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Diversity and Impact of Freshwater Fish Parasites in West Bengal Aquaculture

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Abstract *— Aquaculture in West Bengal, India, is vital for regional food security and livelihoods, but its sustainability is under increasing threat from parasitic fauna. This review consolidates current knowledge on the diversity, biology, and economic impact of freshwater fish parasites in this important geographic and ecological region. We provide a thorough analysis of major parasitic groups, including protozoans, myxozoans, helminths, and crustaceans, highlighting their prevalence, host specificity, and pathogenic mechanisms. The review critically examines how environmental factors, aquaculture practices, and host immunity influence parasite transmission dynamics. Additionally, we evaluate the effectiveness and limitations of existing control methods, from traditional chemotherapeutics to innovative biotechnological and integrated management strategies. By identifying key knowledge gaps, such as the lack of large-scale epidemiological studies and the need for improved molecular diagnostics, this article aims to inform future research priorities. We conclude that adopting a paradigm shift toward sustainable, ecologically sound management practices, supported by a solid scientific understanding, is essential to combat the rising threat of parasitic diseases and to maintain the long-term resilience of West Bengal's aquaculture sector.*

Keywords *— **Aquaculture, West Bengal, freshwater fish, parasite diversity, disease management, protozoa, helminths, crustaceans***

I. INTRODUCTION

The state of West Bengal, often regarded as the cradle of Indian aquaculture, stands as a formidable force in the country's fisheries sector. With its extensive network of perennial rivers, oxbow lakes, and a vast array of ponds and tanks, the state significantly contributes to India's inland fish production, providing both livelihoods and sustenance for millions [1]. The cultivation of Indian major carps (IMCs) such as *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*, along with exotic carps like *Hypophthalmichthys molitrix* and *Cyprinus carpio*, forms the core of this industry. However, the intensification of aquaculture, marked by high stocking densities, the use of formulated feeds, and declining water quality, has unintentionally created a conducive environment for the spread of parasitic diseases [2, 3]. These pathogens, often less noticed than bacterial or viral outbreaks, pose ongoing and economically impactful challenges, causing chronic illness, slower growth, increased vulnerability to secondary infections, and significant mortality.

The study of fish parasites in West Bengal has a rich history, with early faunistic surveys dating back to the pre-independence era that largely focused on taxonomic descriptions of helminth and crustacean parasites in wild-caught fish [4]. These foundational works catalogued a remarkable diversity, establishing the region as a biodiversity hotspot for parasitic organisms. Subsequent decades saw a proliferation of localised studies, primarily from academic institutions in Kolkata, Burdwan, and Kalyani, which

expanded our understanding of parasite life cycles, host ranges, and seasonal prevalence in both wild and cultured systems [5, 6]. Despite this long-standing academic interest, the translation of this knowledge into practical, on-farm management strategies has remained fragmented. The literature is characterised by a predominance of cross-sectional surveys that document prevalence and intensity at single points in time, often lacking the longitudinal scope necessary to understand the complex, multi-factorial dynamics of disease outbreaks [7, 8].

A critical review of the existing literature reveals several persistent gaps and contradictions. Firstly, there is a geographical bias, with the majority of studies concentrated in the districts of Nadia, North 24 Parganas, and Hooghly, leaving vast swathes of the state's aquaculture heartlands undersampled [9, 10]. Secondly, while taxonomic descriptions are abundant, the application of modern molecular techniques (e.g., DNA barcoding, phylogenetics) for accurate species identification, particularly for cryptic species complexes within groups like myxozoans and trematodes, has been limited [11]. This reliance on traditional morphology can lead to misidentifications and an underestimation of true diversity. Thirdly, the economic impact of parasitic infections is often reported in qualitative terms (e.g., "heavy infection leads to economic loss"), with a notable absence of robust quantitative assessments that account for factors like feed conversion ratios, harvestable biomass, and treatment costs [12]. Finally, the region faces a pressing challenge posed by anthelmintic and antiprotozoal resistance. The widespread, often indiscriminate use of chemicals such as formalin, malachite green (now banned), and various organophosphates has raised concerns about environmental contamination, the emergence of resistant parasite strains, and the safety of the final product for human consumption [13].

This review aims to provide a holistic and critical synthesis of the diversity and impact of freshwater fish parasites in West Bengal aquaculture. We will move beyond a simple catalogue of species to analyse the ecological and management factors driving parasite emergence. By integrating findings from disparate studies, we will highlight the most prevalent and pathogenic taxa, evaluate current control paradigms, and identify strategic research priorities. The ultimate goal is to provide a comprehensive resource for researchers, extension specialists, and policymakers, fostering a more proactive and sustainable approach to parasitic disease management in this vital aquaculture region.

II. MAJOR PARASITIC TAXA AND THEIR IMPACT

The parasitic fauna associated with cultured freshwater fishes in West Bengal is remarkably diverse, encompassing representatives from nearly all major metazoan and protozoan groups. The pathogenic impact of these parasites is not uniform; it varies significantly based on the parasite's biology, the host's age and immune status, and prevailing environmental conditions. The following sections dissect the most consequential groups.

2.1. Protozoan and Myxozoan Parasites

Protozoan parasites, due to their direct life cycles and rapid reproductive rates, are often the first to cause clinical disease in intensive aquaculture systems. In West Bengal, ectoparasitic ciliates, particularly *Ichthyophthirius multifiliis* (white spot disease), *Trichodina* spp., and *Chilodonella* spp., are perennial problems in nursery and grow-out ponds [14]. These parasites cause significant epithelial damage, leading to osmoregulatory distress, respiratory impairment, and the creation of entry points for secondary bacterial pathogens. *I. multifiliis*, in particular, is notorious for causing epizootics with near-total mortality if not promptly managed. Studies across the state have reported trichodinid prevalence rates exceeding 70% in juvenile carp during the winter months, correlating with the accumulation of organic matter and lowered water temperatures [15, 16].

Flagellates such as *Trypanosoma* spp. and *Cryptobia* spp. are also prevalent, though their impact is often more insidious, causing chronic anaemia and immunosuppression in infected fish. A recent survey noted a high prevalence of *Trypanosoma danilewskyi* in *L. rohita* from South 24 Parganas, with infection intensity peaking during the post-monsoon season [17].

Among the most economically significant yet understudied groups are the myxozoans. Species such as *Myxobolus* spp. and *Thelohanellus* spp. are notorious for forming histozoic cysts in vital organs, including

the gills, musculature, and viscera. In West Bengal, *Myxobolus cuttackensis* has been linked to severe gill pathologies in *L. rohita*, leading to respiratory distress and mortality in advanced stages [18]. The life cycle of myxozoans involves an alternate oligochaete host, making their management in static pond systems particularly challenging. Recent molecular work has begun to unravel the species diversity in the region, revealing a much higher complexity than previously appreciated based on morphology alone [19]. A summary of prevalence data for key protozoan and myxozoan parasites is presented in Table 1.

Table 1: Prevalence of Key Protozoan and Myxozoan Parasites in Cultured Carps in West Bengal

Parasite Species	Host Fish	Study Location	Prevalence (%)	Key Reference
Ichthyophthirius multifiliis	*Cyprinus carpio*	Nadia	38.5	[14]
Trichodina spp.	*Labeo rohita*	Hooghly	72.1	[15]
Chilodonella cyprini	*Catla catla*	North 24 Parganas	45.3	[16]
Trypanosoma danilewskyi	*Labeo rohita*	South 24 Parganas	18.7	[17]
Myxobolus cuttackensis	*Labeo rohita*	Burdwan	29.4	[18]
Thelohanellus sp.	*Cirrhinus mrigala*	Kalyani	12.5	[19]

2.2. Helminth Parasites: Trematodes, Cestodes, and Nematodes

The helminth fauna of freshwater fish in West Bengal is exceptionally rich, with digenetic trematodes, cestodes, and nematodes exhibiting complex life cycles that often involve arthropod or molluscan intermediate hosts. Their pathogenic effects range from tissue damage at the site of attachment to severe systemic pathology.

Adult digenetic trematodes, primarily from the families Opisthorchiidae and Heterophyidae, localise in the gut, bile ducts, and gall bladder. Metacercarial stages of these flukes are frequently encysted in the musculature and viscera, rendering fish unmarketable and posing a potential zoonotic risk. The prevalence of *Clinostomum complanatum* (yellow grub) metacercariae in IMCs is particularly high in lentic water bodies, with studies reporting infection rates exceeding 50% in certain districts during the summer [20, 21]. This parasite causes significant economic losses due to consumer rejection of infected fish.

Table 2: Comparative Prevalence of Cestode Parasites in Cultured Carps in West Bengal

Parasite Species	Host Fish	Study Location	Prevalence (%)	Pathological Impact	Key Reference
Bothriocephalus acheilognathi	*Cyprinus carpio*	Multiple Districts	41.2	Stunting, enteritis in fry	[22]
Lytocestus indicus	*Cirrhinus mrigala*	Burdwan	23.8	Intestinal blockage	[5]
Lytocestus sp.	*Labeo rohita*	Nadia	16.5	Mucosal damage	[26]

Cestodes, especially species belonging to the genera *Lytocestus* and *Bothriocephalus*, are ubiquitous intestinal parasites of carps. *Bothriocephalus acheilognathi*, a highly pathogenic Asian tapeworm, has been introduced globally through aquaculture and is now firmly established in West Bengal [22]. Heavy infections can lead to intestinal obstruction, enteritis, stunted growth, and high mortality in fingerlings. A comparative analysis of cestode infections across different carp species is provided in Table 2. Nematode infections, while often less clinically apparent, can cause severe pathology when present in high numbers. Species like *Camallanus* spp. are blood-feeding nematodes that attach to the intestinal mucosa, causing hemorrhagic enteritis and anaemia. Recent studies have documented *Camallanus*

cotti infections in various freshwater fish species across West Bengal, with prevalence patterns correlating with seasonal variations and water quality parameters [23, 24]. Studies have shown a positive correlation between the intensity of *Camallanus* infection and poor water quality parameters, particularly high ammonia and low dissolved oxygen levels [25].

2.3. Crustacean Parasites

Among the metazoan parasites, crustaceans such as copepods and branchiurans are often the most visible and directly damaging. The anchor worm *Lernaea cyprinacea* and the fish louse *Argulus* spp. are perennial scourges of carp aquaculture in West Bengal. These ectoparasites inflict severe mechanical damage through their attachment and feeding appendages, causing extensive tissue trauma, secondary infections, and significant physiological stress [27].

Argulus spp. are particularly problematic due to their ability to move freely between hosts, their high fecundity, and their potential to act as mechanical vectors for viral and bacterial pathogens. Outbreaks are often explosive, especially during the warmer months, and can lead to mass mortality in affected ponds. A survey conducted in the districts of Howrah and Hooghly found *Argulus* infestations in over 60% of carp farms, with *A. foliaceus* and *A. siamensis* being the predominant species [28]. The economic impact of lernaeosis is staggering, with estimates suggesting that chronic infections can reduce growth rates by up to 40% and increase production costs due to poor feed conversion [29].

The pathogenic impact of these crustaceans is not limited to physical damage. The feeding activity of *Lernaea* and *Argulus* results in continuous, low-level haemorrhaging, leading to anaemia and a state of chronic stress that suppresses the host's immune system, making it more susceptible to opportunistic pathogens [30]. Furthermore, the control of these parasites is complicated by their complex life cycles and the growing evidence of resistance to commonly used organophosphate pesticides [13]. Recent research has explored eco-friendly alternatives for *Argulus* control, including salt baths, potassium permanganate, and herbal extracts such as turmeric, which have shown promising results in reducing parasite loads [31].

Table 3: Pathogenic Impact of Major Crustacean Parasites on Carp in West Bengal

Parasite Species	Host Fish	Attachment Site	Major Pathological Effects	Impact on Production	Key Reference
Lernaea cyprinacea	Multiple Carp Species	Skin, fins, muscle	Ulcerations, haemorrhages, secondary infections	Growth reduction (20-40%), mortality	[27, 29]
Argulus spp.	Multiple Carp Species	Skin, fins, buccal cavity	Severe tissue damage, stress, a vector for pathogens	High mortality in outbreaks, market rejection	[28, 30]
Ergasilus spp.	*Labeo rohita*	Gills	Gill erosion, hyperplasia, and respiratory distress	Reduced oxygen uptake, chronic stress	[32]

III. DRIVERS OF PARASITE EMERGENCE AND TRANSMISSION DYNAMICS

The prevalence and impact of parasitic infections in West Bengal's aquaculture systems are not random occurrences but are shaped by a complex interplay of environmental, biological, and anthropogenic factors. Understanding these drivers is crucial for predicting outbreaks and designing effective interventions.

- **Environmental Factors:** Seasonal variations significantly influence parasite dynamics. The distinct climatic seasons in West Bengal- pre-monsoon, monsoon, post-monsoon, and winter- create fluctuating conditions that differentially affect parasites and their hosts. Most studies report peak prevalence of ectoparasites like *Trichodina* and *Ichthyophthirius* during the

winter months (December to February), when water temperatures are lower (15-20°C) and fish immune function is suboptimal [15, 16]. Conversely, crustacean parasites such as *Argulus* and *Lernaea* thrive during the warmer pre-monsoon and monsoon periods, where higher temperatures accelerate their life cycles and reproductive rates [28, 33]. Research on endohelminth parasites has shown that climatic conditions directly influence infection intensity, with the highest parasite burdens recorded during winter compared to summer, monsoon, and post-monsoon seasons [2]. Water quality parameters, particularly dissolved oxygen, ammonia, and pH, are critical mediators of host susceptibility. Poor water quality caused by overfeeding and high stocking densities induces chronic stress in fish, suppressing innate immune responses and creating favourable conditions for parasite proliferation [3].

- **Aquaculture Practices:** The intensification of aquaculture has been a double-edged sword. While high stocking densities maximise production per unit area, they also increase host-parasite contact rates and facilitate the rapid spread of infectious agents. The use of untreated or poorly formulated supplementary feeds can lead to nutrient imbalances and deterioration of water quality. Furthermore, the practice of polyculture, while generally beneficial for pond ecology, can complicate disease dynamics by providing a continuous supply of susceptible hosts for generalist parasites [34]. The movement of live fish and seed stock across districts, often without adequate health certification, serves as a primary mechanism for the introduction and dissemination of parasites. The spread of *Bothriocephalus acheilognathi* across West Bengal has been directly linked to the unregulated transport of infected carp fry [22].
- **Host Factors:** Host susceptibility is also influenced by species, age, and genetic factors. Indian major carps are generally more susceptible to certain protozoan and myxozoan infections than exotic carps like common carp, though this is not a universal rule [35]. Fingerlings and juveniles, with their developing immune systems, are the most vulnerable age class, suffering the highest mortality rates from infections that would be sub-clinical in adults. This age-dependent susceptibility has significant implications for hatchery and nursery management, where high-value seed stock is concentrated.

IV. CURRENT MANAGEMENT STRATEGIES AND THEIR LIMITATIONS

In response to the constant threat of parasitic diseases, fish farmers in West Bengal have developed a repertoire of management practices, ranging from traditional pond preparation methods to the widespread use of chemical therapeutics. However, a critical analysis reveals significant limitations in the current approach.

- **Pond Management and Biosecurity:** Traditional practices such as pond liming (using quicklime or slaked lime), drying, and the use of organic manure are foundational to pond health. Sun-drying of pond bottoms is an effective method for disrupting the life cycles of many parasites with resting stages in the sediment [36]. However, in many intensively farmed areas, the pressure to maintain production cycles means ponds are often not adequately dried, and the application of untreated manure can introduce parasitic eggs or intermediate hosts. Biosecurity measures, such as quarantining new stock, disinfecting equipment, and using parasite-free feed, are rarely implemented on a commercial scale, leaving farms vulnerable to the introduction and perpetuation of pathogens [3].
- **Chemotherapy:** The mainstay of parasite control in West Bengal is the use of chemical treatments. A wide array of compounds, including potassium permanganate, copper sulfate, formalin, and various organophosphates (e.g., trichlorfon, dimethoate), are routinely used, often prophylactically, without proper diagnosis or

dosage calculation [13]. This approach has several critical drawbacks. Firstly, the efficacy of these chemicals is often limited. Many are effective only against the free-living stages of parasites (e.g., *Ichthyophthirius* theronts) and have no impact on the trophont stages embedded in the host tissue, necessitating repeated applications. Secondly, the use of these compounds poses significant environmental and food safety risks. Their non-specific nature disrupts beneficial microbial communities in the pond ecosystem and can be directly toxic to fish if misapplied [37]. Perhaps most critically, the intensive and indiscriminate use of these chemicals has selected for resistance in parasite populations. Evidence for resistance to organophosphates in *Argulus* populations in West Bengal is beginning to emerge, mirroring trends seen in global aquaculture [38].

- **Emerging Alternatives:** In response to the limitations of chemotherapy, there is a growing interest in sustainable alternatives. These include the use of immunostimulants (e.g., β-glucans, plant-derived compounds) to enhance host resistance, probiotics to improve water quality and competitively exclude pathogens, and biological control agents [39, 40]. For instance, herbal extracts such as *Swietenia mahagoni* (mahogany) have demonstrated significant antiprotozoan activity against trichodinid ciliates, reducing parasite burdens within days of treatment [41]. Similarly, eco-friendly approaches combining salt baths, formalin, potassium permanganate, and turmeric have shown efficacy in controlling *Argulus* infestations in *Labeo rohita* [31]. However, the transition of these alternatives from laboratory-scale trials to practical, on-farm applications remains a significant challenge, hindered by a lack of standardized protocols, concerns about cost-effectiveness, and limited awareness among farmers.

V. RESEARCH GAPS AND FUTURE DIRECTIONS

Despite decades of research, our understanding of fish parasitology in West Bengal remains incomplete. Several critical knowledge gaps must be addressed to build a more resilient and sustainable aquaculture sector.

a) **Large-Scale, Standardised Epidemiological Surveys: The existing literature is dominated by localised**, small-scale studies with varied methodologies, making it difficult to derive a comprehensive picture of the state's parasitic landscape. There is an urgent need for a systematic, multi-year, and multi-district epidemiological surveillance program using standardised sampling and diagnostic protocols [8, 42]. Such a program would establish baseline data on parasite prevalence, intensity, and spatiotemporal distribution, enabling the development of early warning systems.

b) **Molecular Taxonomy and Diagnostics:** The reliance on traditional morphological identification has likely masked the true species diversity and led to misdiagnoses. Future research must integrate molecular tools (e.g., 18S rDNA sequencing for myxozoans and protozoa, COI barcoding for helminths and crustaceans) to accurately characterise parasite communities and understand their phylogenetic relationships [11, 19]. Concurrently, the development of rapid, field-deployable molecular diagnostics (e.g., LAMP assays) would revolutionise disease management by enabling farmers and extension workers to identify pathogens early and accurately.

c) **Quantifying Economic Impacts:** To advocate for better management and allocate research funding effectively, the economic impact of parasitic diseases must be robustly quantified. Future studies should move beyond reporting prevalence to quantify tangible losses using metrics such as mortality rates, reduced feed conversion ratios, increased treatment costs, and impacts on market value [12, 29]. A summary of reported

parasite diversity across different host species is provided in Table 4.

d) **Understanding Host-Parasite Interactions:** More research is needed on the fundamental mechanisms of host-parasite interactions. This includes investigating the immune response of Indian major carps to key pathogens, identifying genetic markers for resistance, and understanding the role of the host microbiome in modulating infection outcomes [39, 43]. This knowledge is essential for developing effective immunoprophylactic strategies.

e) **Evaluating Integrated Management Strategies:** Research should prioritise the validation and refinement of integrated parasite management (IPM) strategies that combine optimised pond management, biosecurity, biological control, and the judicious use of therapeutics based on resistance profiling [31, 38]. The efficacy, economic viability, and environmental impact of these IPM packages must be assessed through long-term, on-farm trials.

Table 4: Reported Parasite Diversity in Major Cultured Fish Species of West Bengal

Host Species	Protozoan/Myxozoan	Helminth	Crustacean	Total Reported Species	Key Reference
Labeo rohita (Rohu)	18	27	6	51	[5, 14, 25, 32]
Catla catla (Catla)	12	22	5	39	[5, 16, 20]
Cirrhinus mrigala (Mrigal)	10	19	4	33	[5, 19]
Cyprinus carpio (Common Carp)	9	15	7	31	[14, 22, 28]

VI. CONCLUSION

The vibrant aquaculture sector of West Bengal stands at a critical juncture. The immense productivity gains achieved through intensification are now threatened by a complex and dynamic array of parasitic pathogens. As this review has demonstrated, the diversity of these parasites is immense, spanning from ubiquitous ciliates to highly specialised crustaceans, each capable of inflicting substantial economic and biological harm. The current management paradigm, heavily reliant on reactive chemical treatments, is proving to be unsustainable, fostering environmental contamination, chemical resistance, and ultimately, a cycle of recurring disease. The body of scientific literature, while rich in foundational faunistic accounts, reveals a fragmented understanding of the true scale and complexity of the problem. It is characterised by a predominance of isolated prevalence studies that, while valuable, do not provide the integrated, systems-level insight required for effective intervention. The gaps are stark: a lack of unified epidemiological surveillance, a lag in the adoption of precise molecular diagnostics, and a critical shortage of quantitative economic assessments that would compel a shift in policy and practice.

Moving forward, the path to sustainability demands a fundamental reorientation. The future of parasite management in West Bengal cannot be a continuation of the chemical treadmill. Instead, it must be built upon the principles of integrated parasite management (IPM), an ecologically informed approach that prioritises prevention and minimises the need for chemical intervention. This begins with a paradigm shift at the farm level, moving from routine chemical application to proactive health management through optimised pond preparation, strict biosecurity, high-quality, uncontaminated feed, and selective breeding of resistant stocks. For researchers, the imperative is to forge an interdisciplinary agenda. We must leverage the power of molecular tools to build robust diagnostic and surveillance networks that can provide real-time data to farmers. We must delve deeper into the fundamental biology of host-parasite interactions to identify novel targets for

intervention, be they through immunostimulants, probiotics, or biological control agents. Most importantly, the translation of this knowledge must be driven by a commitment to extension and capacity building. The ultimate success of any management strategy hinges on its accessibility and practicality for the smallholder farmers who form the backbone of the industry. The challenge is significant, but so is the prize. By embracing a science-driven, holistic approach to parasite management, West Bengal can not only safeguard its current production levels but also chart a course towards a more resilient, profitable, and environmentally responsible future for its most vital aquaculture sector.

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