not be significant if the environmental factors were stable throughout the season.

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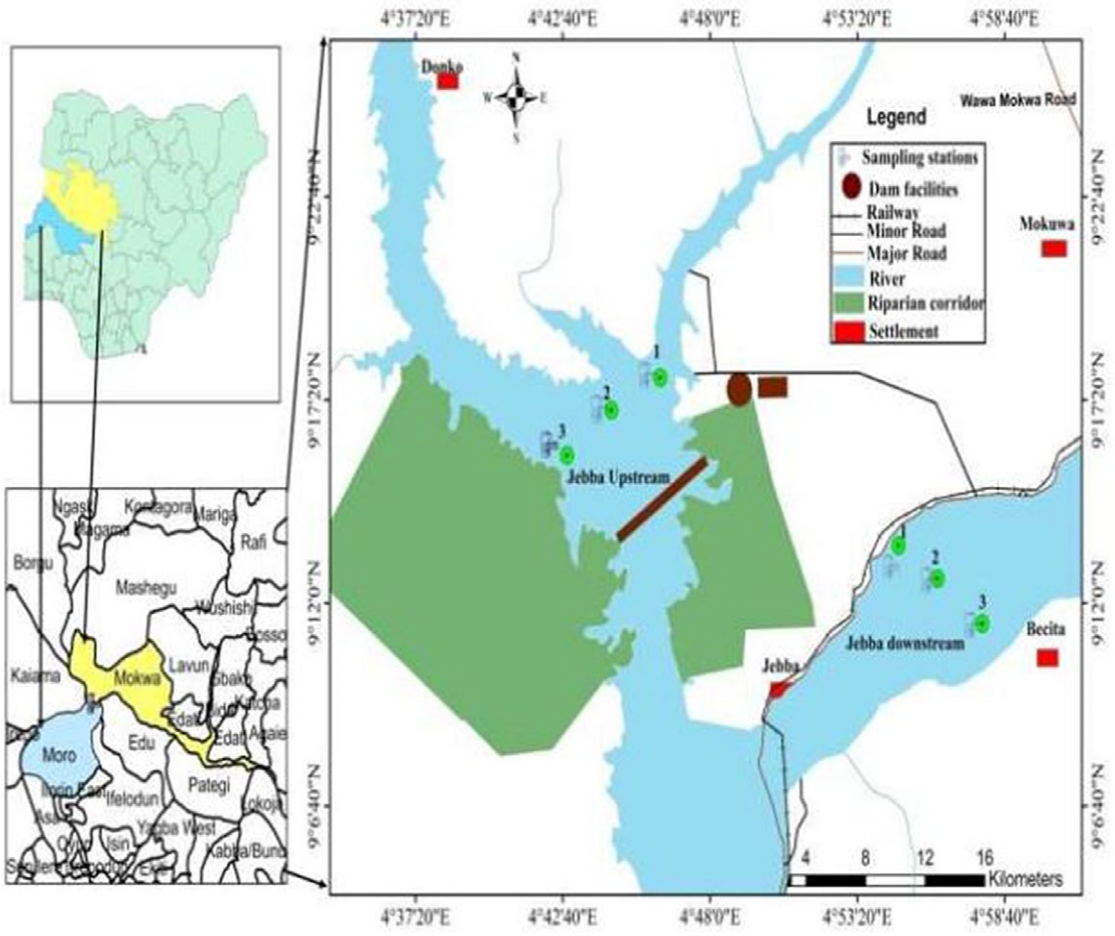


Figure 1. Map of up- and downstream of Jebba Dam showing the sampling points.

Anthropogenic impacts on stream connectivity leading to dams and dewatering have been shown to disrupt the natural water flow as well as alter local species migration and dynamics (Trzcinski *et al.* 2008). A reduction in the water velocity associated with dam creation could lead to significant differences in the oxygen content, the temperature of the water, and the sediment quality in the river bed (Melanie *et al.* 2011). Also, the damming of river has been related to some habitat quality changes such as neutralization of the pH, reduction of the oxygen content, retention of nutrients, and heavy metals in the water (Lazar *et al.* 2015). These factors could affect the survival of fish species. Unfortunately, information on the distribution and abundance of fish in hydroelectric dams in Nigeria is lacking. Recent studies have shown decreased fish diversity and catch assessment in Nigeria (FAO 2018). Despite this, the direct effects of environmental factors in structuring assemblages of certain economically important freshwater fishes in Nigeria are poorly understood.

The objective of our study is to examine the role of local environmental factors in structuring assemblages of three economically important freshwater fishes – *Citharinus citharus* (Geoffroy Saint-Hilaire 1809), *Distichondus rostratus* (Günther 1864), and *Lates niloticus* (Linne, 1762) – in a hydroelectric dam in Nigeria. This study system (Jebba Hydroelectric dam) is known to host diverse and poorly known fish species (Ita, 1993; Oladipo *et al.* 2020). Given that species diversity and abundance is potentially related to environmental factors, such as dissolved oxygen, turbidity, etc., we predict that changes in environmental water conditions would determine the pattern of fish assemblages in Jebba Hydroelectric dam. We used data from a field survey of the selected fish communities in Jebba Hydroelectric dam to determine (i) the environmental variables that best account for distribution patterns of these selected species and (ii) the relative contribution of each of these components to the explained variation.

Methods

Study area and sampling sites

Jebba town is located in North-central Nigeria, separating northern Nigeria from the west (Figure 1). The river Niger divides into Jebba South and Jebba North, forming a lake with a Hydroelectric dam. Jebba Lake is created in 1983 on River Niger at Jebba North, downstream of the Kainji dam. It lies within the middle belt of Nigeria between the coordinates 4°34′12″–4° 43′48″E and latitude 9°10′–9°55′N. The area is characterized by dry and rainy seasons, with notable fishing activities generating freshwater fish for the area and the nation (Adelakun *et al.* 2017; Oladipo *et al.* 2018a; 2020). According to the river's ecological features, the monthly maximum temperature is about 30°C in March and the lowest at about 25°C in August. Annual rainfall ranges between 1270 and 1524 mm, with the highest observed in August (Adelakun *et al.* 2017).

The upstream of the lake has a total length of 134 km, a width of 24.1 km, mean and maximum depths of 11 m and 60 m,

respectively (Ita *et al.* 1984; Obot, 1989; Oladipo *et al.* 2020). It has its source mainly from the Kainji reservoir with six other major rivers: Oli, Wuruma, Moshi, Awuru on the western side, and Kontangora and Eku (Adesina *et al.* 2007; Owolabi, 2008). The lake experiences two major floods events per year, namely the white and black floods. The white flood results from the rainfall that enters mid-August with a peak flow of 4000–6000m^3s^{-1} from September to October.

Jebba hydroelectric dam has good potentials for the fish catch, with an estimate of 909–1818 tons/annum (Adelakun *et al.* 2017). The downstream lake flows through urban populated towns and villages, where human and fishing activities occur mainly at the river banks. Anthropogenic activities such as indiscriminate fish harvest, overexploitation, and obnoxious fishing practices have led to habitat destruction and common challenges to fishery resources in the area (Nwabeze and Erie 2013; Oladipo *et al.* 2018a).

Study species

The focal species – *C. citharus*, *D. rostratus*, and *L. niloticus* – were selected based on their importance and availability. *Lates niloticus* is a valuable large size fish species supporting a large export. It feeds on fishes ranging from medium to large sizes. Environmental factors such as high turbidity and low dissolved oxygen affect its abundance and distribution (Daget *et al.* 1986; Paterson and Chapman 2009; Njiru *et al.* 2011; Taabu-Munyaho *et al.* 2013). Changes in these factors could affect its habitat quality and sustainability in the ecosystem (Goudswaard *et al.* 2011).

Generally, the large Citharinids (the moonfish) and Distichondus (the grass-eater) are of commercial importance, having their abundance recorded between August and December (Daget *et al.* 1984). The grass-eater and the moonfish have small heads with deep and flattened bodies covered with tiny scales (Gupta and Gupta 2006). The small-sized ones are generally found in shallow waters covered by grass, while the larger ones are adapted to open waters during dry seasons (Daget *et al.* 1984). Agbabiaka *et al.* (2010) stated that moonfish is abundant in swamps, creeks, and lakes in Nigeria and usually spawn during the rainy season. Moonfish is highly nutritious, having about 20.4% protein with low lipids and relatively cheap whether cooked, smoked, or in dried form (Agbabiaka *et al.* 2010; Omojowo and Ihuahi 2010).

Data collection

The fish and water samples were collected bimonthly from October 2017 to September 2018. The sampling points were selected purposefully based on fishing activities as follows:

1. UPS A = Rainy season upstream site A
2. UPS B = Rainy season upstream site B
3. UPS C = Rainy season upstream site C
4. DNS D = Rainy season downstream site D
5. DNS E = Rainy season downstream site E
6. DNS F = Rainy season downstream site F
7. UPS G = Dry season upstream site G
8. UPS H = Dry season upstream site H
9. UPS I = Dry season upstream site I
10. DNS J = Dry season downstream site J
11. DNS K = Dry season downstream site K
12. DNS L = Dry season downstream site L

The physicochemical variables of water, such as pH, total dissolved solids (TDS, mg/L), electrical conductivity (µS/cm), and temperature (°C), were measured *in situ* using Hanna portable pH/EC/TDS/Temperature combined waterproof tester model HI 98129. The water samples collected were brought to the laboratory for other water quality analyses using Hanna multi-parameter photometer. The physicochemical parameters were measured between 7.00 and 9:00 am.

Fish samples were collected with gillnets of different mesh sizes, measuring 50 m in length and 20 m deep. The surveys were set for both night and day fishing. Voucher specimens were preserved in a cooler with ice blocks and transported to the laboratory in the Department of Bioscience and Biotechnology, Kwara State University, Malete, Nigeria. Fish specimens were sorted and counted and identified following fish keys of Olaosebikan and Raji (1998), Idodo-Umeh (2003), and FishBase database (Froese and Pauly 2017).

Data analysis

The physicochemical parameters variables were computed in mean ± standard deviation and were compared among sampling stations in seasons. A Pearson correlation and canonical correspondence analysis (CCA) were conducted to investigate the relationship and association of the studied fish species abundance with physicochemical parameters. These analyses were performed using the PAST 3. Significant differences levels were considered at $P<0.05$.

Results

The physicochemical parameters

The temperature range was between 27.6–28.6 °C in the dry season and 27.8–28.5 °C in the rainy season (Table 1). At the end of the study, the reduction in temperature in the dry season followed the pattern: UPS C> UPS A > UPS E > DNS B > DNS F > DNS D (Figure 2a) while in rainy seasons DNS J> UPS I > UPS H >DNS J > DNS L > UPS K (Figure 3a). The conductivity and TDS increase in the same order during the dry season as follows: UPS A > UPS C > UPS B > DNS D> DNS F > DNS E, while in the rainy season, it was UPS J > UPS I > UPS H > UPS K > DNS L > DNS G > DNS J (Figure 2a and 3a). There was a significant difference between conductivity and TDS of the upstream and downstream during the dry season. The highest turbidity range of 178.10–318.80 NTU was recorded in the rainy season, and the lowest range of 13.00–15.90 NTU was observed during the dry season (Figures 2a and 3a). Generally, the DO ranges from 2.50 to 5.30 mg/L, with the lowest value recorded in the dry season. The mean values of the physicochemical parameters of water are shown in Table 1. The range of the mean value of nitrite was 0.42–0.5 mg/L in the dry season and 0.39–0.42 mg/L in the rainy season. Phosphate levels ranged between 4.50–4.90 mg/L in the dry season and 4.70–5.00 mg/L during the rainy season (Figures 3a and 3b). A higher mean Chloride value between 51.60–57.70 mg/L was recorded in the dry season than the rainy season with a mean range of 32.10–38.90 mg/L. The water depth had a range of 76.90–120.90 m during sampling (Table 1).

Patterns of distribution across seasons

The catch abundance for all studied species was higher during the rainy season than in the dry season except for *D. rostratus*. At the upstream, *C. citharus* had a relative abundance of 49.12% in the dry season, followed by *D. rostratus* (26.99%) and *L. niloticus* (23.89%)

Table 1. Physico-chemical parameters in upstream- and downstream of Jebba Dam during the sampling year

	Dry season						Rainy season					
Parameter	UPS A	UPS B	UPS C	DNS D	DNS E	DNS F	UPS G	UPS H	UPS I	DNS J	DNS K	DNS L
Water Volume × 10^3(cm^3)	17597	17597	17597	15015	15015	15015	147352	147352	147352	1260	1260	1260
Depth (m)	9.9±8.1	10.9±10.4	10.7±4.3	7.7±3.9	8.1±6.9	7.7±2.4	11.4±3.8	12.1±8.8	11.5±7.7	9.5±9.7	10.0±19.8	9.5±8.7
Temperature (°C)	28.2±1.7^{a}	28.0±2.3 ^{a}	28.6±1.7 ^{ab}	27.6±1.3 ^{a}	28.1±1.6 ^{a}	27.9±1.5 ^{a}	31.9±2.0 ^{c}	30.5±1.4 ^{c}	31.5±0.9 ^{c}	29.3±0.8 ^{b}	28.4±0.8 ^{ab}	29.3±1.6 ^{b}
Conductivity (µS/cm)	60.8±3.9^{b}	58.8±5.1^{b}	59.8±4.0^{b}	57.2±2.3^{ab}	55.0±4.8^{a}	56.2±2.4^{ab}	51.2±10.9^{a}	57.2±8.9^{ab}	58.3±8.7^{b}	66.2±19.8^{c}	55.8±3.6^{a}	54.5±3.8^{a}
TDS (ppm)	30.0±2.5^{b}	27.2±3.1^{ab}	28.3±4.3^{b}	26.2±1.5^{a}	26.3±2.0^{a}	26.8±0.7^{a}	25.7±5.0^{a}	26.5±3.8^{a}	28.7±4.0^{b}	25.5±3.4^{a}	26.3±3.8^{a}	28.2±3.8^{b}
DO (mg/L)	2.5±1.8^{a}	2.6±1.5^{a}	2.9±1.4^{a}	4.7±0.6^{b}	4.8±1.0^{b}	4.7±0.8^{b}	5.3±0.8^{b}	5.2±0.9^{b}	5.2±0.8^{b}	4.2±0.7^{b}	4.2±0.7^{b}	4.2±0.7^{b}
Turbidity (NTU)	13.5±7.1^{a}	14.3±6.9^{a}	13.0±6.9^{a}	15.9±8.1^{a}	15.2±8.2^{a}	15.7±8.1^{a}	283.5±73.0^{c}	318.8±72.8^{c}	297.8±73.1^{c}	178.1±74.0^{b}	238.2±75.0^{bc}	183.0±73.9^{b}
Nitrite (mg/L)	0.5±0.3^{c}	0.45±0.2^{bc}	0.44±0.3^{b}	0.46±0.2^{bc}	0.42±0.5^{ab}	0.43±0.3^{b}	0.41±1.1^{ab}	0.42±1.2^{ab}	0.42±1.1^{ab}	0.39±1.1^{a}	0.40±1.3^{a}	0.39±1.1^{a}
Phosphate (mg/L)	4.9±1.3^{b}	4.8±1.3^{ab}	4.8±1.3^{ab}	4.5±1.1^{a}	4.6±0.9^{a}	4.8±1.0^{ab}	4.9±1.1^{b}	5.0±1.2^{b}	4.9±1.1^{b}	4.7±1.0^{a}	4.8±0.9^{ab}	4.7±0.9^{a}
Calcium hardness (mg/L)	5.5±2.1^{cd}	4.7±2.0^{b}	5.1±2.0^{c}	6.4±3.3^{d}	7.6±3.6^{e}	7.0±3.4^{e}	4.6±1.9^{a}	4.3±2.3^{a}	4.5±2.1^{a}	4.8±2.9^{b}	5.2±2.9^{c}	4.9±2.9^{b}
Magnesium hardness (mg/L)	8.6±2.2^{c}	8.7±2.1^{c}	8.6±2.2^{c}	8.6±3.2^{c}	8.9±2.4^{c}	8.8±2.8^{c}	5.1±1.9^{a}	5.5±2.0^{ab}	5.2±1.9^{a}	6.0±2.4^{b}	5.8±2.3^{b}	5.9±2.3^{b}
TSS (mg/L)	0.6±0.3^{a}	0.6±0.3^{a}	0.6±0.3^{a}	0.6±0.4^{a}	0.6±0.5^{a}	0.6±0.4^{a}	1.5±0.8^{b}	1.5±0.8^{b}	1.5±0.8^{b}	1.2±0.7^{b}	1.4±0.9^{b}	1.2±0.7^{b}
TS (mg/L)	29.6±2.9^{c}	28.2±1.7^{a}	28.9±2.1^{bc}	28.7±1.9^{b}	30.2±1.7^{c}	29.4±0.8^{c}	28.5±1.6^{ab}	28.0±1.6^{a}	28.4±1.5^{ab}	28.2±2.1^{a}	28.4±2.1^{ab}	28.7±2.5^{b}
Total hardness (mg/L)	14.1±3.9^{b}	13.4±3.9^{b}	13.7±3.9^{b}	15.1±6.4^{c}	16.5±5.8^{c}	15.79±6.1^{c}	9.7±3.4^{a}	9.8±3.8^{a}	9.7±3.6^{a}	10.7±4.9^{ab}	11.0±5.0^{ab}	10.9±5.0^{ab}
BOD (mg/L)	1.1±0.6^{a}	1.1±0.7^{a}	1.2±0.7^{a}	1.7±0.9^{b}	1.9±0.6^{b}	1.8±0.6^{b}	1.1±0.5^{a}	1.2±0.5^{a}	1.2±0.5^{a}	1.4±06^{ab}	1.6±0.6^{b}	1.5±0.6^{ab}
COD (mg/L)	23.7±3.5^{a}	24.3±4.0^{a}	24.0±3.7^{a}	29.6±2.4^{c}	32.0±4.0^{d}	30.8±3.1^{c}	27.3±1.5^{b}	27.5±1.4^{b}	27.4±1.6^{b}	30.8±2.5^{c}	30.7±2.0^{c}	30.6±2.3^{c}
Chloride (mg/L)	52.2±4.1^{c}	51.0±3.9^{c}	51.6±4.0^{c}	57.7±4.5^{d}	54.8±4.2^{d}	56.2±4.3^{d}	32.1±1.4^{a}	32.8±1.4^{a}	32.2±1.4^{a}	37.2±1.1^{b}	38.9±1.2^{b}	37.6±1.1^{b}
Hydrogen carbonate (mg/L)	46.9±1.8^{a}	50.5±1.9^{b}	48.7±1.8^{b}	48.9±1.4^{b}	48.8±1.7^{b}	48.8±1.5^{b}	58.1±2.3cd	61.6±2.7^{d}	60.7±2.5^{d}	55.9±1.8^{c}	54.9±1.9^{c}	54.5±1.8^{c}

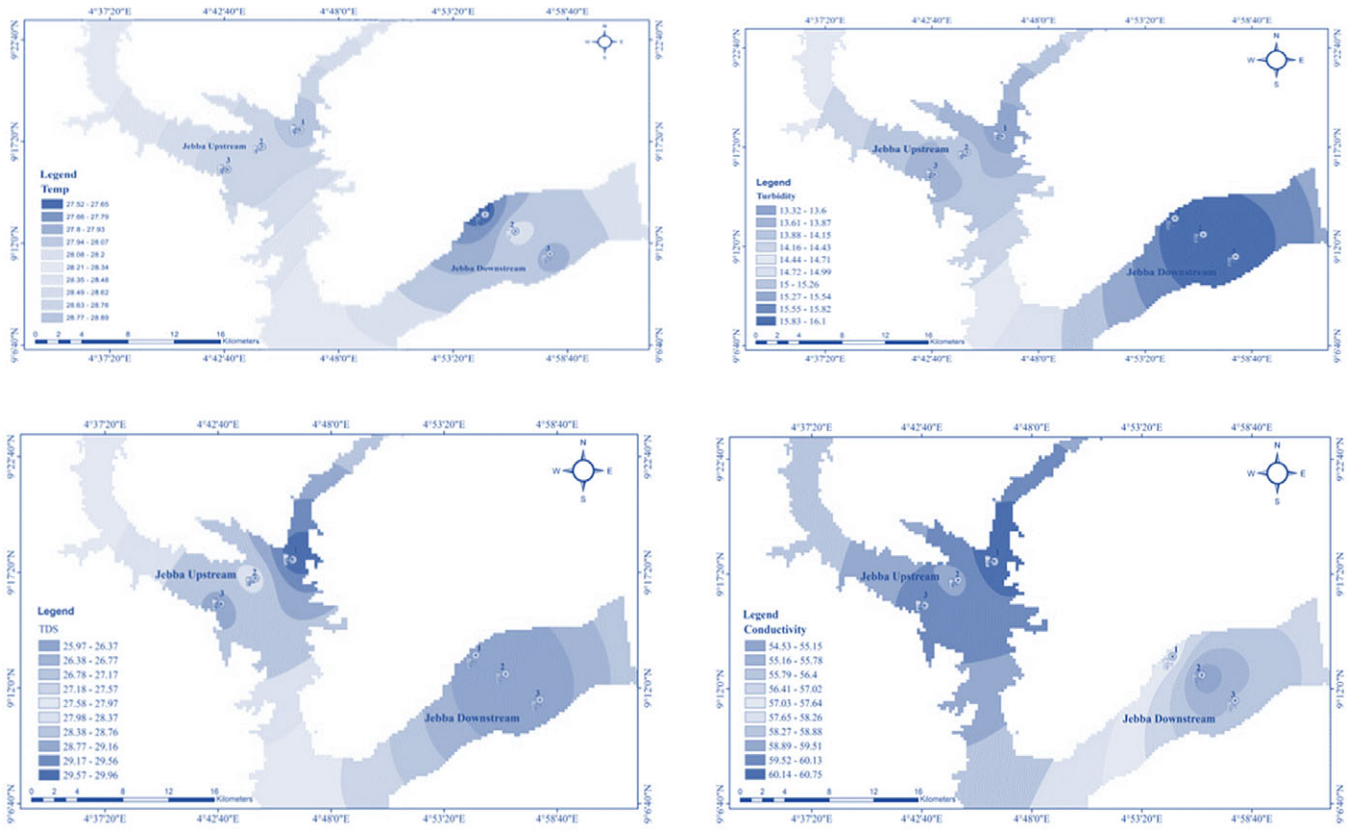


Figure 2a. Two-dimensional map of temperature, turbidity, conductivity, and TDS parameters in up and down-stream of Jebba dam during dry season.

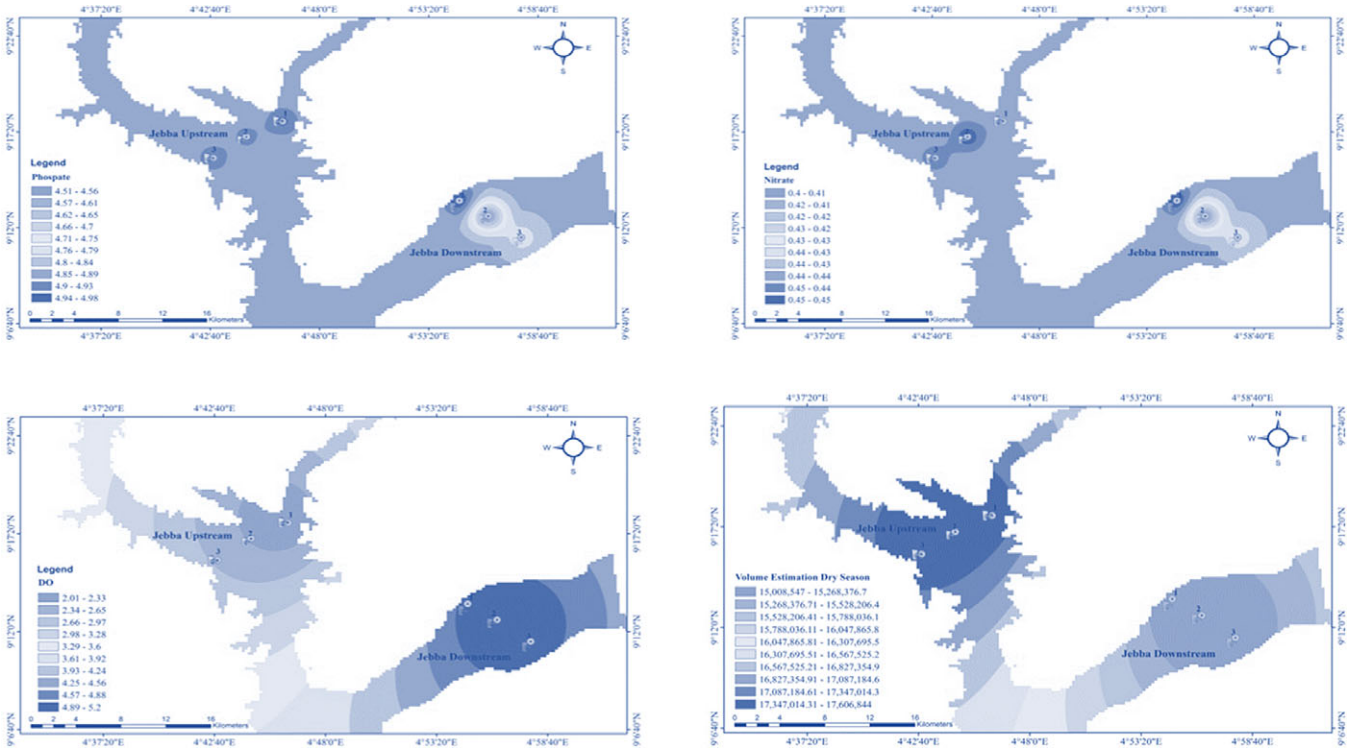


Figure 2b. Two-dimensional map of nitrate, phosphate, DO, and water volume in up and down-stream of Jebba dam during dry season.

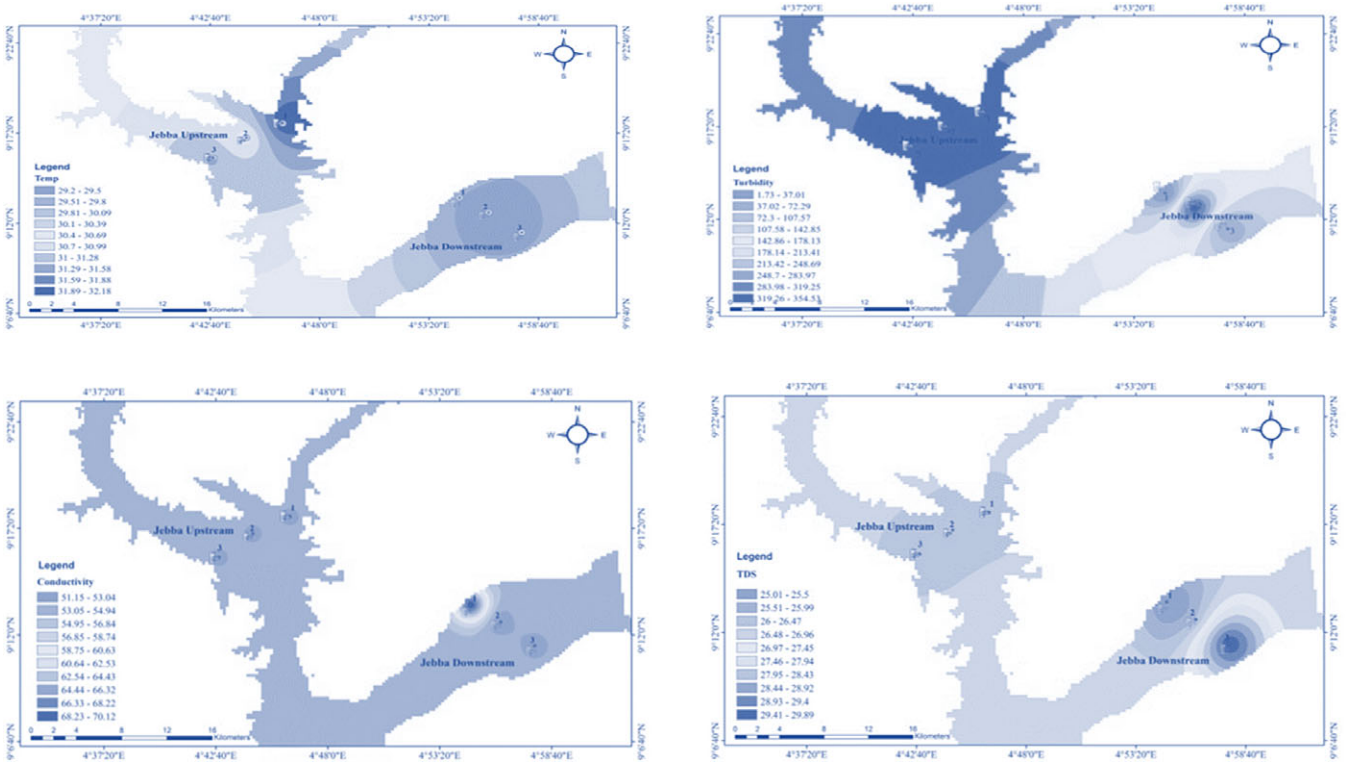


Figure 3a. Two-dimensional map of temperature, turbidity, conductivity, and TDS parameters in up and down-stream of Jebba dam during wet season.

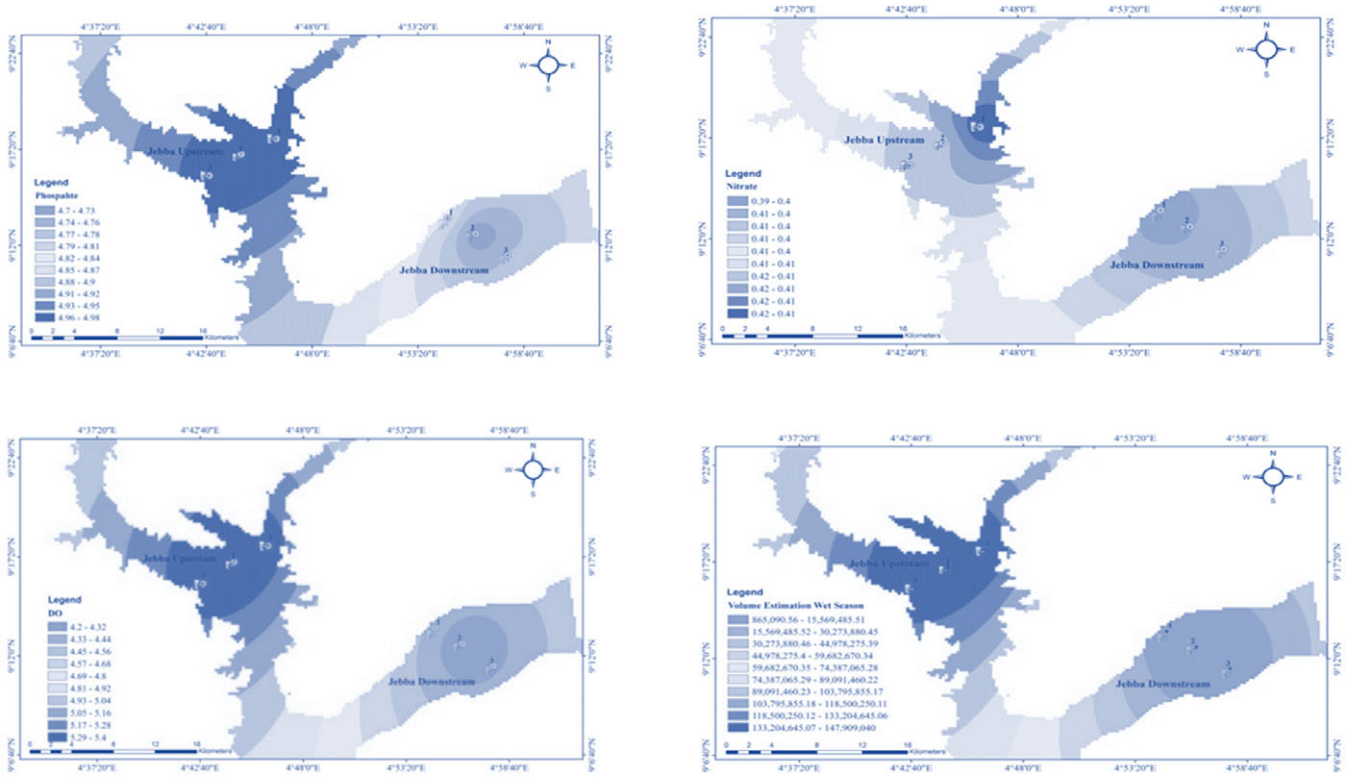


Figure 3b. Two-dimensional map of nitrate, phosphate, DO, and water volume in up and down-stream of Jebba dam during wet season.

Table 2. Overall distribution and abundance of *Distichodus*, *Citharinus,* and *Lates* in upstream and downstream of Jebba Dam

		Dry season		Rainy Season		
Genera	Species	Upper stream	Downstream	Upper stream	Downstream	Total (%)
Distichodus	*Distichodus rostratus*	61	23	47	27	158(24.77%)
	Total (%)	61 (26.99%)	23 (45.10%)	47 (20.00%)	27 (21.430%)	158 (24.77%)
Citharinus	*Citharinus citharus*	111	19	112	61	303 (47.49%)
	Total (%)	111 (49.12%)	19 (37.26%)	112 (47.66%)	61 (48.41%)	303 (47.49%)
Lates	*Lates niloticus*	54	9	76	38	177 (27.74%)
	Total (%)	54 (23.89%)	9 (17.65%)	76 (32.34%)	38 (30.16%)	177 (27.74%)
	Grand Total (%)	226 (35.42%)	51 (7.99%)	235 (36.83%)	126 (19.75%)	638 (100%)

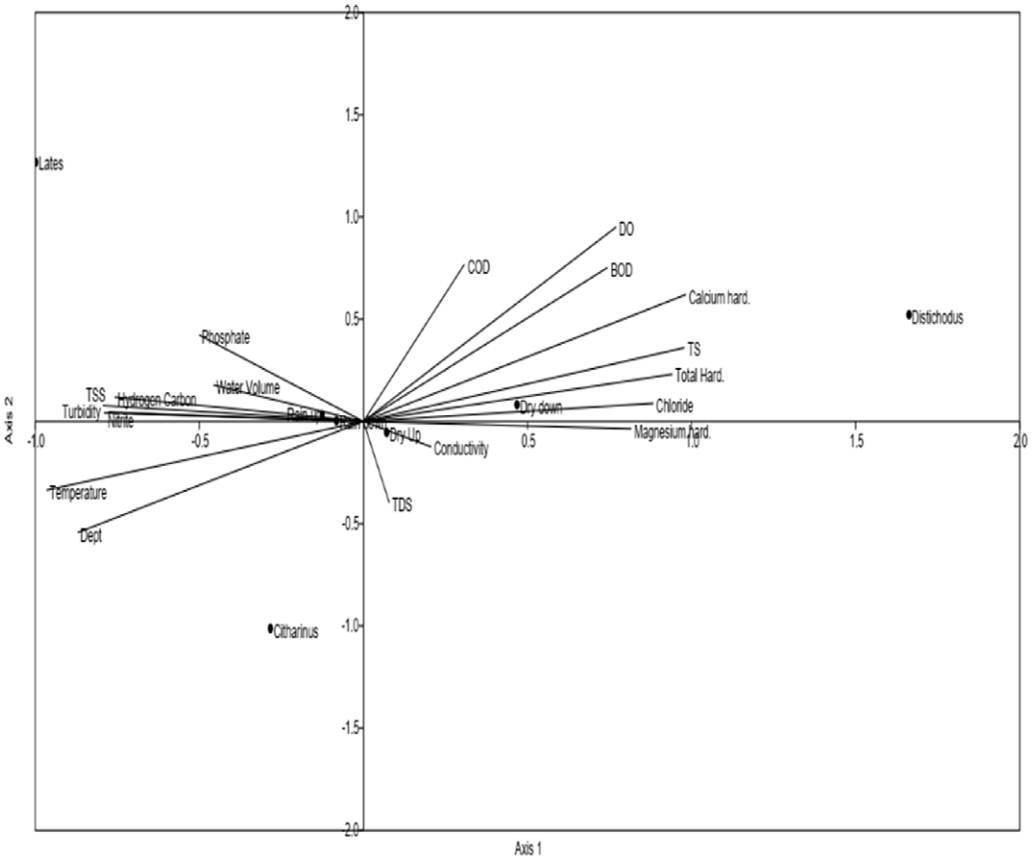


Figure 4. Canonical correspondence analysis bi-plot on the fish family abundance, physicochemical parameters variables, and location based on season.

(Table 2). During the rainy season, the relative abundance of *C. citharus*, *L. niloticus*, and *D. rostratus* were 47.66%, 32.34%, and 20.00%, respectively. Downstream, *D. rostratus* had the highest relative abundance of 45.10% during the dry season, followed by *C. citharus* (37.26%) and *L. niloticus* (17.65%). Downstream, *C. citharus* had a higher relative abundance of 48.41%, followed by *L. niloticus* (30.16%) and *D. rostratus* (21.43%) during the rainy season. The total relative abundance of 47.49%, 27.74%, 24.77% were observed for *C. citharus, L. niloticus,* and *D. rostratus,* respectively.

Relationship of species composition and environmental variables

The influence of the physicochemical variables on the selected fish species was shown in a CCA ordination plot (Figure 4). The first two correspondence axes explain 93.1% and 6.89% of the variance. The CCA model was significant ($P = 0.0027$). Our study showed that the abundance of *L. niloticus* was associated with water volume, phosphate, turbidity, total suspended solids (TSS), and hydrogen carbonate. However, the abundance of *D. rostratus* was associated with calcium hardness, total hardness, biological oxygen demand (BOD), dissolved oxygen (DO), total solids (TS), and chloride. Temperature and depth drove the abundance of *C. citharus*. High water volume, turbidity, TSS, nutrients, temperature, and depth were characteristics of the rainy season.

The linear Pearson correlation showed a strong positive relationship of the abundance of *L. niloticus* with turbidity (0.51), phosphate (0.51), total suspended solids (0.62), hydrogen carbonate (0.68), water depth (0.75), temperature (0.87), and water

Table 3. Correlation coefficient between physico-chemical parameters and fish species abundance in up and down-stream of Jebba dam

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Temperature		−0.14	−0.08	−0.61	0.86	0.84	0.70	−0.95	−0.91	0.90	−0.99	−0.99	−0.69	−0.22	−0.96	0.89	0.35	0.72	0.87	0.65	0.89
2	Conductivity	−0.14		0.96	−0.09	−0.55	−0.59	−0.10	0.03	0.40	−0.35	0.28	0.28	−0.45	−0.73	0.30	−0.19	0.69	0.46	0.34	0.45	0.30
3	TDS	−0.08	0.96		−0.34	−0.56	−0.60	−0.26	−0.11	0.43	−0.40	0.20	0.24	−0.60	−0.88	0.31	−0.27	0.85	0.59	0.42	0.31	0.39
4	DO	−0.61	−0.09	−0.34		−0.23	−0.22	0.12	0.83	0.26	−0.22	0.62	0.51	0.87	0.74	0.38	−0.19	−0.78	−0.85	−0.73	−0.08	−0.76
5	Turbidity	0.86	−0.55	−0.56	−0.23		1.00	0.80	−0.68	−0.99	0.97	−0.89	−0.93	−0.23	0.31	−0.96	0.92	−0.18	0.26	0.51	0.47	0.53
6	Nitrite	0.84	−0.59	−0.60	−0.22	1.00		0.78	−0.66	−0.98	0.96	−0.88	−0.92	−0.20	0.34	−0.94	0.90	−0.21	0.23	0.47	0.43	0.49
7	Phosphate	0.70	−0.10	−0.26	0.12	0.80	0.78		−0.45	−0.86	0.90	−0.66	−0.75	−0.16	0.28	−0.83	0.94	−0.16	0.21	0.51	0.83	0.49
8	Calcium hardness	−0.95	0.03	−0.11	0.83	−0.68	−0.66	−0.45		0.73	−0.72	0.94	0.89	0.85	0.47	0.82	−0.70	−0.58	−0.86	−0.92	−0.51	−0.94
9	Magnesium hardness	−0.91	0.40	0.43	0.26	−0.99	−0.98	−0.86	0.73		−1.00	0.92	0.96	0.33	−0.21	0.99	−0.97	0.07	−0.37	−0.61	−0.61	−0.63
10	TSS	0.90	−0.35	−0.40	−0.22	0.97	0.96	0.90	−0.72	−1.00		−0.90	−0.95	−0.33	0.20	−0.99	0.98	−0.06	0.37	0.62	0.66	0.63
11	TS	−0.99	0.28	0.20	0.62	−0.89	−0.88	−0.66	0.94	0.92	−0.90		0.99	0.63	0.14	0.96	−0.87	−0.27	−0.66	−0.80	−0.54	−0.83
12	Total hardness	−0.99	0.28	0.24	0.51	−0.93	−0.92	−0.75	0.89	0.96	−0.95	0.99		0.57	0.06	0.99	−0.93	−0.19	−0.60	−0.78	−0.61	−0.80
13	BOD	−0.69	−0.45	−0.60	0.87	−0.23	−0.20	−0.16	0.85	0.33	−0.33	0.63	0.57		0.85	0.47	−0.38	−0.92	−1.00	−0.93	−0.51	−0.94
14	COD	−0.22	−0.73	−0.88	0.74	0.31	0.34	0.28	0.47	−0.21	0.20	0.14	0.06	0.85		−0.06	0.13	−0.99	−0.83	−0.64	−0.23	−0.63
15	Chloride	−0.96	0.30	0.31	0.38	−0.96	−0.94	−0.83	0.82	0.99	−0.99	0.96	0.99	0.47	−0.06		−0.97	−0.08	−0.50	−0.72	−0.65	−0.74
16	Hydrogen carbonate	0.89	−0.19	−0.27	−0.19	0.92	0.90	0.94	−0.70	−0.97	0.98	−0.87	−0.93	−0.38	0.13	−0.97		0.01	0.42	0.68	0.78	0.68
17	Distichodus	0.35	**0.69**	**0.85**	**−0.78**	−0.18	−0.21	−0.16	−0.58	0.07	−0.06	−0.27	−0.19	**−0.92**	**−0.99**	−0.08	0.01		0.90	0.74	0.33	**0.73**
18	Citharinus	0.72	0.46	0.59	**−0.85**	0.26	0.23	0.21	−0.86	−0.37	0.37	−0.66	−0.60	−1.00	−0.83	−0.50	0.42	0.90		0.95	**0.55**	**0.95**
19	Lates	**0.87**	0.34	0.42	**−0.73**	**0.51**	0.47	**0.51**	**−0.92**	−0.61	0.62	−0.80	**−0.78**	**−0.93**	−0.64	**−0.72**	0.68	0.74	0.95		**0.75**	**1.00**
20	Water volume	0.65	0.45	0.31	−0.08	0.47	0.43	0.83	−0.51	−0.61	0.66	−0.54	−0.61	−0.51	−0.23	−0.65	0.78	0.33	0.55	0.75		0.71
21	Depth	0.89	0.30	0.39	−0.76	0.53	0.49	0.49	−0.94	−0.63	0.63	−0.83	−0.80	−0.94	−0.63	−0.74	0.68	0.73	0.95	1.00	0.71	

Note: Bold value indicated high correlations between the studied species and physic-chemical parameter.

volume (1.00; Table 3). There was a negative correlation of the abundance of *L. niloticus* with magnesium hardness (−0.61), COD (−0.64), and chloride (−0.72), dissolved oxygen (−0.73), total hardness (−0.78), total solids (−0.80), calcium hardness (−0.92), and BOD (−0.93). Our result showed a strong positive association of the abundance of *C. citharus* with water volume (0.55), TDS (0.59), temperature (0.72), and water depth (0.95) and a strong positive relationship of the abundance of *D. rostratus* with conductivity (0.69), water depth (0.73), and TDS (0.85). Further, our result showed a negative relationship of other variables examined on the abundance of *C. citharus and D. rostratus*.

Discussion

Studies have shown that the physicochemical properties of the freshwater ecosystem determine the nature, abundance, health, and diversity of the fish species (Adeniji 1991; Akinbuwa 1999; Imevbore and Okpo 1975; Mustapha 2010; Oladipo *et al.* 2018). The driving forces of the aquatic ecosystem's health could be attributed to the water hydrology and nutrients that influence the population dynamics at different times and locations (Chalar and Tundisi 1999; Mustapha 2009). The variation in the physicochemical parameters could indicate changes in the environmental conditions of the freshwater ecosystem. Our study shows that the physicochemical properties of the Jebba Hydroelectric dam could account for the abundance and distribution of some of its economically important fish species.

Temperature is a significant determinant of primary production in the aquatic ecosystem, and various environmental conditions could influence it. For optimal growth, aquatic species require a specific temperature range. For instance, in the tropics, fish potentially survives within a temperature range of 8–30°C (Mustapha 2009). Many authors have reported temperature fluctuations in relation to different seasons in the Nigerian freshwater ecosystems, such as Ase river, Kainji lake, Jebba lake, Oyun, and Apodu reservoir (Adeniji 1991; Idodo-Umeh 1987; Imevbore and Okpo 1975; Mustapha 2009; Oladipo *et al.* 2018b). In our current study, we observed variations in temperature across seasons. We observed relatively higher temperatures during the dry season, a period that coincides with the harmattan usually influenced by the northeast trade winds (Mustapha 2009). During the rainy season, the lower water temperature might result from low solar radiation and a high influx of rainwater. In sum, the observed temperatures are within the temperature range for optimal fish growth, which suggests that the temperature range in Jebba hydroelectric dam is suitable for fish growth.

Studies suggest 4–9 mg/L of DO as the optimal range for large and diverse fish populations. The DO levels recorded in the upstream and downstream of the Jebba Hydroelectric dam were generally low during the dry season. The lower DO, particularly below 3 mg/L, may negatively impact certain sensitive fish species (Abdus-Salam *et al.* 2010). The range of the DO concentration observed in this work is similar to those observed by Olaniyan (1969), Oyewo (2005), and Ayoola and Kuton (2009). On the contrary, we observed higher DO concentrations during the rainy season due to lower temperatures and water mixing during rainfall. The higher DO value observed during the rainy season has also been reported by Adeniji 1991) in Jebba Lake, Imvebore (1975) in Kainji Lake, Mustapha 2009) in Oyun reservoirs, and Yakubu (2004) in Shiroro dam. This shows a typical value of DO obtainable in the Nigerian freshwater ecosystem.

Our focal fish species – *C. citharus*, *D. rostratus* and *L. niloticus* – have been previously reported in a considerable number in River Niger, Nigeria (Ita 1978). *Citharinus citharus* is among the significant economic fish exploitable in Jebba hydroelectric dam. It feeds chiefly on insect larvae, plankton, and aquatic plants. They are highly priced due to their size and flesh quality, most times in a smoked-dried form because they die off immediately when removed from the habitat (Uneke 2015). We observed a high abundance of *C. citharus* in the study area throughout the survey period. This observation is similar to the high abundance of *C. citharus* in Njoboliyo Lake and the Anambra River basin in Nigeria (Odo *et al.* 2009; Amos and Linus 2017). The abundance of *C. citharus* could be related to its adaptation to the microphagous and planktivorous-feeding habitats associated with the lacustrine environment (Arawomo 2006). This work also revealed that higher water level and optimal temperature ranges contributed to the high catch abundance of *C. citharus* in the Jebba Hydroelectric dam.

In this study, *D. rostratus* was abundant in the sampling area, especially the upstream. The total catch percentage recorded in this work was similar to the rate recorded by Odo *et al.* (2009) in the Anambra River basin, Nigeria. A higher abundance of *D. rostratus* was reported during the dry season than in the rainy season, and this trend has been reported in other rivers in Nigeria (Offem *et al.* 2009; Odo *et al.* 2009). The abundance of *D. rostratus* might be associated with food availability and suitable environmental conditions upstream of the dam. Also, the increase in water depth, TDS, and conductivity might have increased the species' abundance and availability. Studies have shown that the diet of *D. rostratus* comprises insect, detritus, and annelids worms (Offem *et al.* 2009), which are common at the upstream of Jebba Hydroelectric dam. These factors might have accounted for its high abundance at the upstream of the dam.

Lates niloticus is widely distributed in sub-Saharan African rivers, including River Niger, Volta and Nile, and lakes such as Chad, Kainji, Jebba, Albert, etc. (Paugy *et al.* 2003; Montcho *et al.* 2009). It is of great commercial importance due to its size and flesh quality. The long-term persistence of this species could be explained by the ability of adults to inhabit deep water and the presence of abundant food resources in its local environment (Reed *et al.* 1967; Froese and Pauly, 2017). Also, the species' abundance could be justified by its growth pattern and condition factor of the study area (Oladipo *et al.* 2018a). A similar record of high abundance of *L. niloticus* was reported in the Pendjari River, West Africa (Montcho *et al.* 2009). On the contrary, Odo *et al.* (2009) reported a low abundance of *L. niloticus* from the Anambra River basin, Nigeria. The high abundance of *L. niloticus* reported in our study area could be related to species' response to local environmental conditions and influence of local environmental conditions such as higher temperatures, high water volume, and depth on the species' catch abundance. Although studies showed that *L. niloticus* is intolerant to low DO level at a higher temperature, this study revealed an increase in catch abundance at higher temperatures with low dissolved oxygen (Fish, 1956; Schofield and Chapman 2000; Getabu *et al.* 2003; Goudswaard *et al.* 2011). It also revealed a positive relationship of depth, nutrients, and turbidity with the species' catch abundance. Our result is in contrary to previous study that reported low catch abundance of *L. niloticus* in deeper water with low oxygen due to eutrophication (Wanink *et al.* 2001; Kolding *et al.* 2008; Taabu-Munyaho *et al.* 2013).

This present work confirms the effects of dams on a freshwater ecosystem. Our results confirm an increase in catch abundance of

L. niloticus and *C. citharus* at higher temperatures with low dissolved oxygen, higher depth, nutrient, and turbidity. The downstream also shows variability in the catch abundance with season predictably higher assemblage of the studied species during the rainy season. Hence, the fluctuations in the water volume, during the dry season, may exert negative pressure on these species by altering the conditions required by this species through the higher risk of habitat degradation (Barbarossa *et al.* 2020).

Conclusion

The Jebba Hydroelectric Power dam is a hotspot for many economically important fishes that are of good quality. The lacustrine habitat, the upstream has more relative higher catch abundance in *C. citharus*, *L. niloticus*, and *D. rostratus* than the downstream. This study also presents useful information on the effects of environmental factors on fish catch abundance. Therefore, this study concludes on need of using environmental variable knowledge in generating more protein for humankind through conservation and good management that ensures sustainability.

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