Association of some weather factors with fish assemblage in Asejire Lake, South-western Nigeria

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Abstract: *With the increasing human population, it is important to investigate the condition of Asejire Lake for sustainability. To this end, the effects of some weather factors were investigated on the fish assemblage, so as to provide necessary information to complement the dearth of reports about weather factors on the Lake. The study area was partitioned into three stations (upper, middle and lower) with fortnight collection of water samples, fish sampling and weather parameters for a period of 12 months (November 2017 – October 2018). Water samples were measured in situ using appropriate kits for pH, ammonia, nitrite and nitrates, dissolved oxygen and water temperature. Monofilament gill nets (40 mm and 60 mm) were used for fish sampling and were sorted and identified using appropriate monographs. The mean values across the sampling stations for temperature, pH, dissolved oxygen, ammonia, nitrates and nitrites were 18.36 ± 0.41^{o}C, 7.30 ± 0.06, 2.37 ± 0.10 mg/L, 1.25 ± 0.05 mg/L, 1.34 ± 0.33 mg/L and 0.31 ± 0.03 mg/L, respectively. Across the months, mean values were 17.94 ± 0.48 ^{o}C, 2.67 ± 0.21 mg/L, 7.22 ± 0.21, 0.23 ± 0.02 mg/L, 0.13 ± 0.02 mg/L and 3.03 ± 0.03 for temperature, DO, pH, ammonia, nitrite and nitrates, respectively, with significant values ($P < 0.05$) among some parameters. A total of 1443 individual fishes (720 in the dry and 723 in the wet season) belonging to 27 species were encountered. March had the highest overall relative abundance of fish (23.77%) with Chrysichthys nigrodigitatus being the most abundant species (39.32%). March (47.64%) and April (32.78%) recorded the highest fish abundance in the dry and wet seasons respectively. Rainfall (540 mm) and temperature (35.50 °C) were highest in the month of September. The trend of rainfall and temperature was observed to increase over the months with t-values of 1.77 and 1.64 respectively. A negative relationship was observed between fish abundance with temperature (b_1= -1.08) and rainfall (b_1 = -0.26). It was observed that temperature values increased and rainfall values varied. Therefore, activities must be geared towards environmental management and consciousness of aquatic resources because of sustainability.*

Keywords: Anthropogenic activities, Asejire Lake, Fish diversity, Water quality parameters

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1. Introduction

Weather describes the day-to-day state of atmospheric conditions of an area and it can be influenced by interacting factors such as latitude, elevation, nearby water, ocean currents, topography, vegetation, prevailing winds and human activities. When such conditions are above or below recommended limits, it may alter the physiological processes in the fish such as spawning, survival, rate of recruitment into the exploitable phase of the population, population size, production, yield, food composition and availability (Obot *et al*., 2016). Fish are connected with their immediate environment and are therefore highly vulnerable to changes in weather patterns. These impacts can vary from the coastal areas to the drier northern parts of the country (Froese *et al*., 2022). The effects of rainfall and temperature have been reported to pose a significant impact on Nigeria's freshwater and marine aquatic systems and hence on the country's fisheries resources (Gaines *et al*., 2018). The interplay of rainfall and temperature governs other environmental factors and they can predict the state of the atmosphere (Sixth Assessment Report, 2021). The availability of water in its right quality and quantity plays an essential role in the existence of all living organisms. This valued resource is increasingly being threatened due to its use for various economic, domestic and industrial uses by the increasing human population (Froese *et al*., 2022).

Conversely, the fish species which make these water bodies their haven are affected by water pollution which may be due to the resultant discharge of wastes directly or indirectly into the water bodies. In such areas, fish may be affected in terms of abundance, and biodiversity, migration can occur when water quality is not tolerable and death is imminent in extreme cases. Asejire Lake is encompassed with various domestic and industrial activities; a prominent one is the Nigerian Bottling Company (NBC) plant which manufactures soft carbonated drinks. The bottling plant extracts portable water from the lake for manufacturing activities and releases various solid and liquid wastes into the environment. A constant discharge of fumes was observed from the manufacturing plants which releases carbon monoxide gases and its derivatives into the atmosphere.

Another activity observed on the lake was the intensive fish cage culture system by Triton Company which releases all wastes from the fecal and uneaten feed directly into the lake. Other activities such as crop production, washing of clothes by community inhabitants, water extraction by tankers for domestic supply, dredging, bathing and human defecation were also observed around the lake. However, several studies on the effects of various human activities on the water quality and fisheries resources of the Lake have been reported (Obot *et al*., 2016; Ipinmoroti *et al*., 2018), but there is limited documented information on the effects of weather patterns (rainfall and temperature) on the fish biodiversity in the lake. It is pertinent to study these at this time because of the current concerns of global warming resulting from human activities and the noticeable vulnerability of Nigeria to climate change which has posed a major challenge to fisheries (Omitoyin, 2009).

This study therefore proposes necessary management procedures as elaborated by the Agenda 2030 of the United Nations Sustainable Development Goal number 14 (Life underwater). These measures incorporate adaptation and mitigation procedures towards climate resilience by human activities as elaborated by SDG 13 (Climate resilience). This study also seeks to investigate the effects of rainfall and temperature on fish assemblage in the Lake.

2. Materials and Methods

2.1. Description of the study area

Asejire Lake is a man-made lake that is created on Osun River and is geographically located on 7.3669^o N, 4.1333^o E (Aladesanmi *et al*., 2013). It was impounded in 1970 and supplies about 80 million liters of water per day to Asejire and Osegere water treatment plants. About 80% of the water is used for domestic purposes and the use of chemicals around the lake is banned. Diverse human activities such as agricultural activities, laundry activities, and water withdrawals for domestic uses were observed around the lake catchment. Despite the ban on farming activities, it was observed to be the predominant activity. The lake has a mean depth of 11 m^2, a length of 11.2 km, a surface area of 526 ha and a catchment area of 7242 km^2. The lake was partitioned based on accessibility and logistical characteristics into three sampling stations and sampled fortnightly from November 2017 to October 2018.

Upper station (US): It was located about 300 m away from the middle station and 750 m from the dam wall. This station was located in the North Eastern part of the Lake and characterized by floating aquatic Macrophytes and a dense population of vegetation around the catchment. A few human activities such as washing and farming were observed in this area.

Middle station (MS): It was located about 300 m away from the upper station and 250 m away from the lower station. This area was some wart in the middle of the lake and human activities were intense in this area. The Triton cage culture system was located in this area, as well as increased fishing activities because of the aggregation of fish species around the cage area which feed on the remains and escape of feed from the cages.

Lower station (LS): It was located towards the Southern part of the Lake at 250 m away from the middle station and 250 m away from the dam wall. This area was close to the dam wall which received all forms of waste flowing from the upper region of the lake. Floating wastes such as plastics, nylon, and floating aquatic Macrophytes were observed on the water surface within this area. The spillway which is used to regulate the lake water level was located in this area (Figure 1).

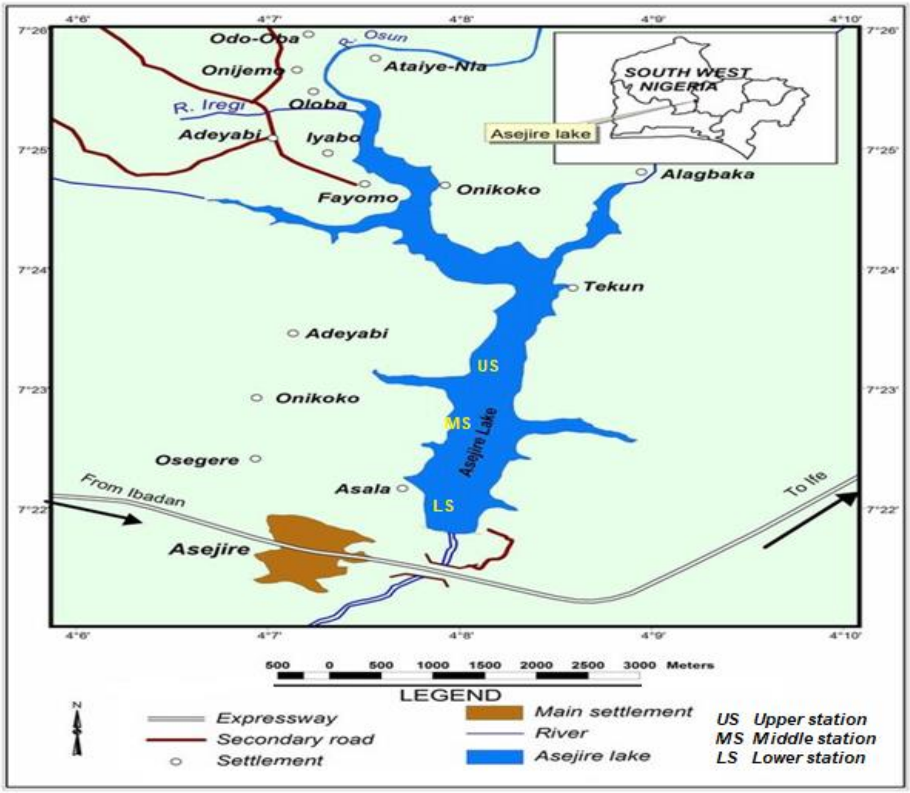

Figure 1: Map of Asejire Lake

2.2. Assessment of water quality

Water samples were collected fortnightly from each station using 10 ml sterilized sampling bottles between the hours of 0700 and 0900 GMT. The samples were measured *in situ* for Dissolved Oxygen (DO) concentration, temperature, pH, ammonia, Nitrite and Nitrates from November 2017 – October 2018.

2.2.1. *Dissolved oxygen*

Dissolved oxygen (DO) was measured using a DO meter manufactured by Lutron, United Kingdom (Model DO-5509) as described by the manufacturer. The meter was first calibrated and the probe was inserted into about 10 cm of the sample water so the water can cover the entire sensor on the probe. Readings were taken on the digital screen of the meter when it was steady and recorded in milligrams per liter (mg/L). The probe was rinsed after each measurement with tap water.

2.2.2. *Water temperature*

It was measured using a mercury-in-glass thermometer which was dipped into the water sample to a depth of 10 cm for about two minutes. Readings were taken when the mercury level in the thermometer was steady and recorded in degrees Celsius (°C).

2.2.3. *Ammonia*

It was measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water samples were poured into a 5 ml container and 2 drops of ammonia reagent A were added to the sample. It was allowed to stand for 30 seconds after which 1 drop of ammonia reagent B was added to the mixture. It was later left to stand for 10 seconds and the final colour of the mixture was compared with the ammonia colour chart provided by the manufacturer. Readings were taken from the corresponding colour on the chart and recorded in mg/L.

2.2.4. *pH*

The pH was measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water samples were poured into a 5 ml container and 2 drops of the pH reagent was added. The solution was left to stand for 30 seconds and the final colour of the mixture was compared with the colour chart so as to know the corresponding pH value of the sample.

2.2.5. *Nitrite*

They were measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. Water sample were poured into a 5 ml container and 2 drops of nitrate reagent was added to the sample. The solution was left to stand for 15 seconds and the final colour of the mixture was compared with the colour chart provided by the manufacturer. The corresponding value of the final colour was read and recorded in mg/L.

2.2.6. *Nitrates*

They were measured using API Freshwater Master Test kit manufactured by MARS Fish care, United States of America. The sample water was poured into a 5 ml container and 2 drops of nitrate reagent was added to the sample. The mixture was left to stand for 30 seconds and the final colour of the mixture was compared with the nitrate colour chart provided by the manufacturer. Readings were taken and recorded in mg/L.

2.3. Assessment of fish abundance and distribution

Fish species were collected fortnightly from the sampling stations using monofilament gill nets of mesh sizes 40 mm and 60 mm. These nets were set at each sampling stations between the hours of 1900 GMT and retrieved at 0700 GMT the next day as described by Kareem *et al.* (2015). The gears were retrieved, fish species collected and identified using monographs by Holden and Reeds (1978); Olaosebikan and Raji (2013), and their numerical abundance and distribution in each station were recorded.

2.4. Weather parameters

2.4.1. *Rainfall*

It was measured fortnightly from November 2017 – October 2018 using a standardized Stratus rain gauge (Model 6330), manufactured in the United States of America. It has a capacity of 280 mm, a weight of 0.9/1.8 kg and a size of 102 mm x 356 mm. It was placed in an open area so as to prevent obstruction from trees and ensure direct collection of water from the atmosphere into the rain gauge. The amount of rain collected was recorded in millimeters (mm).

2.4.2. *Atmospheric temperature*

It was measured fortnightly from November 2017 – October 2018 using Mason's Hygrometer (wet and dry bulb Thermometer) manufactured by Eisco labs, United States of America. It is usually wall-mounted and was placed around the Lake. It was used to measure atmospheric temperature as described by Camuffo (2019). The readings were taken on the tube when the mercury level was steady and values were recorded in degrees Celsius.

2.5. Statistical analysis

Descriptive statistics, such as numeric counts, percentages, means and standard deviations were used on data for fish assemblages, water quality parameters, and weather parameters. Turkeys' pairwise comparison was used to determine the level of significance among water quality parameters across the months and sampling stations. Linear regression analysis was used to determine the association between fish abundance and weather parameters (Equation 1). Linear trend analysis was used to observe the trends of rainfall and temperature over time (Equation 2). R-Statistical software was used for all statistical analysis at a 95% confidence level (P<0.05).

$$Y = bo + b1X \qquad [1]$$
$$Yt = bo + b1 * t \qquad [2]$$

Where:

Y = Fish abundance
b_o = Constant
b_1 = Regression coefficient/trend coefficient
X = Rainfall/temperature
Yt = Trends in rainfall/temperature
t = Time

3. Results and Discussion

3.1. Water quality parameters

The mean value of water quality parameters measured from the sampling stations and across the months during the study is presented in Tables 1 and 2 respectively. Across the sampling stations and months, the mean values were highest in the Middle station (18.44 ± 0.41 °C) and in February (22.00 ± 0.68 °C). Most of the mean values recorded from this study were below the recommended limits of 20 – 30 ºC for aquatic biota (FAO, 2022), except for February and April. The temperature results deviated from the mean value reports of 23.1°C and 25 °C from a Lake within the region (Olanrewaju *et al*., 2017; Sunday and Jenyo-Oni, 2018). Temperature is a very important parameter because it regulates the internal processes and body temperature of fish. Significant differences (P<0.05) in mean values were observed in December, July, August and September.

Most of the mean DO values across the sampling stations and months were below the recommended limits of 3 mg/L for aquatic biota (FAO, 2022), with the highest mean values in the upper station (2.71 ± 0.10 mg/L) and in June (3.64 ± 0.09 mg/L). An overall mean value of 2.37 ± 0.10 mg/L was measured across the sampling stations and it was lower than the recommended limit for aquatic biota (FAO, 2022). The DO concentration was observed to be high at the onset of the wet season and low at the end of the wet season. A possible reason could be due to the low temperature and turbulence of water by high winds. The DO level measured was low in the dry season, which may be due to the high metabolic rate and limited water turbulence. The low mean values were expected because of the increased levels of ammonia which inhibited DO in the lake thereby affecting fish species distribution (Beggel *et al*., 2021). The mean DO values in May – September were observed to be slightly above the recommended limits with significant monthly differences (P<0.05) observed in February, April, June, August and September. Across the sampling stations, the mean value in the middle section was observed to be significantly different (P<0.05) from other sections during the study. A possible reason for this may be the presence of the cage culture system which involves the intensification of supplementary feed and increased waste generation (Beggel *et al*., 2021).

Across the sampling months and stations, all the pH values were above the recommended limits of 6.5 – 8 for aquatic biota (FAO, 2022). Across the sampling stations, the highest pH was measured in the upper station (7.32 ± 0.06) with an overall mean value of 7.30 ± 0.06. For the sampling months, February had the highest mean monthly value (7.8 ± 0.00), and an overall mean monthly value was 7.29 ± 0.21. Significant monthly differences (P < 0.05) in mean pH values were observed in January, February, March, June, August and September. The pH value recorded from this study suggested that the condition of the water is between neutral to a slightly alkaline condition and is a tolerable level for the survival of fish species (Farombi *et al*., 2014; Obot *et al*., 2016).

Ammonia, nitrite and nitrates are products of decomposition. Nitrites are produced from a combination of Nitrosomonas bacteria and nitrates by Nitrobacter bacteria. The ammonia values across the sampling stations and months were extremely high when compared with recommended levels for aquatic biota (FAO, 2022). The highest mean value across the sampling stations was recorded at the middle station (1.96 ± 0.05 mg/L), and an overall mean value of 1.96 ± 0.05 mg/L was measured during the entire study. This was expected because the location of the cage culture system was in this area and it releases huge wastes from uneaten feed, excretory products and organic decomposition from the intensive culture system carried out (Beggel *et al*., 2021; Makori *et al*., 2017). This activity influenced the low dissolved oxygen as observed from the mean values in this station (Beggel *et al*., 2021).

Across the sampling months, the mean concentration of ammonia was highest in August (0.50 ± 0.03 mg/L) and September (0.50 ± 0.00 mg/L), and an overall mean of 0.21 ± 0.02 mg/L was measured during the entire study. These values were also higher than the recommended limit of 0.05 mg/L for aquatic biota (FAO, 2022), and significant monthly differences (P<0.05) were observed in the mean values measured in May and June. Elevated ammonia levels are not tolerable to fish because it can cause gill damage and inhibit DO, therefore its levels should be minimized (Sunday and Jenyo-Oni, 2018). Significant differences (P<0.05) were observed in mean ammonia levels measured in the middle and lower stations.

Table 1: Mean water quality parameters measured across the sampling stations

Parameters	Upper Station	Middle Station	Lower Station	Mean values	Recommended (FAO, 2022)
Temperature (°C)	18.30 ± 0.39	18.44 ± 0.41	18.33 ± 0.42	18.36 ± 0.41	20 – 30
DO (mg/L)	2.71 ± 0.10^{b}	2.00 ± 0.10^{a}	2.41 ± 0.10^{b}	2.37 ± 0.10	3
pH	7.32 ± 0.06	7.29 ± 0.05	7.30 ± 0.06	7.30 ± 0.06	6.5 – 8
Ammonia (mg/L)	0.26 ± 0.06^{b}	1.96 ± 0.05^{a}	1.53 ± 0.05^{a}	1.25 ± 0.05	0.05
Nitrite (mg/L)	0.07 ± 0.03^{b}	0.67 ± 0.03^{a}	0.19 ± 0.03^{b}	0.31 ± 0.03	0.25
Nitrate (mg/L)	0.02 ± 0.33^{b}	2.27 ± 0.34^{a}	1.72 ± 0.32^{b}	1.34 ± 0.33	250

± = the Standard Error of Mean; mean values with different superscripts are significantly different across the rows

Nitrite which occurs from the breakdown of ammonia was high in the middle station with a mean value of 0.67 ± 0.03 mg/L and an overall mean total of 0.31 ± 0.03 mg/L (Table 1). The mean values measured in the middle station were the only value above the recommended limit of 0.25 mg/L for aquatic biota (FAO, 2022). Across the sampling months, July had the highest mean value with 0.25 ± 0.09 mg/L and an overall mean of 0.12 ± 0.02 mg/L. Nitrite values were not detected in January, February and March with recorded mean monthly values (0.13 ± 0.02 mg/L) within the recommended limit of 0.25 mg/L (Table 2). The results from this study deviated from the reported mean values of 0.21 mg/L for aquatic biota (FAO, 2022) and 0.23 mg/L (Farombi *et al*., 2014). Nitrates are less toxic and mean values measured across the months (3.03 ± 0.03 mg/L) and sampling stations (1.34 ± 0.33 mg/L) were within the recommended levels of 250mg/L for aquatic biota (FAO, 2022), with similar values reported by Farombi *et al*. (2014).

Table 2: Mean water quality parameters measured across the sampling months

Season	Months	Temperature (°C)	DO (mg/L)	pH	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)
Dry	November	18.30 ± 0.26^{b}	2.80 ± 0.04^{b}	7.10 ± 0.01^{b}	0.13 ± 0.01^{b}	0.19 ± 0.02^{b}	5.29 ± 0.00^{a}
	December	17.30 ± 0.33^{a}	2.91 ± 0.04^{a}	7.00 ± 0.02^{b}	0.33 ± 0.00^{b}	0.21 ± 0.00^{b}	5.02 ± 0.00^{a}
	January	19.67 ± 0.21^{b}	2.00 ± 0.00^{b}	7.73 ± 0.04^{a}	ND	ND	ND
	February	22.00 ± 0.68^{b}	1.77 ± 0.00^{a}	7.8 ± 0.00^{a}	ND	ND	ND
	March	19.68 ± 0.33^{b}	2.00 ± 0.05^{b}	7.73 ± 0.04^{a}	ND	ND	ND
Wet	April	20.0 ± 0.26^{b}	2.1 ± 0.04^{a}	7.2 ± 0.06^{b}	0.25 ± 0.00^{b}	0.20 ± 0.04^{b}	ND
	May	18.00 ± 0.51^{b}	3.5 ± 0.16^{b}	7.10 ± 0.02	0.08 ± 0.05^{a}	ND	ND
	June	18.00 ± 0.26^{b}	3.64 ± 0.09^{a}	7.27 ± 0.04^{a}	0.13 ± 0.08^{a}	0.17 ± 0.05^{a}	5.67 ± 1.05^{a}
	July	14.33 ± 0.21^{a}	3.23 ± 0.11^{b}	7.00 ± 0.00^{b}	0.43 ± 0.05^{b}	0.25 ± 0.09^{b}	5.20 ± 0.00^{a}
	August	15.00 ± 0.00^{a}	3.00 ± 0.00^{a}	6.90 ± 0.00^{a}	0.50 ± 0.03^{b}	0.22 ± 0.01^{b}	5.00 ± 0.00^{a}
	September	15.00 ± 0.00^{a}	3.00 ± 0.00^{a}	6.90 ± 0.03^{a}	0.50 ± 0.00^{b}	0.22 ± 0.03^{b}	5.00 ± 0.00^{a}
	October	18.00 ± 0.51^{b}	2.10 ± 0.04^{b}	7.00 ± 0.03^{b}	0.13 ± 0.02^{b}	0.20 ± 0.01^{b}	5.02 ± 0.00^{a}
	Mean Total	17.94 ± 0.48	2.67 ± 0.21	7.22 ± 0.21	0.23 ± 0.02	0.13 ± 0.02	3.03 ± 0.03

± is the Standard Error of Mean (SEM); ND – Not Detected; values with different superscripts across each column are significantly different ($P<0.05$)

3.2. Assessment of fish abundance and distribution

A total of 1443 individuals belonging to 27 species were identified with the highest abundance and distribution in the lower section (36.04%) which was close to the dam wall (Table 3). This was expected because the dam wall had created an obstruction which allowed aggregates of food materials and the abundance of fish species was eminent. The cage culture system was located in the middle section of the Lake and it recorded fish abundance (32.08%) which was close to the abundance encountered in the lower station. This was expected because fish species will aggregate around the cages to consume uneaten feed which finds its way out of the cages.

Despite the huge ammonia load (1.96 ± 0.05 mg/L), fish were abundant and must have devised means of survival in the middle section. Ipinmoroti *et al*. (2018) studied the abundance of fish species in the lake and reported an abundance of 1780 belonging to 19 species, which was higher than the abundance during this study but fewer species. Similarly, 27 species were reported by Ipinmoroti (2013) in the Lake. In the dry season (November 2017 – March 2018), a total of 720 individuals were encountered with March recording the most abundant fish species (47.64%). In the wet season (April – October 2022), a total of 723 individuals were encountered, with April recording the most fish species abundance (32.78%). It was observed that these two periods mark the transition between the dry and wet seasons and the natural instincts of fish species are expectant for a change in condition during this period (Negi and Mangin, 2013).

Table 3: Relative abundance and monthly fish distribution in the stations

Seasons	Months	US	MS	LS	Total	Total (%)	T/Sn	T/Sn(%)
Dry	November	11	14	11	67	4.64		9.31
	December	9	10	9	68	4.71		9.44
	January	66	44	66	145	10.05	720	20.14
	February	40	34	40	97	6.72		13.47
	March	92	144	92	343	23.77		47.64
Wet	April	76	85	76	237	16.42		32.78
	May	24	39	24	79	5.47		10.93
	June	105	47	105	234	16.22		32.37
	July	16	11	16	44	3.05		6.09
	August	4	6	4	36	2.49	723	4.98
	September	8	18	8	35	2.43		4.84
	October	9	11	9	58	4.02		8.02
	Total	460	463	520	1443	100	1443	
	Total (%)	31.87	32.08	36.04	100			

US – Upper section, MS – middle section, LS- lower section, T/Sn – total per season, T/Sn (%) – relative abundance of fish per month season

Across the sampling months, March had the highest relative abundance (23.70%) with *Chrysichthys nigrodigitatus* the most abundant (39.32%) fish species (Table 4). The dominance of *C. nigrodigitatus* have been reported in Owalla and Eko-Ende reservoirs (Taiwo, 2010) and Aiba Reservoir (Iyiola *et al*., 2019) which are located within the Osun river system. In contrast, Ipinmoroti *et al*. (2018) reported the dominance of *Tilapia marie* in the Lake. The fish abundance fluctuated over the months with the abundance higher in the dry season (47.20%). This was expected because breeding activities for most fish species had ceased due to reduced rainfall and limited food availability, therefore fish species will aggregate in open waters (Negi and Mangin, 2013). The total fish abundance recorded from the Lake during the study was low (1443) when compared to the reported results of 1780 individuals comprising 19 species (Ipinmoroti *et al*., 2018), and was lower than the number of species identified in this study.

Table 4: Relative abundance of fish species across the months

S/N	Fish species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	Total (%)
1	*Alestes baremoze*	0	8	57	3	3	10	0	0	0	0	3	0	84	5.81
2	*Alestes dentex*	12	0	0	0	0	0	0	0	0	2	0	0	14	0.97
3	*Brycinus longipinis*	0	3	21	0	0	0	0	0	0	0	0	0	24	1.66
4	*Chrysichthys nigroditatus*	39	43	213	63	18	125	38	0	4	5	10	11	569	39.32
5	*Citharinus citharus*	0	1	0	0	0	0	0	0	0	5	2	9	17	1.17
6	*Clarias gariepinus*	0	1	0	0	0	0	0	0	0	1	0	0	2	0.14
7	*Clarias macromystax*	0	0	0	0	0	0	0	0	1	1	1	0	3	0.21
8	*Coptodon mariae*	0	0	0	2	15	7	0	0	0	11	8	18	61	4.22
9	*Coptodon zilli*	0	0	0	86	0	32	0	0	0	0	12	2	132	9.12
10	*Cromeria occidentalis*	0	0	0	0	0	13	0	0	5	4	0	0	22	1.52
11	*Distichodus rostratus*	11	5	0	2	0	0	0	0	0	2	4	0	24	1.66
12	*Hepsetus odoe*	0	0	0	0	1	0	0	0	0	2	0	7	10	0.69
13	*Hemichromis fasciatus*	0	1	0	0	0	0	0	0	0	0	0	2	3	0.21
14	*Hydrocynus forskahlii*	18	0	5	1	8	7	0	0	0	1	0	0	40	2.76
15	*Hyperopisus bebe*	0	1	0	0	0	0	0	0	0	3	0	2	6	0.41
16	*Lates niloticus*	0	0	0	0	1	1	1	0	0	1	1	0	5	0.35
17	*Mormyrups aguilloides*	0	2	0	0	0	0	0	3	4	9	2	1	21	1.45
18	*Mormyrus rume rume*	14	6	6	0	0	0	0	0	0	0	8	0	34	2.35
19	*Oreochromis aureus*	0	2	3	0	0	0	0	0	1	2	3	1	12	0.83
20	*Oreochromis niloticus*	13	3	5	2	22	8	1	11	0	7	8	0	80	5.53
21	*Parachanna obscura*	7	6	0	0	0	0	0	0	0	0	0	2	15	1.04
22	*Polypterus senegalensis*	0	1	0	0	0	0	0	0	0	0	0	1	2	0.14
23	*Synodontis batensoda*	0	0	0	1	0	1	0	11	0	8	2	1	24	1.66
24	*Sarotherondon galilaeus*	0	2	0	1	0	10	0	4	0	0	0	0	17	1.17
25	*Synodontis marophthalamus*	0	0	0	1	0	0	0	0	0	2	0	8	11	0.76
26	*Schilbe mystus*	23	4	23	63	4	11	1	7	2	2	7	4	151	10.44
27	*Synodontis budgetti*	0	5	9	11	7	9	3	0	8	0	5	3	60	4.15
	Total	137	94	342	236	79	234	44	36	25	68	76	72	1443	
	Total (%)	9.49	6.51	23.70	16.35	5.47	16.22	3.05	2.49	1.73	4.71	5.54	4.71		

3.3. Weather distribution

3.3.1. *Weather condition parameters*

The mean rainfall and atmospheric temperature measured during the study are presented in Table 5. The wet season is often characterized by high rains and reduced temperature while the dry season is characterized by low rains and elevated temperature regimes (NiMET, 2019). For both parameters, a fluctuating trend was observed with mean values scattered along the line of trend fit. Total rainfall of 2940 mm was recorded throughout the study, with the highest in September (540 mm) and the least in January (70 mm). The highest and least mean rainfall values recorded from this study were as expected and corroborated by reports of NiMET (2019).

With relation to fish abundance, September which had the least fish abundance (2.0%) recorded the highest value for mean rainfall (540 mm) and atmospheric temperature (35.50 °C) during the study. The possible reason for this may be the response of fish species to increased rainfall and breeding activities in which they migrate to shallow regions for breeding activities (Negi and Mangin, 2013).

Conversely, December which is the peak of the dry season recorded the least rainfall (45 mm) and was expected to record the highest abundance of fish species (Table 5). However, December recorded a relative small abundance of 4.71% and the highest abundance was recorded in March (23.77 %), which denotes the end of the dry season. This occurrence may be due to the expectance of the rains by fish species in April which is the onset of wet seasons breeding activities may commence. Negi and Mangin (2013) reported similar occurrences in Tons River, India. The results on mean temperature from this study deviated from the statements of NiMET (2019) because the wet season which is supposed to be characterized by low temperatures had the highest monthly temperatures (Table 5) and the dry season had the least monthly temperatures instead of measuring the highest monthly temperature ranges. This clearly expresses a change in weather pattern from the normal deviation in characteristics of wet and dry seasons (Omitoyin, 2009; NiMET, 2019; Sixth Assessment Report, 2021).

Table 5: Mean rainfall and temperature and total fish abundance

Month	Mean Rainfall (mm)	Atmospheric Temperature (°C)	Total fish abundance
November	87	34.10	67
December	45	32.11	68
January	70	20.20	145
February	110	24.50	97
March	150	25.50	343
April	170	29.00	237
May	510	29.00	79
June	430	28.00	234
July	360	32.00	44
August	500	33.00	36
September	540	35.50	35
October	218	33.20	58
Total	3190	29.68	1443

3.3.2. *Linear trend analysis*

The linear trend analysis of rainfall and atmospheric temperature over time is presented in Table 6. Statistically, a positive trend that fluctuated across the months was observed over time. This indicated that the mean rainfall (t = 1.77) and average atmospheric temperature (t = 1.65) presented an increasing trend over the months. It explains that for a unit increase in time (months), mean rainfall has increased by 1.77 units and the average atmospheric temperature has increased by 1.645 units. Therefore, it may be said that the weather parameters measured during the study has increased over the months of the study.

3.4. Association between weather conditions and fish abundance

The association between fish abundance and weather factors is presented in Table 7. Statistically, the relationship was observed between fish abundance and weather parameters was not significant (P>0.05), but negative. The negative value implies that as one increases, the other decreases; as rainfall (b_1 = -0.27) and temperature

(b_1= -1.08) increased by one unit, fish abundance reduced by 0.27 units and 1.08 units respectively. It may therefore be said that the observed increase in temperature (Table 6) has declined the fish abundance over the time of study thereby posing negatively on the sustainability of fish species in the reservoir. With these effects, the supply of fish to the rural and urban populace is affected and measures to promote sustainability through management procedures are essential.

Table 6: Linear trend analysis for rainfall and temperature over time

Parameters	b_o	b_1	Relationship	Model $Y_t = b_o + b_1 * t$
Rainfall (mm)	32.50	1.77	Positive	Yt = 3.25 + 1.77*t
Temperature (ºC)	20.30	1.65	Positive	Yt = 20.30 + 1.65*t

Yt = Rainfall/Temperature, b_o= constant, b_1 = trend coefficient, t = time

Table 7: Regression coefficients between weather factors and fish abundance

Parameters	b_o	b_1	P-value	Relationship	Model $Y_t = b_o + b_1X$
Rainfall (mm)	224.3	-0.27	0.24^a	Negative	Y = 224.3 – 0.27 X
Temperature (°C)	480.4	-1.08	0.16^a	Negative	Y = 480.4 – 1.08X

Y = Fish abundance; b_o= constant, b_1 = regression coefficient, X = Mean rainfall/ average atmospheric temperature; P-value with different superscript are significant at P<0.05.

4. Conclusions

It was observed that the Lake was affected by the prevailing water conditions indicated by the low dissolved oxygen and high ammonia and nitrite concentrations. This affected the fish species distribution and abundance in the Lake. Temperature values were observed to have increased across the months while mean rainfall values were variable. These patterns were observed to have a negative effect on the fish species by reducing their abundance, and if it persists their sustainability in the lake is questionable. To address this issue, measures must be in place to ensure a healthy environment in terms of waste discharge into the Lake and gases to the atmosphere from industries within the catchment. These approaches will contribute to the sustenance of aquatic resources and reduction in greenhouse gases.These measures can also ensure the constant supply of fish species which is a major protein source for the human populace.

Conflict of Interest

The authors declare no conflict of interest exists.

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