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ORIGINAL ARTICLE

Impact of water quality and morphometric indices on the spatio-temporal prevalence of fish endo-parasites and diversity in the Ase River, Niger-Delta, Nigeria

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Abstract
Three stations along the Ase River, Delta State Nigeria provided water and 85 fish samples which were analyzed. The fish were measured and examined for endoparasites according to established protocol. All water quality parameters investigated were within the WHO-acceptable values for surface waters. Station variation of physicochemical parameters was not statistically significant ($p > 0.05$). Fish body conformation indices positively correlated with the prevalence of parasites in *Clarias gariepinus, Heterobranchus longifilis, Parachana africana, Chromidotilapia guntheri guntherii*, and *Denticeps clupeodes*. The overall parasite prevalence of 63.53% was established with the most abundant parasite being *Trichodina mutabillis*. The parasites had a predilection for the gastrointestinal tract with a high occurrence of 307 individuals. Stations 1, 2, and 3 had 326, 213, and 259 parasites, respectively, out of a total of 798 parasites detected. *P. laevis* was absent in station 1. All parasites were found in stations 2 and 3. Statistically, there was a significant difference ($p < 0.05$) in the prevalence in all stations. The correlation index of *T. mutabillis* and *R. congolensis* in stations 1 and 3 was positively strong ($p < 0.05$) with the concentrations of water quality. However, water conditions in stations 1 and 3 had a deleterious impact on *P. laevis*. *T. mutabillis* maintained a high positive correlation with physicochemical water quality in all three stations. Shannon-Weiner's index in station 3 (H = 1.337) shows that the parasites were more diverse. PCA and biodiversity indices have enabled us to comprehend how parasite-host-environment systems interact.

Keywords Water quality · Body mass index · Parasite · Prevalence · Correlation matrix · Ase River

Introduction

Fish remain one of the most-traded aquatic commodities worldwide with over 50% of exports coming from developing nations. It is a vital source of food, nutrient, income, and livelihood for more than half the world's population (FAO 2016). Freshwater constitutes 3% of surface earth water with about 69% glaciers, 30% underground, and less than 1% in lakes, rivers, and swamps. Freshwater fishes are the most common sources of protein for humans, live stocks, and other aquatic animals (Arimoro and Utebor 2013). Fish interacts with the various levels of the food chain and influence the structures of rivers, lakes, streams, and estuaries since, they are usually restricted to specific lifestyles in terms of food sources and reproductive requirements (Oribhabor et al. 2012; Ashade et al. 2013).

Freshwater fishes serve as various types of hosts to several parasites (Ito 2017). These parasites are either opportunistic or obligate, with the majority of disease conditions caused by the latter (Ejere et al. 2014). Fish productivity is affected by parasitic diseases, and this valuable economic source of protein is prone to parasite infections (Agbabiaka et al. 2017). Parasitic infections negatively affect fish market value, protein quality, and community health (Ito 2017). Parasitic invasions result in significant fish mortalities responsible for huge economic losses or threats to the abundance and diversity of indigenous fish species (Ito 2017; Aliyu and Solomon 2012). Fish devoid of parasitic infections has been described to be healthy and rich in quality protein (Olagbemide and Owolabi 2022). Fishes are parasitized by endo- and ectoparasites of protozoa and helminth origins triggering heavy mortality (Agbabiaka et al. 2017). High epidemic

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magnitudes are attained in crowded, exposed, and natural conditions due to fish migration (Ravichandran et al. 2012).

Parasitic infections are currently confronting cultured and wild fishes (Fahmy et al. 2022; Afolabi et al. 2020). Fish parasites often reduce the nutritional value and weaken their host's immune system thereby increasing their susceptibility to secondary infections (Onyedineke et al. 2010). One important factor impeding fish productivity is parasites and infection (Kayis et al. 2009). Internal or external fish infection reduces fish productivity by affecting its normal physiology (Imam and Dewu 2010). Consumption of infected fish in some cases may lead to human infection (Noga 2010). Petney et al., (2013) and Pal et al., (2020) have documented the zoonotic role of freshwater fish. Zoonotic diseases that may result from the ingestion of raw or under-cooked fish include opisthorchiasis, diphyllobothriasis, clonorchiasis, gnathostomiasis, and anisakiasis (Ito 2017). Petney et al., (2013) and Pal et al., (2020) have documented the zoonotic role of freshwater fish in the transmission of opisthorchiasis, diphyllobothriasis, clonorchiasis, gnathostomiasis and anisakiasis. *Clonorchis sinensis, Opisthorchis viverrini*, and possibly *O. felineus* can cause human cholangiocarcinoma in addition to various hepatobiliary diseases (Ito 2017). Contrarily, Diphyllobothriasis causes a deficiency of vitamin B_{12} consequently inducing megaloblastic anemia, the onset of subacute combined spinal cord degeneration, and cognitive loss.

The effects of fish parasitic infections cannot be overemphasized. Undoubtedly, acute infection in fish causes severe bodily abnormalities and raises the death rate in fish populations thus affecting fish community structure. Consequently, this reduces the quantity and quality of fish available for human use. In the recent past, emphasis has been on the fish parasites in freshwaters from Owena River and Igbokoda River (Afolabi et al. 2020), Jabi Lake (Solomon et al. 2021), Niger and Benue River (Onoja-Abutu et al. 2021). However, topical studies have shown seasons, water pollution, fish length/weight and condition factors to significantly influence the prevalence of fish parasites (Olagbemide and Owolabi 2022; Fahmy et al. 2022; Oghenochuko et al. 2020; Acosta-Pérez et al. 2022).

Aquatic water pollution is an important factor affecting the availability and distribution of organisms in freshwater bodies (Ito et al. 2023; Ito and Ugbomeh 2017). The physicochemical qualities of water and immediate substratum have been reported to affect the abundance of organisms in the Ase River (Arimoro et al. 2007). Despite the occurrence of deteriorating water quality in the Ase River, no study has documented its effects on the parasite-fauna and fish length–weight relationship except for preliminary studies on fish parasites by Ito (2017). This gap underscores the need to evaluate the effect of water quality parameters and host morphometric indices on the prevalence of parasites in the fish communities in the Ase River. Specifically, the objectives of this present study are to evaluate the physicochemical water quality and the morphometric factors that influence the parasitic fauna of fishes in the upper reaches; identify the composition, distribution and abundance of parasites capable of inducing fish disease conditions in the river.

Materials and methods

Description of study area and sample location

The Ase River is one of several rivers that drain the recent delta top landforms of the western Niger Delta and it is a coalesce of many tributaries originating from the southern and western slopes of the Asaba Plateau. The tributaries include the Oboshi River, which borders the Ibusa sub-urban municipal on the west, the Atakpo Creek, which borders the settlement on the east; the Nooni River, which runs through Nsukwa and Ogwashi-Uku west; while the tributaries headwaters of the Adofi River are at Ejeme Aniogor and Agbor Aladinma (Fig. 1). These tributaries meet at the southern part of Iselegwu to form the main trunk of Ase River which shares a flood plain with the River Niger and flows southwards to join the Nikeroga River in the western branch while the eastern branch of the Niger River terminates at the Nun River (Ito 2017). Ase River further flows through Asaba-Ase, Ase (where its name originated), Ibredeni, Ivorogbo, Awah, Ibrede, Kwale, and Obikwele among other communities (Ito et al. 2024). Water and Fish samples were collected from three selected stations: station 1 (Asaba-ase: Lattitude $N05^0$ 17.655S, Longitude $E006^0$ 17.523W); station 2 (Ibredeni: Lat. $N05^0$ 24.297S, Long. $E006^0$ 20.580) and station 3 (Ivrogbo: Lat. $N05^0$ 25.670S, Long. $E006^0$ 20.759W) in July 2021 with the assistance of fishermen folk at the various locations. The tropical climate of the area is governed by the northeastern and southwestern winds which generally influence the climate of Nigeria.

Laboratory methods

The laboratory methods include physicochemical water quality analysis, fish identification, fish length and weight measurements, parasite identification and preservation as recommended by Ito (2017).

Water quality analysis

Water quality analyses were carried out at three selected stations in July 2021. Temperature (Air and water (^{0}C)) was measured using a glass thermometer. While pH, Biochemical Oxygen Demand, total alkalinity, Dissolved Oxygen, conductivity, and nitrate-nitrogen and phosphate-phosphorus

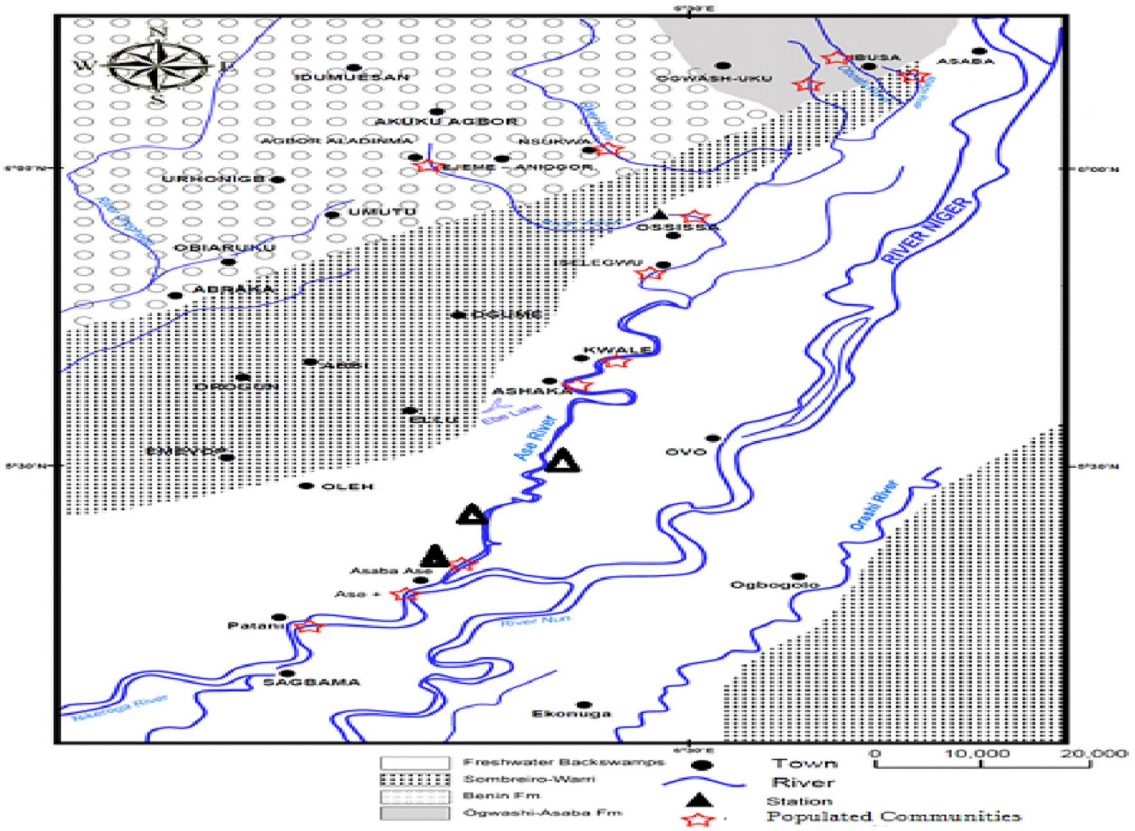

Fig. 1 Physiographic Map of Ase River, showing the study stations in Delta State, Nigeria (Ito et al., 2023)

(PO_4-P) were determined and measured in standard units following APHA methods (2012).

Fish identification

Using the common taxonomic key of Olaosebikan and Raji (2004), fish caught in the river were identified and confirmed to generic and species levels when possible.

Examination for parasites/parasite identification

The fish sampled from Ase River were dissected and the alimentary canal was carefully sectioned and differentiated into the oesophagus, intestine and rectum to enable endo-parasites examination. These sections were then cut open, washed in a Petri dish with 0.1% sodium chloride solution and further rinsed with 0.1% sodium bicarbonate to enhance parasite search. Two drops of the washed gut content were placed on a slide and viewed under microscope at 40 × and 100 × magnification. The dissected alimentary canal walls were also scraped, smeared on a glass slide and subsequently stained with Giemsa for parasites visibility under the microscope. The gills were removed and kept in a sterilized beakers containing little saline solution. Later, 2–3 drops of this solution were added on a microscopic slide, covered with a cover slip and examined with × 40 magnification lens. Using the Marcogliese (2011) and Pouder et al., (2011) key, the parasites obtained were identified to generic and species levels where possible.

Preservation

Muscles were teased to release trematode metacercariae and were immediately fixed in hot alcohol-formal-acetate (AFA) and preserved in vials of 70% ethyl alcohol as described by Ejere et al., (2014). Similarly, extracted parasites from the fish guts were also preserved in a 70% vial of ethanol.

Statistical analysis

The results obtained for fish morphometric indices and physicochemical parametres were subjected to statistical analysis for Mean and standard error. The mean was then subjected to analysis of variance (ANOVA) to test for the level of significant difference between the stations and physicochemical parameters. Parasite prevalence values were also subjected to the PAST version 4.11 statistical package at a significant level of 0.05. Analysis of variance (5% level) was also

used to test for the significant differences in infection in the three stations. Using Principal Component Analysis (PCA) Pearson's correlation, the association between body conformations, physicochemical parameters and prevalence was tested. Parasite diversity indices were also computed with standard formulae.

Results

Physicochemical water quality of the study stations in ase river.

The water quality parameters in Ase River indicating the mean values and standard error for each station is presented in Table 1. Of the 3 sampling stations selected, the mean and standard error values of the parameters determine were as followed: Air temperature (30.46 ± 0.34), water temperature (24.51 ± 0.24 ^{0}C), DO (7.10 ± 0.65 mg/l), BOD_5 (2.88 ± 0.70, mg/L), pH (5.24 ± 0.63), conductivity (14.12 ± 0.84 µs/cm), phosphate (0.28 ± 0.27 mg/L), nitrate (0.18 ± 0.02 mg/L), Sulphate (2.03 ± 0.08 mg/L), alkalinity (6.08 ± 0.09). All water quality parameters investigated were significantly different ($p < 0.05$; $F_{cal} = 525.19$; $F_{crit.} = 2.46$).

Morphometric indices and parasite prevalence

Eighty-five (85) fish samples, belonging to twelve (12) species: *Brycinus longipinnis* (8), *Barbus lagoensis* (7), *Polypterus ansorgii* (6), *Polypterus bichir lapradei* (5), *Barbus bynni occidentalis* (4), *Clarias gariepinus* (11), *Denticeps clupeodes* (9), *Xenomystus nigri* (6), *Heterobranchus longifilis* (9), *Parachana africana* (8), *Chromidotilapia guntheri guntherii* (9) and *Pantodon bucholz* (3) were examined for endo-parasites. Of the 85 fish, 54 were infected with several parasites giving an overall prevalence of 63.53% (Table 2). The prevalence, total length, standard length and weight with their respective minimum and maximum values in parenthesis are presented in Table 2. Generally, *C. gariepinus,* with a mean body conformation index of 34.56 ± 6.40 and 15.89 ± 1.51 (total weight and standard length respectively) had the highest overall prevalence (9.41%). This was closely followed by *P. africana* and *H. longifilis* with 8.24% prevalence. The least on the prevalence ranking were *B. bynni occidentalis* and *P. bucholz* with 1.18% (Table 2). Based on the fish species population, *P. africana* had more parasitic infections with 87.50%. However, *B. b. occidentalis* and *P. bucholz* were the least infected with 1(25.00%) and 1(33.33%) respectively (Table 2). The correlation index between parasite prevalence and fish morphometric indices (total weight and length) was analyzed using a Pearson correlation matrix. The correlation matrix of the *C. gariepinus, H. longifilis, P. Africana*, *C. g. guntherii* and *D. clupeodes* between parasite prevalence with a total weight of fish species was positively correlated as shown by the Principal Component Analysis (Fig. 2) with prevalence between 5.88 and 9.41% (Table 2). Whereas, the negative correlation of *B. b. occidentalis* and *P. bucholz* stands out (with 1.18% prevalence). Similarly, *C. gariepinus* presented a strong positive correlation with the total length of fish (Fig. 3). Here, *H. longifilis* prevalence which was previously and positively correlated presented a weaker correlation coefficient

Table 1 Mean ± Standard Error of Water Quality in the study stations of Ase River, June 2021 [minimum and maximum values in parenthesis]

S/N	Parameters	Station 1	Station 2	Station 3	Mean±SE	WHO, 2011
	Air Temp. (^{0}C)	30.14	31.15	30.10	30.46 ± 0.34 (30.10–31.15)	Ambient
	Water Temp. (^{0}C)	24.23	24.32	25.00	24.51 ± 0.24 (24.23–25.00)	Ambient
	pH	5.01	4.27	6.43	5.24 ± 0.63 (4.27–6.23)	8.2 – 8.8
	DO (mg/L)	8.15	5.90	7.26	7.10 ± 0.65 (5.9–8.15)	Not Available
	BOD_5 (mg/L)	4.24	1.90	2.50	2.88 ± 0.70 (1.9–4.24)	Not Available
	Alkalinity (mg/L)	6.20	6.13	5.90	6.08 ± 0.09 (5.90–6.2)	Not Available
	Phosphate (mg/L)	0.021	0.021	0.82	0.28 ± 0.27 (0.021–0.82)	Not Available
	Nitrate (mg/L)	0.15	0.17	0.21	0.18 ± 0.02 (0.15–0.21)	3.0
	Conductivity (µs/cm)	13.25	13.32	15.80	14.12 ± 0.84 ((13.25–15.80)	Not Available
	Sulphate (mg/L)	1.87	2.09	2.13	2.03 ± 0.08 (1.87–2.13)	100

Table 2 Prevalence of Fish Endo-parasites and Morphometric factors in Ase River

Parasite Host (Fish)	Total Length (cm)	Standard Length (cm)	Total Weight (g)	N.E	N.I(%)	Overall % Prevalence	PCA (Prevalence Vs Total weight)		PCA (Prevalence Vs Total Length)	
							PC 1	PC 2	PC 1	PC 2
B. longipinnis	18.60 ± 0.60 (18.50 – 19.10)	15.12 ± 0.23 (15.00 – 15.30)	125.00 ± 11.38 (124.12 – 140.50)	8	5(62.50)	5.88	69.631	0.13642	-0.397	0.96574
B. lagoensis	18.18 ± 0.30 (18.00 – 18.90)	14.99 ± 0.52 (14.5 – 15.70)	122.01 ± 4.27 (118.00 – 128.01)	7	4(57.14)	4.71	66.633	-1.0143	-1.1536	0.063215
P. ansorgii	24.50 ± 1.35 (23.00 – 26.50)	22.57 ± 1.98 (20.50 – 24.00)	96.07 ± 7.08 (101.20 – 87.95)	6	4(66.67)	4.71	40.694	-0.84752	5.1596	-4.1319
P. b. lapradei	18.91 ± 1.20 (18.50 – 19.32)	16.68 ± 0.54 (15.50 – 17.86)	39.03 ± 0.83 (38.58 – 39.50)	5	2(40.00)	2.35	-16.36	-2.8407	-1.0522	-2.8377
B. b. occidentalis	10.00 ± 0.00 (10.00 – 10.00)	8.00 ± 0.00 (8.00 – 8.00)	11.03 ± 0.00 (11.03 – 11.03)	4	1(25.00)	1.18	-44.36	-3.8306	-8.9292	0.99176
C. gariepinus	18.41 ± 1.52 (16.40 – 20.30)	15.89 ± 1.51 (14.00 – 18.80)	34.56 ± 6.40 (21.08 – 39.90)	11	8(72.72)	9.41	-20.78	4.2479	2.1972	3.4797
D. clupeodes	18.34 ± 1.65 (18.20 – 19.80)	16.26 ± 1.79 (16.00 – 17.10)	33.44 ± 7.27 (28.91 – 37.12)	9	5(55.56)	5.88	-21.92	0.72518	0.55166	0.3348
X. nigri	18.13 ± 1.07 (17.20 – 19.60)	16.08 ± 0.87 (15.00 – 17.00)	37.53 ± 8.15 (31.00 – 48.80)	6	4(66.67)	4.71	-17.84	-0.47109	-0.2458	-0.54005
H. longifilis	20.99 ± 2.16 (18.20 – 25.00)	17.66 ± 2.16 (14.80 – 21.50)	53.70 ± 31.13 (37.08 – 123.10)	9	7(77.78)	8.24	-1.6527	2.9549	3.0238	1.5256
P. africana	19.61 ± 1.73 (17.30 – 22.10)	16.51 ± 1.25 (14.80 – 18.80)	38.10 ± 5.53 (30.71 – 48.80)	8	7(87.50)	8.24	-17.25	3.0552	2.066	2.162
C. g. guntherii	19.43 ± 1.25 (18.00 – 21.30)	17.27 ± 0.93 (16.50 – 18.80)	35.39 ± 4.02 (28.65 – 39.23)	9	6(99.67)	7.06	-19.97	1.8926	2.0459	0.75862
P. bucholz	17.00 ± 0.00) (17.00 – 17.00)	14.80 ± 0.00 (14.80 – 14.80)	38.60 ± 0.00 (38.60 – 38.60)	3	1(33.33)	1.18	-16.798	-4.0079	-3.2656	-2.7717
Total				**85**	**54**	**63.53**				

N.E: Number Examined; N.I: Number Infected; PCA: Principal Component Analysis; PC: Principal Component

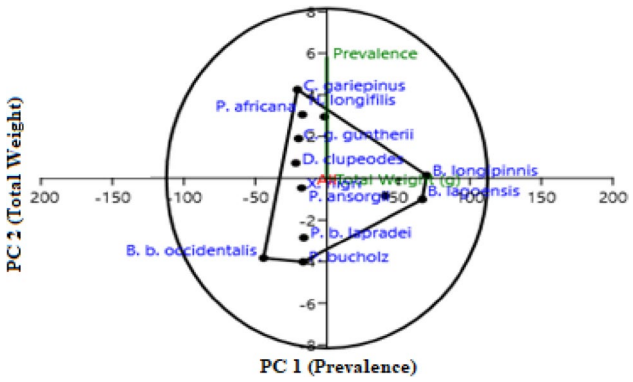

Fig. 2 PCA correlation matrix of Fish Specie Prevalence and Total weight (g)

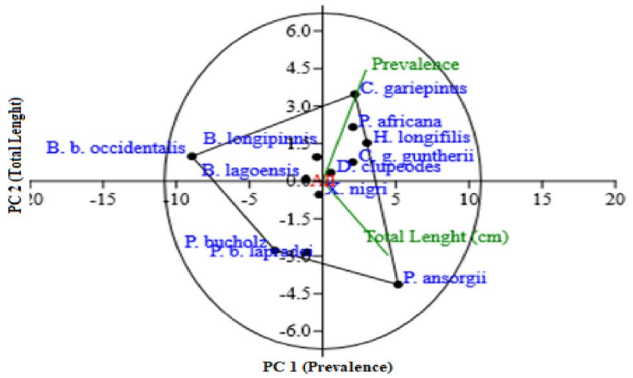

Fig. 3 PCA correlation matrix of Fish Specie Prevalence and Total Length (cm)

compared to *P. africana. F*ish total length and weight was important factor influencing prevalence as exhibited by *P. bucholz* and *P. b. lapradei* negative correlation (Fig. 3).

Specific organ prevalence of fish parasites

The intestine had the highest parasitic occurrence, with a total of 307 individual parasites (Table 3). *T. mutabillis* was the most prevalent parasite in the intestine, flesh and gills with respective 169(55.05%), 128(48.48%) and 116(51.10%) values (Table 3). The least parasitic composition in organs was *Pomphorhynchus laevis* with a total occurrence of 3 individuals in gills and intestine (Table 3). Statistically, parasite occurrence differed considerably ($p < 0.05$; $Fcal = 191.08$; $Fcrit. = 3.3$) but not ($p > 0.05$) in the host's o rgans ($F_{cal} = 9.7 \times 10–07$; $F_{crit.} = 4.10$).

Spatio-temporal prevalence of fish parasites in organs

In space and time, station 1 recorded the highest number of parasites with a value of 326 individual parasites. This was followed by station 3 with 259 individual parasites and lastly station 2 with 213 parasites (Table 4). In all three stations, the intestine was the most parasitized site. In station 1, the gills and flesh were equally (101 individual parasites) parasitized. Generally, the order of organ site parasitism is thus: intestine > flesh > gills. It is important to note that all parasites (*T. mutabillis, N. buttnerae, R. congolensis, L. thecatus, S. guntheri* and *P. laevis*) isolated in this study were present in stations 2 and 3 except for *P. laevis* which were absent in station 1 (Table 4).

Spatio-temporal composition and abundance of endo-parasites

Table 5, Figs. 4, and 5 show the relative abundance of endo-parasites found in this study. A total of 798 individual parasites were identified with stations 1, 2 and 3 having 326, 213 and 259 parasites respectively. Table 5 show the increasing relative abundance of various parasites: *T. mutabillis* 413(51.75%), *R. congolensis* 191(23.93%), *N. buttnerae* 109(113.66%), *S. guntheri* 46(5.76%), *L. thecatus* 36(4.51%), and *P. laevis* 3(0.38%).

Correlation matrix of water quality and endo-parasite abundance in ASE river

A Pearson correlation matrix was used to evaluate the link between the prevalence of parasites and water chemistry

Table 3 Composition of Fish parasites in Host Organ

Parasite identified	Phyla	Taxonomic Class	Intestine (%)	Flesh (%)	Gills (%)
Trichodina mutabillis	Ciliophora	Oligohymenophorea	169(55.05)	128(48.48)	116(51.10)
Neoechinorhynchus buttnerae	Acanthocephala	Palaeacanthocephala	35(11.40)	37(14.02)	37(16.30)
Rhabdochona congolensis	Nematoda	Chromadorea	65(21.17)	71(26.89)	55(24.23)
Leptorhynchoides thecatus	Acanthocephala	Palaeacanthocephala	15(4.89)	14(5.30)	7(3.08)
Spinitectus guntheri	Nematoda	Chromadorea	22(7.17)	12(4.55)	12(5.29)
Pomphorhynchus laevis	Acanthocephala	Palaeacanthocephala	1(0.33)	2(0.76)	0(0.00)
Total No. of Parasites			307	264	227

Table 4 Corresponding Organs Parasite load in Stations

Parasite identified	Station 1			Station 2			Station 3		
	Intestine	Flesh	Gills	Intestine	Flesh	Gills	Intestine	Flesh	Gills
T. mutabillis	64	52	50	55	32	41	50	44	25
N. buttnerae	8	14	19	10	5	2	17	18	16
R. congolensis	29	22	23	13	26	14	23	23	18
L. thecatus	8	9	3	2	3	1	5	2	3
S. guntheri	15	4	6	4	1	2	3	7	4
P. laevis	-	-	-	1	1	-	-	1	-
Total No. of Parasites	124	101	101	85	68	60	98	95	66

Table 5 Relative Abundance and Compositions of Fish Parasite (Parasite Load)

Parasite identified	Station 1 (%)	Station 2 (%)	Station 3 (%)	Total	Abundance (%)
T. mutabillis	166(50.92)	128(60.09)	119(45.95)	413	51.75
N. buttnerae	41(12.58)	17(7.98)	51(19.69)	109	13.66
R. congolensis	74(22.70)	53(24.88)	64(24.71)	191	23.93
L. thecatus	20(6.13)	6(2.82)	10(3.86)	36	4.51
S. guntheri	25(7.67)	7(3.29)	14(5.41)	46	5.76
P. laevis	0(0.00)	2(0.94)	1(0.39)	3	0.38
Total Parasites	326	213	259	798	
% Composition	40.85%	26.69%	32.46%		

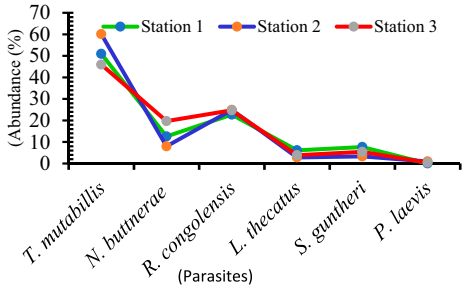

Fig. 4 Percentage (%) Abundance of Fish Endo-parasites in Ase River, Delta State

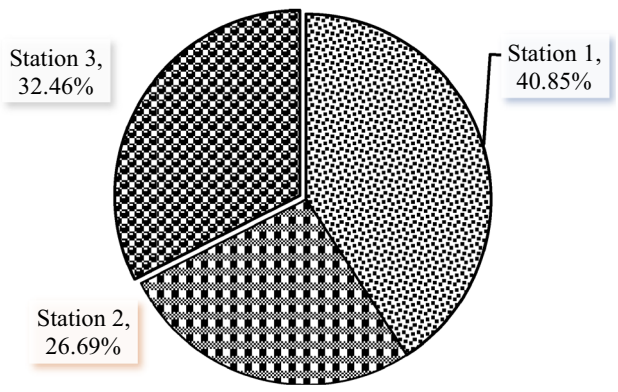

Fig. 5 Percentage (%) Composition of Fish Endo-parasites in the three (3) Sampling Stations in Ase River, Delta State

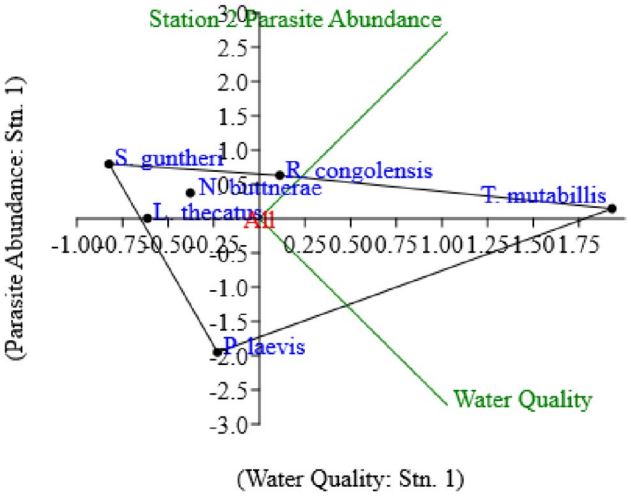

Fig. 6 PCA Correlation matrix between the station parasite prevalence and water quality characteristics at station 1

in all stations (Fig. 6, 7 and 8). Specifically, the correlation index of *T. mutabillis* and *R. congolensis* in stations 1 and 3 was positively strong (Fig. 6 and 8), with temperature, pH, DO, BOD_5, nitrate and conductivity in water ($p < 0.05$). Contrarily, *P. laevis* and *T. mutabillis* were positively correlated (Fig. 8) in station 2. However, water conditions in stations 1 and 3 had a deleterious impact on *P. laevis* along the river course. As observed in the correlation matrix, *T. mutabillis* maintained a high positive

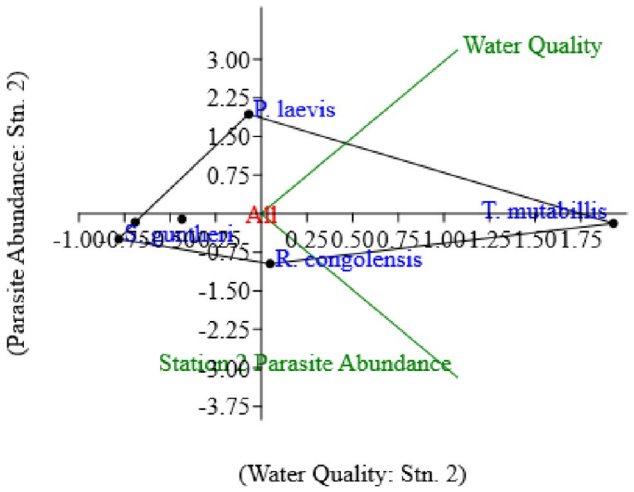

Fig. 7 PCA Correlation matrix between the station parasite prevalence and water quality characteristics at station 2

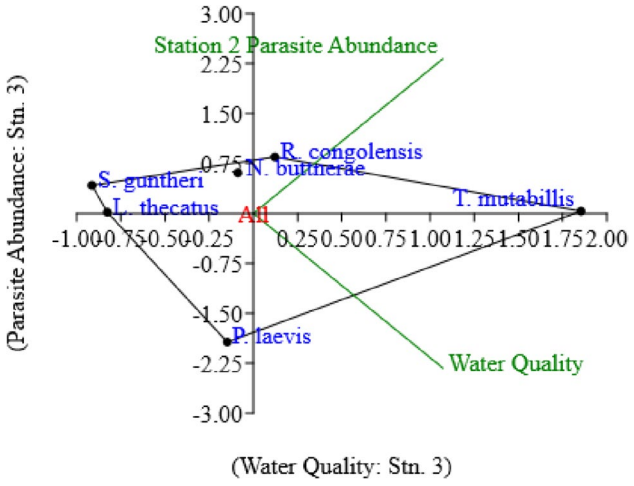

Fig. 8 PCA Correlation matrix between the station parasite prevalence and water quality characteristics at station 3

correlation with physicochemical water quality in all three stations (Figs. 6, 7 and 8).

Ecological indices of endo-parasites in ASE river

The results of this study further show that *T. mutabillis* were the most abundant parasite in station 2 (Fig. 4) while *N. buttnerae* had its highest occurrence in station 3. However, station 1 had the highest (40.85%) percentage abundance of parasites followed by stations 3 and 2 with 32.46% and 26.69% respectively (Fig. 5). Nevertheless, station 1 had only 5 parasites species out of the 6 species of parasites isolated in this study. Analysis of Variance (ANOVA) showed that there was a significant difference ($p < 0.05$) between the parasites found and but not in the stations ($p > 0.05$). The parasite species in station 3 are more diverse than in stations 1 and 2 as evident in the Shannon-Weiner's index (Station 3: H = 1.337). This study further revealed that the Shannon diversity index increased with the corresponding elevation in the species Evenness (E). The presence of *P. laevis* caused an increase in Simpson's index of diversity (1-D) in station 3 (Table 6) with a value of 0.6873 suggesting great diversity in the station. Simpson's index (D) which accounts for the probability of the same parasite species in this study showed high values in station 2 probably due to *T. mutabillis*. The Margalef's index values obtained in this study represent weak species richness (Table 6).

Subjecting the diversity indices in each station to the diversity t-test, the study showed a considerable significant difference ($p < 0.05$) in Station 1 versus 2 ($p = 0.2389$) and Station 1 versus 3 ($p = o.4417$) for the Shannon index (H). However, the Simpson index (D) was not significantly different ($p > 0.05$) for stations 1 versus 2 ($p = 0.2174$) and 2 versus. 3 ($p = 0.6514$) respectively (Table 7).

Discussion

This study documents the examinations of twelve species of fishes collected from Ase River, Southern Nigeria. Endo-parasites fauna was investigated in a total of 85 Pisces belonging to 12 genera and 12 species. Out of the 85 samples analyzed, endo-parasite infections were found in 54 (63.53%) of the samples while 31 (36.47%) were uninfected. The prevalence of 63.53% recorded in this present study was higher than the documentation of Omoniyi and Ojelade, (2017), Ito, (2017), Edeh and Solomon (2016), and Biu and Akorede (2013). This suggests that the prevalence of parasitism varies from one habitat to another and it could be due to the host-parasite relationship and abiotic factors earlier

Table 6 Ecological diversity indices of Some Fish Endo-Parasites

Diversity indices	Station 1	Station 2	Station 3
Dominance_(D)	0.3342	0.4287	0.3127
Simpson_(1-D)	0.6658	0.5713	0.6873
Shannon_(H)	1.315	1.122	1.337
Evenness_(e^H/S)	0.7452	0.512	0.6347
Brillouin	1.277	1.063	1.286
Menhinick	0.2769	0.4111	0.3728
Margalef	0.6912	0.9326	0.8998
Equitability_(J)	0.8173	0.6264	0.7463
Fisher_alpha	0.8381	1.147	1.097
Berger-Parker	0.5092	0.6009	0.4595
Chao-1	0.5092	0.6009	0.4595
Taxa_S	5	6	6
Individual species	326	213	259

Table 7 Diversity t-test

Diversity t-test	Station 1 Vs. 2		Station 1 Vs. 3		Station 2 Vs. 3	
	Station 1	Station 2	Station 1	Station 3	Station 2	Station 3
Shannon index (H):	0.24217	0.35623	0.24217	0.31045	0.35623	0.31045
Variance:	0.003212	0.0061416	0.003212	0.0046531	0.0061416	0.0046531
	t: -1.1794		t: -0.76989		t: 0.44065	
	df: 445.04		df: 564.11		df: 474.88	
	p(same):0.2389		p(same):0.4417		p(same):0.6597	
Simpson index (D):	0.92517	0.88116	0.92517	0.89872	0.88116	0.89872
Variance:	0.00039589	0.00087342	0.00039589	0.00063646	0.00087342	0.00063646
	t: 1.2352		t: 0.082302		t: -0.45199	
	df: 421.46		df: 548.06		df: 470.77	
	p(same): 0.2174		p(same): 0.0410		p(same): 0.6514	

highlighted. The parasitic composition in this study is fewer than in other studies (Abba et al. 2018; Oghenochuko et al. 2020; Afolabi et al. 2020; Onoja-Abutu et al. 2021). However, the parasite-fauna composition is higher than Omoniyi and Ojelade 2017; Nur et al. 2010). The small number of parasite compositions isolated in this study could be because the parasite fauna is influenced more decisively by physicochemical water quality, the fish species and the relatively small numbers of fish examined. The physicochemical water quality investigated was not significantly different ($p > 0.05$). This has been acknowledged by Arimoro et al., (2007) who documented significant differences in physicochemical water quality in the Ase River.

Specifically, the PCA correlation index of *T. mutabillis* and *R. congolensis* in stations 1 and 3 was strongly positive with the concentrations of water Temperature, pH, DO, BOD_5, nitrates and conductivity. *T. mutabillis* correlation was highly positive with physicochemical water quality in all three stations and it is in agreement with Acosta-Pérez et al. (2022) who reported a 0.92 correlation index. Thus, this affirms the claims that increased parasitism in aquatic biota especially fish may be promoted by pollutants (Ito et al. 2023; Oros and Hanzelova 2009). The parasite species in station 3 are more diverse than in stations 1 and 2 as evident in the Shannon-Weiner's index (H = 1.337). This study further revealed that the Shannon diversity index increased with the corresponding elevation in the species Evenness (E).

The differences in prevalence between fish species could be due to differential feeding either by quantity or quality of food eaten and as a result of different degrees of resistance to infection (Emere 2000; Biu and Akorede 2013). Similar to the findings of Aliyu and Solomon (2012), this present investigation revealed that the majority of the parasites occurred in the intestine. This study found a correlation between abundance and prevalence among fish species. The relatively high prevalence for *C. g. guntherii* may be attributed to the suitability of the fish host in the provision of appropriate ecological requirements for parasites (Lagrue et al. 2011). Similarly, the high nutritional content of the intestine may account for the presence of *R. congolensis* and its abundance (Akinsanya et al. 2008). A parasite's predilection for the intestinal area suggests mechanical strain which could lead to inflammation, connective tissue deformation, and host tissue rupture (Ito and Egwunyenga 2017). These pathologic consequences could cause the fish's nutritional values to decline as a result of the parasites' activity.

Most fish species are bottom dwellers/feeders, feeding primarily on aquatic insects which serve as intermediate hosts to various parasites (Ito 2017; Ito and Ugbomeh 2017; Aliyu and Solomon 2012). This might be the reason for the high prevalence of 87.50, 77.78 and 72.72% observed in *P. africana, C. gariepinus,* and *H. longifilis* respectively. Based on the number and type of nematode parasites identified in this study, it seems that the intermediate host *Mesocyclops* (a copepod) in the instance of *T. mutabillis* is abundant in the Ase River. *T. mutabillis* which was found to parasitize *C. g. guntheri* had been recorded in *O. niloticus* and *Clupisudis niloticus* in fish species from semi-arid reservoirs in Burkina Faso (Sinaré et al. 2016). *Bubulcus ibis* (cattle egrets) are the definitive host of most parasites and were found in abundance within the study locations in the Ase River banks. These egrets could serve as potential reservoir/transport hosts for these fishes, since egrets also feed on fish, amphibians and small reptiles. This is further affirmed by Purivirojkul and Sumontha (2013) who stated that heavy parasitic infections occur in areas with large populations of fish-eating birds which act as definitive hosts.

Ase River is characterized by the presence of ostracods (*Cypridopsis vidua*). *C. vidua* has been implicated by Lourenço et al., (2018) to be the intermediate host of *N. buttnerae*. *P. laevis* was the least encountered parasite in this study. This low prevalence might be due to the biomass density of the fish hosts as earlier reported by Perrot-Minnor et al., (2020). Nevertheless, *P. laevis* infection has

no noticeable effect on fish morphometric indices. *P. laevis* tended to accumulate with fish species' size, age, sex, and biomass density, with what appeared to be minor constraints caused by the parasite's intra-host intensity-dependent control or fish morbidity caused by the parasite. However, *N. buttnerae* and *P. laevis* have shown the highest abundance in the Warri River, Delta State (Ejere et al. 2014). This suggests that the main predictor of *P. laevis* distribution in the stations was the availability of resources, such as fish host biomass density. Thus, the relative accessibility of final hosts appears to have the greatest impact on the prevalence of *P. laevis* among fish. The body conformation index was a significant factor influencing the prevalence of fish parasites in the Ase River. The correlation matrix of the *C. gariepinus, H. longifilis, P. Africana*, *C. g. guntherii* and *D. clupeodes* prevalence with a total weight of fish species was positively correlated as observed in PCA, Pearson correlation. Similarly, *C. gariepinus* presented a strong positive correlation with the fish's total length. Fish body mass conformations as revealed in this research are significant determinants influencing parasite prevalence. These correlation assertions are in tandem with Olagbemide and Owolabi, (2022), whose studies witnessed a significant ($p < 0.05$) association between parasite prevalence with body weight and length of *O. niloticus* in Nigeria.

Conclusion and recommendation

A parasitic prevalence of 63.53% from 85 fish in 12 taxa is high. It is, therefore, necessary for Ase coast-line communities to desist from anthropogenic activities that may likely change the water quality, given the positive correlation between parasites and physicochemical parameters. Parasites isolated in this present study are not zoonotic but are capable of rupturing the host (fish) tissues which may initiate secondary bacterial infections that may cause serious complications in immuno-compromised persons and pregnant women.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. The results presented in this manuscript are original data obtained from the Ase River, Delta State, Nigeria and have not been presented for publication elsewhere.

Ethical approval Ethical clearance was obtained from the ethical review board, Faculty of Science, Delta State University, Abraka with reference number REC/FOS/2021/8.

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