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The occurrence of parasitic copepods and isopods infesting the marine teleost fishes of Kerala coast, India

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Abstract The present study reports the occurrence of parasitic copepods and isopods infecting marine teleost fishes from the Kerala coast, India. A total of 1795 fishes belonging to 38 species were collected from the fish landing centres across the Kerala Coast for 5 months. The isopod & copepod infection status of these fishes were assessed. The incidents of site-specific infection were documented for all parasites and a fecundity analysis was conducted in randomly selected species. The single or multiple parasitic crustacean infestation and host preference (single or multiple hosts) were also documented. A total of 32 species of copepods and 6 species of isopod were sourced out. However, the maximum prevalence was recorded for the family Lernanthropidae (71.43%) and the maximum intensity (14) was recorded for a Caligid copepod Euryphorus nordmannii. The predominantly targeted region of infection on the host fish appeared to be gill filament (52.15%). The fecundity showed significant differences between the tested species. Fourteen species of fishes showed multiple parasitic crustacean infestation and eight species of parasites infected multiple hosts. The present study demonstrates that over 68% of marine fish species of Kerala coast were under heavy infection either by isopods or copepods.

Keywords Isopods · Copepods · Prevalence · Intensity · Fecundity

Introduction

Crustaceans are one of the major Arthropod groups preferring aquatic life with diverse levels of adaptation. A significant proportion of crustaceans exhibit parasitism infecting both cultured and captive fishes (Athanassopoulou et al. 2001; Barber and Poulin 2002; Rijin et al. 2017; Başusta et al. 2017) and thus affect the behaviour, growth, health of the host fish (El-Rashidy and Boxshall 2010; Misganaw and Getu 2016). Mostly the infestation gets fatal employing the infectious injuries made by the parasites during its feeding of the host's mucus, blood, muscles and other vital tissues (Margolis and Kabata 1988; Oğuz and Oktener 2007). Most known parasitic crustaceans comprise copepods, isopods, brachyuran, tantulocarids, and rhizocephalic cirripedes (Thamban et al. 2015). They exhibit close interrelatedness in the sustainability of their own with the host organism (Margolis and Kabata 1988; Raibaut and Trilles 1993; Raibaut et al. 1998; Williams and Boyko 2012). Parasitic crustacean diseases in fishes seriously affect aquaculture production and its economic viability (Aneesh et al. 2013; Rania and Rehab 2015).

Many ecologists now recognize that crustacean parasitism is one of the most important factors affecting the viability of captured and cultured fish populations and communities of different aquatic habitat. In the marine environment, it has been demonstrated that individual fish may suffer from parasitic crustaceans (Rohde 1994; Jithin et al. 2016). The possible effects of parasitic crustaceans on their fish hosts are difficult to assess or quantify, in natural

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conditions and it remains to be unexplained why some fish species have a higher parasite species richness than others, and how parasite communities build upon these hosts. Because of the inefficient study about the effects of macroparasites like crustaceans on the teleost host, the alteration in the fitness has rarely been quantified, and their ecological and evolutionary meanings are unknown (Trilles et al. 2011; Rania and Rehab 2015).

Like coastal countries in India, both marine fisheries and aquaculture have witnessed phenomenal growth during the last five decades both in terms of quantitative and qualitative levels (Flaherty et al. 2009). However, during the last decade's aquaculture has been facing the problems posed by pathogens and parasites and their implications for fishery leading to constraints in aquaculture productivity (Sanil et al. 2009; Rijin et al. 2019). In this context, as a prelude, the present survey report on the parasitic copepods and isopods infecting marine fishes along the Kerala Coast is relevant.

Materials and methods

Ethics statement

This study doesn't require ethical approval from an animal ethics committee since the fish were collected from food fish supply and doesn't involve any actions against animal welfare.

Parasite collection

The fresh non-live fish- samples were collected from the fisherman of major fish landing centres including Vizhinjam harbour–Trivandrum (528 m Lat.8°22′37″ N Long.76°59′17″ E), Neendakara harbour–Kollam (743 m Lat.8°56′18″ N Long.76°32′20″ E), Thottappally harbour–Alappuzha (1025 m Lat.9°19′11″ N Long.76°22′43″ E), Beypore harbour–Kozhikode (3968 m Lat.11°10′18″ N Long.75°48′29″ E), Ayikkara harbour–Kannur (827 m Lat.11°51′22″N Long.75°22′32″ E) and Madakkara harbour–Kasaragod (730 m Lat.12°12′39″ N Long.75°07′43″ E) of Kerala Coast. The fish samples were collected from food fish suppliers, hence permission from harbour authorities for sample collection was not required.

The present study was conducted during the period from December 2017 to April 2018. The fresh or live fish for the present study were collected directly from the local fishermen twice a week throughout the study period. Soon after the collection, the fish were subjected to morphometric analysis such as total length, standard length and fork length of the host and the images of the fish were also captured. Then each collected fish was closely observed for the isopod and copepod infection. For the purpose, different parts of the body like fins, gill rack, gill cavity, gill filament, gill arch, opercular region, head, the surface of the body, etc. were observed using a hand lens. The recovered parasites and the host fishes were immediately brought to the laboratory. The parasites were subjected to detailed microscopic examination using a stereo-microscope (Leica-S6D), stereo zoom microscope (Radical RSM-8), compound microscope (Magnus MLX-DX) and photographed. The onsite photographs of macroscopic parasites and fishes were taken using Nikon Coolpix B700.

Species identification of parasites and host fishes

The primary identification of the parasites was carried out using standard taxonomic keys (Kirtisinghe 1964; Pillai 1985; Yamaguti 1985) and WoRMS (2020). Identification to the species level was aided by the available descriptions (Bassett-Smith 1898; Pillai 1964; Cressey and Cressey 1980; Kumar 1990). The identification of the fishes was based on the SeaLifeBase and Fish Base databases (Froese and Pauly 2018).

Preservation of parasite samples

The specimens were preserved in 70% ethanol and kept in the crustacean biology lab for future reference based on the species name and the number of parasites recovered from the respective host. The data were entered into Microsoft Excel spreadsheet for subsequent calculation.

Fecundity analysis

The fecundity of selected representatives of isopod Norileca indica and copepods Euryphorus nordmannii, Cybicola armatus, Penniculus fistula fistula, Brachiella otolithi of different families are calculated and compared. The total number of eggs was counted per selected individuals of the above-mentioned species, its average number of eggs were calculated and compared each other.

Data analysis

The data on the parasitic crustaceans and their respective host fish were subjected to statistical analysis. The fecundity of four copepods and one isopod species was analysed by a two-tailed student's unpaired *t* test using GraphPad Prism version 5.01 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com. The prevalence and intensity were calculated using the following equations:

$$Prevalence = \frac{NFI}{NFO} \times 100$$

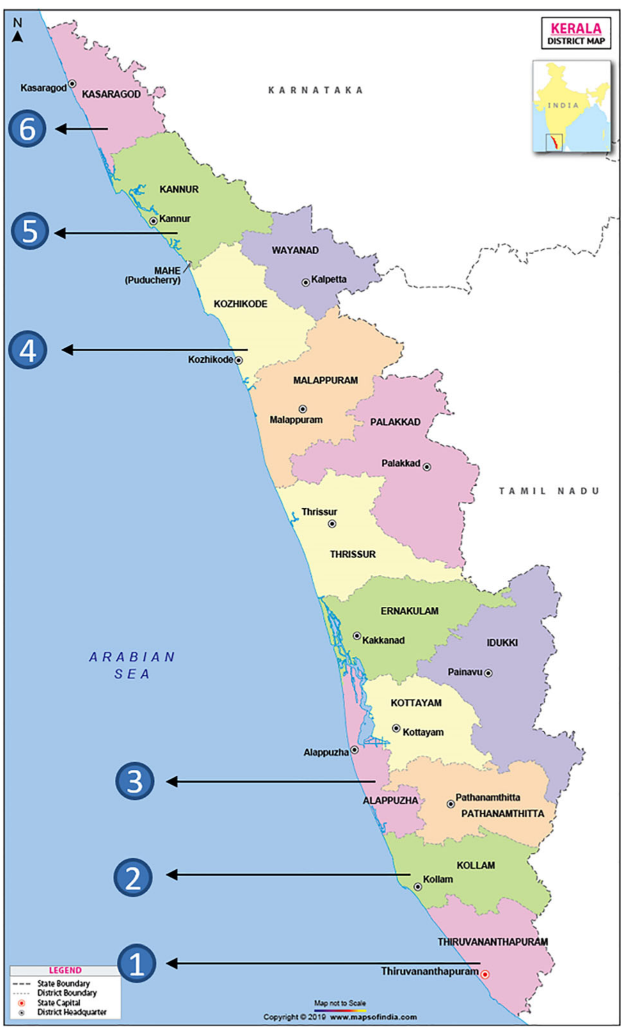
$$Intensity = \frac{TNPR}{NFI}$$

where NFI is the number of fishes infested, NFO is the number of fish observed and TNPR is the total number of parasites recovered (Margolis et al. 1982; Bush et al. 1997).

Results and discussion

The occurrence of parasitic crustaceans

A total of 1795 fish were collected from the different collection sites Fig. 1, including 38 species, 35 genera, 22 families and 7 orders. Among them, 274 fish under 25 species, 25 genera, 12 families and 6 orders were found to be infected with 32 species of copepods and 6 species of isopods (Figs. 2, 3, 4, 5, 6, 7, 8). The details of fish hosts and corresponding parasites along with their family references are provided in Table 1—Supplementary file. The fish families of order Perciformes such as Scombridae, Carangidae, Sciaenidae and Sillaginidae were found to be more prone to infection with 26 copepods and 4 isopod species supporting the previously published reports (Yuniar et al. 2007; Rameshkumar and Ravichandran 2014; Helna et al. 2018). Among the isopods recovered, Norileca indica was recovered with the high prevalence from four host fishes *Rastrelliger kanagurta* (30.53%), *Thryssa malabarica* (2.86%), *Saurida tumbil* (1.96%) and *Sillago lutea* (1.20%) of family Scombridae, Engraulidae, Synodontidae and Sillaginidae, respectively. The present study adds three new host fishes (*Thryssa malabarica*, Saurida tumbil and Sillago lutea) for the Isopod parasite Norileca indica from Ayikkara harbour (Kannur), Neendakara harbour (Kollam) and Thottapally harbour (Alappuzha) as it was previously reported only from host fish *Rastrelliger kanagurta* of



1. Vizhinjam harbour – Trivandrum (528m Lat.8°22’37”N Long.76°59’17”E)
2. Neendakara harbour – Kollam(743m Lat.8°56’18”N Long.76°32’20”E)
3. Thottappally harbour – Alappuzha(1,025m Lat.9°19’11”N Long.76°22’43”E)
4. Beypore harbour – Kozhikode(3,968m Lat.11°10’18”NLong.75°48’29”E)
5. Ayikkara harbour – Kannur(827m Lat.11°51’22"N Long.75°22’32”E)
6. Madakkara harbour – Kasaragod(730m Lat.12°12’39”N Long.75°07’43”E)

Fig. 1 The sampling sites across Kerala Coast

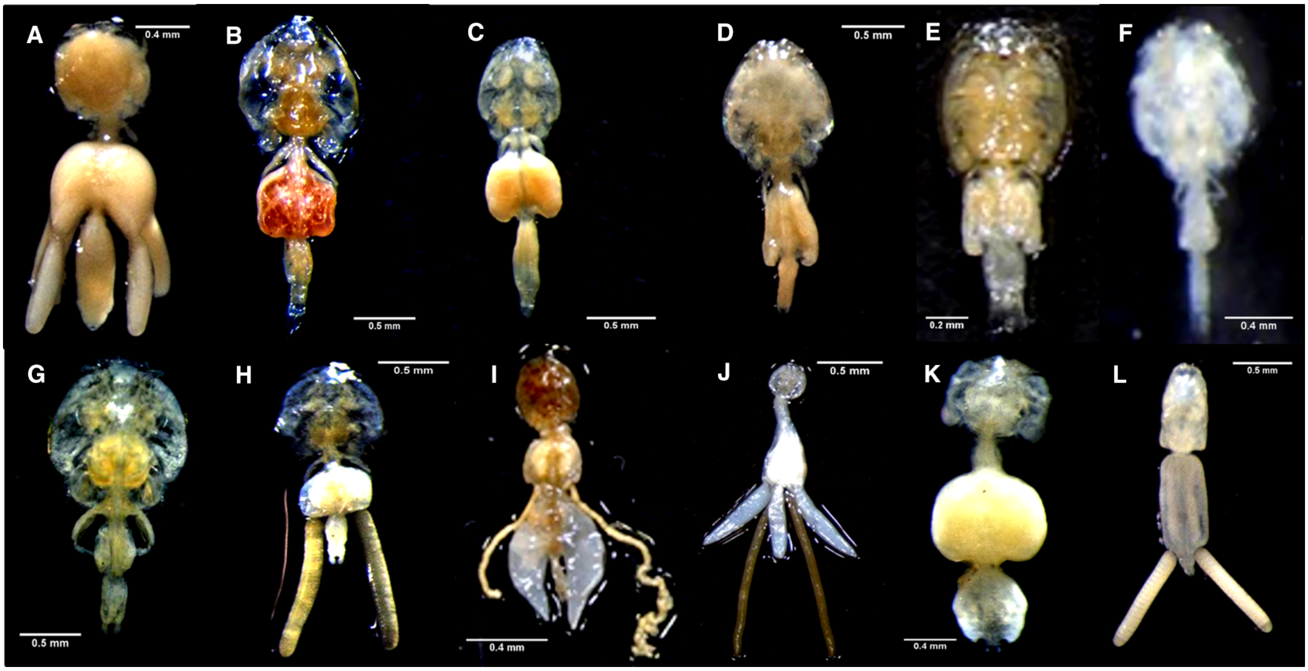


Fig. 2 Family Caligidae **a** Synestius caliginus Steenstrup & Lütken, 1861; **b** Caligus robustus Bassett-Smith 1898; **c** *Caligus kanagurta* Pillai, 1961; **d** Caligus amblygenitalis Pillai, 1961; **e** Caligus coryphaenae Steenstrup & Lütken, 1861; **f** Caligus phipsoni Bassett-Smith 1898; **g** Caligus bonito bonito Wilson C.B., 1905; **h** Caligus rotundigenitalis Yü, 1933; **i** Euryphorus nordmannii Milne Edwards, 1840; **j** Caligodes laciniatus Krøyer, 1863; **k** Abasia platyrostris Pillai, 1963; **l** Hermilius pyriventris Heller, 1865

Malabar Coast (Ghosh et al. 2016; Panakkool-Thamban et al. 2016). Agarna malayi, another Isopod collected from the carangid fish Selar crumenophthalmus from Vizhinjam harbour (Trivandrum) with a prevalence of 1.69% also forms new host record for this parasitic isopod species as it was previously reported only from the clupeid host Tenualosa toli (Rijin et al. 2017) of Malabar Coast.

The occurrence of various Copepod families in the host fishes are shown in Fig. 9 and the foremost among them appears to be the family Pseudocycnidae. Among the parasitic copepods, Lernanthropus corniger infesting Megalaspis cordyla and Pseudocycnus appendiculatus infecting Thunnus tonggol exhibit the highest prevalence of about 71.43% and 66.67%, respectively. Meanwhile, Euryphorus nordmannii recovered from Coryphaena equiselis and Lernanthropus tylosuri recovered from Strongylura leiura shows highest parasitic intensity as 14 and 9.57 respectively. Although, it has been found out that, concerning other fish landing centres Thottappally fish landing centre (Alappuzha District) manifests comparatively less infestation of crustacean parasites. The widely prevalent fish, Sardinella longiceps observed from all regions coming under family Clupeidae showed very less infestation or even say uninfected as 154 fishes have been examined from various harbours of Kerala Coast. While considering the site of infestation of isopods, it is entirely different from that of copepods, where its prominent site of infection seems to be opercular wall, mouth, gill cavity etc. But in the case of copepods, the intensively affected site is the gill filament as represented in Fig. 10, which is corresponding to the previously published report (Panakkool-Thamban et al. 2016).

Differential fecundity in parasite species (egg sac observation and fecundity analysis)

The Fig. 11 shows the relative fecundity of selected representatives of isopods Norileca indica and copepods Euryphorus nordmannii, Cybicola armatus, Penniculus fistula fistula, Brachiella otolithi of different families are comparatively analysed. In the egg sac of Brachiella otolithi, eggs were in a multiseriate arrangement which is an exception from the remaining three copepods which shows uniseriate egg sacs. Uniseriate egg sac could accommodate a greater number of eggs, likely an adaptation for maximum progeny production.

Significant variations in fecundity were found between 7 parasite pairs out of 10 (for $P < 0.05$). The highest fecundity was noted in Cybicola armatus (466.0 ± 56.99) followed by Peniculus fistula fistula (256.2 ± 44.21) compared to other copepods. The average fecundity of Norileca indica was recorded as 262.0 ± 39.01. The significant values for various pairs are as follows. Cybicola armatus vs Euryphorus nordmannii (0.0024**), Cybicola

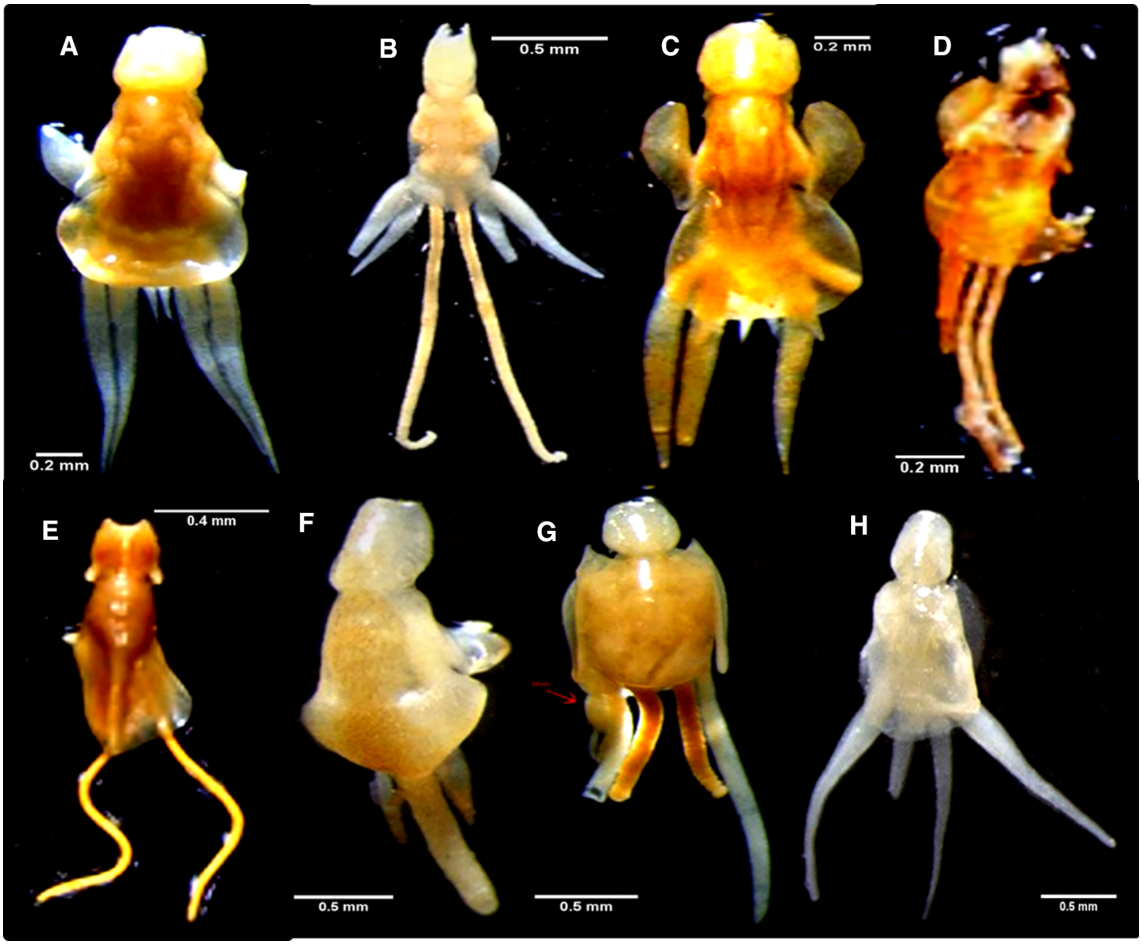


Fig. 3 Family Lernanthropidae **a**: Lernanthropus giganteus Krøyer, 1863; **b** Lernanthropus corniger Yamaguti, 1954; **c** Lernanthropus otolithi Pillai, 1963; **d** Lernanthropus latis Yamaguti, 1954; **e** Lernanthropus tylosuri Richiardi, 1880; **f** Lernanthropus sillaginis Pillai, 1963; **g** Mitrapus oblongus Pillai 1964; **h** Lernanthropus opisthopteri Pillai 1964

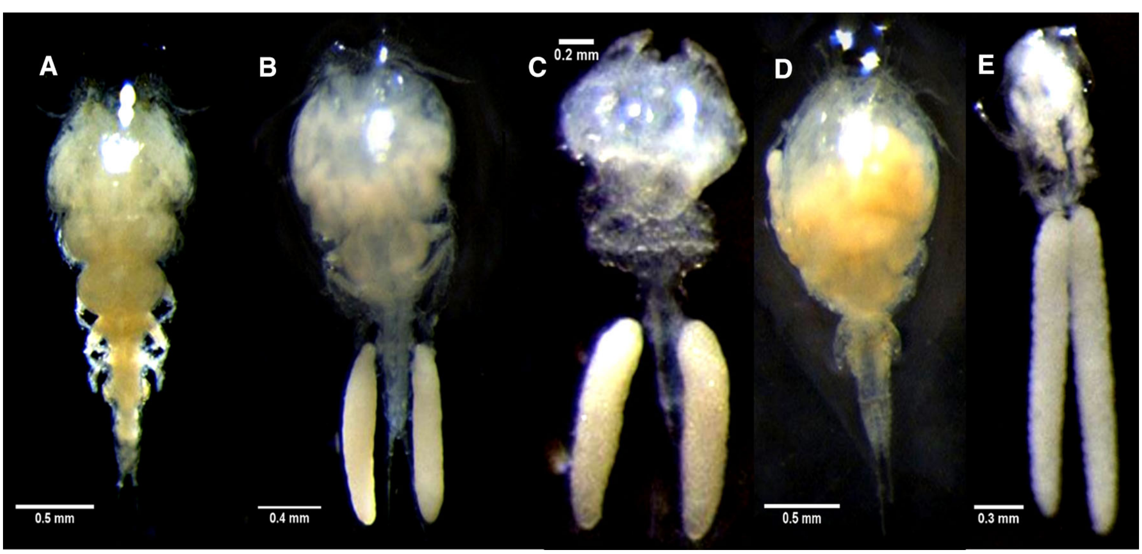


Fig. 4 Family Bomolochidae **a** Bomolochus megaceros Heller, 1865; **b** Bomolochus bellones Burmeister, 1833; **c** Nothobomolochus lateolabracis Yamaguti & Yamasu, 1959; **d** Pseudorbitacolax varunae Bennet, 1968; **e** Bomolochus nitidus Wilson C.B., 1911

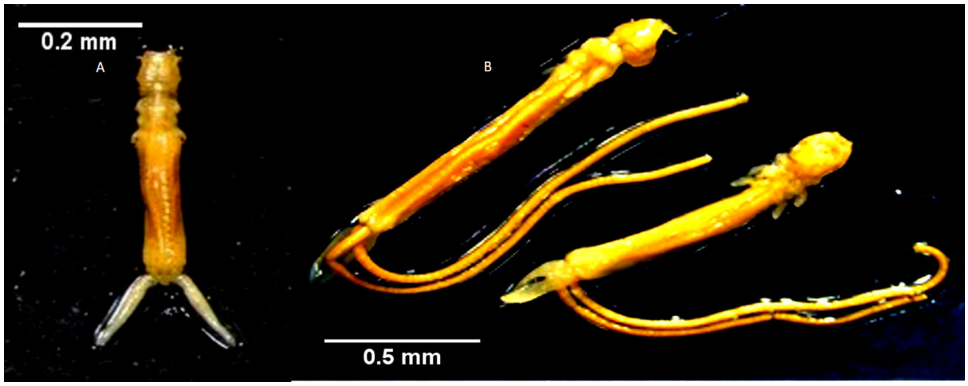


Fig. 5 Family Pseudocycnidae – **A**: Pseudocycnus appendiculatus Heller, 1865; **B**: Cybicola armatus Bassett-Smith 1898

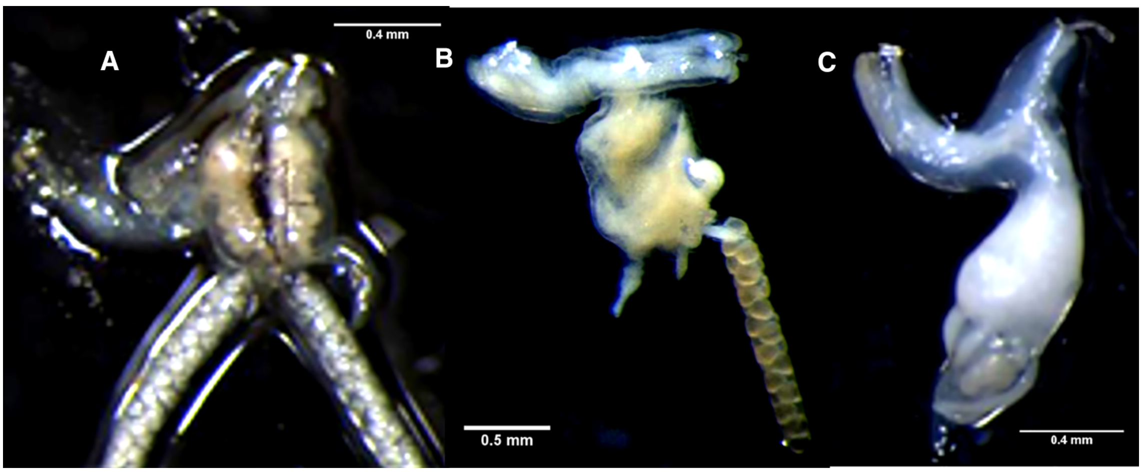


Fig. 6 Family Lernaeopodidae **a** Brachiella otolithi Pillai, 1962; **b**: Parabrachiella albida Rangnekar, 1956; **c**: Brachiella trichiuri Gnanamuthu, 1951

Fig. 7 Family Pennellidae—**a** Lernaeenicus stromatei Gnanamuthu, 1953; **b** Peniculus fistula fistula Nordmann 1832

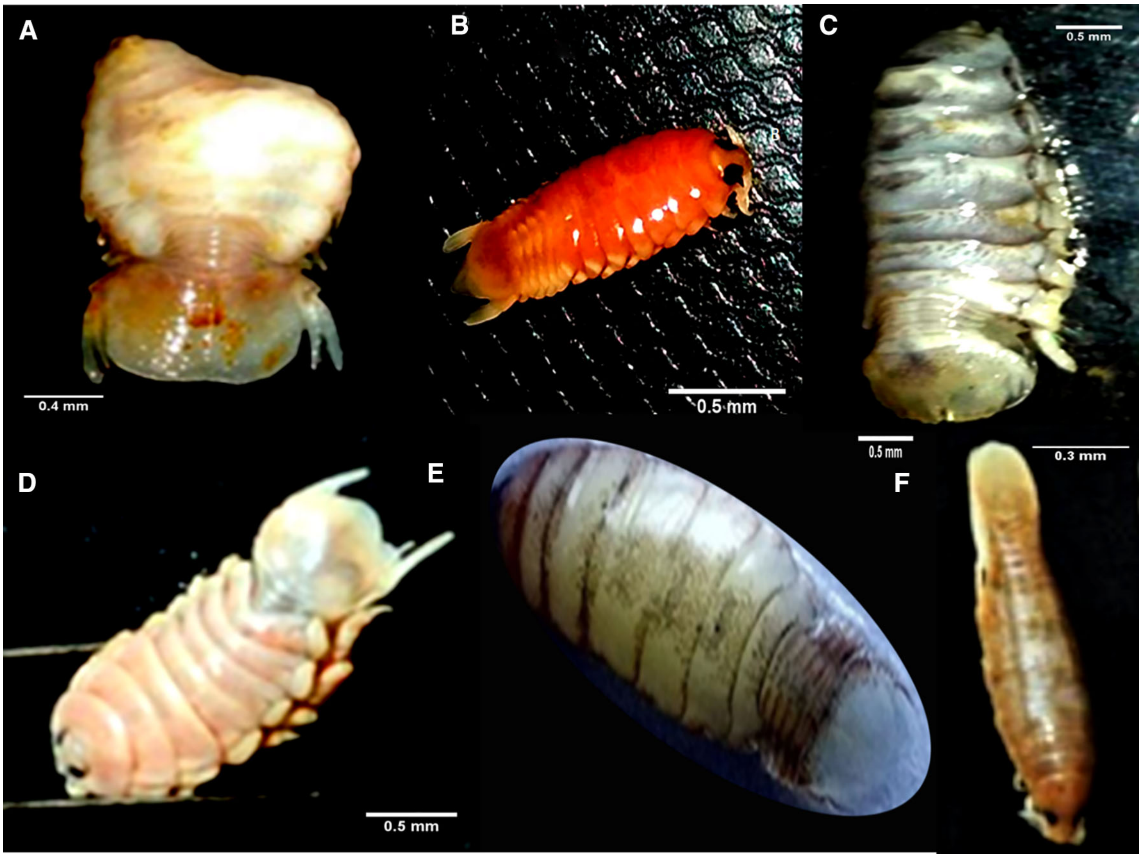


Fig. 8 Family Cymothoidae – **a** Agarna malayi Tiwari, 1952; **b** Norileca indica H. Milne Edwards, 1840; **c** Cymothoa frontalis H. Milne Edwards, 1840; **d** Mothocya renardi Bleeker, 1857; **e** Catoessa boscii Bleeker, 1857; **f** Anilocra leptosoma Bleeker, 1857

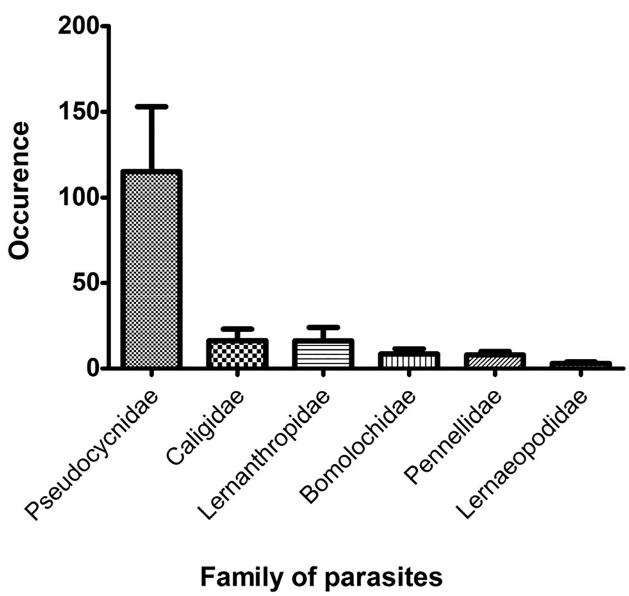


Fig. 9 Occurrence of different Copepod families in the host fish

armatus vs Brachiella otolithi (0.0001***), Cybicola armatus vs Penniculus fistula fistula (0.0196*), Cybicola armatus vs Norileca indica (0.0183*), Euryphorus nordmannii vs Brachiella otolithi (0.0110*), Brachiella otolithi vs Penniculus fistula fistula (0.0024**), and Brachiella otolithi vs Norileca indica (0.0010***). The fecundity has a relation with body size under the quality of water which has been reported earlier that the body size, as well as fecundity increases as the quality of water, improves (Tolba and Holdich 1981; Guha et al. 2013).

Multiple parasitism

The present study could also demonstrate various levels of parasitism seen on the host fish during the study period. Usually, to the best of knowledge, up to Quadruple Parasitism is being evident strongly. Surprisingly we got multiple infestations of five parasitic crustaceans seen in two hosts such as Sillago lutea of about 4 are copepods (Nothobomolochus lateolabracis, Lernanthropus sillaginis, Caligus phipsoni, Caligus bonito bonito) and the 1 left behind is an isopod (Norileca indica) also from the fish host Strongylura leiura, by three copepods(Caligodes laciniatus, Lernanthropus tylosuri & Bomolochus bellones) and two isopods (Mothocya renardi & Cymothoa frontalis) is also supporting the view of (Aneesh et al. 2014).

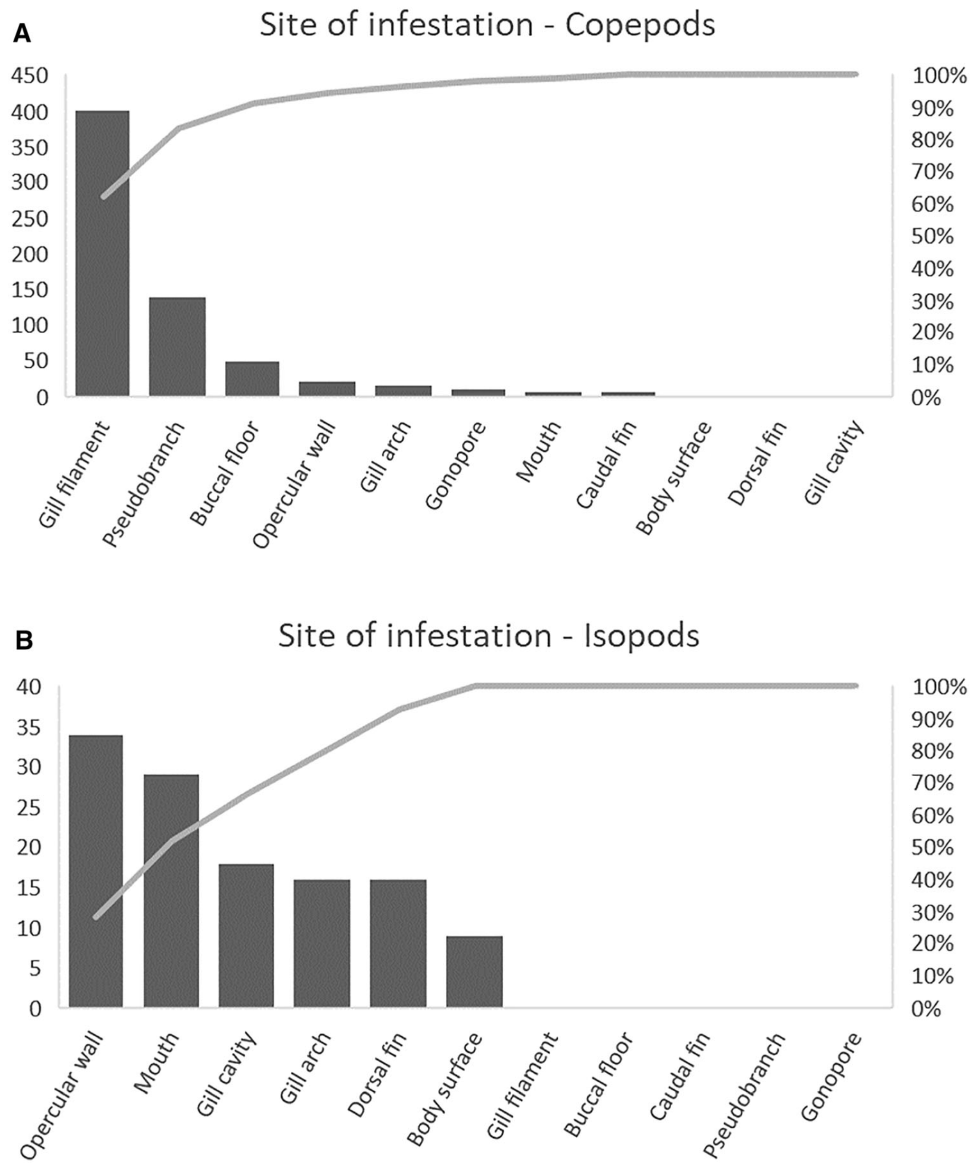


Fig. 10 Graph representing site of infestation of Copepods and Isopods

Along with this, quadruple parasitism was seen in one host, Otolithes cuvieri parasites observed comprises of four copepods (Brachiella otolithi, Lernanthropus otolithi, Lernanthropus latis, Bomolochus bellones). Likewise, triple parasitism was also observed in three hosts such as Parastromateus niger with three copepods (Synestius caliginus, Lernaeenicus stromatei, and Bomolochus megaceros), Otolithes ruber infected by three copepods (Catoessa boscii, Bomolochus bellones, Parabrachiella albida) and Anodontostoma chacunda is also infected by three copepods (Peniculus fistula fistula, Pseudorbitacolax varunae, Mitrapus oblongus). Along with this, double parasitism also exists in eight host fishes Saurida tumbil comprises an isopod (Norileca indica) and a copepod (Abasia platyrostris), Coryphaena equiselis infected by two copepods (Euryphorus nordmannii & Brachiella trichiuri), Thunnus tonggol through two copepods (Pseudocycnus appendiculatus and Caligus amblygenitalis), Katsuwonus pelamis infected by two copepods (Caligus coryphaenae and Pseudocycnus appendiculatus). Caranx sp. comprises two copepods (Lernanthropus giganteus and Bomolochus megaceros), *Rastrelliger kanagurta* with one isopod (Norileca indica) and one copepod (*Caligus kanagurta*), Mugil cephalus through two copepods (Caligus bonito bonito, Bomolochus nitidus) and in Euthynnus affinis with 2 copepods (Pseudocycnus appendiculatus, Caligus amblygenitalis). From a total of about 38 species of fish host species, 14 shows multiple parasitic crustacean infection and about 12 doesn't show any infestation. Hence the 12 fish hosts left behind were under single parasitic crustacean infection.

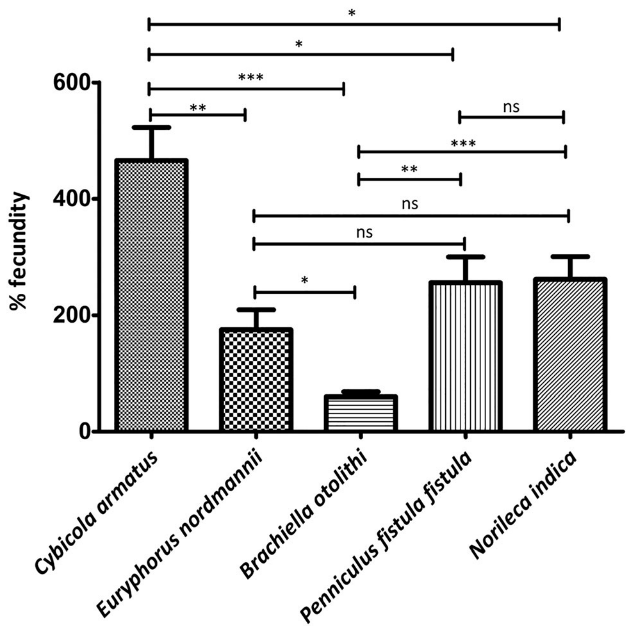


Fig. 11 Fecundity analysis graph

Although the parasitic crustaceans are infecting the host in a wide variety of ways such as single, double, triple, quadruple, etc. irrespective of the infestation pathway, the parasitic crustacean harms the host due to its attachment and feeding habit, it is also responsible for any disease caused (Bharadhirajan et al. 2013; Heckmann 2015). One of the main facts about external body surface parasites, these are likely to be underestimated due to loss during capture and subsequent handling.

Conclusion

The present study could demonstrate that over 68% of marine fish species of Kerala Coast are under heavy infection by the parasitic crustaceans—isopods and copepods. Out of the 38 species of marine fish observed, 25 species were under the infestation of 32 species of copepods and 6 species of isopods. Among the fish species Scombridae, Sciaenidae, Carangidae, and Sillaginidae appeared to be more prone to parasitic crustacean infection. The Sillaginid fish, Sillago lutea and Strongylura leiura were found first-rate hosts for parasitic crustacean as we recovered 5 species of parasites each. The cymothoid Norileca indica shows multiple host infection and their hosts, *Rastrelliger kanagurta*, *Thryssa malabarica*, *Saurida tumbil*, and *Sillago lutea*, belonging to different families respectively Scombridae, Engraulidae, Synodontidae and Sillaginidae. The maximum prevalence was with *R. kanagurta* (30.53%). The present study adds three new host fishes (*T. malabarica*, *S. tumbil*, and *S. lutea*) for *N. indica*. The Carangid fish Selar crumenophthalmus also appears to be the new host for the *A. malayi*. Among 32 species of copepods, the Caligidae family forms the foremost comprising 12 species followed by the family Lernanthropidae with 8 species. Among the parasitic copepods Lernanthropus corniger infesting Megalaspis cordyla and Pseudocycnus appendiculatus infecting Thunnus tonggol exhibit highest prevalence of about 71.43% and 66.67% respectively. Simultaneously Euryphorus nordmannii recovered from Coryphaena equiselis and Lernanthropus tylosuri recovered from Strongylura leiura shows the highest parasitic intensity as 14 and 9.57 respectively. The study needs to be extended to the culture fishes as they are facing the threat of crustacean parasitism.

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Authors contributions SK initiated the study and supervised. TSN, MR and SCP collected and entered the data. SK & TSN analysed and interpreted the data and were involved in writing the manuscript. All authors read, revised and approved the final manuscript.

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Availability of data and material Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no financial or personal conflict that may have inappropriately influenced them in writing this article.

Ethics approval No ethical approval required for the present study.

Research involving human participants and/or animals This study does not include human participants and the parasitic crustaceans involved in this study doesn't require any ethical approval.

Informed consent Not applicable.

Consent to participate All the co-authors have given their consent to participate in the study.

Consent for publication All the co-authors have given their consent to publish the data of the study.

Code availability Not applicable.

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