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Limnological variables as a determinant of fish parasites abundance in the Esa-Odo reservoir, Esa-Odo Southwestern Nigeria

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ABSTRACT

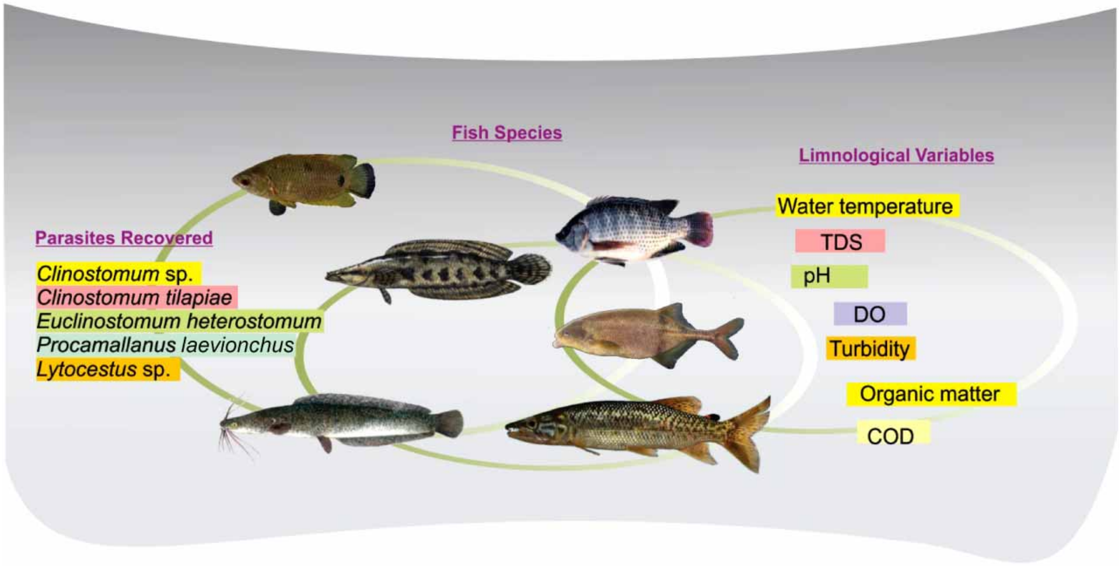
This study investigated fish parasites in relation to limnological variables of the Esa-Odo reservoir since the quality of the aquatic environment might influence parasitic infestation in fish. The purpose of this study was to provide information on the parasite species of the reservoir due to their public health concern and their relationship with selected water quality parameters. The water quality and parasite examinations were analyzed based on standard protocols in the laboratory. The results showed that water quality parameters were not significantly different ($p > 0.05$) across the zones. Seasonally, mean water temperature, pH, TDS, DO, organic matter, COD and turbidity were significantly different ($p < 0.05$) across the different zones of the reservoir while electrical conductivity, alkalinity, NO_3^-, and PO_4^{3-} were not significantly different ($p > 0.05$). *Clinostomum tilapiae*, *Clinostomum* sp., *Euclinostomum heterostomum*, *Procamallanus laevionchus*, and *Lytocestus* sp. were recovered in all the fish sampled. The overall prevalence of the fish parasites was 9.8% with an intensity of 2.13. The result indicated fish parasites had a strong positive correlation with certain water quality properties and parasite abundance which suggested that water quality could determine parasitic loads in fishes of the Esa-Odo reservoir.

Key words: abundance, Fauna, fish parasites, limnology, reservoir

HIGHLIGHTS

- The study provided the first record of an additional fish parasite in the Esa-Odo reservoir fish community.
- It also pinpoints the relationship between fish parasites and selected water quality.
- The selected limnological variables determine the abundance of fish parasites.
- This study will assist in further research of parasite vectors in the reservoir.
- It will encourage proper monitoring of the fisheries resources of the reservoir.

GRAPHICAL ABSTRACT



INTRODUCTION

Fish parasites have been a major concern for freshwater and marine fish all over the world and are of particular significance in the tropical region (Ekanem *et al.* 2011). The examination of fish species for the presence of parasites is a critical aspect of maintaining the sustainability of capture fisheries. This is due to the negative impacts that parasites can have on fish health, including increased susceptibility to diseases, reduced nutrition, and mortality (Onyedineke *et al.* 2010). To effectively support wild fish production, it is necessary to regularly assess fish for the presence of parasites. This practice can help to mitigate the negative impacts of parasites on fish populations and support the overall health and sustainability of capture fisheries. Thereby, serving as an indicator that the fish is healthy for consumption. In addition to the negative effects they can have on fish populations, parasites can also serve as environmental indicators to monitor the quality of aquatic environments (Dzika & Wyżlic 2011; Palm 2011; Unger *et al.* 2014). Limnological variables such as pH, temperature, dissolved oxygen content, and alkalinity, as well as parasitological factors such as parasite prevalence, mean intensity, and mean abundance that indicate a direct relationship between water quality and parasitic infection or fish susceptibility to parasitic infection (Biswas & Pramanik 2016). Water quality is evaluated based on various physical, chemical, and biological characteristics that can affect the suitability of aquatic environments for fish and other aquatic organisms. These characteristics include factors such as temperature, pH, dissolved oxygen levels, and the presence of pollutants or pathogens. Understanding these factors helps to determine the distribution and production of aquatic life (Yerima *et al.* 2017).

Fish could serve as intermediate or final hosts of parasites that are dangerous to man and animals (Okoye *et al.* 2014). Fish parasites could also serve as possible biomarkers for ecology and trophic interactions (Cauyan *et al.* 2013). High-quality fish species that are free from parasites or microbial infection are required to sustain the ever-increasing fisheries production (Abdullahi *et al.* 2017). Hence, the role of freshwater fish in spreading parasites to man had been acknowledged for a long period of time (Omeji *et al.* 2011; Khalil *et al.* 2014; Ali & Faruk 2018). A study conducted on some freshwater fish in Warri River, Nigeria revealed that the highest parasite prevalence was observed in *Synodontis clarias*, while the least prevalence was recorded in *Coptodon zillii* with overall parasite prevalence recorded in the metazoan (Ejere *et al.* 2014). In the lower Benue River, both *Clarias gariepinus* (29.33%) and *Clarias anguillaris* (27.33%) had higher parasite prevalence during the dry season than during the wet season (Uruku & Adikwu 2017).

When the community composition or demographic distribution of hosts or parasites changes, the interaction between hosts and parasites and the ecological conditions changes (Buser *et al.* 2012; Scharsack *et al.* 2012; Budria & Candolin 2014). Water quality changes can impact both host immunity and defensive systems, as well as the transmission pathways of parasites, leading to alterations in the host-parasite relationship (Lazzaro & Little 2009; Kutzer & Armitage 2016). Declines in the abundance of some monogenean parasites have been observed in association with the deterioration of water quality and decreased dissolved oxygen levels (Zargar *et al.* 2012). Several ectoparasite species, including trichodinids, have been shown to proliferate in the presence of low dissolved oxygen levels (Carol *et al.* 2006).

The prevalence and distribution of parasite species are influenced by temperature, rising temperatures increase the pathogenicity and infection rates of parasites (Kutz *et al.* 2005; Larsen & Mouritsen 2014).

Moreover, research has consistently shown that parasitic infections and diseases are among the factors that lead to a reduction in fish production (Dougnon *et al.* 2012). Parasites are well-known to act as pathogens, causing direct death or rendering the fish more susceptible to predators (Kunz & Pung 2004). Although, helminths parasite of *Oreochromis niloticus* and *C. gariepinus* and phytoplankton composition in the reservoir has been documented (Ibironke & Morenikeji 2018; Isichei *et al.* 2020). This study aimed to assess the relationship between fish parasite abundance and water quality parameters in the Esa-Odo reservoir, where no previous records of limnological variables as determinants of fish parasites' abundance exist. The abundance of fish parasites and water quality parameters were analyzed to determine the level of parasitization in the reservoir. This provided background information on the different parasites recovered and water quality influence on the parasite abundance. This study evaluated the relationship between fish parasite abundance and water quality in the Esa-Odo reservoir by comparing the abundance of parasites with water variables. It has been shown that different limnological variables have impacts on the composition of parasites in fish species (Galli *et al.* 2001; Georges *et al.* 2020; Waruiru *et al.* 2021).

The specific objectives of the study were to:

- determine limnological variables of the reservoir,
- assess the parasitic infestation in terms of prevalence and intensity, and
- correlate limnological variables with parasites' abundance of the reservoir.

MATERIALS AND METHODS

Study area

The investigated water body was the Esa-Odo reservoir which is one of the largest surface water bodies in Osun State (Figure 1). The reservoir had a surface area of 50.2 ha when it was initially impounded but has reduced over time as a result of vegetation covering parts of the reservoir (Isichei *et al.* 2020). The reservoir supplies potable water to the entire Obokun local government area, and provides potential for fishery enterprise as well as for tourism and raw water for industrial use at the International Breweries, Ilesa, Nigeria. Esa-Odo lies approximately on Latitude 007°45′0′ N to 007°47′18′ N and Longitude 04°49′0′ E to 04°50′12′ on an elevation of 458 m above sea level. The area is under the Koppens Humid Tropical climate type with a short dry season (November–February) and a rainy season (March–October) with bimodal rainfall distribution. The mean annual rainfall is approximately 1,500 mm. The sampling was carried out between October 2018 and September 2019. Standardized pH buffer solutions were used to determine the pH of the water. Total dissolved solids and electrical conductivity were analyzed using TDS meter (PCE-PHD Version 1.1 Model Q656697) and Conductivity Bridge (PCE-PHD Version 1.1 Model Q656697), respectively. Water samples for dissolved oxygen were collected in 250 mL of Amber bottles and fixed in situ using Winkler's reagents. Similarly, water samples for biological oxygen demand (BOD_5) determination were collected in dark amber bottles and kept in the dark cupboard for a period of 5 days and Winkler's reagents were used after the incubation period (APHA 1999). The following physico-chemical parameters were determined in the laboratory using appropriate titrimetric and instrumentation methods as described by American Public Health Association (APHA): DO, BOD_5, nitrates, phosphates, turbidity, alkalinity, acidity, chemical oxygen demand, total organic carbon. To ensure the accuracy of the analysis, quality assurance, and quality control were strictly observed.

Fish sampling

Fish samples were collected on a monthly basis for an annual season using gill nets, casts net and traps with the help of fishermen. The services of fishermen operating on the reservoir were employed for the setting of fishing gear. Fish species were caught with traps, gears, and cast netting. Gill nets of 20 mm mesh size were used to collect fish. Cast nets of 22 mm were also used. The fishing nets were set at different locations on the reservoir covering the upstream, midstream and downstream. All the fish samples were brought to the laboratory of the Zoology Department at Obafemi Awolowo University, Ile-Ife in an icebox for further analysis. The fishes were identified using standard keys (Paugy *et al.* 2003) while the total and standard lengths of the fish were taken using meter-rule in centimeters.

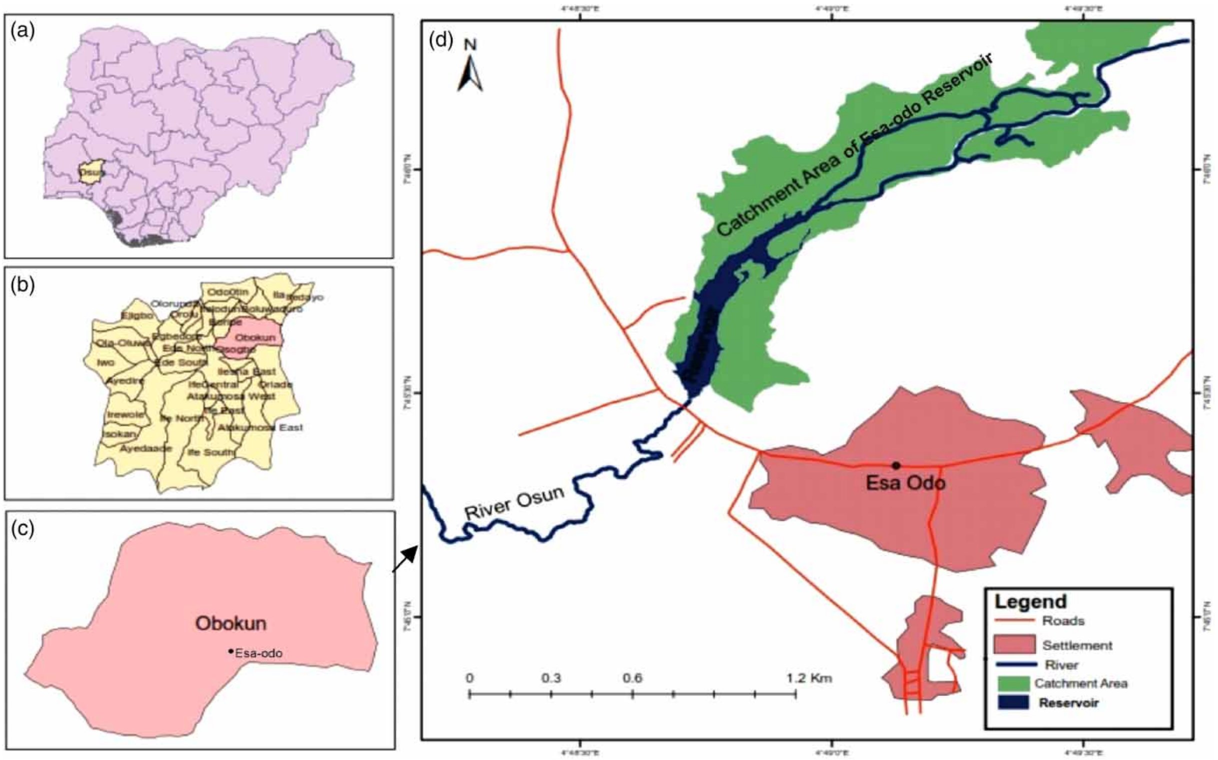


Figure 1 | (a) Map of Nigeria showing Osun State, (b) map of Osun State showing local government area, (c) map of Obokun local government, and (d) map of the Esa-Odo reservoir.

Examination of fish for parasites

Each fish sample was dissected to remove the gills, scales, esophagus, stomach, eggs, liver, and intestines. The organs were examined for parasites. The external body parts were picked by forceps and placed into a Petri dish. Also, the abdomen was dissected and divided into the stomach and intestine. Each segment was slit open, isolated, and placed into Petri dishes containing physiological saline (0.9% NaCl). The isolated segments from the petri dish were examined for the presence of parasites under a dissecting microscope on a black surface for clear visibility.

Collection and preservation of parasites

Parasites recovered from each segment were properly washed and fixed in 70% ethanol as described, location of infection was noted (Olurin & Somorin 2006).

Staining and examination of parasites

The parasites were removed from the preservative (70% alcohol), stained in acetic hematoxylin for 10 min and destained in acid alcohol. Subsequently, they were differentiated in 45% acetic acid and transferred into glacial acetic acid for 10–15 min for dehydration. The dehydrated parasites were cleared in the ratio 3:1, 1:1, 1:3 series of a mixture of glacial acetic acid and methyl salicylate. The parasites were then mounted in Canada balsam on a clean and clear glass slide and examined under the microscope (Oniye *et al.* 2004). Measurement of the worms and their internal organs was done using a digital binocular compound LED microscope (model MD827S30L series).

Identification of parasites

Each parasite species were identified to the least possible taxon and were based on the descriptions and identification keys prepared by Yamaguti (1958) and Paperna (1996), and their microphotographs were taken using a digital binocular compound LED microscope (model MD827S30L series).

Statistical analysis

The data collected for fish were analyzed using descriptive statistics which include frequency tables, means, standard deviation, and percentages as appropriate. The relationships between water quality and parasite composition of fish species were determined using a correlation coefficient matrix. Data for water analysis were subjected to appropriate statistical methods such as descriptive statistics, *t*-test, and analysis of variance (ANOVA) using SPSS version 24. The prevalence, intensity, and mean intensity were evaluated according to Margolis *et al.* (1982) and Busht *et al.* (1997). Inter-correlation between physico-chemical parameters was determined using PAST (Paleontological Statistics) Statistical software version 2.12.

Ethical approval

This study was approved by the committee on animal experiments in the Department of Zoology, Obafemi Awolowo University, Ile-Ife. All the experimental guidelines involving fish were carried out by standard procedures.

RESULTS

Limnological variables

The limnological parameters of water samples collected at different zone of the reservoir is as shown in Table 1. The highest mean water temperature was recorded at the riverine (26.1 ± 0.64 °C) and there was a significant difference ($p < 0.05$) among the reservoir zones. The overall pH of the reservoir was 7.15 ± 0.20 while the highest mean pH was observed at the transition zone (7.16 ± 0.14) and the lowest value was recorded at the dam site (7.14 ± 0.13). The highest mean concentration of conductivity and TDS was recorded at the transition zone 121 ± 6.82 μS/cm and 80.4 ± 7.10 mg/L, respectively. There was no significant difference ($p > 0.05$) in the mean values of dissolved oxygen across the reservoir zones. Also, the highest mean value of alkalinity was obtained at the riverine zone (43.6 ± 7.68 mg/L) while the lowest value was observed at the transition zone (42.3 ± 7.78 mg/L). The maximum mean concentrations of nitrate and phosphate were recorded at the transition zone (1.57 ± 0.47 mg/L) and 1.45 ± 0.72 mg/L at the dam site, respectively. There was no significant difference ($p > 0.05$) in the mean values of organic matter among the various zones of the reservoir. The overall COD of the reservoir was 14.5 ± 4.47 mg/L while the highest mean COD was observed at the transition zone (15.3 ± 5.22 mg/L) and the lowest value was recorded at the dam site (13.6 ± 3.91 mg/L). The highest mean concentration of turbidity was recorded in the dam site (95.9 ± 31.03 mg//L) and there was no significant difference ($p > 0.05$) between the mean value of turbidity observed across the zone of the reservoir.

Seasonally, the highest water temperature was recorded in the dry season (28 ± 0.10 °C) when compared with the rainy season (25.4 ± 0.89 °C) as shown in Table 2. The mean values recorded for pH were higher during the dry season

Table 1 | Overall limnological variables of water sampled across the zones

	Zones					
Parameters	**Dam site Mean ± S.D.**	**Transition Mean ± S.D.**	**Riverine Mean ± S.D.**	**Overall Mean ± S.D.**	***F*-ratio**	***p*-value**
Water temp. (°C)	25.4 ± 0.58^a	25.8 ± 0.80^a	26.1 ± 0.64^a	25.7 ± 0.72	3.20	0.05
pH	7.14 ± 0.13^a	7.16 ± 0.14^a	7.15 ± 0.91^a	7.15 ± 0.20	0.06	0.94
Electrical conductivity (μS/cm)	118 ± 7.44^a	121 ± 6.82^a	120 ± 7.75^a	120 ± 7.24	0.51	0.61
Total dissolved solid (mg/L)	79 ± 5.96^a	80.4 ± 7.10^a	80.2 ± 6.93^a	79.8 ± 6.52	0.16	0.85
Dissolved oxygen (mg/L)	5.12 ± 1.77^a	5.20 ± 1.72^a	5.42 ± 1.47^a	5.25 ± 1.61	0.10	0.90
Alkalinity ($CaCO_3$mg/L)	42.5 ± 6.33^a	42.3 ± 7.78^a	43.6 ± 7.68^a	42.4 ± 7.14	0.25	0.78
Nitrate (mg/L)	1.34 ± 0.50^a	1.57 ± 0.47^a	1.54 ± 0.56^a	1.49 ± 0.51	0.66	0.52
Phosphate (mg/L)	1.45 ± 0.72^a	1.41 ± 0.63^a	1.03 ± 0.38^a	1.30 ± 0.61	1.84	0.18
Organic matter (mg/L)	9.52 ± 2.74^a	10.3 ± 3.09^a	10.7 ± 3.14^a	10.2 ± 3.14	0.44	0.65
Chemical oxygen demand (mg/L)	13.6 ± 3.91^a	14.6 ± 4.40^a	15.3 ± 5.22^a	14.5 ± 4.47	0.44	0.65
Turbidity (NTU)	95.9 ± 31.03^a	93.8 ± 30.6^a	92 ± 30.5^a	93.9 ± 29.9	0.05	0.95

Note: row mean scores with same superscript (a,b) are not significantly different ($p > 0.05$) from each other.

Table 2 | Seasonal limnological variables of water sampled

Parameter	Rainy season Mean ± S.E.	Dry season Mean ± S.E.	*t*	*p*-value
Water temp. (°C)	25.4 ± 0.89	28 ± 0.10	2.21	0.04*
pH	7.10 ± 0.12	7.22 ± 0.09	−3.25	0.00*
Electrical conductivity (μS/cm)	119 ± 1.33	121 ± 2.24	−0.83	0.42
Total dissolved solid (mg/L)	78.2 ± 1.58	82.2 ± 1.17	−2.07	0.05*
Dissolved oxygen (mg/L)	4.75 ± 0.32	5.94 ± 0.42	−2.26	0.03*
Alkalinity ($CaCO_3$mg/L)	44 ± 1.48	40.3 ± 1.87	1.56	0.12
Nitrate (mg/L)	1.53 ± 0.11	1.43 ± 0.14	0.59	0.58
Phosphate (mg/L)	1.29 ± 0.01	1.31 ± 0.21	0.57	0.58
Organic matter (mg/L)	9.03 ± 0.69	11.8 ± 0.62	−2.95	0.00*
Chemical oxygen demand (mg/L)	12.9 ± 0.98	16.8 ± 0.88	−2.30	0.00*
Turbidity (NTU)	115 ± 4.13	65.1 ± 3.57	9.06	0.00*

Note: *$p < 0.05$ based on seasonal variation with respect to Student *t*-test.

(7.22 ± 0.09) than the rainy season (7.10 ± 0.12). High mean concentrations of conductivity (121 ± 2.24) μS/cm and TDS (82.2 ± 1.17 mg/L) were recorded in the dry season. Also, there was a significant difference ($p < 0.05$) in the dissolved oxygen of water samples across the seasons. The alkalinity mean concentration was higher in the rainy season than in the dry season (Table 2). The highest mean concentration of nitrate was recorded during the rainy season (1.53 ± 0.11 mg/L) whereas the dry season was recorded to have the highest mean value of phosphate (1.31 ± 0.21 mg/L). Mean values recorded for organic matter and COD were higher during the dry season than during the rainy season. A high mean turbidity value of 115 ± 4.13 mg/L was recorded in the rainy season when compared to the dry season which obtained a mean value of 65.1 ± 3.57 mg/L (Table 2).

Fish morphometric, parasites and correlates of limnological variables with respect to fish parasites

The total length of *O. niloticus* recorded in this study ranged between 12.9 and 37.5 cm with a mean standard length of 17 cm and weight of 212 g (Table 3). The mean total length of 23.6 cm was recorded for *P. obscura* with a standard length that varied from 13 to 32.9 cm and a fish weight of 140 g. In the same vein, the total length of *C. gariepinus* varied widely from 19.5 to 35.1 cm with a standard length mean value of 21.6 cm and mean weight of 183 g. *Marcusenius senegalensis* had mean total and standard lengths of 16.9 and 14.8 cm, respectively, with a weight that ranged between 26 and 278 g. The total length of *Hepsetus odoe* recorded ranged between 13.1 and 36.5 cm with a mean standard length of 18.4 cm and a mean weight of 212 g. The morphometric measurements of *Ctenopoma kingsleyae* with respect to the mean total length, standard length and weight were 13.6, 11.2, and 53 g, respectively.

Five (5) different fish parasite species with a total number of 114 individual parasites belonging to three classes were recovered among 540 fish samples during the sampling period (Table 4). Fish species were infected with various species of parasites

Table 3 | Length (cm) and weight (g) of fish species

	Total length (cm)		Standard length (cm)		Weight (g)	
Fish species	Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.	Min–Max	Mean ± S.D.
Oreochromis niloticus	12.9–37.5	21.1 ± 4.9	10.4–31.5	17 ± 4.4	32–1,220	212 ± 167
Parachanna obscura	16–37.1	23.6 ± 4.2	13–32.9	21.1 ± 3.9	44–486	140 ± 86
Clarias gariepinus	19.5–35.1	25.5 ± 3.5	16–30.6	21.6 ± 3	74–454	183 ± 65
Marcusenius senegalensis	12.4–27.8	16.9 ± 2.7	10.9–22.8	14.8 ± 2.3	26–278	73 ± 44
Hepsetus odoe	13.1–36.5	22.1 ± 6	10.7–31	18.4 ± 5.1	46–592	133 ± 39
Ctenopoma kingsleyae	10.3–18.3	13.6 ± 2.3	8.5–15	11.2 ± 2	26–120	53 ± 28

Table 4 | Checklist, location of infection, and overall prevalence and intensity of fish parasite in relation to fish species

Location of infection	Parasite species	Host	No. of Fish Examined	No. of Fish Infected	No. of Parasite Recovered	Prevalence (%)	Mean intensity
Gills	*Clinostomum tilapiae*	*Ctenopoma kingsleyae*	21	3	7	14.3	2.33
Liver		*Oreochromis niloticus*	177	2	2	1.13	1.0
Gill cover		*Parachanna obscura*	86	1	5	1.16	5.0
Intestine	*Clinostomum* sp.	*Ctenopoma kingsleyae*	21	10	32	47.6	3.2
Stomach		*Marcusenius senegalensis*	132	3	4	2.27	1.33
Gills		*Clarias gariepinus*	110	8	18	7.27	2.25
Body cavity	*Euclinostomum heterostomum*	*Clarias gariepinus*	110	1	1	0.91	1.0
Stomach	*Procamallanus laevionchus*	*Hepsetus odoe*	14	2	2	14.3	1.0
Intestine		*Marcusenius senegalensis*	132	14	21	10.6	1.5
Gills		*Oreochromis niloticus*	177	5	9	2.82	1.8
Gills		*Parachanna obscura*	86	3	12	3.49	4.0
Eye	*Lytocestus* sp.	*Ctenopoma kingsleyae*	21	1	1	4.76	1.0

at different parts such as gills, liver, gill cover, intestine, stomach, body cavity, and the eye. Parasites encountered include: *Clinostomum tilapiae*, *Clinostomum* sp., *Euclinostomum heterostomum*, *Procamallanus laevionchus* and *Lytocestus* sp. The highest prevalence and mean intensity during this study were 9.81% and 2.15, respectively. Across the fish species, the highest prevalence was recorded in *C. kinsglayae* with prevalence rate of 47.6 and was infested with *Clinostomum* sp. while the least prevalence rate was recorded in *C. gariepinus* with prevalence rate of 0.91% and *E. heterostomum* was the recovered parasite. The mean intensity of the parasite varied from parasite to parasite with a maximum mean intensity of 5.0 recorded in *C. tilapiae* with *P. obscura* being the host fish species. The fish parasites and their hosts differ with respect to the standard length of the fish as shown in Table 5. In standard length that varied from 0 to 15 cm, *Clinostomum* sp. recorded the highest prevalence rate and mean intensity of 47.6% and 3.2, respectively, in *C. kinsglayae* while the least prevalence rate and mean intensity was observed in *Lytocestus* sp. A similar trend in *Clinostomum* sp. was observed in fish lengths that ranged between 20.1 and 25 cm with a high prevalence rate of 7.27% recorded in *C. gariepinus* and the least prevalence observed in *E. heterostomum* of the same fish species. *P. leavionchus* infected only *O. niloticus* of length between 25.1 and 30 cm with prevalence and mean intensity of 7.14% and 1.67, respectively. Also, *P. leavionchus* infested both *H. odoe* and *P. obscura* with high prevalence and intensity recorded in *H. odoe* and *P. obscura*, respectively.

The male fish species in the Esa-Odo reservoir had varying degrees of prevalence rate and mean intensity (Table 6). The maximum prevalence rate was recorded in *Clinostomum* sp. (42.1%) with *C. kinsglayae* recorded as the fish host when compared with *E. heterostomum* which had the least prevalence of 1.92%. Similarly, the mean intensity of 5.0 recorded in *C. tilapiae* was higher than the intensity of 1.0 in *C. tilapiae* and *Lytocestus* sp. which were recovered from *C. kinsglayae*. Also, in the female fish, the highest prevalence of 100% was recorded in *Clinostomum* sp. and *P. leavionchus* with *C. kinsglayae* and *H. odoe* as the fish host. High mean intensity of 4.0 was observed in *Clinostomum* sp. when compared to *C. tilapiae, Clinostomum* sp. and *P. leavionchus* which had the lowest value of 1.0 each.

In the correlation matrix table, all the parameters positively correlated with different fish parasites (Table 7). The water temperature had a strong positive correlation ($p \leq 0.01$) with *Clinostomum* sp. abundance, a similar trend was observed in

Table 5 | Prevalence and intensity of fish parasite in relation to fish lengths

Fish Standard Length (cm)	Fish Parasite	Fish Species (Host)	NFE	NFI	NPR	Prevalence (%)	Mean Intensity
0–15.0	*Clinostomum tilapiae*	*C. kinsglayae*	21	3	7	14.3	2.33
	Clinostomum sp.	*C. kinsglayae*	21	10	32	47.6	3.2
	Lytocestus sp.	*C. kinsglayae*	21	1	1	4.76	1.0
	Procamallanus laevionchus	*M. senegalensis*	52	14	21	26.9	1.5
15.1–20.0	*Clinostomum* sp.	*M. senegalensis*	80	3	4	3.75	1.33
20.1–25.0	*Clinostomum tilapiae*	*O. niloticus*	135	2	2	1.48	1.0
	Clinostomum tilapiae	*P. obscura*	56	1	5	1.79	5.0
	Clinostomum sp.	*C. gariepinus*	110	8	18	7.27	2.25
	Procamallanus laevionchus	*P. obscura*	56	1	3	1.79	3.0
	Procamallanus laevionchus	*O. niloticus*	135	2	4	1.48	2.0
	Euclinostomum heterostomum	*C. gariepinus*	110	1	1	0.91	1.0
25.1–30.0	*Procamallanus laevionchus*	*O. niloticus*	42	3	5	7.14	1.67
30.1–35.0	*Procamallanus laevionchus*	*H. odoe*	14	2	2	14.3	1.0
	Procamallanus laevionchus	*P. obscura*	30	2	9	6.67	4.5

Table 6 | Prevalence and intensity of parasite infection from fish sample based on sex

		Sex									
		Male					Female				
Parasite species	Fish species	NFE	NFI	NPR	Prevalence (%)	Mean Intensity	NFE	NFI	NPR	Prevalence (%)	Mean Intensity
Clinostomum tilapiae	*C. kinsglayae*	19	2	6	10.5	3.0	2	1	1	50	1.0
	O. niloticus	91	2	2	2.2	1.0	86	0	0	0	0
	P. obscura	46	1	5	2.17	5.0	40	0	0	0	0
Clinostomum sp.	*C. gariepinus*	52	5	12	9.62	2.4	58	3	6	5.17	2.0
	C. kinsglayae	19	8	24	42.1	3.0	2	2	8	100	4.0
	M. senegalensis	58	2	3	3.45	1.5	74	1	1	1.35	1.0
Euclinostomum heterostomum	*C. gariepinus*	52	1	1	1.92	1.0	58	0	0	0	0
Procamallanus laevionchus	*H. odoe*	12	0	0	0	0	2	2	2	100	1.0
	M. senegalensis	58	12	17	20.7	1.42	74	2	4	2.7	2.0
	O. niloticus	91	3	6	3.30	2.0	86	2	3	2.33	1.5
	P. obscura	46	2	9	4.35	4.5	40	1	3	2.5	3.0
Lytocestus sp.	*C. kinsglayae*	19	1	1	5.26	1.0	2	0	0	0	0

Note: NFE, No. of fish examined; NFI, No. of fish infected; NPR, No. of parasites recovered.

DO with a strong positive correlation with *E. heterostomum.* Also, there is a strong correlation between the DO of the reservoir water and the abundance of *C. tilapiae* and *P. leavionchus* recovered from the fish. *E. heterostomum* and *Lytocestus* sp. recorded a strong correlation with conductivity, alkalinity, phosphate, organic matter, COD, and turbidity. In the same vein, a significant correlation ($p \leq 0.05$) was observed between *P. leavionchus* and some water quality parameters such as DO, conductivity, alkalinity, phosphate, and organic matter. The relationship between limnological variables and fish parasite abundance is presented in Figure 2. Parasites such as *P. leaviochus*, *C. tilapiae*, and *Clinostomum* sp. showed a closed relationship with DO and phosphate. Nitrate, water temperature, alkalinity clustered with *E. heterostomum* and *Lytocestus* sp.

Table 7 | Correlation coefficient matrix showing relationship between the investigated limnological variables and fish parasites

Parasite species	Water temp.	DO	pH	EC	TDS	Alkalinity	Nitrate	Phosphate	OM	COD	Turbidity
Clinostomum tilapiae	0.317	0.804**	0.702**	0.201	0.435	0.714**	0.244	0.449	0.523*	0.142	0.142
Clinostomum sp.	0.992***	0.471	0.553*	0.552*	0.281	0.294	0.560*	0.308	0.443	0.812**	0.812**
Euclinostomum heterostomum	0.484	0.952***	0.208	0.762**	0.486	0.758**	0.289	0.860**	0.626*	0.762**	0.761**
Procamallanus laevionchus	0.351	0.675*	0.211	0.643*	0.128	0.598*	0.469	0.673*	0.627*	0.139	0.138
Lytocestus sp.	0.484	0.952**	0.208	0.762**	0.486	0.758**	0.289	0.860**	0.626*	0.762**	0.761**

*Significant ($p < 0.05$).
**Highly significant ($p < 0.01$).
***Very highly significant ($p < 0.001$).

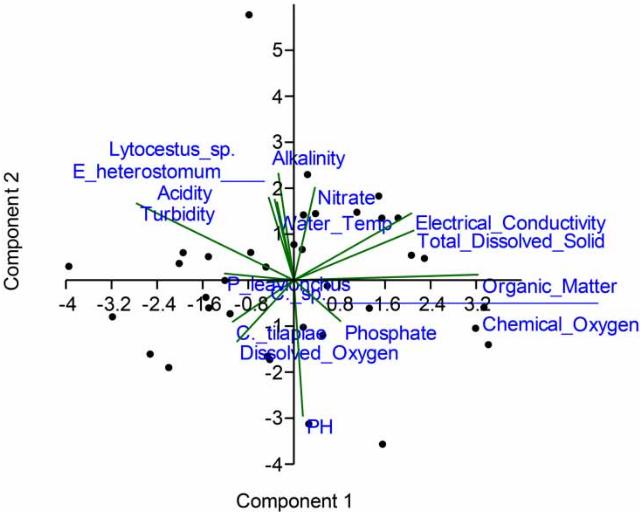


Figure 2 | Principal component analysis (PCA) showing the relationship between investigated limnological variables and fish parasites.

DISCUSSION

Limnological variables

Water quality parameters in an aquatic biota could be influenced by various human activities and other natural causes which may affect the aquatic environment. In this study, the value of the water temperature recorded was within the range documented for inland waterbodies in the tropical region (Adesakin *et al.* 2020; Anyanwu *et al.* 2021). This was also in agreement with Yusuf (2020) and Omoboye *et al.* (2022) who recorded a similar range for the water temperature in the tropics. The mean water temperature of 25.7 ± 0.72 °C observed in this study was within the recommended limit for fish (Egun & Oboh 2022). Some authors have suggested that the transfer of heat due to climatic change either from the air or sunlight might cause variations in the temperature of water (Arnell *et al.* 2015; Bello *et al.* 2017). Significant changes in both air and water temperatures during the dry season could be as a result of extreme harmattan and high intensity of sunlight in the habitat while moderate temperature in the rainy season might be due to heavy rainfall. The mean pH value ranged from 7.14 to 7.6 indicating that the reservoir water was slightly alkaline. However, the pH recorded for this study was in contrast with the findings of Koszelnik *et al.* (2018) who reported pH value that varied from 7.84 to 7.98 in Southeastern Poland reservoirs. Reasons for pH differences in reservoir water could be as a result of the temperature of the day, soil composition and bedrock.

The highest mean value (121 ± 6.82 μS/cm) of electrical conductivity was recorded in the transition zone while the lowest mean electrical conductivity (118 ± 7.44 μS/cm) was recorded at the dam site. These findings were consistent with the results obtained by Adesakin *et al.* (2020) in Samaru River with a mean value of 128.67 ± 2.25 μS/cm. In Obudu river system of Opa reservoir, a mean temperature value of 122.59 ± 12.58 μS/cm was recorded (Aliu *et al.* 2020). The mean TDS (79.84 ± 6.52 mg/L) observed in this study was within the recommended limit for drinking water (WHO 2017) and for fish in the water (FAO 2006). A similar finding was also recorded by Ilechukwu *et al.* (2020) in Usuma Dam. However, Kalgwai dam (Edegbene 2020) recorded contrast values at three different sites that ranged from 108.5 to 141.8 mg/L.

TDS is the most significant to water quality when it concerns selected uses and has been listed by the Environmental Protection Agency as secondary ground water and drinking water pollutant (Akpan *et al.* 2007). Factors such as the type of water body, temperature as well as biological and chemical processes taking place in the reservoir determine the level of dissolved oxygen in the water (Manning 2017). The mean concentration of dissolved oxygen during the study period was 5.25 ± 1.61 mg/L. The levels recorded for DO in the reservoir were consistent with the work of Abowei *et al.* (2010) that a DO concentration of 5.0 mg/L and above is necessary for fish survival.

Alkalinity values (42.4 ± 7.14 mg/L $CaCO_3$mg/L) observed in this study were characteristics of inland water bodies. The levels of Alkalinity were below the WHO permissible limit of 120 mg/L for drinking water. Some authors have suggested that anthropogenic activities are the main source of natural alkalinity (Onuoha & Alum-udensi 2018; Adeosun 2019). The results showed that the level of alkaline was within the permissible limits that support the growth and survival of fish in inland waterbodies (Komolafe *et al.* 2014; Ignatius & Rasmussen 2016).

The end product of the aerobic breakdown of organic nitrogenous substance are nitrates (Walakira & Okot-Okumu 2011). The concentration of nitrates in the Esa-Odo reservoir conforms to records from some investigated freshwater bodies in Nigeria such as the Erelu reservoir which recorded a mean nitrate value of 0.67 ± 0.06 mg/L (Kareem *et al.* 2018). Most of the water samples in each zone were within the permissible range of nitrate values as recommended by the Nigerian Standard for Drinking Water Quality (2007). In this current study, the mean phosphate value of 1.30 ± 0.61 mg/L was recorded. A possible explanation could be a result of NPK fertilizer being used by Nigerian farmers. Also, the catchment area of the reservoir is surrounded by farmlands. Moreover, the findings of the present study were in contrast with the report of Olanrewaju *et al.* (2017) which recorded phosphate levels between 1.9 and 2.0 mg/L in the Eleyele reservoir. Also, Oba reservoir, Ajala & Olatunde (2015) recorded phosphate levels of 0.09 and 0.07 during the rainy and dry seasons.

The mean values recorded for organic matter in the Esa-Odo reservoir ranged from 9.52 to 10.7 mg/L across the zones. In the Opa reservoir, Adesakin *et al.* (2017) documented organic matter levels with ranged between 0.63 and 14.54 mg/L at the surface level of the water. The level of organic matter in the Esa-Odo reservoir could probably be due to sediment properties and the soil-type of the reservoir. The nitrate level in any inland waterbodies indicated the level of nutrients and extent of organic matter pollution in the water body (Adesuyi *et al.* 2015). The mean chemical oxygen demand concentration recorded during the study period was 14.5 ± 4.47 mg/L. Irrespective of the period, the dam site had the lowest mean value of 13.56 ± 3.91 mg/L. Similar values were reported in the Ogbese river by Akinbile & Omoniyi (2018) who recorded COD values that ranged between 5.70 and 49.00 mg/L in the reservoir. Turbidity of the reservoir had a mean value of 93.9 ± 29.87 NTU. The mean values of Turbidity in the rainy season (115 ± 4.13 NTU) was higher than the values recorded in the dry season (65.1 ± 3.57 NTU). Turbidity values recorded in the Esa-Odo reservoir were above the recommended limits of 5.0 NTU according to WHO and NSDWQ standard values. Increased turbidity could probably be a result of run-off from rainfall, and the movement of soil particles into the reservoir. An increase in turbidity has a significant impact on aquatic ecosystems since the effect is the reduction in light intensity for plants which is necessary for photosynthesis (Akinbile & Omoniyi 2018). Fish and other aquatic biotas that are resident in freshwater bodies might have physiologically evolved over some time to adapt to changes in water clarity associated with their habitat (Ajala & Fawole 2016).

Fish parasites recovered in the reservoir

The presence of parasites in fish during this study revealed the extent water quality can have on the composition and abundance of fish parasites which to some extent affects the health of the fish. Different parasites such as *C. tilapiae, Clinostomum* sp., *E. heterostomum, P. leavionchus,* and *Lytocestus* sp. recovered in this study are similar to reports carried out in other inland waterbodies on fish (Manning 2017; Osho 2019; Neves *et al.* 2020). According to Hussen *et al.* (2012), helminths parasites are mostly found in freshwater fish. The authors considered species of parasite and their biology, host and their diets, and the presence of intermediate hosts as contributing factors to the rate of infection and intensity. Natural and anthropogenic activities that find their way into the aquatic environment can influence the presence of free-living stages of fish parasites (Un Nissa *et al.* 2022). Parasites have been known to cause changes in growth, behavioral changes which are negative in reaction and mechanical injury (Iwanowicz 2011). In this study, prevalence rate was low (9.8%) when compared to other reports on fish parasites in the tropics reservoir (Okoye *et al.* 2014; Bedasso 2015; Oso *et al.* 2017). In order to survive, reproduce and have access to food, parasite depends on their host (Un *et al.* 2022). An intensity level of 2.15 was recorded in the fish parasites during this study was higher than the reports of Atalabi *et al.* (2018) who reported intensity that varied from 1.19 to 1.72 in Zobe dam.

In this study, the rate of prevalence at different fish lengths showed that as the length of fish increases the rate of infection also increases (Amos *et al.* 2018; Akinsanya *et al.* 2020). Changes in the rate of infection as a result of fish length could probably be due to diet changes and water column habitation of the fishes. In this present study, high prevalence of parasites occurred in the male fish than in the females and a significant prevalence rate in male fish has been previously reported (Adegoroye *et al.* 2019; Akinsanya *et al.* 2020). According to Reimchen & Nosil (2001), activities such as competition for mates, and territorial defence impose a demand on fish that may affect their immune system. This might be responsible for the overall high prevalence rate (12.97%) based on sex as recorded in male fishes. Abiyu *et al.* (2020) suggested that differences in the infection rate of male and female fish could be as a result of genetic makeup and differential vulnerability due to the differences in their physiological condition. Similarly, female fishes in the reservoir might have high resistance to parasites when compared with male fishes.

Relationship between limnological variables with respect to fish parasites load

The water quality of a waterbody in an aquatic biota regulates the primary productivity, composition of organisms, diversity, and abundance and serves as a bio-indicator of aquatic environment well-being (Koledoye *et al.* 2022). In this current study, some parasites strongly correlated with some limnological parameters such as dissolved oxygen, pH and conductivity showed a strong correlation with *C. tilapiae.* Water temperature, pH, conductivity, nitrate and chemical oxygen demand had a strong correlation with *Clinostomum* sp. and an increase in temperature tends to increase the rate of parasite infective stages (Khan 2012; Lõhmus & Björklund 2015; Ojwala & Otachi 2018). It has been established that water temperature has an effect on the abundance of monogenean parasites. Also, dissolved oxygen, conductivity, alkalinity, phosphate, and organic matter showed a positive correlation with *P. leavionchus*.

Productivity in water bodies could be a result of high levels of nutrients leading to healthy food chains for the population of intermediate hosts and an abundance of different parasitic stages (Bhatnagar & Devi 2013).

C. tilapiae, E. heterostomum, and *Lytocestus* sp. had life cycles which are transmitted from one host to another and are sensitive to changes in dissolved oxygen concentrations (Wangare *et al.* 2020). Dissolved oxygen, conductivity, alkalinity, phosphates, organic matter, and chemical oxygen demand showed a positive correlation with *Lytocestus* sp. Increased nutrient concentrations in waterbodies could lead to a decline in the water quality thereby making aquatic animals such as fish to be weak and exposed to parasites attack and infections (Sures 2004). Ecological variations have been recognized to affect parasitism, irrespective of whether the fish species are cultured or in the wild. This was due to exposure to environmental factors such as rainfall together with wind patterns that have the tendency to mix with the water column, thus increasing the likelihood of ingesting prey that are intermediate hosts (Pech *et al.* 2010).

Several studies show that there exist relationships between the environmental conditions and the level of parasites in the environment (Bayoumy *et al.* 2015; Kiprono 2017; Abba *et al.* 2018). The present condition of the reservoir showed that water quality properties had little effect on the parasitic loads of the fish which could be a result of the environment that has fewer anthropogenic activities.

The level of parasitism in this study could probably be as a result of the water quality parameters of the aquatic biota that favors low parasitic load. The overall water quality variables of the reservoir may be disturbed but it poses little threat to the survival and health of the fish. However, monitoring of the excess nutrient level in the reservoir is required for conservation purposes.

CONCLUSION

This study shows that there was a relationship between limnological variables and the abundance of fish parasites in the reservoir. The findings of this study suggested that fish parasites of freshwater are sensitive to changes in the quality of their biota and as bio-indicator of its quality. The freshwater parasites of this study were less abundant than the fish host which revealed less anthropogenic influence. Although parasites have to undergo some of their life cycles in intermediate or definite hosts, these hosts might be less numerically thereby affecting the parasitic community. Therefore, fish parasites can be used in monitoring and can serve as indications of the limnological quality of the biota.

AUTHOR CONTRIBUTIONS

O.O. performed the experiment, analyzed and interpreted the data, and wrote the paper. O.O.K. conceived and designed the experiments. E.E.O. analyzed the data and identified the parasites.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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