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Owalla Reservoir in South-western Nigeria: Assessment of Fish Distribution, Biological Diversity, and Water Quality Index

A. O. Iyiola[1*], S. C. Izah[2], S. Morya[3], A. M. Akinsorotan[4], and M. C. Ogwu[5]

[1]Department of Fisheries and Aquatic Resources Management; Faculty of Renewable Natural Resources Management; College of Agriculture and Renewable Resources, Osun State University, Nigeria
[2]Department of Microbiology, Bayelsa Medical University, Yenagoa, Bayelsa State, Nigeria
[3]Department of Food Technology & Nutrition, School of Agriculture, Lovely Professional University, India
[4]Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University Oye-Ekiti, Nigeria
[5]Goodnight Family Department of Sustainable Development, Living Learning Center, Appalachian State University, USA

Abstract. The Water Quality Index (WQI) was used to evaluate the ecological health and status of Owalla Reservoir and the implications on fish species distribution and biological diversity of the reservoir. Water quality and fish species were collected from three sampling zones (A, B, and C) from September 2019 to August 2020 and biological diversity indices such as dominance, Shannon-Weiner, Evenness, Brillouin, Menhinick, Margalef, Equitability, and Fishers index were calculated. The mean values measured for the temperature (25.9 ± 0.48 °C), dissolved oxygen (4.14 ± 0.10 mg/L), pH (7.0 ± 0.01), and nitrate (0.68 ± 0.25 mg/L) of Owalla Reservoir were within the recommended range; while ammonia (0.13 ± 0.20 mg/L), nitrite (0.14 ± 0.21 mg/L) were high and above the recommended limits. The WQI was highest in zone A (155.97) with an overall index value of 152.73 for the reservoir. Zone A recorded the highest relative fish abundance (49.95%) and was more diversified than other sampling zones. In terms of fish biodiversity indices, zone A had the highest richness (9), number of individuals (136), Shannon (1.84), and Brillouin (1.62) index values. Zones B and C were highest in terms of Dominance (1.0), and Evenness (1.0). Zones A and C were highest in terms of Simpson (0.83); zone B was highest in terms of Menhinick (1.58), and Fisher_alpha index (3.98) while zone C was highest in terms of Margalef (2.0), and Equitability (0.99) indices. The elevated levels of WQI, ammonia, and nitrite pose a danger to fish species and watershed systems. It is important to maintain the quality of water within Owalla Reservoir by ensuring best human practices and averting inappropriate human wastes as well as sewage disposal and agricultural activities. These should be checked for the sustainability of fish species.

Keywords: fish distribution, human activities, sustainability, water quality

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*Corresponding author at: Department of Fisheries and Aquatic Resources Management; Faculty of Renewable Natural Resources Management; College of Agriculture and Renewable Resources, Osun State University, P.M.B. 4494, Osogbo, Nigeria

E-mail address: adams.iyiola@uniosun.edu.ng

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1. Introduction

Fish is a renewable resource that can be harnessed for various purposes such as recreation, food, fish oil, and the production of fish meal. Their population can be affected by human activities, environmental pressures, fishing activities, climatic fluctuations, and pollution which may be from zone or non-zone sources [1]. Water is the medium in which fishes live and their sustenance is based on the appropriate quantity and quality which is crucial for their survival [2] – [3]. Fishes are very sensitive to changes in the aquatic medium and the quality of such waters dictates the physiological responses of the fishes [4]. It is imperative to properly manage our waterways because fish can serve as a biological indicator in determining the quality of the aquatic habitat in which it dwells [5]. The study of the inter-relationship between water quality and the fish environment is very important as the condition of the water determines the fish abundance and diversity [6] – [12]. Species have been reported to increase when the environmental variables are conducive and reduce when conditions are not favorable; as the condition for one species may not favor another [13]. Therefore, the quality of water must be checked so the aquatic biota can be healthy and sustained [14] – [15].

The Water Quality Index (WQI) is a method that can be used in water quality assessment. It is a simple index that has been used by individuals and private authorities to present the classification of water quality [16]. The WQI is dictated by the choice of water quality parameters to be assessed, the calculation of sub-indices, and the determination of the weight and summation to get the index value of water [16]. The variations in water quality based on time and seasons can be assessed and characteristics such as excellent, good, poor, very poor, etc. are the indices used for the classification of water quality [17]. It may also be used as a measure in dictating the condition of fish species in a particular water body. The under-studied Owalla reservoir is encompassed with diverse activities that generate solid and liquid wastes. Most of these wastes find their way into the water body thereby posing a great danger to the quality for both human use and the sustenance of fish species [17]. The use of WQI in assessing the quality status of water is limited in the Southwestern Inland waters. It has been widely used for water quality assessment in various Niger Delta Rivers and underground water sources such as Bomadi Creek [18], Bayelsa Creek [18], Otamiri and Oramiriukwa Rivers [19], Orashi River [20], Isiodu River [21], Brass River [19], River Ase [22], and Nworie River [23]. It has also been used to assess the quality of water in waterways and reservoirs within developing countries [24] – [31]. The current research aims to assess the quality and health status of the Owalla reservoir using the WQI approach as well as the implication of the index on the diversity and distribution of fish species. The information derived will be useful in decision-making, planning, and implementation of key sustainability measures and movement towards the attainment of the United Nations Sustainable Development Goals Agenda 2030 [32].

2. Materials and Methods

2.1. Study Area

The Owalla reservoir is in Okinni town in Irepodun Local Government Area of Osun State; between Latitude 7°44′30.44″ and 7°57′00.79″ N, Longitude 4°26′21.71″and 4°41′23.48″ East of the Greenwich Meridian (Figure 1) and forms a part of the Osogbo-Ede water supply extension scheme. It has a surface area of 12 km^2 with elevations ranging from 250m to over 400 m above sea level. The reservoir is located on Erinle River which is a tributary of the Osun River and was dammed close to the old Ede dam with the catchment area extending to the Otin River tributary with a maximum width of 3.5m. The reservoir supplies portable water to Osogbo, Ede, Ife, Gbongan, Erin-Osun, Ilobu, and Ifon as well as other towns and rural communities in Osun Central, Osun West, and Ife area in Osun state. It is one of the largest and oldest man-made lakes in Osun State and supplies potable water to many towns in the state

Activities around the reservoir are mostly human activities such as laundry, refuse and sewage discharge, horticulture activities, and mechanic activities. Most of the wastes from these activities are discharged into the river at some zones. A section of the reservoir was also covered by aquatic weeds and terrestrial vegetation forming shade. The entire reservoir was sectioned into three zones (A, B, and C) with fortnight water and fish samples collected from fishermen's landings from each identified sampling zone from September 2019 to August 2020. Samples were not collected in April 2020 due to the total lockdown imposed by the Federal Government of Nigeria.

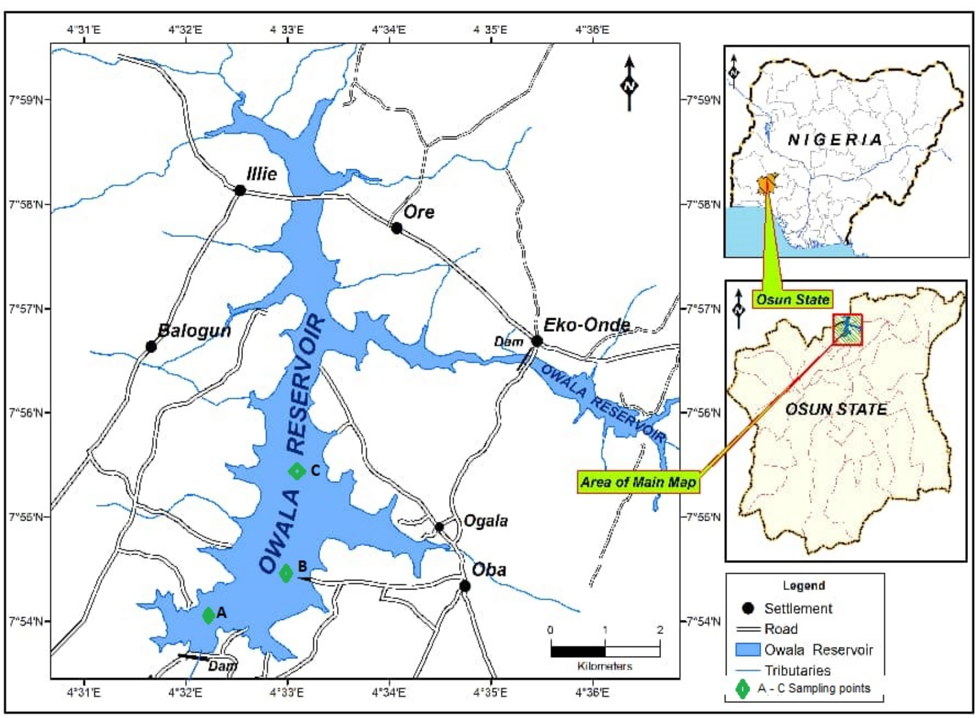

Figure 1. Map of Owalla Reservoir
Source: Iyiola et al. [33]

2.2. Water Quality Parameters

Water samples were taken fortnightly from the sampling zones in the reservoir from September 2019 to August 2020 in sterile 50ml containers between the hours of 7.00 am and 8.00 am. Temperature, Dissolved Oxygen (DO), pH ammonia, nitrite, and nitrates were the water quality parameters analyzed and were measured *in-situ.*

2.2.1. Dissolved oxygen (DO) and temperature

DO was measured from the water sample as described by the manufacturer using a DO meter (DO-5509) manufactured by Lutron, UK. The readings were recorded from the digital meter when it was steady and recorded in mg/L. Temperature was measured from the screen of the digital meter when it was dipped to the level of the sensor. It was recorded in degrees Celsius (^oC).

2.2.2. Ammonia, pH, nitrite, and nitrates

They were measured as described by the manufacturer using API Freshwater Master Test Kits manufactured by MARS Fish Care, USA, and recorded in mg/L.

2.3. Water Quality Index (WQI)

The WQI of the sampling zones in the reservoir was calculated as described by Aigberua and Tarawou [16]. The first step is to assign the unit weights of each parameter in the water sample and assign Equation (1):

$$Wi = {}^{K}/_{Si} \tag{1}$$

where Si = the standard permissible value of i^{th} water quality parameter; K = constant of proportionality which is 1.645.

WQI was calculated using the expression in Equation (2):

$$WQI = {}^{\sum Qi * Wi}/_{\sum Wi} \tag{2}$$

where Qi = the quality rating of i^{th} water quality parameter; Wi = the unit weight of the water quality parameter.

The Quality Rating (QI) was calculated using Equation (3):

$$Qi = [(Vi - Vid)/Si - Vid)] \text{ x } 100 \tag{3}$$

where Vi = estimated value of i^{th} water quality parameter in the reservoir; Vid = the ideal value for the i^{th} parameter in pure water (Vid of pH = 7, DO = 14.6 and 0 for other parameters); Si = Standard value of i^{th} water quality parameter.

The WQI and its respective status of water quality are presented in Table 1.

Table 1. The WQI and its Respective Water Quality Status

WQI Level	Water Quality Status
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very Poor
> 100	Unsuitable

Source: Aigberua and Tarawou [16]

2.4. Fish Distribution and Biological Diversity Indices

Fish species were collected fortnightly from the fishermen's landings and experimental monofilament gill nets with mesh sizes 25mm, 40mm, and 45mm from the sampling zones during the period of study. The fish abundance from each zone was recorded and measurements of dominance, Shannon Weiner, Evenness, Brillouin, Menhinick, Margalef, Equitability, and Fisher's index of fish species were calculated as described by Shannon and Weiner [34].

2.5. Statistical Analysis

The monthly means of the water quality parameters measured were separated using Tukeys' mean comparison. Data on sampled fish species were presented using simple percentages. All statistical analysis was done using Minitab 20.0 statistical package at a 95% confidence level ($P<0.05$).

3. Results and Discussion

3.1. Water Quality

The investigation of water quality is important because it determines the abundance and distribution of fish species in relation to the various physic-chemical and biological factors that dictate the quality of water [35]. As the tolerance level to these water quality parameters differs with species, a slight increase or decrease beyond these levels can have adverse effects on aquatic life and their body functions [24], [26], [28]. Therefore, good quality water is essential for sustained growth and performance instead of meeting the ever-increasing fish demand based on population growth [13]. The mean water parameters measured across the sampling zones are presented in Table 2. The highest mean temperature was measured in zone C (26.40 ± 0.00 ºC) with an overall mean value of 25.90 ± 0.48 ºC. The mean values measured were within the between 25-32 ºC are recommended as stated by the Food and Agricultural Organization [FAO] [35], and the United States Environmental Protection Agency [USEPA] [36]. These results were corroborated by the findings of Sunday and Jenyo-Oni [37], who reported mean values of 25.1 ºC from Eleyele Reservoir.

Dissolved oxygen is vital in respiratory activities as it affects the growth, survival, biology, and physiology of aquatic organisms [37]. Levels below 4mg/L are not tolerable for fish survival [38]. The highest was measured in zone C (4.19 ± 0.03 mg/L), and an overall mean of 4.14 ± 0.10 mg/L was measured from the reservoir. These values indicated that the dissolved oxygen concentration in the reservoir is tolerable for fish survival. Similar values were reported in Eleyele Reservoir [39] and Osun River [40]. These mean pH values recorded across the zones (7.00±0.00) and overall mean (7.00 ± 0.00) were within the range of 6.5 – 9 as stated by USEPA [35]. The value recorded indicated that the water has a neutral buffer capacity and is ideal for fish survival and increased biological productivity in the reservoir [41]. The highest mean value of Ammonia was measured in zone A (0.14 ± 0.12 mg/L), and an overall mean of 0.13 ± 0.20 mg/L. These values were higher than the recommended level of 0.10 mg/L as reported by Andem [42]. Similarly, the mean concentration measured across the sampling zones recorded similar increased values which were higher than the recommended values. These indicated that the organic activities and other forms of waste decomposition around the reservoir must be put to check [33].

Nitrite and Nitrates are products of ammonia breakdown. Ornamental Aquatic Trade Association [OATA] [43] recommended that nitrite and nitrate levels must not exceed 0.2 and 0.1 – 4.0 mg/L respectively in freshwater systems. The overall mean values of nitrite (0.41 ± 0.21 mg/L) and nitrates (0.68 ± 0.25 mg/L) were measured during the study above and within the recommended levels of 0.2 and 0.1 – 4.0, respectively. The elevated levels of nitrite were expected because of the elevated concentration of ammonia, nitrite results from the breakdown of ammonia by ammonia-oxidizing bacteria (Nitrosomonas), and it is toxic to fish. These increased levels especially for nitrites, have been reported to cause adverse damage to fish hatchlings and growth rate in aquatic systems [5], [44].

Table 2. Mean Water Quality Parameters Measured Across the Sampling Zones

Parameters/ Zones	**A**	**B**	**C**	**Mean**	**Range**
Temperature (^{o}C)	25.30 ± 0.01	26.10 ± 0.31	26.40 ± 0.00	25.90 ± 0.48	25 - 32^{a}
Dissolved Oxygen (mg/L)	4.10 ± 0.00	4.12 ± 0.11	4.19 ± 0.03	4.14 ± 0.10	4^{b}
pH	7.00 ± 0.00	7.00 ± 0.00	7.00 ± 0.00	7.00 ± 0.01	6.5 – 9^{a}
Ammonia (mg/L)	0.14 ± 0.12	0.13 ± 0.11	0.13 ± 0.12	0.13 ± 0.20	0.10^{c}
Nitrite (mg/L)	0.39 ± 0.11	0.42 ± 0.03	0.41 ± 0.01	0.41 ± 0.21	0.2^{d}
Nitrates (mg/L)	0.61 ± 0.02	0.73 ± 0.21	0.69 ± 0.02	0.68 ± 0.25	40^{e}

USEPA [36] ^{a}; USEPA [38] ^{b}; Andem et al. [42] ^{c}; OATA [43] ^{d}; Bhatnagar and Devi [41]^{e}

3.2. Water Quality Index (WQI)

3.2.1. WQI in zone A

The WQI values calculated during the study from this zone are presented in Table 3. The observed values for temperature (25.30 ºC), pH (7.00), and nitrate (0.61 mg/L) in this zone were observed to be below the recommended standard value of 32.00ºC, 6.5 - 9.00, and 40.0 mg/L for temperature, pH, and nitrate as stated by USEPA [36], USEPA [38], and Bhatnagar and Devi [41] respectively. The values for dissolved oxygen (4.10 mg/L), ammonia (0.14 mg/L), and nitrite (0.39 mg/L) were above the recommended values of 4.00 mg/L, 0.13 mg/L, and 0.41 mg/L as stated by USEPA [38], Andem et al., [42], and OATA [43] respectively. The observed values for water quality parameters in this zone were the highest which indicated an increase in biological activity. This zone is located downstream and is mostly characterized by receiving an influx of diverse materials from upstream, which is due to the obstruction created by the dam wall in this zone [45] – [46]. This statement was corroborated by findings by Chen et al., [47] in an urban river in East Africa. The overall calculated WQI from this zone was 155.97 which implied that the quality of water is unsuitable because it exceeds the value of > 100 as recommended by Aigberua and Tarawou [16].

Table 3. Calculated WQI in Sampling Zone A

Parameters	Observed Values (Vi)	Standard Value (Si)	Recommended value for (Si)	Ideal Value (Vid)	K - Value	Unit Weight (Wi= k/Si)	Quality Rating (Qi)	Qi * Wi
Temperature (ºC)	25.30	32.0	USEPA [36]	0.00	1.65	0.05	79.06	4.03
DO (mg/L)	4.10	4.0	USEPA [38]	14.60	1.65	0.41	99.06	40.71
pH	7.00	9.0	USEPA [38]	7.00	1.65	0.18	0.00	0.00
Ammonia (mg/L)	0.14	0.10	Andem et al. [42]	0.00	1.65	16.45	140.00	2303.00
Nitrite (mg/L)	0.39	0.2	OATA [43]	0.00	1.65	8.23	195.00	1603.88
Nitrate (mg/L)	0.61	40	Bhatnagar and Devi [41]	0.000	1.65	0.02	0.61	0.01
						∑ Wi = 25.35		**∑Qi*Wi =** 3951.63
WQI = ∑Qi*Wi/ ∑ Wi = 155.97								

3.2.2. WQI in zone B

The WQI values calculated during the study are presented in Table 4. The observed values for temperature (26.10 ºC), pH (7.00), and nitrate (0.73 mg/L) in this zone were observed to be below the recommended standard value of 32.00 ºC, 6.5 - 9.00, and 40.0 mg/L for temperature, pH, and nitrate as stated by USEPA [36], USEPA [38], and Bhatnagar and Devi [41] respectively. The values for dissolved oxygen (4.12 mg/L), ammonia (0.13 mg/L), and nitrite (0.73 mg/L) were above the recommended value of 4.00 mg/L, 0.13 mg/L, and 0.41 mg/L as stated by USEPA [38], Andem et al., [42], and OATA [43] respectively. The observed values for water quality parameters were like values measured in zone A; as they both have similar characteristics in terms of human activities and exposure to pollutants. The overall calculated WQI from this zone was 154.35, and it implied that the quality of water is unsuitable because it exceeds the value of > 100 as recommended by Aigberua and Tarawou [16]. However, this value (154.35) was slightly lower than the mean value in zone A (155.97) because water into zone B flows into zone A and this may be a possible reason for the increased value in zone A [23].

Table 4. Calculated WQI in Sampling Zone B

Parameters	Observed Values (Vi)	Standard Value (Si)	Recommended value for (Si)	Ideal Value (Vid)	K - Value	Unit Weight (Wi= k/Si)	Quality Rating (Qi)	Qi * Wi
Temperature (°C)	26.10	32.0	USEPA [36]	0.0	1.65	0.05	81.56	4.16
DO (mg/L)	4.12	4.0	USEPA [38]	14.6	1.65	0.41	98.87	40.63
pH	7.00	9.0	USEPA [38]	7.0	1.65	0.18	0.00	0.00
Ammonia (mg/L)	0.13	0.10	Andem et al. [42]	0.0	1.65	16.45	130.00	2138.50
Nitrite (mg/L)	0.42	0.2	OATA [43]	0.0	1.65	8.23	210.00	1727.25
Nitrate (mg/L)	0.73	40	Bhatnagar and Devi [41]	0.0	1.65	0.02	0.73	0.01
						∑ Wi = 25.34		**∑Qi*Wi = 3910.56**
WQI = ∑Qi*Wi/ ∑ Wi = 154.35								

3.2.3. WQI in zone C

The WQI values calculated during the study are presented in Table 5. The observed values for temperature (26.40 ºC), pH (7.00), and nitrate (0.69 mg/L) in this zone were observed to be below the recommended standard value of 32.00 ºC, 6.50 - 9.00 and 40.0 for temperature, pH, and nitrate as stated by USEPA [36], USEPA [38], and Bhatnagar and Devi [41] respectively. The values for dissolved oxygen (4.19mg/L), ammonia (0.13 mg/L), and nitrite (0.41 mg/L) were above the recommended value of 4.00 mg/L, 0.13 mg/L, and 0.41 mg/L as stated by USEPA [38], Andem et al., [42] and OATA [43] respectively. The overall calculated WQI value from this zone was 152.72, and it implied that the quality of water is unsuitable because it exceeds the value of > 100 as recommended by Aigberua and Tarawou [16] The overall mean value was lower than values in zones A (155.97) and B (154.35) despite being exposed to similar anthropogenic activities. A possible reason is the flow of water from zone C which is upstream to zone A which is downstream, which washes all pollutants by gravity downstream [40].

Table 5. Calculated WQI in Sampling Zone C

Parameters	Observed Values (Vi)	Standard Value (Si)	Recommended value for (Si)	Ideal Value (Vid)	K - Value	Unit Weight (Wi= k/Si)	Quality Rating (Qi)	Qi * Wi
Temperature (°C)	26.40	32.00	USEPA [36]	0.0	1.65	0.05	82.50	4.21
DO (mg/L)	4.19	4.00	USEPA [38]	14.6	1.65	0.41	98.20	40.36
pH	7.00	9.00	USEPA [38]	7.0	1.65	0.18	0.00	0.00
Ammonia (mg/L)	0.13	0.10	Andem et al.[42]	0.0	1.65	16.45	130.00	2138.50
Nitrite (mg/L)	0.41	0.20	OATA [43]	0.0	1.65	8.23	205.00	1686.13
Nitrate (mg/L)	0.69	40.00	Bhatnagar and Devi [41]	0.0	1.65	0.02	0.7	0.01
						∑ Wi= 25.34		**∑Qi*Wi= 3869.21**
WQI = ∑Qi*Wi/ ∑ Wi = 152.72								

3.2.4. WQI in overall zones

Across zones A-C, the WQI was 155.97, 154.35, and 152.72 respectively with the highest WQI value in zone A (Table 6). As observed across the zones, the overall observed values across the zones for temperature (25.90 ºC), pH (7.00), and nitrate (0.68 mg/L) were observed to be below the recommended standard values of 32.00, 9.00, and 40.0 for temperature, pH, and nitrate as stated by USEPA [36], USEPA [38], and Bhatnagar and Devi [41] respectively. The values for dissolved oxygen (4.10 mg/L), ammonia (0.13 mg/L), and nitrite (0.41 mg/L) were above the recommended value of 4.00 mg/L, 0.13 mg/L, and 0.41mg/L as stated by USEPA [38], Andem et al., [42], and OATA [43] respectively. The overall WQI index of the reservoir was calculated to be 152.73 (Table 7), and it implied that the water in the reservoir is unsuitable for human use because the WQI is > 100 as stated by Aigberua and Tarawou [16]. Similarly, the use of water at its state can pose serious health challenges to humans when used for domestic purposes unless water treatment measures are employed for safe human use [49]. Similar increased WQI values were calculated in Otamiri and Oramiriukwu rivers in Rivers state with 174.79 [19], Orashi River, Brass River in Bayelsa state [20], Isiodu River in Niger Delta [21], Taylor Creek [17] measuring a value of 148.94, and these were attributed to human, domestic and industrial activities around these water bodies.

Similarly, cases of water pollution resulting from human and industrial activities have been reported [48] – [51]. Apart from mortality, it has been reported to cause several aquatic degradations, the gradual disappearance of fish species diversity, and altering the natural carrying capacity of the water body [52]. A major pollutant observed around the reservoir was agricultural activities which have the potential to divulge into the reservoir when there is run-off [13]. There isa dire need to check on this activity as it directly impacts the sustenance of the fish species and use of water as observed and reported by Abdel-Satar et al., [53] in the Nile River and Belal et al., [54] in Timsah Lake and the Suez Canal, Egypt where water pollution was attributed to run-off from agricultural fields.

Table 6. Summary of WQI Values across the Zones

Zone	WQI value	Status
Zone A	155.97	Unsuitable (> 100)
Zone B	154.35	Unsuitable (> 100)
Zone C	152.72	Unsuitable (> 100)
Overall	152.73	Unsuitable (> 100)

Table 7. Calculated WQI for the Entire Reservoir during the Study

Parameters	Observed Values (Vi)	Standard Value (Si)	Recommended value for (Si)	Ideal Value (Vid)	K - Value	Unit Weight (Wi= k/Si)	Quality Rating (Qi)	Qi * Wi
Temperature (°C)	25.90	32.00	USEPA [36]	0.00	1.65	0.05	80.94	4.13
DO (mg/L)	4.10	4.00	USEPA [38]	14.60	1.65	0.41	99.06	40.71
pH	7.00	9.00	USEPA [38]	7.00	1.65	0.18	0.00	0.00
Ammonia (mg/L)	0.13	0.10	Andem et al. [42]	0.00	1.65	16.45	130.00	2138.50
Nitrite (mg/L)	0.41	0.20	OATA [43]	0.00	1.65	8.23	205.00	1686.13
Nitrate (mg/L)	0.68	40.00	Bhatnagar and Devi [41]	0.00	1.65	0.02	0.68	0.01
						∑ Wi = 25.34		**∑Qi*Wi = 3869.45**
			WQI = ∑Qi*Wi/ ∑ Wi = 152.73					

3.3. Fish Distribution

The distribution of fish species across the three sampling zones is presented in Table 8. A total of 1035 individuals were identified with zone A having the highest relative fish distribution (49.95%); followed by zone B with 29.08% and the lowest distribution was in zone C (20.97%). The highest distribution in zone A was expected due to the obstruction created by the dam wall in this area causing an aggregate of fish species. These results were corroborated by findings of Iyiola and Iyantan [55] in the Erinle reservoir, Ipinmoroti et al. [51] in the Asejire reservoir; Komolafe et al. [11] on the Osinmo reservoir, reported cases of the highest abundance in zones close to the dam wall. This also can be attributed to the high WQI (155.97) in zone A (Table 3) which results from increased waste discharge and metabolic processes due to fish aggregation. Across the months, the highest relative abundance encountered in December (29.47%) was expected. This was due to the prevailing environmental conditions which occur in the dry season which is characterized by reduced rainfall [56]. This resulted in the aggregate of fish species in the open water in search of food [57]. Ipinmoroti et al. [58] and Iyiola et al. [59] in Asejire and Owalla reservoirs respectively reported similar occurrences of increased fish abundance in the peak dry season periods. In zone A, all the species collected across the months were higher than in other zones, with the highest mean abundance in December for zones A (28.23%), B (26.91%), and C (35.94%). Generally, the distribution of fish species is determined by the prevailing water quality which predetermines the well-being, decline, and extinction of some economically important fish species [60]. As observed from the water quality index of the reservoir, it indicates high pollution and is not tolerable for fish species. These statements were corroborated by the findings of Aly and Abouelfadl [61] who reported the effects of pollution on *Coptodon zillii* in River Nile, Egypt.

Table 8. Fish Distribution Across the Sampling Zones

Months	A	A (%)	B	B (%)	C	C(%)	Total	Total (%)
September	21	4.06	15	4.98	10	4.61	46	4.44
October	11	2.13	10	3.32	7	3.23	28	2.71
November	46	8.90	17	5.65	26	11.98	89	8.60
December	146	28.24	81	26.91	78	35.94	305	29.47
January	101	19.54	72	23.92	13	5.99	186	17.97
February	31	6.00	17	5.65	11	5.07	59	5.70
March	21	4.06	11	3.65	9	4.15	41	3.96
May	36	6.96	10	3.32	14	6.45	60	5.80
June	22	4.26	18	5.98	18	8.29	58	5.60
July	36	6.96	22	7.31	11	5.07	69	6.67
August	46	8.90	28	9.30	20	9.22	94	9.08
Total	517	100	301	100	217	100	1035	100
Total (%)	49.95		29.08		20.97		100	

A very low and positive relationship was observed between fish abundance and temperature which indicated a direct relationship with a magnitude of 0.104 between them; while it was negative with nitrite which indicated an inverse relationship with a magnitude of 0.106 between them. Similarly, a very low and negative relationship was observed between pH and ammonia, and a positive relationship with nitrate. These values implied indirect and direct relationships with a magnitude of 0.174 and 0.045 respectively between these parameters. A very low and positive relationship was observed between nitrite and nitrate. The relationship between these parameters was tagged "very low" because the r-values were between 0.01 and 0.2. A low relationship was observed between fish abundance and dissolved oxygen, ammonia, and nitrate which implied a direct relationship with magnitude of 0.390, 0.348, and 0.230 respectively; and a negative low relationship with pH which implied an inverse relationship with magnitude 0.260. Similarly, dissolved oxygen had a positive and low relationship with ammonia and nitrate and a negative and low relationship with pH. These values implied that there was a direct relationship with a magnitude of 0.368 and 0.266 and an indirect relationship with a magnitude of 0.345, respectively. These relationships were tagged "low" because the r-values were within 0.21 – 0.4. A moderate and positive relationship was observed between temperature and dissolved oxygen, ammonia, and nitrite which implied a direct relationship with a magnitude of 0.416, 0.431, and 0.533 respectively. The relationship was tagged "moderate" because the r-values were within 0.41 – 0.60. A high negative relationship was observed between temperature and pH, and it was significant ($p<0.05$), this implied that there was an inverse and significant relationship between both parameters. The relationship was tagged "high" because the r-value was within 0.61 – 0.80 (Table 9).

Table 9. Pearson Correlation Between Fish Abundance and Water Quality Parameters Measured During the Study

Parameters	Fish Abundance	Temperature (°C)	Dissolved oxygen (mg/L)	pH	Ammonia (mg/L)	Nitrite (mg/L)
Temperature (°C)	0.104 0.761					
Dissolved Oxygen (mg/L)	0.390 0.236	0.416 0.203				
pH	-0.260 0.440	-0.655 0.029*	-0.345 0.299			
Ammonia (mg/L)	0.348 0.294	0.431 0.185	0.368 0.266	-0.174 0.609		
Nitrite (mg/L)	-0.016 0.963	0.553 0.078	0.297 0.376	-0.372 0.260	-0.030 0.930	
Nitrate (mg/L)	0.230 0.497	-0.252 0.454	-0.272 0.419	0.045 0.987	-0.346 0.298	0.175 0.606

Cell contents: Pearson Correlation
*p-value ($p<0.05$)

3.4. Biological Diversity Indices

3.4.1. Biological diversity in zone A

The abundance and diversity indices of fish species across the months in zone A are presented in Table 10. The number of species and individuals were 2, 5, 6, 9, 6, 5, 5, 7, 5, 5, 7, and 21, 11, 46, 136, 101, 23, 21, 36, 22, 36, and 46 respectively from September to August. Despite the least species richness and number of individuals, September recorded the highest fish species dominance, and fish species were well represented across the month when compared with other months of study. Taiwo [62] reported similar results in Owalla and Eko-Ende reservoirs. Simpson's index was highest in May and least in September which indicated a low and high diversity, respectively. As stated by Shannon and Weiner [40], the higher the fish abundance the lower the diversity and vice versa. The Shannon diversity indices had most of the calculated values across the months higher than 1, which indicated a fairly high diversity of fish species across the months of study. August had the highest Shannon diversity because it had the highest value as stated by Shannon and Weiner [34] that the highest value implies the highest diversity. Fish species evenness was fairly even across the months of study because values were close to 1 [34]. Margalef and Menhinck index was highest in May and October and least in September, respectively. Generally, it was observed that most of the diversity indices were least in September and had values less than 1 except for dominance which was the highest. The Brillouin, Menhinck, Equitability, and Fisher indices had most values greater than 1 and implied a fairly high diversity because the values were slightly above 1 [34].

Table 10. Diversity of Fishes from Zone A in Owalla Reservoir

Diversity indices	Sept	Oct	Nov	Dec	Jan	Feb	Mar	May	June	July	Aug
Tax	2	5	6	9	6	5	5	7	5	5	7
Individuals	21	11	46	136	101	23	21	36	22	36	46
Dominance	0.91	0.26	0.29	0.27	0.24	0.39	0.32	0.17	0.41	0.23	0.17
Simpson	0.09	0.74	0.71	0.73	0.76	0.61	0.68	0.83	0.60	0.77	0.83
Shannon	0.19	1.47	1.34	1.52	1.55	1.19	1.30	1.84	1.12	1.52	1.84
Evenness	0.61	0.89	0.63	0.51	0.78	0.66	0.73	0.90	0.61	0.92	0.90
Brillouin	0.15	1.08	1.19	1.43	1.45	0.98	1.06	1.58	0.91	1.34	1.62
Menhinick	0.44	1.51	0.88	0.77	0.60	1.04	1.09	1.17	1.07	0.83	1.03
Margalef	0.33	1.67	1.31	1.63	1.08	1.28	1.31	1.67	1.29	1.12	1.57
Equitability	0.28	0.91	0.75	0.69	0.86	0.74	0.81	0.94	0.69	0.95	0.94
Fisher_alpha	0.54	3.54	1.84	2.17	1.40	1.97	2.08	2.59	2.02	1.58	2.30

3.4.2. Biological diversity in zone B

In zone B, the diversity indices values are presented in Table 11. The number of individuals and taxa Richness was observed to fluctuate across the months of study (September – August) with 15, 7, 17, 81, 65, 13, 11, 10, 18, 22, 28, and 1, 3, 4, 6, 5, 2, 4, 5, 2, 5, 6 respectively. Fish species were more dominant in September as observed in zone A, despite the single fish species present. This was a result of the highest value in the month which indicates the highest dominance. Across the months, most of the values of the Shannon diversity index were higher than 1 which indicated a high diversity of species across the months [34]. Despite the high diversity in August, the fish species were least dominant, and vice versa for September. Similarly, Simpson's index was lowest in September which indicated a high diversity as observed in zone A, and the highest was in August which indicated a low diversity with most of the monthly values observed to be close to 1 [34]. The fish species were evenly distributed across the months of study with the highest evenness in September and the least in December. Across the values of Menhinick, Margalef, and Fisher indices, May recorded the highest values, indicating a high distribution in these months.

Table 11. Diversity of Fishes from Zone B in Owalla Reservoir

Diversity Indices	Sept	Oct	Nov	Dec	Jan	Feb	Mar	May	June	July	Aug
Taxa	1	3	4	6	5	2	4	5	2	5	6
Individuals	15	7	17	81	65	13	11	10	18	22	28
Dominance	.00	0.43	0.31	0.27	0.25	0.74	0.37	0.24	0.60	0.26	0.22
Simpson	0.00	0.57	0.69	0.73	0.75	0.26	0.63	0.76	0.40	0.74	0.78
Shannon	0.00	0.96	1.23	1.43	1.47	0.43	1.17	1.51	0.59	1.47	1.64
Evenness	1.00	0.87	0.86	0.70	0.87	0.77	0.80	0.90	0.90	0.87	0.86
Brillouin	0.00	0.66	1.00	1.32	1.35	0.33	0.87	1.08	0.50	1.22	1.38
Menhinick	0.26	1.13	0.97	0.67	0.62	0.55	1.21	1.58	0.47	1.07	1.13
Margalef	0.00	1.03	1.06	1.14	0.96	0.39	1.25	1.74	0.35	1.29	1.50
Equitability	0.00	0.87	0.89	0.79	0.91	0.62	0.84	0.94	0.85	0.91	0.92
Fisher_alpha	0.24	1.99	1.65	1.50	1.26	0.66	2.26	3.98	0.58	2.01	2.34

3.4.3. Biological diversity in zone C

In zone C, the diversity indices values are presented in Table 12. The number of individuals and taxa Richness was observed to fluctuate across the months of study (September – August) with 15, 7, 17, 81, 65, 13, 11, 10, 18, 22, 28, and 1, 3, 4, 6, 5, 2, 4, 5, 2, 5, 6 respectively. Fish species were more dominant in September as observed in zones A and B because the highest value was recorded in the month. Most of the values of the Shannon diversity index recorded across the months were higher than 1 which indicated a high diversity of fish species, most especially in August which had the highest value. Despite this occurrence in August, the fish species were least dominant, and vice versa for September [34]. Simpson's index was least in September which indicated a high diversity as similarly observed in zone A, and the highest was in August, which indicated the lowest diversity with most of the monthly values observed to be close to 1 [34]. The fish species were evenly distributed across the months of study with the highest evenness in September because of the high value recorded in the month. The monthly values of the Menhinick, Brillouin, and Margalef indices were highest in August, while the Fisher index was highest in October. All of these indicated a high distribution of fish species across these months.

Table 12. Diversity of Fishes from Zone C in Owalla Reservoir

Diversity Indices	Sept	Oct	Nov	Dec	Jan	Feb	Mar	May	June	July	Aug
Taxa	1	3	4	6	2	1	3	4	2	3	7
Individuals	10	7	26	68	13	11	9	14	8	11	20
Dominance	1.00	0.389	0.31	0.32	0.74	1.00	0.51	0.26	0.53	0.36	0.18
Simpson	0.00	0.61	0.69	0.68	0.26	0.00	0.49	0.74	0.47	0.64	0.83
Shannon	0.00	1.00	1.22	1.25	0.43	0.00	0.85	1.38	0.66	1.07	1.82
Evenness	1.00	0.91	0.85	0.58	0.77	1.00	0.78	0.99	0.97	0.97	0.88
Brillouin	0.00	0.70	1.05	1.14	0.34	0.00	0.61	1.09	0.50	0.83	1.45
Menhinick	0.32	1.13	0.78	0.73	0.55	0.30	1.00	1.07	0.70	0.90	1.57
Margalef	0.00	1.03	0.92	1.19	0.39	0.00	0.91	1.13	0.48	0.83	2.00
Equitability	0.00	0.91	0.88	0.70	0.62	0.00	0.77	0.99	0.95	0.97	0.92
Fisher_alpha	0.28	1.99	1.32	1.59	0.66	0.27	1.58	1.87	0.86	1.36	3.83

4. Conclusion and Recommendation

It was observed that the mean concentration of ammonia and nitrites measured were above the recommended limits for fish survival. Similarly, the WQI calculated across the sampling zones was high and above the safe recommended limit. This indicates that the water is not fit for fish survival and for humans who use the water for several purposes. The causes of this are the resultant effects of the human activities around the water catchment which empties most of its solid and liquid wastes into the water thereby affecting the water chemistry and sustenance of aquatic life. To achieve sustainable fisheries and water quality management of Owalla reservoir, the following is recommended:

1. There is an urgent need for synergy between water agencies and the fisheries department on sustainable management.

2. Fish status and water quality parameters of Owalla reservoir should be updated regularly
3. There should be sensitization of communities around the Owalla Reservoir on the need for best environmental practices for sustainability.

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