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Occurrence of Ectoparasitic Infections in Cultured Food and Ornamental fish of the Cauvery Delta Region, Tamil Nadu

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Abstract

A research study was conducted to investigate the occurrence, prevalence, mean intensity and abundance of parasite infestations in the Cauvery Delta region during a span of 15-20 days. The study focused on cultured food and ornamental fishes, with a total of 30 different fish samples including carps, Nile tilapia and goldfish collected and brought to the laboratory for analysis. The fishes were examined for ectoparasites using a wet mount preparations under a light microscope, focussing on the gills, skin mucus, and fins like pelvic fins, pectoral and caudal fins. The examination revealed the occurrence of three ectoparasites: *Argulus* sp., *Lernaea* sp., and *Trichodina* sp. The overall parasite prevalence was recorded at 78.3%, with a mean intensity of 400 and an abundance of 0.78. Infection rates were significantly higher in larger fish, with some cases showing 100% prevalence, indicating a strong correlation between fish size and susceptibility to parasitic infections. The study also highlighted the influence of environmental factors such as water quality and stocking density on the severity of infestations. These findings emphasize the importance of routine health monitoring and effective management practices to control ectoparasitic infections and improve fish health in aquaculture systems.

Key words: Fish, Ectoparasites, Mean intensity, Prevalence, Abundance, Cauvery delta

Parasitism in aquatic organisms is recognized globally as one of the major biological constraints affecting fisheries resources and aquaculture sustainability. The intensification of aquaculture practices, coupled with rapid environmental degradation of inland waters, has created conditions that favour the emergence and persistence of parasitic diseases in fish populations [1-2]. Increasing anthropogenic pressures, nutrient enrichment, and habitat modifications have altered limnological characteristics of aquatic ecosystems, thereby enhancing parasite survival, transmission, and host exposure [3-4]. The interaction between environmental stressors and host–parasite dynamics has become a major concern for fish health management worldwide, as parasitic outbreaks are now frequently associated with polluted and eutrophic aquatic environments. Parasites are organisms that live on or inside another living host, often causing harm while deriving benefits like food or shelter. In aquaculture, parasitic infections are a major challenge as they can affect the health, growth and survival of fish [5]. The establishment and proliferation of ectoparasites are strongly influenced by environmental stressors and deterioration of water quality, which compromise host immunity and facilitate parasite attachment and survival [6]. Globally, there is growing evidence that parasitic prevalence and intensity are strongly influenced by environmental quality. Aquatic ecosystems subjected to organic pollution and nutrient loading often exhibit higher parasite burdens due to increased availability of intermediate hosts and favourable conditions for parasite reproduction [6]. Altered trophic status of water bodies has been shown to significantly regulate parasite community structure and infection pressure in fishes, with eutrophic systems supporting higher parasitic loads [7]. In addition, chronic exposure to pollutants has been demonstrated to impair fish immune responses, thereby reducing resistance to parasitic infections and enhancing disease severity [8].

In India, freshwater fisheries and aquaculture are vital components of food security and rural livelihoods. However, parasitic diseases remain one of the most persistent constraints to productivity and sustainability. The degradation of inland waters through domestic sewage discharge, agricultural runoff, industrial effluents, and aquaculture waste has resulted in widespread eutrophication and deterioration of water quality [9]. Such changes in environmental conditions are known to enhance parasite transmission and establishment in fish

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populations. Several investigations from diverse freshwater ecosystems in India have demonstrated that parasitic bio load in fishes increases significantly under polluted and nutrient-enriched conditions. The incidence and intensity of parasitic infections in fishes inhabiting degraded riverine and lacustrine environments are consistently higher than those observed in relatively pristine waters [10-11]. Environmental parameters such as temperature, dissolved oxygen, organic matter content, and nutrient concentrations play a crucial role in determining parasite distribution patterns. Additionally, native freshwater fishes have been shown to reflect underlying environmental quality through variations in parasite communities, indicating their potential as biological indicators of aquatic pollution [12]. Changes in parasite assemblages and infection intensity in fishes have been linked with ecological disturbances, thereby providing valuable insights into ecosystem health.

At the physiological level, exposure to environmental contaminants and chronic stress has been reported to suppress immune functions in fishes, thereby enhancing susceptibility to both ectoparasitic and endoparasitic infections. This immunosuppression, combined with environmental favourability for parasite reproduction, creates a feedback loop that amplifies disease outbreaks in polluted waters [8]. Furthermore, parasitic infestations have been associated with severe histopathological alterations in vital organs such as gills and skin, leading to impaired respiration, reduced feeding efficiency, and stunted growth. Such pathological effects are particularly pronounced in fishes inhabiting degraded environments, where combined stress from pollution and parasitism acts synergistically to compromise health and survival [13].

Tamil Nadu has emerged as one of the leading states in freshwater and ornamental fish culture in India. The rapid expansion of aquaculture activities has increased production but has also intensified disease risks due to high stocking densities, frequent handling, and inconsistent water quality management have concurrently elevated disease risk in cultured fish populations [14]. Organic enrichment of culture waters resulting from uneaten feed and metabolic wastes promotes eutrophic conditions that are conducive to parasite proliferation. In intensive aquaculture systems, ectoparasitic infections are more prevalent due to crowding, fluctuating water quality, and inadequate biosecurity measures**.** Such conditions facilitate rapid transmission of parasites among hosts, leading to outbreaks that cause significant production losses. Ornamental fish culture is particularly vulnerable, as even mild ectoparasitic infestations can compromise aesthetic quality and market value. Visible ectoparasites, tissue lesions, and behavioural abnormalities render ornamental fishes unfit for trade, resulting in economic losses [15]. The high sensitivity of ornamental fishes to environmental fluctuations further exacerbates susceptibility to parasitic infections.

The Cauvery Delta Region represents an ecologically sensitive and economically important landscape characterized by intensive agriculture, dense human settlements, and expanding aquaculture practices. Aquatic systems in this region receive substantial inputs of nutrients, organic matter, and agrochemicals, which alter water quality and ecological balance [3]. In the Cauvery Delta Region, where aquaculture is intensively practiced, both food fishes like carps and catfishes and for ornamental fishes are vulnerable to such infections due to high stocking densities, fluctuating water quality, and poor biosecurity. Cultured food and ornamental fishes are exposed to multiple stressors, including organic pollution, nutrient enrichment, and unstable water quality, which collectively favour ectoparasite establishment and transmission. The nutrient-rich environment supports rapid parasite multiplication and increases the probability of disease outbreaks in culture systems. Comparative observations from polluted freshwater ecosystems elsewhere in India suggest that parasite prevalence is positively correlated with trophic enrichment and deteriorating water quality. However, region-specific data on ectoparasitic diversity, prevalence, and intensity in the Cauvery Delta remain fragmented and limited. Although substantial research has addressed parasitic infections in fishes inhabiting natural freshwater systems and cold-water environments, comparatively fewer studies have focused on ectoparasitic infestations in intensively managed aquaculture systems of South India. Most existing investigations emphasize endoparasitic helminths in natural waters, while systematic documentation of ectoparasite diversity and prevalence in cultured food and ornamental fishes remains inadequate. Despite the recognized influence of pollution, eutrophication, and management-related stressors on parasitic disease dynamics, integrated assessments linking environmental quality with ectoparasite occurrence in aquaculture-dominated landscapes are scarce.

Among them, ectoparasites are those that live externally on the body of fish-commonly attaching to the skin, fins or gills. These include groups such as monogeneans, parasitic copepods, leeches, argulus, isopods, and protozoan ciliates like *Trichodina* which can cause physical damage, stress and make fish more susceptible to secondary infections [16]. One of the most commonly observed ectoparasites in this region is Argulus, also known as fish lice. These parasitic crustaceans attach to the skin of fish using suckers and feeding stylets. They pierce the skin and feed on host blood and body fluids, leading to ulcerations, haemorrhaging and abnormal swimming behaviour. Argulus infestations are often visible to the naked eye and can spread quickly in closed culture systems [17]. Another significant ectoparasite is *Lernaea*, commonly called anchor worm. It is a copepod that undergoes several development stages before the mature female embeds itself deeply into the fish's flesh, leaving part of its body protruding. This parasite causes inflammation, localized redness and open wounds, making the fish vulnerable to secondary infections. In ornamentals fishes, *Lernae*a greatly reduces visual appeal and market value [18]. *Trichodina* is another important ectoparasites found on the skin, fins and gills of freshwater fishes. Though many *Trichodina* species are ectocommensals that feed on suspended bacteria, under stressful or overcrowded conditions, they can become pathogenic. Infections are often linked to eutrophication and poor management practices, and severe infestations can impair respirations, feeding and general behaviour of the host fish.

Ectoparasitic infections such as those caused by *Argulus, Lernaea* and *Trichodina* not only decrease fish welfare but also result in reduced growth rates, increased treatments costs and stock losses. In ornamental fish farming, the presence of even a few visible parasites can render the fish unsellable. Ectoparasitic infestations not only reduce the aesthetic value of ornamental fishes but also lead to economic losses in food fish farming. The most common fish parasitic diseases, particularly in freshwater aquaria and food fishes include gill flukes, skin fluke, velvet disease, white spot disease, fish lice, Costia and Chilodonella [19]. The paper deals with the prevalence and abundance of parasites of ornamental aquarium and food fishes. Therefore, studying the occurrence and diversity of ectoparasites in this region is vital for effective health management and sustainable aquaculture practices.

Therefore, the present study aims to document the occurrence, prevalence, and diversity of ectoparasitic infections in cultured food and ornamental fishes of the Cauvery Delta Region and to relate parasite occurrence with environmental and management-related stressors. This work is expected to generate baseline data for disease surveillance, support evidence-based health management strategies, and contribute to sustainable aquaculture development in the region.

MATERIALS AND METHODS

The present study has been conducted at the Department of Aquatic Animal Health Management, Dr. M.G.R Fisheries college and Research Institute, Thalainayeru, Nagapattinam.

Study area and sample collection

Fishes samples including carps Nile tilapia and Gold fish were collected randomly from different fish farms in Cauvery delta region over a period of 15 to 20 days. They were transported to the laboratory in polythene bags containing pond water to keep them alive until analysis. The total length, weight, date, and collection site of each fish were recorded. The specimens were then brought either alive or freshly collected to the Department of Fish Pathology and Health Management, Dr. M.G.R Fisheries College and Research Institute, Thalainayeru, for further examination.

Wet mounts preparation

Skin samples were collected from different spots from any visible lesions. Mucus was gently scraped from the dorsal fin, pectoral fin, pelvic fin, anal fin and caudal peduncle using cover glass. The collected mucus was then placed on a glass slide with a drop of distilled water and examined under the light microscope for observing the occurrence of ectoparasites. For gill examination, the operculum was carefully dissected using scissors to expose the gill filaments. A small portion of the gill mounted on a clean glass slide with a drop of distilled water was added. Glass slide with a piece of gill was covered with a cover slip and examined under the light microscope at magnification of 40 X for observation of monogenean parasites.

Identification and preservation of parasites

Parasites were placed under the light microscope and identified following the description and figures of Dash [20] and Stoskopf [21]. Parasites were magnified 40×, 100× by the help of a light microscope and parasites were identified. Identified parasites were carefully preserved in 10% formalin acetic acid alcohol solution for long time storage.

Statistical analysis of the data

On occurrence of parasites from the fishes was carried out using the following formulae:

Prevalence (%) = Number of infected hosts/ Number of hosts examined × 100

Mean Intensity (MI) = Total amount of parasites/ Number of Infected hosts × 100

Abundance = Number of parasites recovered/ Number of hosts examined

RESULTS AND DISCUSSION

During the present study, a total of 30 specimens of food fishes and ornamental fishes they are *Catla catla, Oreochromis niloticus* and *Carassius auratus* were examined to investigate the prevalence, Mean intensity and abundance of parasitic infections. A total of 3 ectoparasite species were identified from the food and ornamental fishes during the study period. The parasites isolated from investigated host fishes were *Argulus* sp., *Lernaea* sp., *Trichodina* sp.

Day wise parasite infestation in the cultured food and ornamental fishes

The overall prevalence, mean intensity and abundance of the total parasites are shown in (Table 1, Fig 1). The prevalence of parasites was ranging from 0 to 100% during the study period. The highest parasite prevalence (100%), (66.67%) and (50%)

Table 1 Prevalence, mean intensity and abundance of parasites in the cultured food and ornamental fishes

Study periods	Number of hosts examined	Number of hosts infected	Prevalence (%)	Mean intensity	Abundance
Day 1	3	2	66.67	50	0.33
Day 2	1	1	100	100	1
Day 3	-	-	-	-	-
Day 4	-	-	-	-	-
Day 5	4	2	50	100	0.5
Day 6	-	-	-	-	-
Day 7	1	1	100	100	1
Day 8	3	1	33.3	300	1
Day 9	-	-	-	-	-
Day 10	-	-	-	-	-
Day 11	1	1	100	100	1
Day 12	2	2	100	100	1
Day 13	3	0	0	0	0
Day 14	-	-	-	-	-
Day 15	2	1	50	100	0.5

Table 2 Prevalence, mean intensity and abundance of parasitic infection of food and ornamental fishes in different length groups

Length groups (cm)	No of hosts examined	No of host infected	Total no of parasites recorded	Prevalence (%)	Mean intensity	Abundance
3- 6 cm	7	6	5	85.71	83.33	0.71
6-10 cm	10	4	3	40	75	0.3
Above 10 cm	3	1	2	33.34	200	0.66

Prevalence, mean intensity and abundance of cultured food and ornamental fishes in different length groups

The present investigation indicated that parasitic infections are influenced by the size of the fish. An effort was made to examine the correlation between fish length and the percentage of infected individuals. The distribution of fish across various length categories is presented in (Table 2, Fig 2). Findings suggest that larger fish tend to be more vulnerable to parasitic infections compared to smaller ones, as a higher level of infestation was observed in fish of greater length. The highest prevalence value (85.71%) was found in length groups 2-6 cm and lowest prevalence value (33.34%) was found in above 10 cm length groups. The highest abundance value (0.71) was found in 2-6cm length groups but lowest (0.3) was bound in 6-10cm length groups. The highest Mean intensity value (200) was found in above 10cm and lowest value (75) was found in median lengths. The present findings agree with those of Petchimuthu *et al.* [22] who described highest prevalence of parasite (23.71%) was recorded from higher length group (>10 cm) and the lowest (14.28%) from smaller length group (3-5cm). Highest abundance value was recorded from medium length group (3.32) but lowest abundance value from smaller length group (0.35). Farhaduzzaman *et al.* [23] reported the highest parasite prevalence (75%) in fish of 160–180 mm length, and the lowest (33.34%) in those of 80–100 mm. Parasite abundance ranged from 1.56 (80–100 mm) to 3.52 (100–120 mm).

Prevalence, mean intensity and abundance of each parasite species during the study period

The parasitological examination of fish from the Cauvery Delta region revealed the presence of three ectoparasitic species (Table 3, Fig 3): *Argulus sp.*, *Lernaea sp.*, and *Trichodina* sp. Among the examined hosts, *Argulus* sp. Haad the highest prevalence (33.3%), with two out of 6 hosts being infected. *Lernaea* sp. exhibited a prevalence of 25% with a mean intensity of 200, indicating a higher burden on infected fish despite a lower overall occurrence. *Trichodina* sp. Was detected in 20% of the examined hosts, with a moderate mean intensity of 100. The abundance of parasites ranged from 0.2 to 0.33, suggesting relatively low infestation levels. The presence of *Argulus sp.*, *Lernaea sp.*, *Ichthyophthirius multifiliis*, and gill flukes in both ornamental and food fishes highlight the importance of effective ectoparasite control strategies.

Table 3 Prevalence, mean intensity and abundance of parasitic infections in Cauvery Delta Region

Parasites	No. of host examined	No. of host infected	No. of parasites recovered	Prevalence (%)	Mean intensity	Abundance
Argulus sp.	6	2	2	33.3	100	0.33
Lernaea sp.	4	1	2	25	200	0.25
Trichodina sp.	5	1	1	20	100	0.2

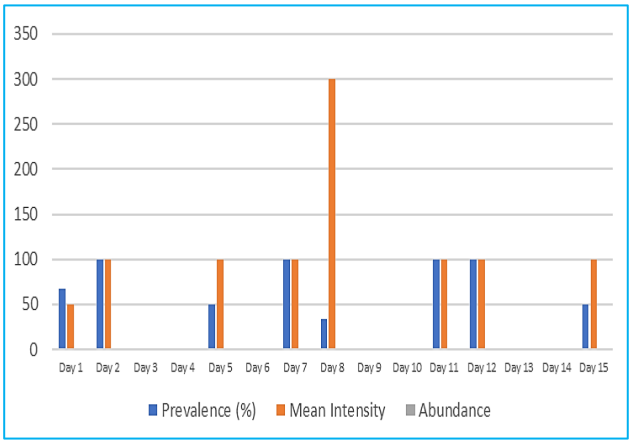

Fig 1 Prevalence and abundance of parasites in the cultured food and ornamental fishes

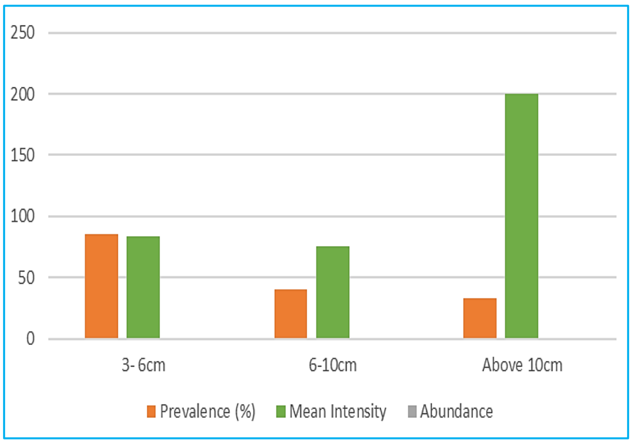

Fig 2 Prevalence and abundance of parasitic infection of food and ornamental fishes in different length groups

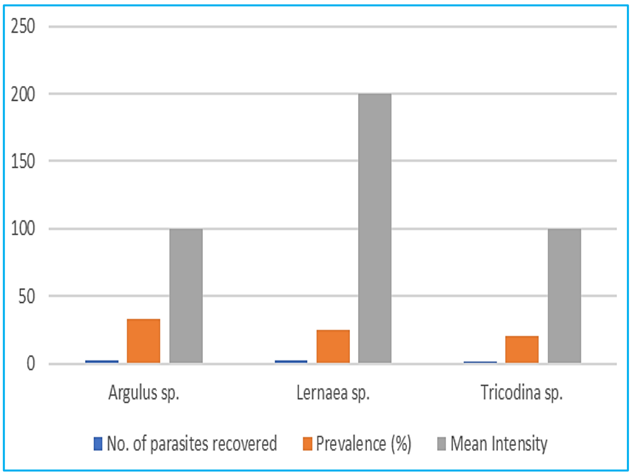

Fig 3 Prevalence and abundance of parasitic infections in Cauvery Delta Region

The present study provides baseline information on the occurrence and intensity of ectoparasitic infections in cultured food fishes and ornamental fishes from the Cauvery Delta Region. The detection of three ectoparasite taxa *Argulus, Lernaea, and Trichodina* indicates that cultured systems in the region are exposed to multiple parasitic stressors. Similar parasite assemblages are commonly reported from tropical aquaculture systems under semi-intensive and intensive management [24]. Although overall abundance values were relatively low, the occurrence of high prevalence (up to 100%) on certain sampling days suggests episodic outbreaks, likely driven by short-term fluctuations in environmental conditions and management practices [25-26]. Petchimuthu *et al.* [22] investigated the prevalence and abundance of fish parasites in aquaculture farms of South Tamil Nadu. Their study revealed that *Dactylogyrus sp.* showed the highest prevalence (7.44%), followed by *Argulus sp.* (6.97%) and *Lernaea sp.* (6.04%). Conversely, *Ichthyophthirius multifiliis*, *Caligus sp.*, and

Capsalid sp. had the lowest prevalence (0.46%), each being reported from only one farm. In terms of abundance, *Dactylogyrus sp.* again ranked highest (0.97), while *Argulus sp.*, *Lernaea sp.*, and *Caligus sp.* recorded values of 0.33, 0.24, and 0.03, respectively. The lowest abundance (0.004) was observed for *Ichthyophthirius multifiliis* and *Capsalid sp*. According to Adel *et al*. [27], *Ichthyophthirius multifiliis* showed the highest rate of infection in *Carassius auratus*. Among other parasites, members of the families *Gyrodactylidae* and *Dactylogyridae* were most prevalent in *C. auratus*, while their occurrence was comparatively lower in *Pterophyllum scalare* and *Symphysodon discus*. High stocking density, shallow water levels, temperature fluctuations, and other physico-chemical factors often create stressful environments for fish, making them more prone to parasitic infections.

The marked day-wise variation in prevalence (0–100%) and abundance observed in the present study highlights the dynamic nature of ectoparasitic infestations in culture systems. Such fluctuations are commonly associated with rapid changes in water quality parameters (e.g., temperature, dissolved oxygen, organic load), stocking density, and handling stress [8], [28]. Periods showing 100% prevalence, even with a small number of hosts examined, indicate that under favourable conditions parasites can spread rapidly among confined fish populations. Similar short-term spikes in parasite prevalence have been reported from aquaculture systems, where crowding and poor water exchange promote rapid transmission [6], [25]. The absence of parasites on certain days likely reflects either reduced sampling effort or temporary unfavourable conditions for parasite attachment and survival, emphasizing the episodic nature of ectoparasite outbreaks in managed culture environments [29].

The present investigation suggests that parasitic infection is influenced by host size, with variation in prevalence, mean intensity, and abundance across different length groups. Higher prevalence and abundance in smaller size groups (3–6 cm) may be attributed to the relatively weaker immune competence of juveniles and their thinner epithelial barriers, which facilitate parasite attachment [30]. Conversely, the highest mean intensity recorded in larger fish (>10 cm) indicates that once infected, larger individuals may harbour heavier parasite loads, possibly due to increased surface area, longer exposure time, and more stable microhabitats on the host body [31-32].

These findings broadly agree with earlier observations that host size influences parasite burden, although the direction of the relationship may vary depending on host species, parasite biology, and culture conditions [29], [31]. Larger fish often experience prolonged exposure to infective stages, whereas smaller fish may be more susceptible to initial infection due to underdeveloped immune defenses [30]. The observed size-related trends underscore the importance of size-specific health management strategies in aquaculture, particularly during early life stages when fish are more vulnerable to parasitic attachment [33-34].

Among the three ectoparasites recorded, *Argulus sp.* showed the highest prevalence, reflecting its high mobility and ability to actively seek hosts in confined environments. Its visible nature and direct attachment to the skin facilitate rapid spread in culture systems, particularly under crowded conditions [24]. *Lernaea sp*., although exhibiting lower prevalence, showed the highest mean intensity, indicating that infected fish carried heavier parasite loads. This is consistent with the biology of anchor worms, where the embedded adult female causes localized tissue damage and prolonged attachment, leading to severe inflammatory responses and secondary infections [35]. *Trichodina sp*. exhibited moderate prevalence and intensity, which is typical of opportunistic ectocommensals that become pathogenic under stress and poor water quality conditions [36].

Comparisons with previous studies from aquaculture farms in Tamil Nadu and other regions indicate similar parasite assemblages, although prevalence and abundance values vary widely depending on management practices, water quality, and host species [25-26]. The detection of these ectoparasites in both food and ornamental fishes emphasizes the broad host range of common aquaculture parasites and their capacity to spread between different culture units when biosecurity measures are inadequate [33].

The occurrence of ectoparasites in the present study is likely influenced by a combination of environmental and husbandry-related stressors, including high stocking density, shallow water depth, temperature fluctuations, and suboptimal water quality. Such stressors are known to compromise host immune function, increasing susceptibility to parasite attachment and proliferation [8], [30], [37]. Nutrient enrichment and organic loading in culture waters further enhance the survival of free-living infective stages and microbial communities that support protozoan ectoparasites [28-29].

The relatively low overall abundance observed in the present study may reflect early-stage or low-intensity infestations; however, the presence of 100% prevalence on several sampling days highlights the potential for rapid escalation into outbreaks if environmental conditions deteriorate further [26]. This underlines the need for routine monitoring of water quality and parasite load in aquaculture systems, particularly in regions with intensive culture practices [25], [38].

Ectoparasitic infestations pose dual challenges in food fish and ornamental fish farming. In food fishes, chronic parasitism leads to reduced growth rates, impaired feed conversion efficiency, and increased susceptibility to secondary infections, ultimately affecting production yields [13]. In ornamental fishes, even low-intensity infestations can significantly reduce market value due to visible lesions, attached parasites, and behavioural abnormalities [36], [39]. The economic implications are therefore substantial, particularly for small-scale farmers who rely on high survival and aesthetic quality of stock [33].

The present findings highlight the necessity of implementing preventive health management strategies, including improved water quality management, optimal stocking densities, routine parasite screening, and strict biosecurity measures to prevent cross-contamination between culture units [25]. Early detection of ectoparasites and timely intervention can prevent minor infestations from escalating into severe outbreaks [26].

Future studies should focus on integrating parasitological assessments with detailed monitoring of physico-chemical water quality parameters to establish stronger causal links between environmental stressors and ectoparasite dynamics in the Cauvery Delta Region. Molecular identification of parasite species and experimental evaluation of host immune responses under varying environmental conditions would further strengthen understanding of parasite–host–environment interactions in tropical aquaculture systems [30], [40].

Therefore, this study highlights the occurrence, prevalence, mean intensity and abundance of ectoparasites in food and ornamental fishes collected from aquaculture farms in the Cauvery Delta region. The findings indicate a significant influence of environmental factors such as temperature, stocking density, and water quality on parasitic infections. The identified parasites including *Argulus* sp., *Lernaea* sp., and *Trichodina* sp., have been reported in previous studies as common ectoparasites affecting freshwater fish species. The observed prevalence, mean intensity and abundance of parasites varied across different fish length groups, with larger fish being more susceptible to infections than smaller ones. This may be attributed to increased surface area, prolonged exposure to environmental contaminants, and host-specific susceptibility to parasites. Similar findings have been documented in previous studies, where higher infection rates were observed in longer fish due to their increased susceptibility to external parasites.

The highest prevalence of parasitic infection was recorded on certain days, reflecting fluctuating environmental conditions that favour parasite proliferation. The results also demonstrate a clear association between host size and parasite load, supporting the hypothesis that fish length plays a crucial role in determining infection susceptibility. Effective management strategies, such as regular water quality monitoring, proper aeration and the use of antiparasitic treatments are necessary to mitigate parasite outbreaks. The study underscores the need for improved aquaculture management practices, including quarantine measures and periodic health assessments to minimize economic losses caused by ectoparasitic infections.

CONCLUSION

The present study provides valuable insights into the occurrence, mean intensity prevalence and abundance of parasites in cultured finfish in the Cauvery Delta Region. The Findings reveal that ectoparasitic infections, particularly by *Argulus* sp., *Lernaea* sp., and *Trichodina* sp., are prevalent among freshwater food and ornamental fishes. The study also establishes a correlation between fish length and parasite infestation, highlighting the increased susceptibility of larger fish to parasitic infections. The results emphasize the importance of effective aquaculture management practices to control and prevent ectoparasitic outbreaks. Regular health monitoring, improved water quality management, and the implementation of biosecurity measures are essential to reducing parasite-induced economic loses in fish farming. Future research should focus on identifying advanced treatment strategies and sustainable management practices to enhance fish health and productivity in aquaculture systems.

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Authors contribution

R. Senthamil: Writing - original draft, methodology; conceptualization, review & Editing, resources; J. Siva Shanmugam: Review and editing & Visualization; V. K. Vedant and P. Shailesh- Review & editing, resources; Pankaj R. S.: Supervision; Vishal S.: Investigation; Narendra S. D.: Data analysis; Vidya B. T.: Supervision and resources; Renuka B. C., and Hemvarsha: Writing - review and editing, conceptualization and supervision.

Conflict of interest

Authors declare that no conflict of interest exists.

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