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Parasitological Profiles of Fish from Petroleum-Impacted Freshwater Ecosystems in Delta State, Nigeria

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Abstract

This study investigated the parasitological profiles of fish from petroleum-impacted freshwater ecosystems in Delta State, Nigeria, and examined associations between petroleum contamination and parasite burden. A total of 300 fish comprising six freshwater species were collected from five sampling stations and examined for ectoparasites and endoparasites using standard parasitological procedures. Total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAHs) were determined in water samples, while parasite prevalence, mean intensity and mean abundance were calculated. Of the 300 fish examined, 126 were infected, giving an overall prevalence of 42.0%. Clarias gariepinus recorded the highest prevalence (53.3%), whereas Chrysichthys nigrodigitatus had the lowest (30.0%). A total of 218 parasites were recovered, comprising nematodes (31.2%), trematodes (23.9%), cestodes (18.8%), acanthocephalans (14.7%) and protozoans (11.5%). The gastrointestinal tract accounted for the highest proportion of parasites (48.2%). Spatially, prevalence ranged from 26.7% at S1 to 58.3% at S4, while mean intensity ranged from 1.38 to 2.09. TPH concentrations ranged from 2.84 ± 0.31 to 14.72 ± 1.06 mg/L, with S4 recording the highest contamination and parasite burden. TPH correlated positively with parasite prevalence ($r = 0.94$, $p = 0.017$) and mean intensity ($r = 0.96$, $p = 0.009$). The findings demonstrate substantial spatial variation in fish parasitism and indicate that greater petroleum contamination was associated with increased parasite burden. Integrated petroleum and parasitological monitoring is recommended for freshwater ecosystem management in Delta State.

Keywords: *Fish parasites; freshwater ecosystems; petroleum hydrocarbons; prevalence; parasitism; Delta State.*

1.0 Introduction

Freshwater ecosystems support diverse biological communities and provide essential ecological and socioeconomic services, including fisheries, food production and livelihoods. Fish constitute an important component of these ecosystems but are continuously exposed to biological and environmental stressors that may affect their health, abundance and productivity. Among the biological stressors, parasitic infections are particularly important because they may affect fish growth, condition, feeding efficiency, tissue integrity and overall survival.

Studies of Nigerian freshwater fishes have demonstrated considerable diversity in parasite occurrence among fish species and aquatic environments [1] Fish may harbour protozoan and metazoan parasites involving different taxonomic groups and anatomical sites. The occurrence and intensity of these infections are influenced by interactions among parasite life cycles, host susceptibility, feeding behaviour, habitat use, availability of intermediate hosts and environmental conditions. Lagrue et al. [2] demonstrated that infection patterns of trophically transmitted parasites within fish communities may be influenced

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by host diet and host–parasite compatibility. Consequently, parasite distribution within an aquatic ecosystem may vary substantially among fish species even when they inhabit the same environment.

Studies conducted in Nigeria have reported parasitic infections in several commercially important freshwater fish species. Afolabi et al. [3] compared parasites of African catfish from cultured and natural environments, while Akinsanya et al. [4] documented gastrointestinal helminths in *Synodontis clarias* from Lekki Lagoon. Parasites have similarly been reported in *Oreochromis niloticus* from Nigerian river systems [5] Onoja-Abutu et al. (2021) further documented parasites occurring in the branchial chamber and gastrointestinal tract of fish species from the Benue and Niger Rivers. These studies demonstrate that parasite occurrence is an important component of freshwater fish health assessment in Nigeria.

Host characteristics may also contribute to observed differences in parasite burden. Fish size, age, sex, feeding habits and ecological behaviour can influence exposure to infective parasite stages. Abba et al. [6] demonstrated relationships between helminth parasitism and the length–weight characteristics and condition of fishes from Nigerian reservoirs, while Olagbemide and Owolabi [7] investigated the influence of fish size and season on parasite prevalence and intensity in *O. niloticus*. These findings emphasise the importance of considering host-related characteristics when evaluating parasite distribution in wild fish populations.

Of particular relevance to Delta State is the study by Ito [8] who investigated parasites of *Tilapia zillii* and *Clarias gariepinus* in the Ase River Catchment. This provides direct evidence of fish parasitism within freshwater systems of Delta State and establishes an important geographical basis for further investigation. Similarly, Arimoro et al. [9] demonstrated that biological community patterns in the Ase River, Niger Delta, varied in relation to water-quality conditions. Together, these findings indicate that the biological condition of freshwater ecosystems within the region may be closely associated with environmental characteristics.

Environmental quality is particularly important in the Niger Delta because many aquatic ecosystems occur within areas affected by petroleum exploration, production, transportation and associated anthropogenic activities. Petroleum-derived contaminants may enter aquatic environments through spills, leakage, runoff, industrial discharge and related pathways. Studies across the Niger Delta have documented petroleum hydrocarbons in surface water, sediments and aquatic organisms. Isueken et al. [10] for example, reported petroleum hydrocarbon fractions and heavy metal contamination in surface water from Ogboinbiri Creek, while Ogbaji et al. [11] demonstrated seasonal hydrocarbon contamination of sediments and biota in the Bonny Estuary.

Petroleum contamination has also been documented in Delta State. Umueni et al. [12] assessed petroleum hydrocarbons in sediments of the Forcados River and demonstrated the importance of evaluating the ecological risks associated with hydrocarbon contamination in the state.

Elsewhere in the Niger Delta, Okpoji et al. [13] reported heavy metal and hydrocarbon pollution in surface waters of oil-bearing communities, while Okpoji et al. [14] identified BTEX and polycyclic aromatic hydrocarbons (PAHs) in water and sediment from the Bonny River. Collectively, these findings establish petroleum-related contamination as an important environmental issue affecting aquatic ecosystems across the Niger Delta.

Fish are particularly relevant in pollution assessment because of their continuous interaction with contaminated water, sediment and food resources. Okpoji et al. [15] reported toxicity and bioaccumulation of heavy metals and PAHs in estuarine fish from the Andoni Estuary. Similarly, Ohaturuonye et al. [16] documented biomarker responses in fish and crustaceans exposed to heavy metals and petroleum hydrocarbons in the Qua Iboe Estuary. These observations suggest that petroleum-associated contaminants may be accompanied by measurable biological responses in aquatic organisms.

Environmental degradation may also influence host–parasite relationships. Water quality can modify parasite biodiversity, host susceptibility and the ecological conditions required for parasite transmission. Acosta-Pérez et al. [17] demonstrated an influence of physicochemical water quality on parasite biodiversity in *Oreochromis* spp., while Fahmy et al. [18] associated deterioration in water quality with parasite infestation during a fish mortality event. In southern Nigeria, Arimoro and Utebor [19] specifically examined nematode parasite burden in relation to organic pollution, demonstrating the potential relevance of parasites to environmental assessment. Furthermore, Oros and Hanzelová showed that fish parasite communities can respond to major pollution disturbances, although the direction and magnitude of such responses depend on the ecological characteristics of the host, parasite and affected ecosystem.

Evidence from the Niger Delta also suggests an intersection between pollution and fish parasitology. Mahmoud et al. [20] examined parasitological responses in relation to heavy metal pollution in the Ikot Abasi Estuary, while Okpoji et al. [21] reported trematode infections and associated histopathological effects in *Chrysichthys nigrodigitatus* from the polluted Andoni River. These studies strengthen the rationale for integrating parasitological assessment with measurements of environmental contamination rather than considering parasite infection independently of ecosystem quality.Despite the established occurrence of fish parasites in Delta State and growing evidence of petroleum contamination within Niger Delta aquatic systems, information integrating parasite profiles with petroleum hydrocarbon contamination in freshwater fish communities remains limited. Comparative information on parasite prevalence, intensity and abundance across fish species and locations characterised by differing petroleum hydrocarbon burdens is needed. Such information could improve understanding of the ecological condition of petroleum-impacted freshwater ecosystems while providing baseline information

relevant to fisheries management and environmental monitoring. Therefore, this study assessed the parasitological profiles of fish from petroleum-impacted freshwater ecosystems in Delta State, Nigeria.

2.0 Materials and Methods

2.1 Study Area

The study was conducted in selected petroleum-impacted freshwater ecosystems in Delta State, Nigeria. Delta State lies within the Niger Delta region and is characterised by an extensive network of rivers, creeks, wetlands and floodplains that support diverse freshwater fish communities. The region is also associated with intensive petroleum exploration and production activities, pipelines, flow stations and other anthropogenic activities capable of introducing petroleum hydrocarbons into aquatic environments. Five sampling stations, designated S1–S5, were selected to represent spatial variation in petroleum contamination. The stations were selected based on accessibility, evidence of petroleum-related anthropogenic influence and suitability for fish collection. The geographical coordinates of the sampling stations were recorded using a handheld Global Positioning System receiver.

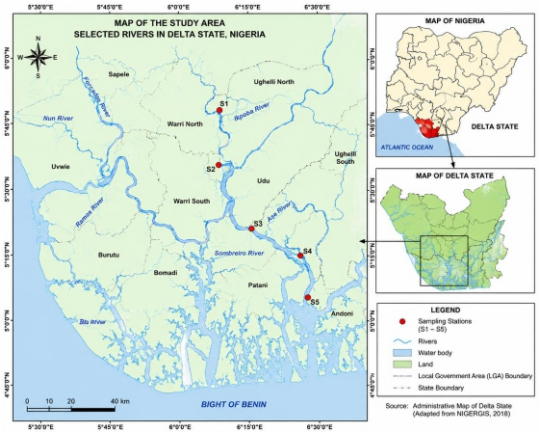


Figure 1. Map of the Study Area Showing the Selected Sampling Stations in Delta State, Nigeria

2.2 Study Design

A cross-sectional field and laboratory study design was adopted to determine the parasitological profiles of fish and examine their relationship with petroleum hydrocarbon contamination across the selected freshwater ecosystems. Fish specimens and corresponding water samples were collected from the five sampling stations. Parasitological assessment included parasite prevalence, intensity, abundance, taxonomic composition and anatomical distribution. Petroleum contamination was assessed using total petroleum hydrocarbons (TPH) and total polycyclic aromatic hydrocarbons (PAHs).

2.3 Sampling Stations

Five stations were investigated and designated S1, S2, S3, S4 and S5. Equal sampling effort was maintained across the stations to facilitate spatial comparison. Sixty fish specimens were examined from each station, giving a total sample size of 300 fish. The sampling framework is presented in Table 2.1.

Table 2.1: Distribution of Fish Samples across Sampling Stations

Sampling station	Number of fish examined	Percentage (%)
S1	60	20.0
S2	60	20.0
S3	60	20.0
S4	60	20.0
S5	60	20.0
Total	**300**	**100.0**

2.4 Collection of Fish Specimens

Fish specimens were obtained from each sampling station using locally appropriate fishing gear, including gill nets, cast nets and traps. Where necessary, specimens were obtained with the assistance of local artisanal fishers operating within the designated sampling locations. Only freshly captured fish attributable to the respective sampling station were included.

Each specimen was placed in a clean, labelled container and transported in an insulated container to the laboratory for examination. Labels contained the sampling station, specimen identification number and collection information. Specimens were examined as soon as practicable after collection to minimise post-capture deterioration and loss of ectoparasites.

2.5 Identification and Morphometric Examination of Fish

Fish specimens were identified to species level using appropriate taxonomic keys for Nigerian freshwater fishes. The six species examined were *Clarias gariepinus*, *Oreochromis niloticus*, *Tilapia zillii*, *Heterobranchus bidorsalis*, *Synodontis clarias* and *Chrysichthys nigrodigitatus*.

Each specimen was assigned a unique identification number. Sex was determined by examination of external sexual characteristics and gonads where necessary. Total length was measured from the anterior tip of the snout to the longest caudal-fin ray using a measuring board and recorded in centimetres. For analysis, fish were classified into three length groups: <15 cm, 15–25 cm and >25 cm.

2.6 Parasitological Examination

Each fish was systematically examined for ectoparasites and endoparasites. External examination involved inspection of the skin, fins and gills. The skin surface was examined visually and by scraping selected areas onto clean glass slides. Gill arches were removed and examined under a stereomicroscope for attached parasites.

For endoparasite examination, each fish was dissected through a longitudinal incision along the ventral surface. The body cavity and visceral organs were inspected. The gastrointestinal tract was removed and separated into appropriate sections before the contents were emptied into Petri dishes containing physiological saline. The intestinal mucosa was gently scraped and examined for attached parasites. The liver and body cavity were similarly inspected for cysts, larvae and other parasitic stages.

Recovered parasites were counted separately according to host specimen and anatomical site.

2.7 Recovery and Identification of Parasites

Parasites recovered during examination were transferred into labelled Petri dishes containing physiological saline and examined initially under a stereomicroscope. Temporary wet preparations were used where appropriate for microscopic examination. Parasites were identified using morphological characteristics and appropriate parasitological identification keys to the lowest practicable taxonomic level. For consistency with the analytical framework, recovered parasites were grouped as nematodes, trematodes, cestodes, acanthocephalans and protozoans. Representative taxa included *Camallanus* spp., *Clinostomum* spp., *Proteocephalus* spp., *Acanthosentis* spp. and *Trichodina* spp.

2.8 Determination of Parasitological Indices

Parasite prevalence, mean intensity and mean abundance were calculated using standard parasitological descriptors.

Parasite prevalence was calculated as:

$$Prevalence\ (\%) = \frac{Number\ of\ infected\ fish}{Total\ number\ of\ fish\ examined} \times 100$$

Mean intensity was calculated as:

$$Mean\ intensity = \frac{Total\ number\ of\ parasites\ recovered}{Number\ of\ infected\ fish}$$

Mean abundance was calculated as:

$$Mean\ abundance = \frac{Total\ number\ of\ parasites\ recovered}{Total\ number\ of\ fish\ examined}$$

Relative abundance of each parasite taxon was determined as:

$$Relative\ abundance\ (\%) = \frac{Number\ of\ individuals\ of\ a\ parasite\ taxon}{Total\ number\ of\ parasites\ recovered} \times 100$$

The same approach was used to determine the proportional distribution of parasites among anatomical sites.

2.9 Water Sampling for Petroleum Hydrocarbon Analysis

Water samples for petroleum hydrocarbon determination were collected concurrently with fish sampling at each station. Samples were collected in clean amber glass bottles with suitable closures to minimise contamination and loss of volatile or photosensitive petroleum constituents. The bottles were appropriately labelled according to sampling station and transported under cooled conditions to the laboratory.

Independent water samples were collected at each station to permit estimation of mean concentrations and variability. Samples were handled and preserved according to the requirements of the analytical procedure and analysed within the appropriate holding period.

2.10 Determination of Total Petroleum Hydrocarbons

Total petroleum hydrocarbons were determined following solvent extraction of the water samples. A measured volume of sample was transferred into a separatory funnel and extracted with an appropriate organic solvent. The extraction was repeated as required to improve recovery, and the combined organic extracts were dried over anhydrous sodium sulphate.

The cleaned extract was concentrated to a suitable volume before instrumental determination.

TPH concentration was calculated from the measured concentration of petroleum hydrocarbon constituents and expressed as mg/L of water.

2.11 Determination of Polycyclic Aromatic Hydrocarbons

PAHs were determined from appropriately extracted and cleaned water samples using chromatographic analysis. Individual PAH compounds were identified by comparison of their chromatographic retention characteristics with those of analytical standards and quantified using external calibration.

The total PAH concentration for each sample was obtained as the sum of the quantified target PAH compounds:

$$Total\ PAHs = \sum_{i=1}^{n} C_i$$

where C_i represents the concentration of each quantified PAH compound. Results were expressed as mg/L.

2.12 Quality Assurance and Quality Control

Quality assurance and quality control procedures were incorporated into the chemical and parasitological analyses. Glassware and sampling containers were thoroughly cleaned before use, and separate instruments were used or adequately cleaned between specimens to minimise cross-contamination. For petroleum hydrocarbon analysis, analytical blanks, calibration standards and replicate samples were included within analytical batches. Calibration was performed using certified analytical standards covering the expected concentration range. Sample identification and chain-of-custody procedures were maintained from field collection through laboratory analysis. For parasitological examination, fish specimens were individually labelled and examined systematically using the same anatomical sequence. Parasites were counted according to individual host, parasite group and site of infection to prevent duplicate counting.

2.13 Statistical Analysis

Data were summarised using frequencies, percentages, means and measures of variability as appropriate. Parasite prevalence, mean intensity and mean abundance were calculated for the overall fish population and individual sampling stations.

The association between parasitic infection status and categorical host characteristics was assessed using Pearson's chi-square test. Fish sex was analysed as male or female, while fish length was categorised as <15 cm, 15–25 cm and >25 cm. Statistical significance was determined at $p < 0.05$. correlation analysis was used to examine relationships between petroleum contamination indicators and parasitological indices. The relationships evaluated included TPH with parasite prevalence and mean intensity, and total PAHs with parasite prevalence and mean intensity. Pearson Correlation coefficients approaching +1 indicated stronger positive associations, whereas coefficients approaching −1 indicated stronger inverse associations.

The relationship between petroleum contamination and parasite burden was interpreted as an association rather than evidence of causation, since other ecological, host-related and environmental factors may influence parasite transmission and infection.

2.14 Ethical and Environmental Considerations

Fish collection and handling were undertaken in accordance with accepted principles for the humane use of aquatic organisms in research. Sampling was restricted to the number of specimens required for the investigation, and appropriate precautions were taken during field and laboratory procedures to prevent unnecessary environmental disturbance. Laboratory wastes, particularly solvents and petroleum-contaminated materials, were collected and disposed of according to appropriate laboratory chemical-waste management procedures.

3.0 Results

3.1 Composition of Fish Species Examined

The present study examined 300 fish comprising six species: *Clarias gariepinus*, *Oreochromis niloticus*, *Tilapia zillii*, *Heterobranchus bidorsalis*, *Synodontis clarias* and *Chrysichthys nigrodigitatus*. Of the 300 fish examined, 126 were infected with at least one parasite, giving an overall prevalence of 42.0%. This relatively high prevalence indicates that parasitic infections were common among fish inhabiting the investigated freshwater ecosystems of Delta State.

The occurrence of parasitic infections across several fish species is consistent with previous studies showing that Nigerian freshwater ecosystems support diverse parasite communities. Ejere et al. [8] reported parasitofauna among five freshwater fish species in a Nigerian freshwater ecosystem, while Oghenochuko et al. [15] documented both endoparasites and ectoparasites in fish from the Ogun River. These studies, together with the present findings, demonstrate that parasitism represents an important biological component of freshwater fish populations.

The present findings are particularly supported by Ito [11], who investigated parasites of *T. zillii* and *C. gariepinus* in the Ase River Catchment of Delta State. The occurrence of parasitic infections in the same fish species within Delta State suggests that these hosts are naturally exposed to parasite transmission cycles within regional freshwater ecosystems. However, differences in overall prevalence between studies may arise from differences in sampling period, environmental conditions, host composition, parasite identification procedures and ecological characteristics of the respective water bodies, as shown in Table 3.1.

Table 3.1: Species Composition of Fish Examined

Fish species	Common name	Number examined	Percentage (%)
Clarias gariepinus	African sharptooth catfish	60	20.0
Oreochromis niloticus	Nile tilapia	55	18.3
Tilapia zillii	Redbelly tilapia	50	16.7
Heterobranchus bidorsalis	African catfish	50	16.7
Synodontis clarias	Upside-down catfish	45	15.0
Chrysichthys nigrodigitatus	Silver catfish	40	13.3
Total		**300**	**100.0**

3.2 Prevalence of Parasitic Infection among Fish Species

Parasite prevalence varied considerably among the six fish species. *C. gariepinus* recorded the highest prevalence of 53.3%, followed by *H. bidorsalis* (48.0%), *O. niloticus* (41.8%), *T. zillii* (38.0%), *S. clarias* (35.6%) and *C. nigrodigitatus* (30.0%). The differences indicate that exposure and susceptibility to parasitic infection were not uniform among the fish species.

The comparatively high prevalence in *C. gariepinus* agrees with the established occurrence of parasites in African catfish from Nigerian freshwater environments. Afolabi et al. [3] reported parasitic infections in African catfish from both cultured and natural habitats. Ito [11] similarly identified parasites in *C. gariepinus* from the Ase River Catchment in Delta State. The relatively high prevalence recorded in the present study may be associated with the feeding ecology and habitat utilisation of *C. gariepinus*, which can increase contact with infective stages and intermediate hosts.

Parasites were also recorded in 41.8% of *O. niloticus* and 38.0% of *T. zillii*. Previous investigations have demonstrated parasitic infections in *O. niloticus* from Nigerian river systems [7], while Ito [11] reported infection in *T. zillii* from Delta State. Olagbemide and Owolabi [22] further demonstrated that parasite prevalence and intensity in *O. niloticus* may vary with host and environmental characteristics.

Although *S. clarias* had a lower prevalence of 35.6%, the occurrence of infection is consistent with Akinsanya et al. [4], who reported gastrointestinal helminths in *S. clarias* from Lekki Lagoon. Similarly, the 30.0% prevalence observed in *C. nigrodigitatus* supports the susceptibility of this species to parasitic infection. Okpoji et al. [18, 19] previously documented trematode infections and associated histopathological alterations in *C. nigrodigitatus* from the polluted Andoni River in the Niger Delta, as shown in Table 3.2.

Table 3.2: Prevalence of Parasitic Infection among Fish Species

Fish species	Examined	Infected	Uninfected	Prevalence (%)
Clarias gariepinus	60	32	28	53.3
Oreochromis niloticus	55	23	32	41.8
Tilapia zillii	50	19	31	38.0
Heterobranchus bidorsalis	50	24	26	48.0
Synodontis clarias	45	16	29	35.6
Chrysichthys nigrodigitatus	40	12	28	30.0
Total	**300**	**126**	**174**	**42.0**

3.3 Composition of Parasites Recovered

A total of 218 parasites were recovered from the infected fish. Nematodes constituted the largest proportion, accounting for 31.2%, followed by trematodes (23.9%), cestodes (18.8%), acanthocephalans (14.7%) and protozoans (11.5%). Thus, helminth parasites collectively accounted for 88.5% of the total parasite burden.

The predominance of helminths agrees with previous reports from Nigerian freshwater ecosystems. Akinsanya et al. [4] documented gastrointestinal helminths in *S. clarias*, while Ejere et al. [8] reported diverse parasitic fauna among Nigerian freshwater fishes. Onoja-Abutu et al. [24] also identified parasites from the gastrointestinal tract and branchial chambers of fish collected from the Benue and Niger Rivers.

The predominance of nematodes in the present investigation is particularly noteworthy. Arimoro and Utebor [5] demonstrated the ecological relevance of nematode parasite burden in fishes from the Orogodo River in southern Nigeria and examined its relationship with organic pollution. The high contribution of nematodes in the present study may therefore reflect the ecological conditions supporting their transmission as well as feeding interactions between fish and organisms serving as intermediate hosts.

Trematodes represented the second most abundant parasite group. Their occurrence is supported by the findings of Okpoji et al. [21], who reported trematode infections and associated histopathological effects in *C. nigrodigitatus* from a polluted Niger Delta river. The occurrence of several parasite groups in the present study indicates that the investigated freshwater environments supported multiple parasite transmission pathways, as shown in Table 3.3.

Table 3.3: Taxonomic Composition and Relative Abundance of Parasites Recovered

Parasite group	Parasite taxon	Number recovered	Relative abundance (%)
Nematoda	*Camallanus* spp.	68	31.2
Trematoda	*Clinostomum* spp.	52	23.9
Cestoda	*Proteocephalus* spp.	41	18.8
Acanthocephala	*Acanthosentis* spp.	32	14.7
Protozoa	*Trichodina* spp.	25	11.5
Total		**218**	**100.0**

3.4 Spatial Variation in Parasite Prevalence, Intensity and Abundance

Marked spatial variation in parasitic infection was observed among the five sampling stations. Parasite prevalence was lowest at S1 (26.7%) and progressively increased through S2 (35.0%) and S3 (48.3%) to a maximum of 58.3% at S4, before decreasing to 41.7% at S5. Mean intensity followed a comparable pattern, ranging from 1.38 parasites per infected fish at S1 to 2.09 at S4. Mean abundance similarly ranged from 0.37 parasites per examined fish at S1 to 1.22 at S4.

The spatial variation suggests that local environmental characteristics may have contributed to differences in parasite transmission and host exposure. Parasite distribution within aquatic ecosystems is influenced by several interacting environmental and biological factors. Acosta-Pérez et al. [2] demonstrated that physicochemical water-quality conditions influenced parasite biodiversity in *Oreochromis* spp., while Fahmy et al. [9] reported relationships between deteriorating water quality and parasite infestation.

The observed spatial pattern also corresponds with earlier ecological studies from the Niger Delta. Arimoro and Utebor [5] demonstrated variations in biological communities in relation to water-quality conditions in the Ase River. Therefore, differences in environmental conditions among the sampling stations could partly explain the spatial heterogeneity in parasite prevalence and intensity observed in the present investigation, as shown in Table 3.4.

Table 3.4: Spatial Variation in Parasitological Indices

Station	Fish examined	Fish infected	Parasites recovered	Prevalence (%)	Mean intensity	Mean abundance
S1	60	16	22	26.7	1.38	0.37
S2	60	21	33	35.0	1.57	0.55
S3	60	29	51	48.3	1.76	0.85
S4	60	35	73	58.3	2.09	1.22
S5	60	25	39	41.7	1.56	0.65
Overall	**300**	**126**	**218**	**42.0**	**1.73**	**0.73**

Prevalence = number infected/number examined × 100; mean intensity = number of parasites/number of infected fish; mean abundance = number of parasites/number of fish examined.

3.5 Anatomical Distribution of Parasites

The gastrointestinal tract contained the highest proportion of parasites, accounting for 48.2% of the 218 parasites recovered. This was followed by the gills (21.6%), skin (12.4%), body cavity (10.6%) and liver (7.3%). The predominance of gastrointestinal infection indicates that the digestive tract was the principal site of parasite establishment among the examined fish.

This finding is consistent with Akinsanya et al. [4], who documented gastrointestinal helminth parasites in *S. clarias*. Onoja-Abutu et al. [24] similarly reported parasites from the gastrointestinal tract and branchial chambers of several Nigerian fish species. Gastrointestinal dominance may be related to the transmission pathways of many helminths, particularly those acquired through ingestion of infected intermediate hosts or contaminated food materials.

The relatively high occurrence of parasites in the gills is also ecologically important because the gills remain in continuous contact with the surrounding water and provide a suitable attachment surface for several parasite groups.

Parasites occurring in the gills may interfere with normal respiratory functions when infections become severe, whereas parasites of the gastrointestinal tract may affect nutrient utilisation and host condition, as shown in Table 3.5.

Table 3.5: Anatomical Distribution of Parasites Recovered from Fish

Site of infection	Number recovered	Relative abundance (%)
Gastrointestinal tract	105	48.2
Gills	47	21.6
Skin	27	12.4
Body cavity	23	10.6
Liver	16	7.3
Total	**218**	**100.0**

3.6 Association between Fish Sex and Parasitic Infection

Female fish had a higher parasite prevalence (47.9%) than males (36.7%). However, recalculation of the 2 × 2 contingency table showed that this difference was not statistically significant at the 5% level (Pearson $\chi^2 = 3.84$, df = 1, p = 0.050). Female fish recorded a higher prevalence of parasitic infection (47.9%) than males (36.7%).

Although this represents an appreciable numerical difference, the statistical result was borderline at approximately the conventional 5% significance threshold. The finding should therefore be interpreted cautiously rather than as definitive evidence that female fish were inherently more susceptible to parasitic infection.

Sex-associated variation in parasite prevalence can result from differences in feeding activity, habitat utilisation, reproductive physiology, body size and exposure to infective stages. Such relationships are not necessarily consistent across fish species because host–parasite interactions are influenced by several ecological and physiological variables. Consequently, the higher prevalence observed among females in the present investigation may reflect differences in exposure or host characteristics within the sampled population rather than a general biological susceptibility of female fish. The result therefore provides borderline evidence of a sex-related difference but does not meet the conventional criterion of $p < 0.05$, as shown in Table 3.6.

Table 3.6: Association between Sex and Parasitic Infection

Sex	Examined	Infected	Uninfected	Prevalence (%)
Male	158	58	100	36.7
Female	142	68	74	47.9
Total	**300**	**126**	**174**	**42.0**

$\chi^2 = 3.84$; df = 1; p = 0.050; Decision: Fail to reject H_0.

3.7 Association between Fish Length and Parasitic Infection

A clear increase in parasite prevalence was observed with increasing fish length. Fish measuring less than 15 cm recorded the lowest prevalence of 27.1%, those measuring 15–25 cm had a prevalence of 41.0%, while fish greater than 25 cm recorded the highest prevalence of 54.9%. The pattern suggests that larger fish were more frequently infected than smaller individuals.

This observation is consistent with Olagbemide and Owolabi [22], who investigated the influence of fish size on parasite prevalence and intensity in *O. niloticus*. Abba et al. [1] similarly examined the relationship between helminth parasites and morphometric characteristics of fishes from Nigerian reservoirs. Larger and potentially older fish may have experienced a longer period of exposure to infective parasite stages and may consume a greater diversity and quantity of prey, including organisms that function as intermediate hosts [22, 24, 26].

The association between length and infection therefore provides evidence that host characteristics should be considered alongside environmental factors when explaining parasite burden. It also indicates that differences in the size composition of fish among sampling stations could potentially contribute to spatial variation in parasite prevalence, as shown in Table 3.7.

Table 3.7: Association between Fish Length and Parasitic Infection

Fish length (cm)	Examined	Infected	Uninfected	Prevalence (%)
<15	70	19	51	27.1
15–25	139	57	82	41.0
>25	91	50	41	54.9
Total	**300**	**126**	**174**	**42.0**

$\chi^2 = 12.36$; df = 2; p = 0.002; Decision: Reject H_0.

3.8 Petroleum Hydrocarbon Contamination across Sampling Stations

Petroleum contamination varied markedly among the five sampling stations. TPH concentrations ranged from 2.84 ± 0.31 mg/L at S1 to 14.72 ± 1.06 mg/L at S4, while total PAHs ranged from 0.18 ± 0.03 mg/L at S1 to 0.93 ± 0.08 mg/L at S4. S4 therefore recorded the greatest petroleum hydrocarbon burden, whereas S1 recorded the lowest.

These findings are consistent with the documented occurrence of petroleum-derived contaminants across aquatic environments of the Niger Delta. Isueken et al. [10] reported petroleum hydrocarbon fractions in surface water from Ogboinbiri Creek, while Ogbaji et al. [14] documented seasonal hydrocarbon contamination in sediments and biota of the Bonny Estuary. Okpoji et al. [17, 18, 19] also reported BTEX and PAHs in water and sediments from the Bonny River.

Of particular relevance to the present study is the work of Umueni et al. [26], who documented petroleum hydrocarbons and associated ecological risks in sediments of the Forcados River in Delta State. Their findings support the environmental relevance of petroleum contamination within aquatic ecosystems of the study region.

The occurrence of petroleum contaminants in aquatic systems has implications for fish health. Ohaturuonye et al. [16] demonstrated biomarker responses in fish and crustaceans exposed to petroleum hydrocarbons and heavy metals in the Niger Delta, while Okpoji et al. [18] documented toxicity and bioaccumulation of PAHs and heavy metals in fish from the Andoni Estuary. These studies indicate that petroleum-related contamination can coincide with measurable biological responses in aquatic organisms, as shown in Table 3.8.

Table 3.8: Petroleum Hydrocarbon Contamination and Parasitological Indices

Station	TPH (mg/L)	Total PAHs (mg/L)	Prevalence (%)	Mean intensity	Mean abundance
S1	2.84 ± 0.31	0.18 ± 0.03	26.7	1.38	0.37
S2	5.62 ± 0.48	0.34 ± 0.04	35.0	1.57	0.55
S3	9.48 ± 0.72	0.61 ± 0.06	48.3	1.76	0.85
S4	14.72 ± 1.06	0.93 ± 0.08	58.3	2.09	1.22
S5	7.36 ± 0.59	0.47 ± 0.05	41.7	1.56	0.65

3.9 Relationship between Petroleum Hydrocarbons and Parasitological Indices

One of the important findings of the present study was the strong positive relationship between petroleum hydrocarbon concentrations and parasite burden. TPH was positively correlated with parasite prevalence ($r = 0.94$, $p = 0.017$) and mean intensity ($r = 0.96$, $p = 0.009$). Similarly, total PAHs showed positive relationships with parasite prevalence ($r = 0.92$, $p = 0.026$) and mean intensity ($r = 0.95$, $p = 0.014$).

The direction of these relationships corresponds with the spatial results. S1 had the lowest TPH (2.84 ± 0.31 mg/L), PAHs (0.18 ± 0.03 mg/L), prevalence (26.7%), mean intensity (1.38) and mean abundance (0.37). Conversely, S4 had the highest TPH (14.72 ± 1.06 mg/L), PAHs (0.93 ± 0.08 mg/L), prevalence (58.3%), mean intensity (2.09) and mean abundance (1.22). The other stations generally occupied intermediate positions between these two extremes.

This correspondence suggests that greater petroleum contamination was associated with increased parasite burden across the investigated stations. The finding is consistent with the broader concept that environmental quality can influence host–parasite interactions. Acosta-Pérez et al. [2] demonstrated that water quality affected parasite biodiversity, while Arimoro and Utebor [5] associated nematode parasite burden with pollution in a southern Nigerian aquatic environment. Oros and Hanzelová [25] also demonstrated that pollution disturbance can alter fish parasite communities.

Evidence from the Niger Delta provides additional support for considering parasitological responses alongside chemical pollution. Mahmoud et al. [13] investigated parasitological responses associated with environmental contamination in the Ikot Abasi Estuary, while Okpoji et al. [18] documented trematode infections and histopathological effects in fish from a polluted Niger Delta river. These findings support an integrated approach in which parasite burden is considered alongside chemical and biological indicators of aquatic ecosystem condition.

However, the strong positive correlations observed in the present study should not be interpreted as demonstrating that petroleum hydrocarbons directly caused parasitic infection. Parasite transmission is influenced by host species, host size, diet, intermediate-host availability, habitat characteristics and environmental conditions. Furthermore, the hydrocarbon–parasite correlations represent relationships across the five sampling stations. The results therefore demonstrate a strong ecological association but do not independently establish a causal mechanism, as shown in Table 3.9.

Table 3.9: Correlation between Petroleum Contamination and Parasite Burden

Relationship	Pearson r	p-value	Statistical inference
TPH vs parasite prevalence	0.94	0.017	Significant positive association
TPH vs mean intensity	0.96	0.009	Significant positive association
Total PAHs vs parasite prevalence	0.92	0.026	Significant positive association
Total PAHs vs mean intensity	0.95	0.014	Significant positive association

3.10 Integrated Spatial Parasitological Profile

The integrated assessment demonstrated a consistent spatial gradient between petroleum contamination and parasitological burden. S1 represented the least impacted station, with the lowest TPH and PAH concentrations and the lowest parasite prevalence, intensity and abundance. S2 also showed relatively lower contamination and parasite burden. In contrast, S3 showed elevated hydrocarbon concentrations accompanied by increased parasitism, while S4 recorded the highest contamination and parasite burden. S5 displayed intermediate conditions.

The correspondence between chemical contamination and biological response is important because chemical measurements alone describe contaminant occurrence but may not fully reflect ecological consequences. Studies from the Niger Delta have demonstrated petroleum hydrocarbons in water, sediment and aquatic organisms [10, 26], while biological studies have demonstrated contaminant-associated responses in fish and other aquatic organisms [16. 17, 19]. Incorporating parasitological assessment therefore provides an additional biological dimension to environmental monitoring, as shown in Table 3.10.

Table 3.10: Integrated Spatial Profile of Petroleum Contamination and Fish Parasitism

Station	TPH (mg/L)	Total PAHs (mg/L)	Prevalence (%)	Mean intensity	Mean abundance	Relative burden
S1	2.84	0.18	26.7	1.38	0.37	Lowest
S2	5.62	0.34	35.0	1.57	0.55	Lower
S3	9.48	0.61	48.3	1.76	0.85	High
S4	14.72	0.93	58.3	2.09	1.22	Highest
S5	7.36	0.47	41.7	1.56	0.65	Intermediate

Conclusion

This study established the occurrence of diverse parasitic infections among fish inhabiting petroleum-impacted freshwater ecosystems in Delta State, Nigeria. An overall parasite prevalence of 42.0% was recorded, with *Clarias gariepinus* exhibiting the highest prevalence and *Chrysichthys nigrodigitatus* the lowest. Helminths dominated the parasite assemblage, particularly nematodes and trematodes, while the gastrointestinal tract was the principal site of infection.

Marked spatial differences were observed in both petroleum contamination and parasitological indices. S4 recorded the highest TPH and PAH concentrations and simultaneously exhibited the highest parasite prevalence, mean intensity and mean abundance, whereas S1 recorded the lowest values. The significant positive correlations between petroleum hydrocarbon concentrations and parasite burden indicate that increasing petroleum contamination was associated with greater parasitic infection across the investigated locations.

Fish length was also significantly associated with infection, with larger fish showing greater prevalence.

The findings demonstrate that parasitological assessment can provide complementary biological information for evaluating the ecological condition of petroleum-impacted freshwater environments. However, the observed relationships represent associations and should not be interpreted as evidence that petroleum hydrocarbons directly caused parasitic infection, as parasite transmission may also be influenced by host, intermediate-host and environmental factors. Routine monitoring integrating petroleum hydrocarbons, fish parasitology and other ecological indicators is therefore recommended to support early detection of environmental deterioration and sustainable management of freshwater fisheries in Delta State.

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