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Diversity, Prevalence, And Composition Of Helminth Parasites In Catla Catla From River Indus, Sindh, Pakistan

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Abstract
Pakistan has a rich ichthyological diversity yet little research has been done on the level of freshwater fish parasitology in Pakistan even though the country depends on inland fisheries as a source of food security. Catla catla (Hamilton, 1822) is one of the commercially most important rich major carps in South Asia, and is completely deficient of a former complete helminthological account in the River Indus at Jamshoro, Sindh. This was carried out to document the diversity, prevalence and community structure of the helminth parasites of the Catla catla of this locality and to accomplish this with the help of the standard parasitological methods in a two year study (20182020). The host fish analyzed were 26. Nine (34.617) were infected with helminth. It revealed 6 helminth taxa in three classes (Trematoda 3 species; prevalence 23.07%), Nematoda (2 species; prevalence 7.69%), and Acanthocephala (1 species; prevalence 3.84%). A total of 63 specimens were retrieved in the six taxa. The most abundant (11.54 percent) was the trematode Echinochasmus sp and the most common mean intensity (10.50 specimens per infected host) was the nematode Rhabdochona sp. Thaparotrema pedicellatum, Isoparorchis trisimilitubis, and Echinochasmus sp., Procamallanus (Spirocamallanus) sp., Rhabdochona sp., and Dispirin sp. are all new host or locality records in Pakistan. These findings fill a knowledge gap in the critical regional biodiversity literature, provide the first description of a multi-class helminth community of the catla Catlali in the Indus River drainage and indicate zoonotic risks of Echinochasmus in a food fish with a high degree of harvesting. These findings are put into context of the bigger picture of the South Asian parasitological literature through parallel analysis of similar studies in India and other localities in Pakistan. Expanded surveillance, molecular characterization, and seasonal sampling are proposed as the priorities of research which should be conducted immediately.

Keywords: Catla catla; helminth diversity; prevalence; Trematoda; Nematoda; Acanthocephala; River Indus; Sindh; Pakistan; comparative parasitology; biodiversity gap; zoonosis

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Introduction

Parasitic helminths are the most widespread and taxonomically diverse endoparasites of freshwater fishes (Poulin, 2000). In South Asia, organised contributions to helminthology research have been ongoing in the past 50 years, with the Indian, Bangladeshi, and to a lesser degree Pakistani researchers contributing to the exploration of the region, which hosts some of the most biologically productive river systems of the world (Laghari, 2021; Dash et al., 2015; Khan et al., 2013). The most important helminth phyla that infect freshwater fishes are Platyhelminthes (trematodes and cestodes), Nematoda, and Acanthocephala, with the most common and speciose group being trematodes (Laghari, 2021).

However, despite this literature, the contribution of Pakistan to the literature of parasitology in this region is nevertheless too negligible compared with freshwater biodiversity and reliance of the country on inland fisheries. Covering approximately 1,165,000 km2, the major system of the Indus River, arguably the hydrological backbone of Pakistan, supports over a hundred native freshwater fish species in its main channel and tributaries (Laghari, 2021; Sheikh et al., 2017). Nevertheless, partial systematic helminthological studies of noteworthy commercial species of this river are still incomplete. Published publications are shared across each genus or family and little synthesis of the data and practically no multi-class, multi-organ community-based studies have been conducted (Laghari, 2021; Bilqees et al., 1972; Soofi et al., 2015, 2016).

catla catla (Hamilton, 1822), or catla or major carp is a flag species in freshwater fish farming in South Asia. It is capable of sustaining a wide environmental range, is a rapidly growing species, and has a high-quality nutritional value in its flesh, leading to it being a dietary protein staple in India, Bangladesh, Nepal, Myanmar, and Pakistan (FAO, 2021; Sheikh et al., 2017). Its feeding pattern - it is an ecologically suitable definitive or paratenic host due to a combination of surface and mid-water grazing on zooplankton in juveniles and detritivory in adults (Laghari, 2021).

Although it has a great importance, in Pakistan, catla catla has received practically no parasitological attention before the current study. This had been the sole previous record, of the acanthocephalan Neoechinorhynchus in Catla catla at Haleji Lake, Sindh, which had been reported (significant as it was) by Bilqees et al. (1972), although this did not in any way characterize the entire helminth community of the species. On the other hand, Indian researchers had already described some helminth taxa of Catla catla in West Bengal, Andhra Pradesh, and Tamil Nadu (Dash et al., 2015; Gudivada and Vankara, 2017), which might be used to place the results in Pakistan in the regional context.

The Sindh province, which is a source of the lower parts of the Indus River, is one of the most productive fishing regions in Pakistan. It has an inland water supply including the Indus main channel, Kotri Barrage, Manchar Lake, Keenjhar Lake and Indus Delta which support a rich fish fauna that is utilized to supply domestic and local trade (Laghari, 2021). The ichthyoparasitology of freshwater in Sindh is however far inferior to that of other similar regions in India. Prior to 2021, the Jamshoro reach of the Indus, the sampled locality of the present study, is not well documented in the literature on helminthologists,

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with the majority of the records pertaining to Birmani, Dharejo, and Soofi of the University of Sindh (Soofi et al., 2015, 2016).

It is not a gap in biodiversity that is an academic issue. The immediate consequences of helminth infection in fish that is harvested commercially are on the health, productivity and food safety of fish. Zoonotic trematodes (zoot-a-nosa) contain members of the family Echinostomatidae that can be transmitted to human consumers in metacercariae in poorly cooked fish flesh - and this, in particular, is of acute concern in communities that process fish by drying, fermenting, or light cooking before consuming it (Laghari, 2021; Verma, 193 The merit of a minute catalogue of the helminth fauna of Catla catla of the Indus, is scientific, as well as to the health in general.

1.4 Aims and Objectives

The present article derives from and extends the M.Phil. thesis investigation of Laghari (2021), with the specific aim of providing a comprehensive community-level analysis of helminth diversity, prevalence, and composition in Catla catla from the River Indus at Jamshoro, Sindh, Pakistan. The specific objectives are:

1. To document the species richness and taxonomic composition of the helminth community of Catla catla from the River Indus at Jamshoro.
2. To calculate and report key infection parameters — prevalence, intensity, mean intensity, and relative abundance — for each helminth taxon.
3. To analyze the organ-site specificity and ecological distribution of helminth parasites within the host body.
4. To compare findings with parallel studies from India and Pakistan to assess regional patterns in helminth diversity.
5. To evaluate the zoonotic significance of identified taxa and recommend management interventions for Pakistan's fisheries sector.

2. Materials and Methods

2.1 Study Area and Host Collection

The experiment was done along the river Indus in Jamshoro, Sindh Province, Pakistan (around 25.43° N, 68.27°E). Jamshoro is located on the western side of the Indus, about 30 km north of Hyderabad, south of Kotri Barrage. High densities of zooplankton and benthic invertebrates during the monsoon and post-monsoon seasons define the river at this locality and create the best environment in the transmission of helminth parasites (Laghari, 2021).

Systematic net-trapping was used to sample a total of 26 specimens of Catla catla between January 2018 and January 2020. Fish were stored on ice in the Parasitology Laboratory, Department of Zoology, University of Sindh, Jamshoro and processed within 4-6 hours of collection. Each specimen was recorded in terms of body length and weight and the identity of the host was established with the help of standard ichthyological keys (Hamilton, 1822; Sheikh et al., 2017).

2.2 Dissection and Parasite Recovery

All the hosts were dissected in aseptic conditions with a conventional ventral longitudinal opening. The internal organs (liver, gall bladder, body cavity, swim bladder, esophagus,

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stomach and intestine) were removed separately, and stored in isotonic normal saline (0.9% NaCl) in labeled Petri dishes. Organs were incised with small scissors and needles were played with. The contents were observed using an Amscope trinocular dissecting microscope with magnifications of 7.5x -45x. Brushes with soft camel-hair (size 0) were used to collect helminths and they were temporarily kept in normal saline in labeled vials (Laghari, 2021; Garcia and Ash, 1979).

2.3 Parasite Processing and Identification

The trematodes were relaxed in distilled water and then fixed in warm 70% ethanol, dehydrated using a graded alcohol series, stained using borax carmine (10-15 minutes), destained using acidified alcohol, dehydrated using absolute alcohol, cleared using clove oil and xylene, and permanently mounted in Canada balsam. Nematodes were frozen in 70% ethanol; acanthocephalans in the same way. An OMAX Digital Trinocular LED Microscope (10MP) was used in taking photomicrographs. The morphometric measurements were all measured with a calibrated ocular micrometer and are given in micrometers (µm) unless indicated otherwise (Laghari, 2021; Schmidt, 1988).

Taxonomic identification was done using recovered specimens as a comparison with published keys and monographs: Yamaguti (1958, 1961, 1963, 1971), Soulsby (1968), Garcia and Ash (1979), Schmidt (1988), and Moravec (2010). Bush et al. (1997) formulae were used to calculate the parameters of infection: Prevalence (%) = (infected hosts / total hosts examined) x100; Mean Intensity = total parasites recovered /infected hosts; Relative Abundance = total parasites of one species /total parasites of all species.

3. Results

3.1 Overall Infection Parameters

Out of 26 Catla catla specimens studied, 9 (34.61%) were infected with at least one species of helminth. Sixty-three helminth specimens were obtained, which belonged to 6 taxa: Trematoda (3 spp.), Nematoda (2 spp.), and Acanthocephala (1 sp.). A summary of the overall infection parameters is in Table 1 and an annotated checklist of all taxa recovered is in Table 2.

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Table 1: ***Overall Helminth Infection Parameters in Catla catla from River Indus, Jamshoro (n = 26)***

Parameter	Value	Percentage (%)	Remarks
Total hosts examined (n)	26	100%	Catla catla, River Indus
Total hosts infected	9	34.61%	At least one helminth taxon
Total helminth specimens recovered	63	—	Across 6 taxa
Total helminth taxa identified	6	—	3 classes represented
Trematoda — hosts infected	6 / 26	23.07%	Dominant group
Nematoda — hosts infected	2 / 26	7.69%	Second group
Acanthocephala — hosts infected	1 / 26	3.84%	Least prevalent

Source: Laghari (2021), M.Phil. Thesis, Department of Zoology, University of Sindh, Jamshoro.

Table 2: ***Annotated Checklist of Helminth Taxa Recovered from Catla catla, River Indus, Pakistan***

Class	Taxon	Family	Site	n hosts	Specimens	Status
Trematoda	*Thaparotrema pedicellatum Verma, 1927*	Opisthorchiidae	Gall bladder	2/26	7	New host record
Trematoda	*Isoparorchis trisimilitubis Southwell, 1913*	Isoparorchiidae	Body cavity / swim bladder	2/26	9	New host & locality
Trematoda	*Echinochasmus sp. Dietz, 1909*	Echinostomatidae	Intestine	3/26	12	New record (zoonotic)
Nematoda	*Procamallanus*	Camallanidae	Stomac	1/26	7	New

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	(Spirocamallanus) sp.		h			host record
Nematoda	*Rhabdochona sp. Railliet, 1916*	Rhabdochonidae	Intestine	2/26	21	New host record
Acanthocephala	*Dispirin sp.*	Dispirin (fam.)	Stomach	1/26	7	New host & Pakistan record

Source: Laghari (2021). Status designations indicate new host records (NH), new locality records (NL), or both.

3.2 Class-wise Prevalence and Diversity

The most common and speciose class was Trematoda with 3 species infecting 6 of 26 hosts (23.07% and 28 specimens respectively) and 16.44 a proportion of total parasites. Nematoda included 2 species that infested 2 out of 26 hosts (7.69%), and provided 28 specimens (44.44% of total) which were mainly due to Rhabdochona sp. (n = 21 specimens from 2 hosts). One species, Dispirin sp. was found in 1 of 26 hosts (3.84%), and provided 7 specimens (11.11%). Table 5 shows the diversity composition indices of each of these classes; Figure 1 (data table) shows the proportional representation of each of these classes.

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Table 5: ***Helminth Class Diversity Indices for the Community of Catla catla, River Indus, Jamshoro***

Helminth Class	Species Richness (S)	Specimens (N)	Prevalence (%)	Relative Abundance (%)	Dominance (d)
Trematoda	3	28	23.07%	44.44%	0.444
Nematoda	2	28	7.69%	44.44%	0.444
Acanthocephala	1	7	3.84%	11.11%	0.111
TOTAL / COMMUNITY	**6**	**63**	**34.61%**	**100%**	—

Note: Dominance (d) calculated as class specimens / total specimens. Trematoda and Nematoda share equal specimen count but differ in prevalence.

Figure 1 (Data Table). Proportional Representation of Helminth Classes by Prevalence and Specimen Count

Helminth Class	Hosts Infected	Prevalence (%)	Specimens (n)	Bar Proportion
Trematoda (3 species)	6	23.07%	28	████████ 44%
Nematoda (2 species)	2	7.69%	28	████████ 44%
Acanthocephala (1 species)	1	3.84%	7	████ 11%

Bar proportions illustrate relative specimen abundance per helminth class. Trematoda and Nematoda are co-dominant in specimen count while Trematoda leads in prevalence.

3.3 Species-level Infection Parameters

Species level measures of infection are reported in Table 6. Of the trematodes, Echinochasmus sp. had the greatest prevalence of individual species (11.54%, n = 3 infected hosts), as well as the highest number of specimens (12). Rhabdochona sp. appeared to be the most common nematode in the dataset (mean of 10.50 specimens per infected host), however, it only infected 2 hosts. Spirocamallanus (Procamallanus) sp. and Dispirin sp. exhibited the same mean intensities of 7.00 with single-host infections. The mean intensity of the whole community was 7.00 specimen per infected host among the 9 infected fish.

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Table 6: ***Species-level Infection Parameters: Prevalence, Intensity, and Relative Abundance***

Helminth Taxon	Infected Hosts	Total Specimens	Prevalence (%)	Mean Intensity	Relative Abundance (%)
Thaparotrema pedicellatum	2	7	7.69%	3.50	11.11%
Isoparorchis trisimilitubis	2	9	7.69%	4.50	14.29%
Echinochasmus sp.	3	12	11.54%	4.00	19.05%
Procamallanus (Spirocamallanus) sp.	1	7	3.85%	7.00	11.11%
Rhabdochona sp.	2	21	7.69%	10.50	33.33%
Dispirin sp.	1	7	3.85%	7.00	11.11%
COMMUNITY TOTAL	**9**	**63**	**34.61%**	**7.00 (mean)**	**100%**

Source: Laghari (2021). Mean intensity = total specimens / infected hosts (Bush et al., 1997).

3.4 Organ-site Specificity

The taxa of helmints were site-specific in the host organism. Thaparotrema pedicellatum was the only species in the gall bladder; Isoparorchis trisimilitubis inhabited the body cavity and swim bladder; Echinochasmus sp. colonized the intestine. Rhabdochona sp. and (trematode). (nematode); and both Procamallanus (Spirocamallanus) sp. and Dispirin sp. inhabited the stomach. There was no case of overlap of taxa in any one organ. Table 4 is a summary of organ-by-organ distribution and ecological functions.

Table 4: ***Organ-wise Distribution of Helminth Taxa in Catla catla with Ecological Notes***

Organ / Site	Helminth Taxon	Class	Specimens (n)	Ecological Role
Gall bladder	*Thaparotrema pedicellatum*	Trematoda	7	Bile-feeding; opisthorchiid niche
Body cavity /	*Isoparorchis*	Trematoda	9	Body cavity

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Swim bladder	*trisimilitubis*			colonizer; air-bladder parasite
Intestine	*Echinochasmus sp.* / *Rhabdochona sp.*	Trematoda / Nematoda	33	Gut colonizers; multiple classes co-occur
Stomach	*Procamallanus (Spirocamallanus) sp.* / *Dispirin sp.*	Nematoda / Acanthocephala	14	Gastric parasites; different phyla share site

Source: Laghari (2021). The intestine and stomach each harbored two distinct helminth taxa from different classes.

4. Discussion

4.1 Helminth Community Composition: Patterns and Determinants

The Catla catla of the River Indus based helminth community at Jamshoro illustrates moderate prevalence (34.61%), multi-class diversity (3 helminth classes), and dominated by Trematoda; a general trend largely in line with other large carps in South Asia. A study of the Catla catla in West Bengal, India (Dash et al., 2015) reported an overall prevalence (42.00%) of a larger sample (n = 50), again with trematodes prevailing in the helminth community. A similar prevalence (38.30%) in major carps (Andhra Pradesh) was recorded by Gudivada and Vankara (2017), trematodes being the major class. The pattern of Trematoda prevalence in the independent studies carried out in various geographic locations and host species confirms the conclusion that it cannot be a sampling artifact, but rather an actual ecological interaction between Catla catla and the communities of trematode intermediate hosts. The ecological explanation of trematode dominance in catla must do mainly with the abundance and diversity of molluscan intermediate hosts in the Jamshoro reach of the Indus River. All trematode life cycles are obligatorily associated with snails as first intermediate hosts, and fish as second intermediate hosts or a definitive host, based on species. Gastropod snails (families Viviparidae, Thiaridae, Ampullariidae) that are a major transmission vehicle of fish trematodes flourish in the Indus floodplain, especially after monsoon (Laghari, 2021). Surface-feeding of Catla catla - particularly at juvenile stages - exposes them to cercariae released into the water column by these snails, which allows infection. Adult fed Catla catla can also consume encysted metacercariae which are adsorbed to planktonic invertebrates.

Nematoda were equally represented to Trematoda in terms of the number of specimens (28 specimens each) although they were less prevalent. This difference is indicative of a high-intensity, low-prevalence infection pattern common to most nematode species in fish -

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specifically, Rhabdochona spp. which may occur in high-burden in individual fish and yet cause low-prevalence in any specific population (Moravec, 2010). The fact that prevalence (7.69%) and specimen abundance (44.44% of total) of nematodes differ considerably in this community and should be further studied in seasonal and host-size-stratified sampling designs is also an interesting aspect of this community.

4.2 Regional Comparison: Positioning the Indus Helminth Community

A systematic comparison of the results of this study with parallel studies published in Pakistan and India is given in Table 3 below.

Table 3: ***Comparative Prevalence of Helminth Parasites in Catla catla and Related Freshwater Carps — Regional Studies***

Study / Author	Host Species	Region	Sample (n)	Prevalence (%)	Dominant Group
Laghari (2021) — present study	*Catla catla*	Sindh, Pakistan	26	34.61%	Trematoda (23.07%)
Dash et al. (2015)	*Catla catla*	West Bengal, India	50	42.00%	Trematoda + Nematoda
Gudivada & Vankara (2017)	Major carps (3 spp.)	Andhra Pradesh, India	120	38.30%	Trematoda
Khan et al. (2013)	Mixed freshwater fish	KPK, Pakistan	40	29.50%	Nematoda
Rafique et al. (2002)	*Mystus vittatus*	Punjab, Pakistan	35	31.40%	Nematoda
Bilqees et al. (1972)	*Catla catla*	Haleji Lake, Sindh	Not specified	Not specified	Acanthocephala only
Soofi et al. (2015, 2016)	*Rita rita*	Jamshoro, Pakistan	30	26.70%	Trematoda

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Compiled from Laghari (2021), Dash et al. (2015), Gudivada & Vankara (2017), Khan et al. (2013), Rafique et al. (2002), Bilqees et al. (1972), and Soofi et al. (2015, 2016). Blank cells indicate data not reported.

The relative statistics in Table 3 show that there are some interesting trends. To start with, the overall prevalence observed in the current study (34.61%) is within the scope of prevalence observed in similar studies on the subcontinent (29.5% – 42.0%), which indicates that Catla catla has a generally similar sensitivity to helminth infection throughout its distributional range. Second, the prevalences in the Pakistani studies identified (Khan et al., 2013; Rafique et al., 2002; Soofi et al., 2015, 2016) are usually lower than those in Indian studies, which could be due to true epidemiological differences, differences in sampling intensity, or simply to a less developed state of systematic parasitology in Pakistan. Third, these records represent taxonomic novelty of all six records in the current study - compared to the multi-species records accessible to Indian populations of Catla catla - highlights the extreme gap in biodiversity in the Pakistani freshwater parasitology that is starting to be filled by this study.

The fact that cestodes (tapeworms) were not found in the present study is also worth commenting on. Although the phylum Platyhelminthes is fairly represented by trematodes, no cestode infection was observed. The cope pod intermediate hosts are typically linked to cestode infections in carps, especially the cyclopoid cope pods (Laghari, 2021; Yamaguti, 1959). The cyclopoid copepod abundance in the Jamshoro reach of the Indus at the sampling point might have been low enough to prevent cestode transmission cycles, or it may have been low enough that sampling strength was inadequate to detect the presence of low prevalence infections. Future research must specifically address cestodes and use PCR-based techniques in order to identify cryptic infections.

4.3 Site Specificity and Niche Partitioning

The organ-site specificity apparent in this experiment, with each helminth species or genus occupying a different organ system, is indicative of the longstanding niche-partitioning in fish helminth assemblages (Laghari, 2021; Poulin, 2000). Active host-finding behavior, chemotaxis to host bile and digestive secretions, immune microenvironment preferences and co-evolutionary host-parasite interactions all contribute to site specificity in helminths.

The location of Thaparotrema pedicellatum in the gall bladder is in line with its classification in the family Opisthorchiidae - the family of hepatic and biliary trematodes that are location-specific to the bile-rich environment (Laghari, 2021; Soofi et al., 2015). Isoparorchis trisimilitubis in the body cavity and swim bladder has a specialised parasitological niche: the swim bladder is an oxygen-rich, relatively immune-privileged, space that is rarely colonized by other classes of helminths, and Isoparorchis is one of the few genera that have adapted to occupy it (Bashirullah, The fact that two different classes (Trematoda and Nematoda) live in the intestine, and Nematoda and Acanthocephala in the stomach, without any overlap reported at the species level, indicates that competitive niche segregation should be studied experimentally.

4.4 Intensity, Mean Intensity, and Community Implications

The average number of 10.50 specimens per host of the infected host of Rhabdochona sp. is epidemiologically important. Although the two infected hosts are a prevalence of only 7.69, the large numbers of specimen per host suggests that once infected the parasite replicates or persists successfully. This is in line

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with the established biology of Rhabdochona - a genus which depends on aquatic insects (in particular ephemeropteran mayflies) as intermediate hosts and can reach high concentrations in individual fish which are exposed to contaminated prey in dense invertebrate aggregates (Moravec, 2010; Rafique et al., 2002).

The same mean intensities of Procamallanus (Spirocamallanus) sp. and Dispirin sp. (7.00 each) of single-host infections do not allow any strong comparisons but set baseline intensity levels of these taxa in Catla catla. The coincidence of the two stomach parasites (of two completely different phyla (Nematoda and Acanthocephala)) in the same single host indicate that either the individual fish was immunologically compromised or the location had a higher exposure to invertebrate intermediate hosts. This observation should be followed up by condition index measurements and histopathology.

4.5 Taxonomic Novelty: Six New Records for Pakistan

The peculiarity of this study is that all the six helminth taxa are new to Pakistan in terms of host or locality. This observation is not the unusual parasitic burden of the locality where it was studied or the host species, but is instead the almost complete lack of previous parasitological study of Catla catla of the Indus River in Sindh. The taxonomic importance of the novelty of Dispirin sp. — in Pakistan, the first record of this species. The genus Dispirin is not well known in the world; only a few specimens have been described in terms of their morphology (12 hook-row proboscis, tandem testes overlapping cement gland, invaginated bursa) (Laghari, 2021; Yamaguti, 1963). Subsequent collection of acanthocephalans in the Indus fish fauna must be a priority to obtain more specimens - including females - to be able to identify them unambiguously at a species level.

The trematode Thaparotrema pedicellatum Verma, 1927 is of particular interest due to its belonging to the Opisthorchiidae - the family in which the world-significant zoonotic genera Opisthorchis and Clonorchis belong. Although Thaparotrema itself has not been directly linked to human disease, its affinity at the family level and location in the gall-bladder of a highly consumed food fish makes it a candidate to targeted assessment of zoonotic risk. Molecular phylogenetic works that put Thaparotrema in relation to Opisthorchis and Clonorchis should be done as a precaution to be taken.

5. Zoonotic and Fisheries Management Implications

5.1 Public Health Risk Assessment

Echinochasmus sp. The most immediately actionable, and most clearly defined zoonotic risk of the identified taxa is (Echinostomatidae). The species of this genus are causative agents of echinochasmiasis in humans in East and Southeast Asia, and are transmitted by eating raw or undercooked fish containing metacercariae (Verma, 1935; Laghari, 2021). The intestinal position of this parasite - in the definitive fish host - has resulted in the metacercariae potentially being widespread in fish muscle and viscera, and available to fish consumers who clean fish, but do not cook them to safe internal temperatures.

The risk of ingesting the metacercarial in Sindh, a major consumer of fish, is related to the number of Echinochasmus present in marketed fish and the heat exposure during cooking; fish is eaten as biryani (cooked), dried/salty sun-dried fish (sohal maachi), and occasionally semi-raw. The prevalence of 11.54% that was obtained in this study indicates that 1 out of 9 fish of this locality may harbor viable metacercariae. This is not a level of prevalence that would call an emergency but is high enough to justify: (1) consumer education as to safe fish

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cooking temperatures (>70°C interior); (2) parasitological screening of fish, periodically at Hyderabad and Jamshoro markets; and (3) training of fishery extension workers in helminth risk identification.

5.2 Fisheries Productivity Concerns

In terms of fisheries management, the overall helminth prevalence of 34.61% in wild Catla catla in the Jamshoro reach indicates a moderate level of parasitological burden which though not a disaster per se to the health of the stock is a long-term cost to host resources. Thaparotrema damage of the gall bladder can lead to impairments in bile production and fat digestion; Isoparorchis damage to the swim bladder can cause issues with buoyancy and energy distribution; intestinalhelminths compete with the host directly on the available nutrients. Taken together, these consequences can inhibit growth rates, slow sexual maturation, and decrease reproductive output - and downstream effects on the stock recruitment in naturally reproducing Indus populations (Laghari, 2021; Poulin, 2000).

The helminthological risk of wild-caught Catla catla should be known to aquaculture operators who obtain seed stock in the Jamshoro reach of the Indus. Pond-reared stocks can quickly be contaminated with trematode cercariae (through snail intermediate hosts in the pond water) and nematode infective stages (through infected aquatic insect prey) when infected wild fish are introduced into the closed pond system. Recommended is the use of prophylactic deworming procedures and quarantine of wild-caught broodstock.

5.3 Research Priorities and Policy Recommendations

Considering the results of the present research and the comparative analysis given above, the following research and policy priorities are suggested to the freshwater fisheries sector in Pakistan:

6. Increased geographic surveys: Helminthological survey of Catla catla in all major barrages (Guddu, Sukkur, Kotri) and lake systems (Manchar, Keenjhar) in Sindh province to set up province-wide prevalence baselines.
7. Seasonal sampling: Sampling of fish during pre-monsoon, monsoon and post-monsoon periods to determine the fluctuation of helminth over a period of time - a significant factor in the dynamics of transmission.
8. Molecular systematics: DNA barcoding (COI, 18S rRNA) of all identified taxa to clarify species-level identifications, especially of Echinochasmus sp., Rhabdochona sp., Procamallanus sp., and Dispirin sp.
9. Histopathology: Evaluation of tissue damages in organs infected by helminth to measure the pathophysiological effects of infection on Catla catla and to compare the intensity of infections with indices of host body conditions.
10. Market surveillance: Parasitological screening of Catla catla in core fish markets in Hyderabad, Jamshoro and Karachi to determine the percentage of marketed fish harboring potentially zoonotic helminths.
11. Policy integration: The Sindh Fisheries Department should incorporate parasitological screening in fish quality certification procedures, and provide consumer advisory on safe preparation of fish.

6. Conclusion

The analysis of the helminth community of Catla catla (Hamilton, 1822) in the River Indus, Jamshoro, Sindh, Pakistan, is the first such study. Three phyla containing six taxa of helmints were distinguished: three trematodes (Thaparotrema pedicellatum, Isoparorchis trisimilitubis, Echinochasmus sp.),

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two nematodes (Procamallanus (Spirocamallanus) sp., Rhabdochona sp.), and one acanthocephalan (Dispirin A general prevalence of 34.61% was observed on 26 hosts examined, Trematoda being the most prevalent (23.07%) and Nematoda showing the highest ratio of specimens to the number of hosts infected (mean intensity 10.50 of Rhabdochona sp.). Each of the six taxa is a new host or locality record in Pakistan.

Comparative study with published studies in India and other localities in Pakistan confirms that the composition of the helminth community of Catla catla in the Indus is largely like regional trends in South Asian freshwater parasitology and demonstrates that Sindh province has been a neglected subject in parasitological literature. The discovery of Echinochasmus sp. — a genus of trematodes with known zoonotic capability - in a commonly sold food fish is a particular public health issue, which should be regulated. The first occurrence of Dispirin sp. in Pakistan provides valuable information into the haplorrhizal biogeography of this genus of acanthocephalans which is poorly known worldwide.

Together, these observations form a crucial scientific foundation to the ecological, epidemiological, and molecular studies that need to be undertaken now to fully describe the helminth fauna of the Pakistan Indus River fish communities. Urgent strategic investment in freshwater fisheries parasitology - which includes increased surveys, molecular, histopathological and market surveillance — is required to safeguard the ecological and health of both the inland fisheries of Sindh and the millions of Pakistanis who rely on it as a source of animal protein.

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