Airo International Journal
Peer-Reviewed
Multidisciplinary

ISSN: 2320-3714
Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

PARASITE DIVERSITY AND HOST–PARASITE INTERACTIONS IN FRESHWATER FISHES

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ABSTRACT

The current paper explored the diversity of parasites and host-parasite relationships in freshwater fishes using the descriptive observational methodology. One hundred and twenty freshwater fish samples that constituted a variety of fish species were studied to determine parasite composition, infection prevalence, host specificity, and geographical distribution. Four key groups of parasites were discovered like protozoa, trematodes, nematodes, and cestodes where protozoa were the most notable (40.0%), then trematodes (26.7%). The overall infection rate was 70.0 percent with single infections (45.0 percent) being the most prevalent and multiple infections (25.0 percent) being the least prevalent. The prevalence of infection was also different in fish species, which is related to host specificity that can be affected by ecological and behavioral factors. Analysis at the site showed that the most infected body organs were gills (36.7% and intestines 31.7%), indicating their contact with infectious stages and transmission with food. The results indicate that host-parasite interactions in freshwater ecosystems are complex but structured and that environmental conditions, host biology, and parasite life-history characteristics play a key role in determining the distribution of parasites.

Keywords: *Parasite Diversity, Freshwater Fishes, Host–Parasite Interactions, Infection Prevalence, Site-Specific Distribution, Aquatic Ecosystem Health.*

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1. INTRODUCTION

Freshwater fishes form a vital part of aquatic ecosystem and fulfil a very important role in ensuring ecological balance, sustaining biodiversity as well as a source of nutritional and economic value to man population. They are the most important food web components and are good indicators of environmental change. The parasitic infections among the other biological factors which influence the health of freshwater fish are of great significance because they may reduce the level of growth, affect the reproductive capacity, cause a change of behavior and predispose the fish to consumption by other infections. The parasites thus do not just impact the health of a single fish but also have an impact on population structure and ecosystem stability.

Parasite diversity in freshwater systems is controlled by a broad array of biotic and abiotic factors, which may include water quality, habitat complexity, seasonal changes and host-related traits such age, size, feeding behaviors as well as immune responses. Freshwater parasites are also diverse in their life cycles which can be simple direct transmission and complex cycles with more than one intermediate host. Host-parasite relationships are dynamic and evolutionary in nature and are determined by evolutionary pressures, which define the host specificity, the sites of the infection, and the means of transmission. Such interactions can differ between very different fish species that inhabit various ecological niches leading to different patterns of prevalence distribution of parasites.

Although the ecological importance of parasite organisms is essential the whole research on parasite diversity and host-parasite relationships in fishes of fresh water is yet to be done in most of the fresh water. There is little baseline data that will limit efficient tracking of fish health and ecosystem integrity. A study of parasite composition, prevalence of infection, host specificity, and site-specific distribution can yield useful information on disease ecology, and the environmental status. In this regard, the current study will examine the parasite diversity and host-parasite relationship in freshwater fish, which will help in enhancing the understanding of parasitism and its effects on the health of freshwater ecosystems and management of freshwater fisheries.

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2. LITERATURE REVIEW

Berkhout et al. (2020) explored how the host assemblage structure and environmental variables were related to the 88-diversity of freshwater parasite communities on a continent-wide scale. They found that the variation in parasite communities was mainly due to the difference in host species composition, heterogeneity of habitat and environmental gradient like climate and water characteristics. The authors have highlighted that the patterns of β-diversity of parasites were not accidental, but tightly associated with both ecological and biogeographical processes acting at broad spatial levels. Their results emphasized the role of host diversity and environmental filtering in developing freshwater parasite assemblages of diverse taxonomic groups.

Calhoun et al. (2018) studied the fauna of parasites of invasive freshwater fishes and measured the determinant factors of richness of parasites. The research has shown that invasive fish species tended to have lower parasite richness than native fishes, which supported the hypothesis of enemy release hypothesis. The authors also noted that richness of parasites increased with the duration of time since invasion and depended on the host characteristics of body size and trophic position. The effects of environmental conditions and habitat characteristics were also determined to influence parasite acquisition making it clear that biological and ecological processes controlled the diversity of parasites in invading freshwater fish population.

Deflem et al. (2022) expressed the environmental and spatial predictors of parasite community structure in native and invasive freshwater fishes. Their study revealed that a complex of host identity, environmental variables and spatial connectivity of habitats determined parasite assemblage. The research observed some differences in parasites community structure between native and invasive fishes, which indicated that an environmental filtering process and dispersal constraints were a major factor in the establishment of parasites. The authors inferred that a holistic approach to the ecology of freshwater host-parasite interactions incorporates host biology, environment and space processes operating at a variety of ecological scales.

Esposito, Foata, and Quilichini (2023) carried out a systematic review of the dynamic interaction between the introduced freshwater fishes and parasitic helminths in Europe. Their review was able to synthesize the evidence that fish introductions caused an extensive change in the composition

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Volume: 1 Issue: 1
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Impact Factor: 11.9
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of helminth communities by process involving parasite spillover, parasite spillback and enemy release. The authors also indicated that introduced fishes usually carried a non-native helminthic species into new habitats, whereby the parasites may survive and be in contact with the local host species. The paper has stressed that factors such as environmental conditions, availability of hosts, and ecological compatibility had a strong effect on the establishment and transmission of helminths and the paper has indicated that host-parasite interactions are complex and dynamic after the introduction of fish into new environments.

Lima-Junior et al. (2021) studied the effect of host diversity and phylogenetic relationships and local environmental conditions on the infection patterns of a non-native parasite in tropical floodplain fish assemblies. Their results revealed that the prevalence and intensity of infection in the community was greater in those communities whose host diversity and phylogenetic relatedness were high, indicating that the closely related species of hosts promoted the transmission of the parasites. It was also demonstrated that the local environmental factors, including the connectivity of habitats and floodplain processes, were also instrumental in the determination of patterns of infection. The authors found that the interactions among host community structure, evolutionary interactions, and environmental variability in freshwater ecosystems caused parasite establishment and spread.

3. RESEARCH METHODOLOGY

The research design was a descriptive observational design that implied the gathering and laboratory analysis of 120 freshwater fish specimens to determine the diversity of parasites, their prevalence, host specificity, and location-specific distribution. Descriptive statistics were applied to the parasitic data and the results represented in form of frequencies and percentages and tabular and graphical means.

3.1 Study Design and Sampling

The current study used descriptive and observational research design to record parasite diversity, prevalence and host-parasite interactions in freshwater fishes. A sample of 120 freshwater fish species found in various freshwater bodies was taken using traditional fishing methods. The sample

ISSN: 2320-3714
Volume: 1 Issue: 1
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was collected under natural environmental conditions so that the parasitic infections that were observed reflected actual ecological interactions. A representative sample of the available fish fauna was taken.

3.2 Identification of Host Fishes

Fish specimens were collected and transported to lab in aerated containers to ensure that they did not suffer much stress or degeneration. The identifications to the species level were done using standard taxonomic keys and some of the morphological features used included body shape, the arrangement of the fins, and the scales as well as the coloration of each specimen. Host-specific parasites were necessary to be analyzed with proper identification of host fishes.

3.3 Parasitological Examination and Parasite Identification

The systemic examination of parasitic infections was done on all fish specimens. The skin, fins, and gills were also carefully examined under a stereomicroscope in order to identify the existence of ectoparasites. To check the presence of endoparasites, internal examination was done by dissecting the fish to examine the intestine and body cavity. The isolated parasites were cleansed using physiological saline, kept in condition and identified into major parasite groups such as protozoa, trematodes, nematodes and cestodes according to the morphological features using standard manuals of parasitological identifications.

3.4 Assessment of Infection Parameters

Descriptive parameters have been used to measure parasitic infections which include parasite diversity, prevalence of infection and patterns of interaction between the hosts and the parasites. Infection was classified into being uninfected, single or multiple infections. The presence of host specific parasites was measured by comparing infectivity rates of the various fish species and site specific it was measured by recording the anatomical positioning of the parasite in the host.

3.5 Data Analysis

The data collected during the parasitological examinations was analyzed and systematized with the help of the descriptive statistical techniques. Calculations were done to ascertain the diversity

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Volume: 1 Issue: 1
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of parasites, their prevalence based on infection, specificity to the host and location based on site. To make the findings clear and easier to interpret, the findings were represented in the form of tables and graphical representation. No inferential statistical tests were used, because the research was an exploration study.

4. RESULT

This paper has reported the diversity, prevalence and distribution of parasites in freshwater fishes and has also investigated the patterns of host-parasite interactions. The number of X freshwater fish exhibits of various species was observed and assessed with regard to parasitic infections. The analysis demonstrated that there was a significant difference in the diversity of parasites, the level of infections, and the selectivity towards the host in fish species.

4.1. Overall Parasite Diversity in Freshwater Fishes

Table 1 and Figure 1 provide the generalized diversity of parasite groups in the freshwater fishes. A total of 120 parasite isolates were captured, and they included four major groups, namely protozoa, trematodes, nematodes, and cestodes. The group that was the most dominant represented protozoan parasites (48 isolates - 40.0%), then trematodes (32 isolates - 26.7). Nematodes and cestodes were relatively less popular and made 22 isolates (18.3) and 18 isolates (15.0), respectively. The graphical analysis shows well how the individual groups of parasites contribute proportionately to the overall parasite diversity.

Table 1: Percentage Distribution of Parasite Groups Identified in Freshwater Fishes

Parasite Group	Number of Isolates	Percentage (%)
Protozoa	48	40.0
Trematodes	32	26.7
Nematodes	22	18.3
Cestodes	18	15.0

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ISSN: 2320-3714
Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

Total	**120**	**100**

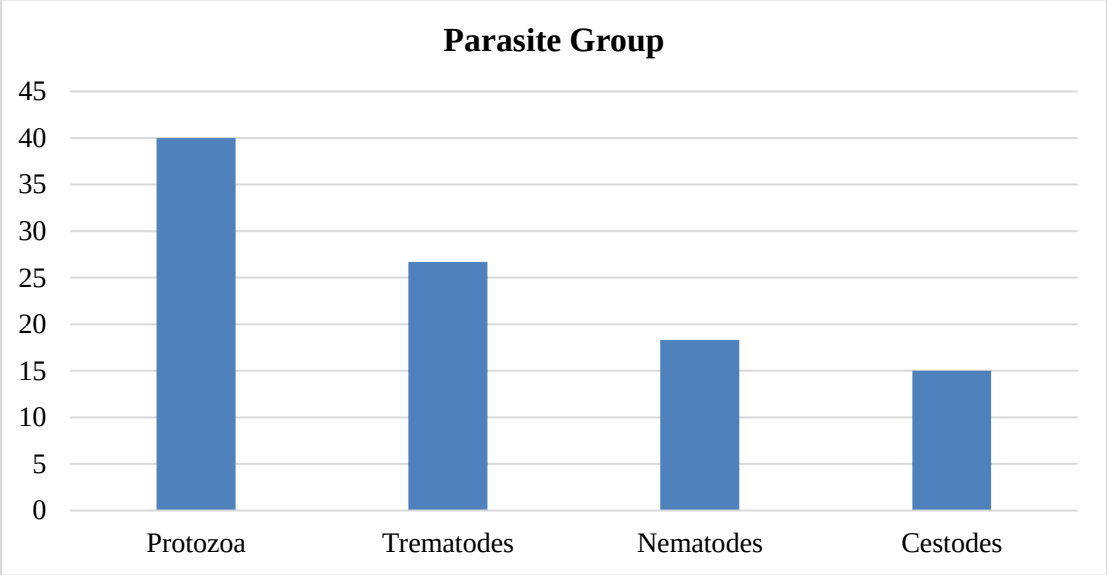

Figure 1: Graphical Representation of Percentage Distribution of Parasite Groups Identified in Freshwater Fishes

The prevalence of protozoan parasites shows that they are highly adaptive, reproduce quickly, and are able to transmit effectively in the freshwater. The high levels of the trematodes indicate good ecological conditions and presence of intermediate hosts involved in the life cycles of the trematodes. Reduced proportions of nematodes and cestodes can be an indication of more complex life cycles, host specificity, or restricted chances of transmission. By and large, the pattern of distribution sheds light on a rich parasite community in fresh water fishes and emphasizes the role of environmental and biological determinants on the prevalence of parasites and host-parasite relationships.

4.2. Prevalence of Parasitic Infection Among Host Fishes

The levels of parasitic infections prevalence of the freshwater fish hosts were represented in Table 2 and Figure 2. Of the 120 fishes examined, 36 fishes (30.0 percent of the total) were identified as uninfected and 84 fishes (70.0 percent of the total) were infected with one or more parasites. The

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Volume: 1 Issue: 1
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Impact Factor: 11.9
Subject: Zoology

most frequent were single infections which were identified in 54 fishes (45.0%), and multiple infections were found in 30 fishes (25.0%). The figure depicts clearly the relative percent of uninfected, singly infected, and multiply infected fish host.

Table 2: Percentage of Fish Hosts Based on Infection Status

Infection Status	Number of Fishes	Percentage (%)
Uninfected	36	30.0
Single infection	54	45.0
Multiple infections	30	25.0
Total	**120**	**100**

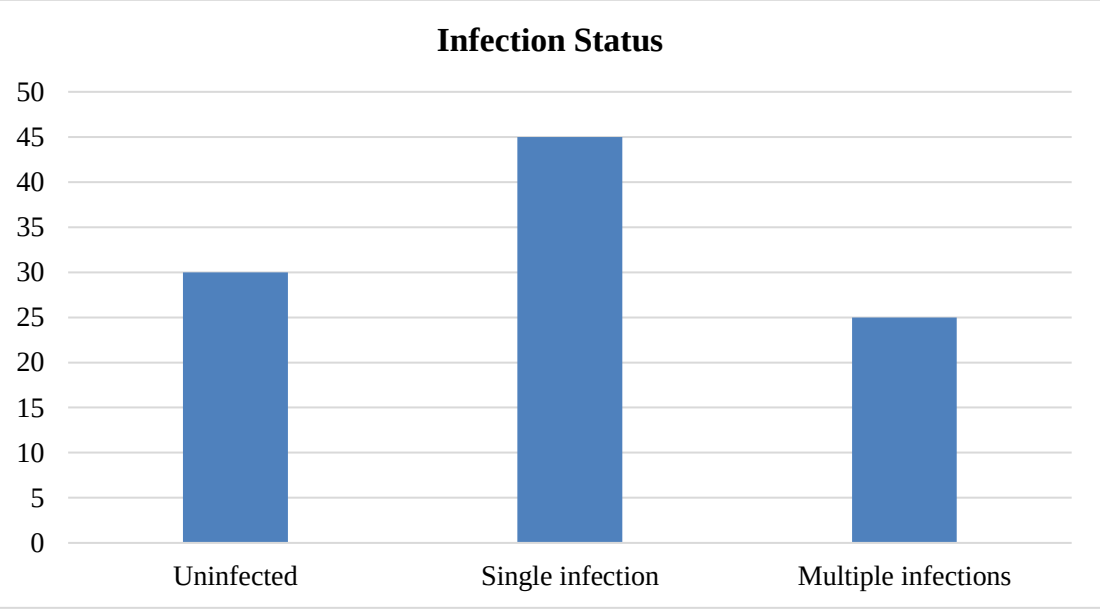

Figure 2: Graphical Representation of Percentage of Fish Hosts Based on Infection Status

The large general infection rate indicates that the parasitic agents of freshwater fishes are significantly vulnerable to the aquatic environment. The prevalence of single infections suggests that most hosts are infected simultaneously by a single species of parasite, perhaps because of

ISSN: 2320-3714
Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

reduced cross-over of the pathogens or because of the suppression of co-infections by host immune systems. The significant percentage of multiple infections, however, indicates complicated interactions between hosts and parasites and similar ecological niche, which underlines the importance of environmental factors and host behavior in defining infection patterns.

4.3. Host-Specificity and Parasite Occurrence

Table 3 and Figure 3 represent the proportion of prevalence of parasitic infections in the chosen species of freshwater fish. Four species of fishes were studied (120). Species A had the greatest rate of infection and 70.0 percent of people were infected compared to Species B (60.7) and C (53.1) respectively. The least prevalence of infection was recorded in species D with 46.7 percent infected fishes. The general infection rate of all species was 57.5 and 42.5 of the fishes were not infected. The graphical representation brings out the interspecific difference in occurrence of the parasites.

Table 3: Percentage of Parasite Occurrence Among Selected Freshwater Fish Species

Fish Species	Number Examined	Infected (%)	Uninfected (%)
Species A	30	70.0	30.0
Species B	28	60.7	39.3
Species C	32	53.1	46.9
Species D	30	46.7	53.3
Overall	**120**	**57.5**	**42.5**

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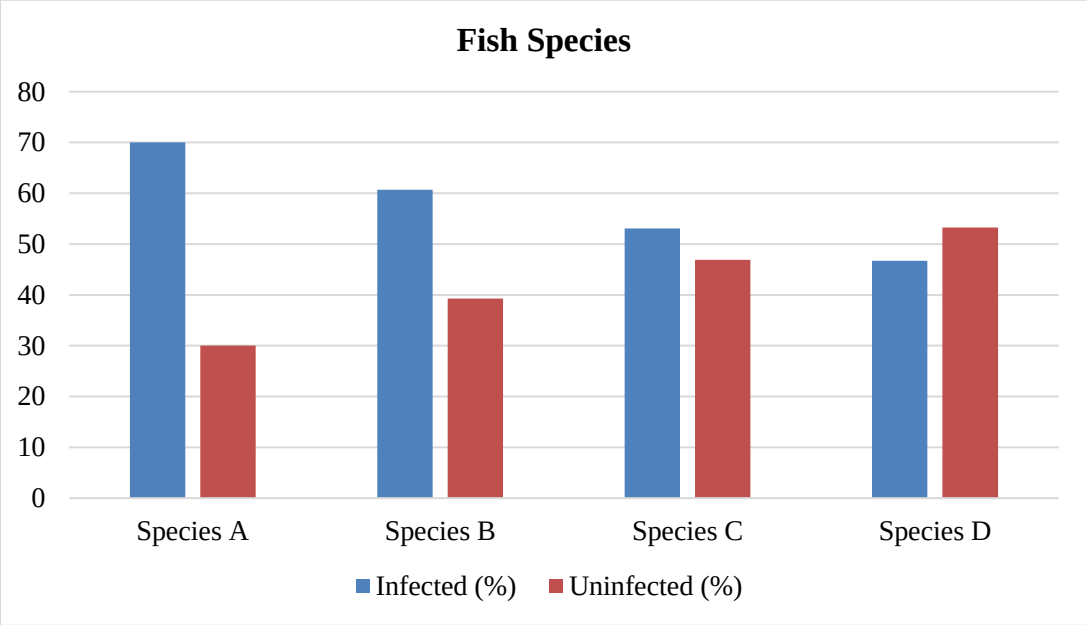

Figure 3: Graphical Representation of Percentage of Parasite Occurrence Among Selected Freshwater Fish Species

The noted difference in the prevalence of the infection of fish specimen suggests the difference in host vulnerability, ecological niche, feeding habits and use of habitats. The reason why Species A and B were more often infected could be more exposure to infective stages, benthic feeding behavior or omnivorous feeding behavior, or as well as contact with intermediate hosts. Conversely, the reduced prevalence of Species D may indicate a relatively lesser exposure or good resistance to parasitic infections. These results highlight the contribution of host-specific ecological and biological variables to the pattern of parasite distribution and host-parasite interactions in freshwater ecosystems.

4.4. Site-Specific Distribution of Parasites in Fish Hosts

The local distribution of parasites in freshwater fish hosts is found in Table 4 and Figure 4. One hundred and twenty parasites were obtained in the various anatomical locations. The most common site of infection was the gills, which had 44 parasites (36.7%), then the intestine that had 38 parasites (31.7). The skin had the largest number of parasites (18.3%), with the body cavity having

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Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

the least number of parasites (13.3%). The graphical illustration shows clearly the proportionality of different infection sites of parasites.

Table 4: Percentage Distribution of Parasites Based on Infection Site

Site of Infection	Number of Parasites	Percentage (%)
Gills	44	36.7
Intestine	38	31.7
Skin	22	18.3
Body cavity	16	13.3
Total	**120**	**100**

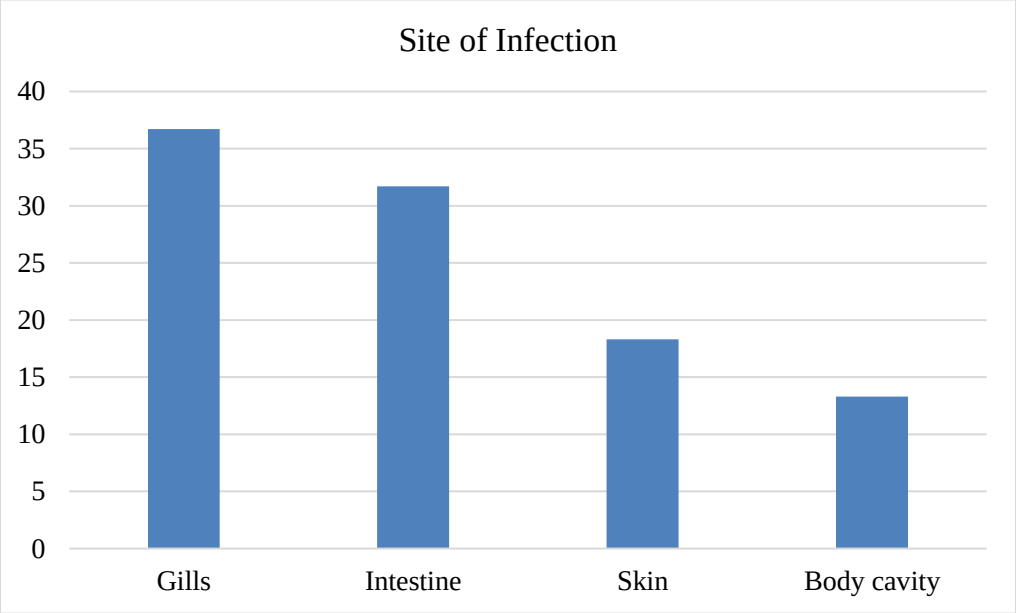

Figure 4: Graphical Representation of Percentage Distribution of Parasites Based on Infection Site

The abundance of the parasites on the gills indicates that it is the main point of entry since there will always be water and hanging infective stages. The significance of the feeding habits and

ISSN: 2320-3714
Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

ingestion of the intermediate hosts in the spread of the parasites is indicated by intestinal infections. Protective barriers as well as more complicated invasive pathways may explain lower infection rates on the skin and in the body cavity. Altogether, the site-specific distribution highlights the impact of life cycles, patterns of transmission, and host physiology on patterns of infection among freshwater fishes.

4.5. Host–Parasite Interaction Patterns

The outcome shows that the interactions between hosts and parasites are intricate, depending on the host species and habitat preference, feeding habits, and life history characteristics of the parasite. The increased infection rate in some fish species implies that they are exposed to more infective stages in the environment. The direct life-cycle parasites were more prevalent than the indirect life-cycle ones, which need an intermediate host, indicating the importance of the ecological simplicity factors in transmission success.

5. DISCUSSION

The current study identifies that there is a great deal of parasite diversity and high rate of parasitic infections in freshwater fishes which show that the host-parasites are interacting with one another in the water ecosystem. The prevalence of protozoan parasites can be explained by the simplicity of their life cycles, high rates of multiplication and effective transmission in freshwater. Trematodes are also very famous indicating good ecological status and the presence of appropriate intermediate hosts. Conversely, the reduction in the number of nematodes and cestodes can be attributed to their complicated life cycle and increased host specificity that limits transmission. In general, the noted diversity is due to the high impact of environmental and biological factors on the distribution of parasites.

The variation in the prevalence of infection in fish species and location also highlights the importance of host ecology and behavior. Increased infection of some species is a sign of exposure to feeding habits and habitat choice. The single infections are more likely to occur, indicating that there is not much co-infection, perhaps because of the host immune response or separation between niches between parasites, whereas the occurrence of multiple infections indicates overlapping

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Volume: 1 Issue: 1
January 2026
Impact Factor: 11.9
Subject: Zoology

routes of transmission. The elevated rate of infection in gills and intestines emphasizes the fact that they are under constant attack of infective stages and transmission through ingestion. A combination of these results supports the idea that host-parasite interactions in freshwater fishes are both complex and structured.

6. CONCLUSION

The current paper contains a detailed evaluation of the parasite diversity and hostparasite relationships in freshwater fish, and it was found that parasitic infections occurred on a high level and there was also a lot of difference in the distribution of parasites both among different host species and among different areas of the body. The control of protozoan parasites and the considerable prevalence of trematodes explain the role of the environmental conditions, parasite life-cycle strategies and host ecology in the dynamics of the transmission. Differences in prevalence of infections among fish species highlight the importance of host-specific factors including feeding behavior, habitat preference and susceptibility, whereas the importance of the gill and intestine infections highlights continued exposure of the host to infective stages. On the whole, the results prove that the interaction between hosts and parasites in freshwater environments is complicated and organized and these findings imply that parasitism in fish is important as an indicator of fish health and ecosystem stability with potential consequences on freshwater biodiversity maintenance and sustainable fishery.

ISSN: 2320-3714
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January 2026
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Airo International Journal
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