RESEARCH

The influence of temporal variation of some limnological parameters on finfish assemblage in Osun River, Nigeria.

Adams Iyiola[1,2]* and Adetola Jenyo-Oni[1]

Abstract

Background Anthropogenic activities is a major factor that determines the condition and sustainability of an environment. The nature and type of activities will determine the health, ecosystem services and general well-being of the environment. These activities have increased as a result of industrialization and urbanization, notwithstanding pressure on fish species for balanced nutrition and economic returns. The paucity of documented information about the limnological parameters and finfish assemblage in Osun River nessiciated this study.

Results Mean temperature ($18.7 \pm 2.69\,°C$) and dissolved oxygen (3.2 ± 0.54 mg/L) values were below the recommended limit for fish survival, pH (7.1 ± 0.25) and ammonia (1.2 ± 0.18 mg/L) were within and above the recommended limits. The river had a total of 4544 finfish belonging to 11 families and 19 species. *Chrysichthys nigrodigitatus,* sampling zone A and Cichlid family had the highest abundance in the river with 21.00%, 24.20% and 32.50% respectively. Fin fish abundance had a negative relationship between dissolved oxygen ($r=-0.032$), ammonia ($r=-0.668$), pH ($r=-0.819$); temperature and DO with ammonia ($r=-0.668$, $r=-0.590$) and pH ($r=-0.043$, $r=-0.011$) respectively. Dissolved oxygen ($b=-137.1$), ammonia ($b=-522$) and pH ($b=-93.4$) had a negative effect on finfish assemblage in the river. Significant correlated values ($p < 0.05$) were observed between fin fish and temperature ($p=0.008$), ammonia ($p=0.017$), pH ($p=0.001$). dissolved oxygen ($b=-2.14$), ammonia ($b=-2.72$) and pH ($b=-1.97$) had a negative association with fin fish abundance while significance ($p < 0.05$) were observed with dissolved oxygen ($p=0.048$).

Conclusion It is worthy to note that human activities principally dictates the quality and quantity of limnological parameters which directly affect finfish assemblage; therefore proper environmental management is essential for sustenance of finfish in the river as elaborated by the United Nations Sustainable Development Goals.

Keywords Fish abundance, Human activities, River Osun, Sustainability, Water quality parameters

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Background

The environmental conditions of an area govern the fish abundance, biological conditions, spawning seasons, water level fluctuations, and flooding which can affect breeding activities of fish (Admassu et al., 2015). Rivers have contributed significantly to fish production with little attention to its quality and this has become increasingly important due to the clamor for a cheap source of protein which fish proffer. Fish provides up to 20% of animal protein intake in 127 developing countries (FAO, 2005), it is a cheap source of various vitamins,

iron, calcium, and omega 3 fatty acids and contributes 0.48% to the agricultural Gross Domestic Product (GDP) in Nigeria (FAO, 2016). There has been an increase in demand for fish in Nigeria because it provides about 41% animal protein to the inhabitants (FDF, 2010) and the successful management of this resource will require a periodic assessment of water quality (UNEP, 2012). Nigeria is rich in diverse fish species and their presence can be affected by factors such as climatic conditions, anthropogenic activities, and habitat degradation (Badejo & Oriyomi, 2015; UNEP, 2012). These factors can affect the well being of the fish by limiting the availability of food and water quality degradation (Adedokun et al., 2013; Kareem et al., 2015).

Rapid industrialization and urbanization is one of the major activities that threaten the health of natural ecosystems and it is important to note the effects of these on the water quality as it affects the productive capacity of the river and fish assemblage. In the time past, nature's own waste treatment systems took care of decomposition of wastes generated on land; the case is not the same today because the wastes generated are far beyond what nature can degrade. This is due to the different types of wastes especially non-biodegradable which have adverse effects on the aquatic ecosystem and the services provided by it (Makori et al., 2017). These in turn cause serious environmental problems which trickles to the aquatic systems which is mostly seen and serves as a sink for all activities on land, therefore aquatic resources are threatened (Adedokun et al., 2015; FAO, 2019; Iyiola et al., 2023). This scenario is not good for the environment and advocates are kicking against such activities; a majpr one is the United Nations 17 Sustainable Development Goals (17 SDGs). These goals were geared towards year 2030 and tagged Agenda 2030, such that the environment, humans and life in general can be maintained and ecosystem services can be in continuoum. Goals 14 and 15 which emphasizes on preservation of life under water and life on land respectively are the major focal point of this study (United Nations, 2015). Ait-Kadi (2016) reported that the success of the united Nations Goals depends on water and it is essential to develop integrated water manageemt systems. The clean use of resources and ecosystem services in ways to promote sustainability of aquatic and terrestrial life must be advocated (Giggs et al., 2013). This will go a long way in provision of food and improved nutrition for humans that depend on them as elaborated by Goal 2 (Zero humger) and Goal 3 (Good health and well being).

Osun River is a major river in the Ogun-Osun river basin located in South-western Nigeria. Due to its stretch and size, it is estimated that it will house diverse fin fish species. The status of fin fish species in various reservoirs flowing into the Osun River has been reported; Taiwo, (2010) on Owalla reservoir, Badejo and Oriyomi, (2015), Komolafe et al., (2016) on Eko Ende reservoir, Ipinmoroti et al., (2018) on Asejire reservoir, and Iyiola and Iyantan (2021) on Erinle reservoir. An assessment of the fish species in the river was reported by Iyiola and Jenyo-Oni (2018) but there is limited documented information on the influence limnological factors have on finfish assemblage in the Osun River. This study will, therefore, provide baseline information on the status of the finfish species and the effects of water quality for sustainable management of the river.

Methods

Study area

Osun River located between coordinates 7° 23′ 0″–7° 35′ 0″ North and 4°5′ 0″–4° 5′ 15″ East (Fig. 1) and is fed by various rivers and reservoirs. The river is encompassed with various activities such as agricultural practices, industrial, domestic, and effluent discharge. The upper course of the river is majorly surrounded by agricultural activities while the Nigerian Bottling Company plant is located at the lower end of the river at Asejire. Sampling points were identified based on the information on drainage, soil type, land usage, and geological formation of the river catchment, and seven sampling points (A–G) were purposively selected based on accessibility for the study. The sampling points were identified using an handheld Etrex 2000 Global Positioning System (GPS) manufactured by Garmin. The description and characteristics of each of the sampling points and coordinates are presented in Table 1. Sampling was done fortnightly for twelve months (November 2017–October 2018) and covered both dry and wet seasons.

Limnological parameters

Water samples were collected fortnightly from the river for twelve months between the hours of 7.30 am and 8.00 am in 50 ml sterile bottles and measured in situ for Temperature, Dissolved Oxygen (DO), pH and Ammonia. Temperature was measured using a mercury-in-glass thermometer calibrated in degrees Celcius (°C). DO was measured using Dissolved Oxygen Meter (Model: DO-5509) manufactured by LUTRON, UK. pH and Ammonia were measured in situ using the API Freshwater Master Test Kit manufactured by MARS Fishcare, USA following the protocols described for each parameter. DO and Ammonia were recorded in mg/L.

Finfish assemblage

Fish were sampled fortnightly from the sampling points using monofilament gill nets (10 m × 2 m) with mesh sizes 25 mm, 38 mm, 76 mm, 101 mm, 126 mm, and
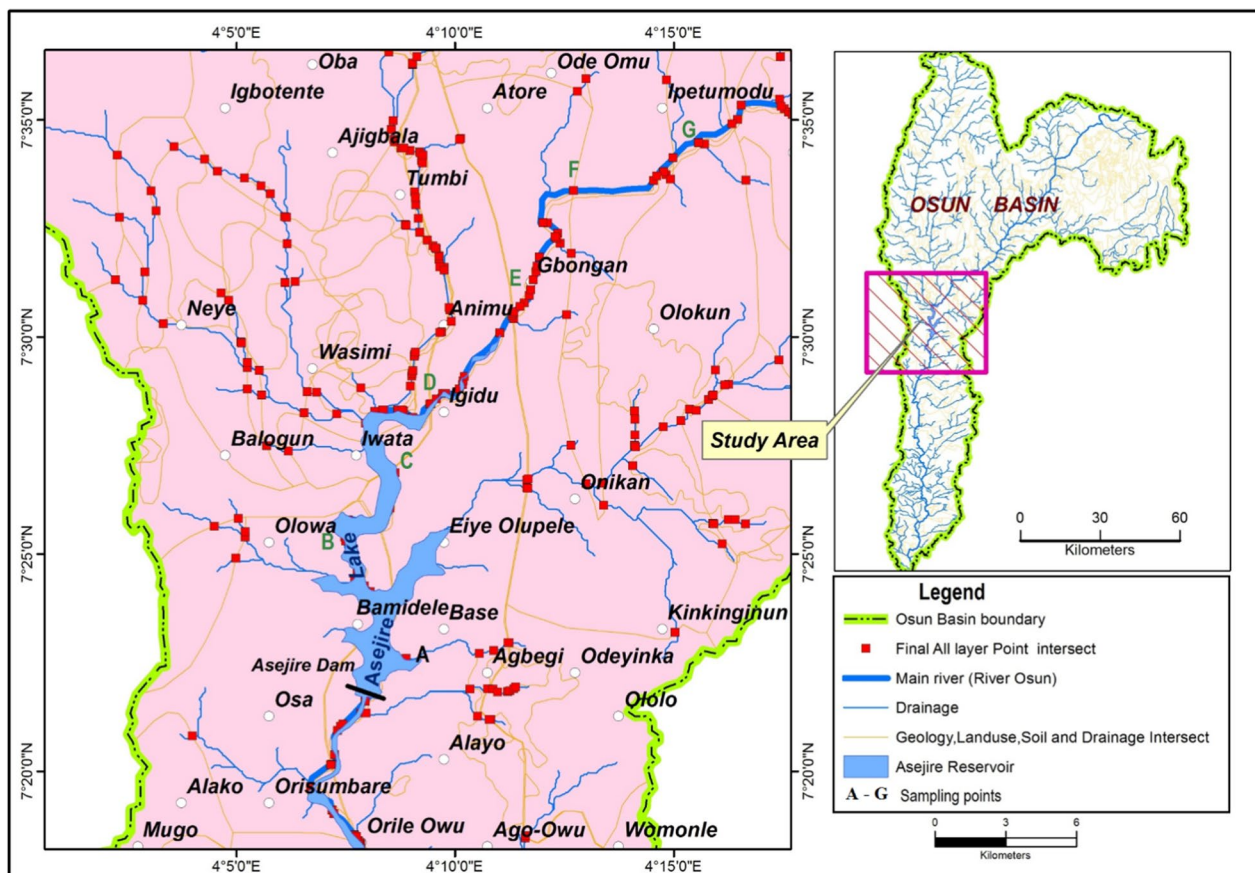
Fig. 1 Map of Osun River Catchment showing the sampling points (A–G). *Source*: Iyiola and Jenyo-Oni, (2018)

Table 1 Coordinates and characteristics of identified Sampling points A–G for the study

Sampling point	Coordinates		Characteristics
	Longitude	Latitude	
A	4° 8′ 52.211″ E	7° 22′ 39.475″ N	This point is characterized by intense human activities and the Nigerian Bottling Copmany is located here. The rock formation is is schist-magmatitised rocks and soil is sandy. Water flow is gentle because it is close to dam wall
B	4° 7′ 22.766″ E	7° 25′ 20.128″ N	The cage culture system is located at this point, the water flow is gentle and the rock formation in this area is this area is made of porphyritic granite with fine soils
C	4° 8′ 40.901″ E	7° 26′ 56.768″ N	Intensive agricultural activities were observed in this area and the rock formation was fine-grained leucogranite. The flow of water is slow
D	4° 9′ 23.053″ E	7° 28′ 34.437″ N	This area consists of rocks that are partly porphyritic nayure and partly fine-gained leucogranite. The flow of water is gentle and farming was observed in this area
E	4° 15′ 39.790″ E	7° 31′ 7.623″ N	This area consists of schist-magmatised rocks with hilly terrain making agricultural practices difficult. The flow of water is steep and soil contains pebbles
F	4° 15′ 39.790″ E	7° 31′ 7.623″ N	This area consists of charnockitic meta intrusive/gneiss and migmatised rocks with hilly terrain making agricultural practices difficult. The flow of water is steep and there was huge influx of ahumans for prayers on these hilly terrain
G	4° 17′ 51.211″ E	7° 35′ 33.475″ N	The rock formation is partly charnockitic-meta intrusive/gneiss and migmatised and partly schist-mag-matized characteristics. The flow of water in this area is fast

177 mm. These nets were set for 12 h i.e. set at 7.00 pm and retrieved at 7.00 am the next day as described by Iyiola and Jenyo-Oni, (2018). A large number of the fish species were dead due to the long duration and were identified to species level using a combination of monographs by Olaosebikan and Raji (2013) and Froese and Pauly (2019). The abundance by family and species were recorded and relative abundance determined.

Statistical analysis

Tukeys mean comparism was used to separate the monthly means of the limnological parameters measured. Pearson correlation analysis was used to determine the relationship between the mean of limnological parameters and between fish abundance and limnological parameters measured across the months. Regression analysis (Eq. 1) was used to estimate the degree of association between finfish assemblage (Dependent variable) and limnological parameters (Independent variable). All statistical analyses were at $p < 0.05$ significance level and graphical illustrations were done using Minitab 19.0 and SPSS 23.0 statistical software.

Multiple Linear regression model:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \tag{1}$$

where $Y =$ Finfish assemblage (Dependent variable), $a =$ intercept, $b_1 - b_4$—regression coefficients, $X_1 - X_4$ (Independent variables—Temperature, DO, Ammonia, pH).

Results

Limnological parameters

The monthly mean limnological parameters measured during the study is presented in Table 2. Monthly mean

Table 3 Correlation coefficient between limnological parameters measured across the sampling months

	Temperature (°C)	DO (mg/L)	Ammonia (mg/L)
DO (mg/L)	0.477		
	0.117		
Ammonia (mg/L)	−0.668	−0.043	
	0.017*	0.895	
pH	−0.590	−0.011	0.748
	0.044*	0.973	0.005*

Cell Contents: Pearson correlation value. *p-Value is significant at < 0.05

temperature was measured in November (22.60 ± 0.20 °C) while the least was measured in May (18.30 ± 0.18 °C) and an overall mean of 18.70 ± 2.69 °C was measured throughout the study. Mean monthly dissolved oxygen was highest in November (4.28 ± 0.05 mg/L) and the least measured in March (2.60 ± 0.16 mg/L) with an overall mean value of 3.20 ± 0.54 mg/L was measured in the study. Mean monthly ammonia levels was highest in July (0.30 ± 0.09 mg/L) were not detected in November and January. An overall mean of 1.20 ± 0.18 mg/L was measured throughout the study with mean monthly values in July, August and October were significantly different ($p < 0.05$) from other months of study. The highest mean pH value was measured in January (7.40 ± 0.10) and the least was in August (6.80 ± 0.06) with an overall mean value of 7.10 ± 0.25 throughout the study.

Correlation between limnological parameters

The correlation coefficient between limnological parameters across the sampling months during the study is presented in Table 3. A negative significant value ($p < 0.05$) was observed between mean temperature and mean

Table 2 Mean monthly temporal values and SEM of some limnological parameters measured during the study

Parameters	Temperature (°C)	DO (mg/L)	Ammonia (mg/L)	pH
November 2017	22.60 ± 0.20	4.28 ± 0.05	ND	7.30 ± 0.03
December 2017	19.30 ± 0.29	2.63 ± 0.16	0.10 ± 0.05	7.30 ± 0.43
January 2018	24.00 ± 0.22	3.89 ± 0.03	ND	7.40 ± 0.10
February 2018	19.10 ± 0.26	2.89 ± 0.06	0.10 ± 0.05	7.00 ± 0.79
March 2018	19.30 ± 0.29	2.60 ± 0.16	0.10 ± 0.05	7.00 ± 0.03
April 2018	19.10 ± 0.26	2.87 ± 0.14	0.10 ± 0.05	7.10 ± 0.05
May 2018	18.30 ± 0.18	3.47 ± 0.10	0.10 ± 0.05	7.10 ± 0.34
June 2018	17.00 ± 0.00	3.04 ± 0.30	0.10 ± 0.07	7.20 ± 0.03
July 2018	15.10 ± 0.14	3.34 ± 0.15	0.30 ± 0.09*	7.00 ± 0.08
August 2018	15.40 ± 0.37	3.14 ± 0.06	0.20 ± 0.10*	6.80 ± 0.06
September 2018	15.90 ± 0.63	3.14 ± 0.06	0.10 ± 0.09	7.00 ± 0.01
October 2018	18.90 ± 0.51	3.19 ± 0.07	0.20 ± 0.10*	6.90 ± 0.07
Mean	18.70 ± 2.69	3.20 ± 0.54	1.20 ± 0.18	7.10 ± 0.25

Superscript with astericks (*) within the same column are significantly different ($p < 0.05$), *SEM* Standard error of mean, *DO* Dissolved oxygen

ammonia values ($r = -0.668$, $p = 0.01$) and mean temperature and mean pH values ($r = -0.59$, $p = 0.04$). Negative relationship were observed between mean dissolved oxygen and mean ammonia values ($r = -0.04$, $p = 0.89$) and mean dissolved oxygen and mean pH values ($r = 0.01$, $p = 0.97$). The relationship between mean ammonia and mean pH va;ues ($p = 0.00$) was significant ($p < 0.05$).

Finfish assemblage

The relative abundance by species, across the sampling zones and family of fin fish identified during the study period are presented in Tables 4, 5 and 6 respectively. A total of 4544 individuals comprising of 19 species belonging to 11 families were identified. The fin fish abundance fluctuated across the months and the highest relative abundance was in February (13.20%) while the least abundance was in July and August with 2.00% respectively. *Chrysichthys nigrodigitatus* was the most abundant fish species (21.00%) while the least was *Clarias macromystax* with 0.2%. Across the sampling zones, it was observed that fin fish abundance reduced from zone A to Zone G with the highest relative abundance in zone A (24.20%) and the least in zone G (6.20%).

Cichlids were observed to record the highest relative abundance (32.50%) and had the highest number of fish species (5) namely *Oreochromis niloticus* (14.10%), *Sarotherondon galileaus galileaus* (6.80%), *Coptodon zilli* (10.40%), Red Tilapia (0.60%) and *C. marie* (0.60%). *O. niloticus* was the most abundant cichlid while red tilapia and *C. marie* were the least. Alestidae recorded the presence of three species (29.80%), Schilbeidae and Mormyridae recorded the presence of two species with 6.80% and 2.20% respectively. Lastly, Distichontidae (1.80%), Latidae (0.80%), Claroteidae (21.00%), Mochokidae (3.40%), Kneriidae (0.30%) and Clariidae (0.20%) had just one species each identified.

Correlation coefficient between limnological parameters and fish assemblage

The correlation coefficient between limnological parameters and fin fish assemblage diting the study is presented in Table 7. A negative significant relationship ($p < 0.05$) was observed between fin fish assemblage with mean ammonia ($r = -0.668$, $p = 0.017$) and pH ($r = -0.819$, $p = 0.001$) values. Mean temperature value had a negative significant relationship ($p < 0.05$) with mean pH value ($r = -0.590$, $p = 0.044$). A negative relationship was observed between fin fish assemblage and mean dissolved oxygen value ($r = -0.032$), mean temperature with mean ammonia value ($r = -0.668$), mean dissolved oxygen

Table 4 Temporal relative abundance of finfish encountered in the river during the study period

Fish species/months	Dry season					Wet season							Total	%
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct		
Alestes baremoze	54	53	65	82	86	59	89	6	–	–	57	12	563	12.40
Brycinus macrolepidotus	9	49	56	66	33	–	–	–	–	–	–	–	213	4.70
Chrysichthys nigrodigitatus	106	105	156	131	110	94	80	–	71	24	50	29	956	21.00
Clarias macromystax	–	–	–	–	–	–	–	–	–	–	5	3	8	0.20
Coptodon marie	11	–	–	–	16	–	–	–	–	–	–	–	27	0.60
Coptodon zilli	98	54	50	50	65	40	69	6	–	–	25	17	474	10.40
Cromeria occidentalis	–	–	–	–	–	–	–	–	–	–	5	10	15	0.30
Distichodus rostratus	3	6	–	–	4	–	–	–	–	–	38	25	76	1.80
Hepsetus akawo	–	–	–	–	–	–	15	–	–	–	39	–	54	1.20
Hydrocynus forskalii	40	44	55	63	106	29	22	130	–	7	44	38	578	12.70
Lates niloticus	2	2	4	5	6	–	3	–	2	–	10	3	37	0.80
Mormyrops anguilloides	–	–	–	–	–	–	–	–	–	5	5	8	18	0.40
Mormyrus rume rume	3	7	11	17	37	–	–	–	–	–	–	9	84	1.80
Oreochromis niloticus	101	92	95	79	87	54	32	20	10	22	31	18	641	14.10
Red tilapia	8	2	4	7	4	–	–	–	–	–	–	–	25	0.60
Sarotherodon galileaus galileaus	2	74	78	67	63	–	–	–	–	8	–	17	309	6.80
Schilbe mystus	39	18	15	27	29	88	57	10	2	10	–	11	306	6.70
Schilbe uranoscopus	–	–	–	–	–	–	–	–	–	–	5	–	5	0.10
Synodontis budgetti	2	5	4	8	20	17	44	19	6	15	11	4	155	3.40
Total	478	511	594	602	666	381	411	191	91	91	325	204	4544	100
Total (%)	10.50	11.20	13.00	13.20	14.70	8.30	9.00	4.20	2.00	2.00	7.20	4.90	100	

Nov - November, *Dec* - December, *Jan* - January, *Feb* - February, *Mar* - March, *Apr* - April, *Jun* - June, *Jul* - July, *Aug* - August, *Sept* - September, *Oct* - October

Table 5 Relative abundance across the sampling points

Months/points	A	B	C	D	E	F	G	Total	Total (%)
November 2017	140	97	69	82	42	29	19	478	10.50
December 2017	115	110	102	76	46	41	21	511	11.30
January 2018	123	149	113	80	57	45	26	593	13.10
February 2018	164	120	112	87	60	35	24	602	13.30
March 2018	158	131	123	86	71	56	41	666	14.70
April 2018	85	76	84	28	39	39	30	381	8.40
May 2018	55	67	44	52	61	69	63	411	9.00
June 2018	40	28	50	33	9	21	10	191	4.20
July 2018	17	11	16	12	14	9	12	91	2.00
August 2018	39	27	8	7	3	4	3	91	2.00
September 2018	97	61	48	34	37	28	20	325	7.20
October 2018	68	40	26	33	16	9	12	204	4.50
Total	1101	917	795	610	455	385	281	4544	100.00
Total (%)	24.20	20.20	17.50	13.40	10.00	8.50	6.20	100.00	

Table 6 Relative abundance of finfish assemblage by family in the river

S/N	Family	Species	Relative abundance (%)
1	Cichlidae	*Oreochromis niloticus*	14.10
		Sarotherondon galileaus galileaus	6.80
		Coptodon zillii	10.40
		Red Tilapia	0.60
		Coptodon marie	0.60
2	Distichontidae	*Distichodus rostratus*	1.80
3	Latidae	*Lates niloticus*	0.80
4	Claroteidae	*Chrysichthys nigrodigitatus*	21.00
5	Alestidae	*Alestes baremoze*	12.40
		Brycynus macrolepidotus	4.70
		Hydrocynus forskalii	12.70
6	Schilbeidae	*Schilbe mystus*	6.70
		Schilbe uranoscopus	0.10
7	Hepsetidae	*Hepsetus akawo*	1.20
8	Mormyridae	*Mormyrus rume rume*	1.80
		Mormyrups anguilloides	0.40
9	Mochokidae	*Synodontis budgetti*	3.40
10	Clariidae	*Clarias macromystax*	0.20
11	Kneriidae	*Cromeria occidentalis*	0.30
	11 families	19 species	100

value with mean ammonia value ($r = -0.043$) and mean pH value ($r = -0.011$). A significant relationship ($p < 0.05$) was observed between mean ammonia and mean pH values ($p = 0.005$).

Regression parameters between fin fish assemblage and limnological parameters

The regression parameters between fin fish assemblage and limniligical parameters during the study is presented in Table 8. The multiple regression model was observed to be significant ($p < 0.05$) as well as the relationship between fin fish assemblage and mean dissolved oxygen values ($b = -2.14$), ammonia ($b = -2.72$) and mean pH values ($b = -1.97$). The regression model for the relationship was:

Fish abundance $= 3.63 + 1.75$ Temperature $- 2.14$ DO $- 2.72$ Ammonia $- 1.97$ pH.

Discussion
Limnological parameters
Water is important for life and it is therefore essential to periodically assess its quality to maintain a healthy aquatic system (Bhalerao, 2012). The quality of water can also dictate the abundance and composition of resources in them (USEPA, 2019a). The mean limnological parameters measured across the sampling months are presented in Table 1. The highest mean monthly temperature was measured in January (24.00 ± 0.22 °C) and the least was in July (15.10 ± 0.14 °C) with an overall mean monthly temperature of 18.70 ± 2.69 °C. Generally, it was observed that most of the mean parameters measured across the months were were below the recommended limit of 20–32 °C for the survival of freshwater organisms as stated by USEPA (2019b) except for November (22.60 ± 0.20 °C) and January (24.00 ± 0.22 °C) which had mean values within the recommended limit. Both months were in the dry season and their mean values

Table 7 Correlation coefficient between limnological parameters and fish assemblage

Parameters	Fin fish	Temperature (°C)	DO (mg/L)	Ammonia (mg/L)
Temperature (°C)	0.724			
	0.008*			
DO (mg/L)	− 0.032	0.477		
	0.906	0.117		
Ammonia (mg/L)	− 0.668	− 0.668	− 0.043	
	0.017*	0.017	0.895	
pH	− 0.819	− 0.590	− 0.011	0.748
	0.001*	0.044*	0.973	0.005*

Cell Contents: Pearson correlation values. *p-value is significant at < 0.05

Table 8 Summary of regression coefficients between fish assemblage and limnological parameters

Parameters	Coefficient	p-value	Relationship
Constant (a)	3.63	0.029*	Positive
Mean temperature (X_1)	1.75	0.054	Positive
DO (X_2)	− 2.14	0.048*	Negative
Ammonia (X_3)	− 2.72	0.338	Negative
pH (X_4)	− 1.97	0.067	Negative

*p-value is significant at $p < 0.05$

may be due to the environmental conditions of the dry season because water temperature can be influenced by rainfall and air temperature (Adedeji, 2011). During the wet season (April to October), the mean temperature across the months was below the recommended levels as similarly reported by Kolawole and Aramowo (2011) and Komolafe et al., (2014).

DO is vital for the survival of fish species and the overall mean values measured from the river (3.20 ± 0.54 mg/L) were below the recommended level of 4 mg/L as stated by USEPA (2019a). The values measured fluctuated throughout the study period with the highest monthly value in November (4.28 ± 0.05 mg/L) and least in March (2.60 ± 0.16 mg/L) and were above and below the recommended level respectively. The low DO concentration can be attributed to the presence of various pollutants from anthropogenic activities around the river catchment area, from suspended materials that can be brought in by rains and organic decomposition which can inhibit oxygen in the river (Komolafe et al., 2014).

Ammonia values were Not Detected (ND) in November and January with the highest monthly value measured in July (0.30 ± 0.09 mg/L) and the overall monthly mean was 1.20 ± 0.18 mg/L which was higher than the recommended level of 0.1 mg/L as reported by Andem et al., (2012). This peak value measured in July may be attributed to the excessive wastes from land which is washed by the continuous torrential rains which preceeds the August break as stated by NiMET (2019). Most of the mean monthly values were below the recommended level and values in July, August and October were significantly different ($p < 0.05$) from other months with p values of 0.00, 0.04 and 0.01 respeectively. High ammonia levels can cause various gill damages, slow growth in fish, and a reduction in resistance to diseases (Jenyo-Oni et al., 2014). Sunday and Jenyo-Oni (2018) reported similar elevated levels of ammonia and attributed it to organic waste decomposition. The highest mean monthly pH value was measured in January (7.40 ± 0.10) and least in August (6.80 ± 0.06) and the overall monthly mean was 7.10 ± 0.25. Slight differences were observed in mean monthly pH levels all of which were within the recommended levels of 6.5–9 (USEPA, 2019b). The overall mean monthly value measured (7.10 ± 0.25) was within the recommended range. Similar results of the mean pH range were reported by Olanrewaju et al., (2017) and Sunday and Jenyo-Oni (2018).

Correlation coefficient between limnological parameters

From the analysis, a negative relationship was observed between ammonia and temperature ($r = -0.668$) which was significant significant ($r = 0.017$); pH and temperature ($r = -0.590$) which was significant ($p = 0.044$), ammonia and DO ($r = -0.043$) and pH and DO ($r = -0.011$). All these negative relationship implied that the increase in one parameter resulted to a decrease in the other parameter. A significant relationship was observed between pH and ammonia ($p = 0.005$).

Fin fish assemblage

Seasons play a principal factor in the distribution and abundance of fish species (Negi and Mamgain, 2013) notwithstanding factors such as habitat degradation, pollution, and overfishing which are consequences of various anthropogenic activities (Jenyo-Oni and Oladele, 2016). The dry season had the highest fish species with

peak abundance in March (14.7%) as corroborated by reports of Komolafe et al., (2014) and Badejo and Oriyomi, (2015). During this period, the volume of water was reduced because there is little or no rain (NIMET, 2019) thereby breeding activities ceased and fish are out in the open waters in search of food. *C. nigrodigitatus* was most abundant in the river and similar results were reported on the dominance of *C. nigrodigitatus* in Nigerian waters and the dominance of Cichlids as the case of Osun River (32.5%) have been reported (Iyiola and Jenyo-Oni, 2018; Taiwo, 2010). The wet season is peculiar with an abundance of average rainfall and low mean temperatures (NiMET, 2019) and these two factors are principal in the stimulation of fish species for breeding activities (Negi and Mamgain, 2013). During this period, some fish species were observed to be absent and generally, the abundance of fish species was low. A possible biological explanation for this was the breeding activities peculiar to the wet season in which most of the fish species had migrated to shallow areas of the river for spawning activities thereby causing a decline in the fish population (Agumassie, 2019).

It was observed that fish abundance was highest in zone A; which was expected due to the obstruction created by the dam wall. This enabled aggregation of fish species due the huge volume of water created by the obstruction, as well as the accumulation of various food materials which flowed by gravity from upstream (zone G) to downstream (zone A) (Table 5). Similarly, these results have been reported by various authors in man-made reservoirs and attributed the increased aggregates of fish species within the dam wall region. Badejo and Oriyomi, (2015); Ipinmoroti et al., (2018), Taiwo et al., (2018) to mention a few reported these cases in Erinle, Asejire, and Opa reservoirs respectively. Another possible reason for increased fish abundance can be attributed to the movement of fish with water current (Fish, 2010), in which fish flows with currents from upstream to downstream thereby accumulating in this area due to the dam wall. Lima et al., (2016) and Mostafavi et al. (2020) reported similar results in neotropical freshwaters and Karaj River; Iran respectively.

Correlation coefficient between limnological parameters and fin fish assemblage
From the analysis, a negative relationship was observed between finfish assemblage and DO ($r = -0.032$), significant with ammonia ($r = -0.668$, $p = 0.017$) and pH ($r = -0.819$, $p = 0.001$). These implied that an increase in ammonia, DO and pH resulted to a corresponding decrease in fish abundance. This was expected because ammonia buildup is toxic to fish survival and inhibits DO concentration as observed from the analysis (Makori

et al., 2017). Temperature had a negative relationship with ammonia ($r = -0.668$) and pH ($r = -0.590$) and DO with ammonia ($r = -0.043$) and pH ($r = -0.011$) Significant differences was observed between temperature and fish abundance ($p = 0.008$) and pH and ammonia ($p = 0.005$).

Regression parameters between fin fish assemblage and limnological parameters
From the analysis, the degree of association between finfish assemblage and the limnological parameters measured was observed to be very dynamic. The regression model was observed to be significant and the mean temperature measured (1.75 X_1) had a positive effect on the finfish assemblage in the river (Y). This implied that an increase in the mean concentration of temperature in the river increased the finfish assemblage. The effects of DO ($-2.14 X_2$), Ammonia ($-2.72 X_3$) and pH ($-1.97 X_4$) on the finfish assemblage was negative and DO was at a significant level ($p = 0.048$) which implied that as DO, ammonia and pH increased by one unit, finfish assemblage reduced by 2.14, 2.72 and 1.97 units respectively. The negative relationship with DO was expected because of the increased concentration of ammonia which reduces the dissolved oxygen concentration in water (Olanrewaji et al., 2017).

Conclusion
It was observed from the study that Osun River is very rich in fin fish composition and diversity although it fluctuated across the months due to activities associated with particular periods of the year. The limnological parameters measured were observed to below the recommended limits for mean temperature and dissolved oxygen; above and within the recommended limits for ammonia and pH respectively. The elevated levels of ammonia were expected and was due to the presence of the intense cage culture activity at a region of the river. Temperature recorded a negative significant difference with ammonia and pH; likewise ammonia with pH. *Chrysichthys nigrodigitatus* was the most abundant fin fish species and cichlids the most abundant family and temperature, ammonia and pH having significant differences with fin fish assemblage in the river. An indirect relationship was observed between fin fish assemblage and dissolved, ammonia and pH with significance with dissolved oxygen. It is imperative that the quality of limnological paramenets in water can influence the finfish composition in a river and its severity is a function of the human activities around the river catchment. Strict attention should also be given to the various anthropogenic activities along the water bodies because in the long run; all their wastes flush into the river system and

degrades the water quality. Sustenance of fin fish species is directly affected thereby affecting its sustainability; with this scenario being advocated against by the United Nations Sustainable Development Goals. It emphasizes good nutrition (Goal 2), preservation of life under water (Goal 14) and life on land (Goal 15). Management strategies such as mesh size regulations, enforcement of open and closed seasons and constant monitoring of river can be proposed, which will enable sustainability of fin fish specie sin the river.

Abbreviations

DO	Dissolved oxygen
FAO	Food and Agricultural Organization
FDF	Federal department of fisheries
GDP	Gross domestic product
GPS	Global positioning system
SEM	Standard error of mean
UK	United Kingdom
UNEP	United Nations Environmental Programme

Availability of data and materials
Data are available on request.

Declarations

Ethics approval and consent to participate
Not applicable for this kind of research.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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