Turk. J. Fish.& Aquat. Sci. 19(3), 241-249
http://doi.org/10.4194/1303-2712-v19_3_07

RESEARCH PAPER

Turkish Journal of FISHERIES and AQUATIC SCIENCES

Seasonal Variation in the Occurrence of Parasitic Isopods and Copepods (Crustacea) Infecting the Clupeidaen Fishes of Malabar Coast, India

Kattambally Rijin[2], Kappalli Sudha[1,*], Parunthuveettil Joseph Vineesh[3], Gopinathan Anilkumar[4]

[1] Central University of Kerala, Department of Animal Science, School of Biological Sciences, Kasaragode, Kerala, India – 671316.
[2] Sree Narayana College, Post Graduate Department of Zoology and Research Centre, 670 007, Kannur, Kerala, India.
[3] St. Joseph's College, Post Graduate and Research Department of Zoology, Devagiri, 673008, Calicut, Kerala, India
[4] VIT University, School of Biosciences and Technology, 632014, Vellore, Tamil Nadu., India.

Article History
Received 25 August 2017
Accepted 02 April 2018
First Online 08 April 2018

Corresponding Author
Tel.: + 91 9447689646
E-mail: sudhakappalli@cukerala.ac.in

Keywords
Parasitic isopod
Copepod, prevalence
Seasonal variation
Clupeids

Abstract

Occurrence of parasitic isopods and copepods infecting the clupeidaen fishes of Malabar coast (India) was assessed in terms of prevalence, intensity, host/ site specificity and seasonal variation. 3 isopods (*Joryma brachysoma*, *Anilocra leptosoma* and *Agarna malayi*) and 4 copepods (*Clavellisa hilsae, Peniculus fistula fistula, Pseudorbitacolax varunae* and *Naobranchia cygniformis*) were recovered from the fishes, *Escualosa thoracata, Tenualosa toli* (hosts two parasites), *Sardinella fimbriata* and *Anodontostoma chacunda* (hosts three parasites) respectively. The prevalence and/or intensity of each recovered parasitic species showed statistically significant variation (P<0.05) according to seasons; the prevalence of isopod species was high during pre-monsoon and least in monsoon. Except *P. varunae,* which is more prevalent in pre- monsoon, all copepod species exhibited high prevalence during post- monsoon. The floor of branchial cavity forms the major site of infection for *J. brachysoma* and *A. malayi* recovered from *E. thoracata* and *T. toli* respectively. *A. leptosoma* prefers dorsal body surface, behind the head of *T. toli* for infection. *P. fistula fistula, P. varunae and N. cygniformis* prefer to infect respectively caudal fin, anterior and posterior mucus layer of inner operculum of *A. chacunda* indicating their microhabitat preference likely to avoid niche competition during the circumstance of triple parasitism.

Introduction

Crustacean parasitism is one of the important factors affecting the viability of captive and cultured fish populations (Athanassopoulou, Bouboulis, & Martinsen, 2001; Barber & Poulin, 2002; Rijin & Sudha, 2017; Başusta, Mutlu, & Deval, 2017), but the assessment of their possible effects on their fish hosts is quite difficult especially in fish under wild conditions (Pillai, 1985; Williams Jr & Bunkley-Williams, 2000; Yu & LI, 2003; Carr & Whoriskey, 2004). Further, it still remains to be explained why some fish species have a higher parasite species richness than others, and how parasite communities build up on these hosts (Trilles & Oktener, 2004; Smit, Bruce, & Hadfield, 2014; Rameshkumar & Ravichandran, 2014). When the prevalence of a parasitic crustacean is high, they can significantly diminish reproductive output of host populations (Lafferty & Kuris, 1993; Leonardos & Trilles, 2003; Johnson *et al*., 2004) and also host density (Fogelman, Kuris, & Grutter, 2009).

Even though the incidence of many parasites varies conspicuously from season to season (Altizer *et al*., 2006) studies were still meager on the pattern of seasonality of parasitic occurrence.

Recent report from our laboratory on the parasitic isopod, *Nerocila sp.*, infecting the marine fishes along the Malabar Coast showed that four species under this genus were more prevalent during post- monsoon/ pre-monsoon seasons and by the onset of monsoon, the prevalence showed a gradual and significant decrease (Panakkool-Thamban, Kappalli, Keethadath, Gopinathan & Jean-Paul, 2013).

Clupeidaen fishes represent a large part of the fish biomass in Malabar coast of India and our preliminary observation indicates that these fishes are under the heavy infection of parasitic crustaceans including both isopods and copepods (Aneesh, 2014). The present paper reports the pattern of occurrence of parasitic isopods and copepods infecting the Clupeidaen fish species of Malabar coast in terms of prevalence, intensity, host and site specificity and seasonal variation.

Materials and Methods

Collection and Identification

The present study was conducted during the period from June 2014 to May 2017. Fresh Clupeidaen fishes were collected from the Ayyikkara fish landing centre, one of the major fish landing center in Malabar region (Lat. 11°51'N, Long. 75°22'E; Malabar Coast, Kerala, India). Soon after collection they were brought to the laboratory and closely examined the body surface, lateral line region, base of the pectoral fin, branchial cavity and gill filaments, inner wall of the operculum, buccal cavity etc for the presence of parasitic isopod and/or copepod using hand lens (Rijin & Sudha, 2017). Recovered parasitic crustaceans were preserved in 70% ethanol for further detailed examination under dissection microscope and a stereo microscope Leica-S6D. The taxonomic identification was performed according to Pillai (1985), Aneesh, (2014), Panakkool-Thamban, Kottarathil & Kappalli (2016). Prevalence (P) and intensity (I) of infection were calculated according to Bush, Lafferty, Lotz & Shostak (1997). Host nomenclature and fish taxonomy are done according to Fish Base (Froese & Pauly, 2016). The period February – May, June- September and October – January were considered respectively as Pre- monsoon, Monsoon and Post- monsoon periods with view to assess the seasonal wise variation, if any, in the prevalence and/or intensity of parasitisation.

Voucher specimens of all recovered isopods and copepods were deposited in the Parasitic Crustacean Museum, Crustacean Biology Research Laboratory, Sree Narayana College, Kannur, Kerala, India.

Data Analysis

Seasonal variation, if any, in prevalence and intensity of recovered parasitic crustacean was analyzed using one-way ANOVA followed by Tukey's pairwise comparisons. Significance level was set at P<0.05. Shannon diversity (H') was estimated for all three seasons. Normality of data was analyzed by Jarque-Bera test and opted parametric tests for seasonality studies. All aforesaid statistical analysis were done using PAST software (version 2.17c) (Hammer, Harper & Paul, 2001).

Results

A total of 4272 members of Clupeidaen fishes belonging to eight species were collected during the study period (Table 1). Among these, two fish species, *Escualosa thoracata* (Valenciennes, 1847) and *Tenualosa toli* (Valenciennes, 1847), showed infection with three isopods and two clupeids (*Sardinella fimbriata* and *Anadontostoma chacunda*) with copepods. *E. thoracata* hosts *Joryma brachysoma* (Pillai, 1964) and *T. toli* hosts two isopods, *Anilocra leptosoma* (Bleeker, 1857) and *Agarna malayi* (Tiwari, 1952). The fish, *A. chacunda* (Hamilton, 1822) is highly potential to host three copepods including *Peniculus fistula fistula* (Von Nordman, 1832), *Pseudorbitacolax varunae* (Bennet, 1968) and *Naobranchia cygniformis* (Hesse, 1863). Copepod *Clavellisa hilsae (*Pillai, 1962) was recovered from *Sardinella fimbriata* (Valenciennes, 1847) (Table 2; Figure 1). The clupeids *Amblygaster sirm* (Walbaum, 1792), *Sardinella longiceps* (Valenciennes, 1847), *Hilsa kelee* (Cuvier, 1829) and *Tenualosa ilisha* (Hamilton, 1822) were found to be completely free from both isopod and copepod infection during the study period (Table 1).

Out of 1039 white sardine, (*E. thoracata*) collected, 271 members were infected with *J. brachysoma*, and prevalence (P) and intensity (I) being 26.11±0.73 and 1.59±0.08 respectively; the floor of the branchial cavity appears to be the site of infection (Table 2; Figure 1, 2 & 3).

The prevalence of *A. leptosoma* and *A. malayi* infecting *T. toli* is relatively less comparing to that of *J. brachysoma*. Of 542 members of fish host, only 78 were found parasitized by *A. leptosoma* (P = 11.93±0.95; I =1.00) and 99 by *A. malayi* (P = 14.38±1.34; I = 1.31±0.15) (Table 2; Figure 2 & 3); the dorsal body surface just behind the head of the host fish forms the

Table:1. List of Clupeidaen fishes observed for the presence of parasitic isopods and copepods

SI No	Clupeid Fish	NFO	InI	InC
1	*Tenualosatoli* (Valenciennes, 1847)	670	**	-
2	*Escualosathoracata* (Valenciennes, 1847)	1039	*	-
3	*Amblygastersirm*(Walbaum 1792)	368	-	-
4	*Sardinellalongiceps* (Valenciennes, 1847).	612	-	-
5	*Sardinellafimbriata* (Valenciennes, 1847)	576	-	*
6	*Anodontostomachacunda* (Hamilton, 1822)	754	-	***
7	*Tenualosailisha* (Hamilton, 1822)	190	-	-
8	*Hilsakelee* (Cuvier, 1829)	63	-	-

(NFO_ Number of fishes observed, InI_Infected with isopod ,InC_ Infected with copepod, * _ Single parasitism, **_ Double parasitism, ***_ Triple parasitism, - _ Absence of parasite).

Table 2. Prevalence (P), Intensity (I) of recovered parasitic isopods and copepods and the site of attachment onthe Clupeidaen host fish

Sl No	Parasitic Crustaceans	Species/ Family	Host Fish	P (Mean±SD)	I (Mean±SD)	Site of attchment
1	Isopod	*Joryma brachysoma*/ Cymothoidae	*E. thoracata*	26.11±0.73	1.59±0.08	Branchial cavity-floor
2		*Anilocra leptosoma*/ Cymothoidae	*T. toli*	11.93±0.95	1.00±0.00	Dorsal Body surface behind head
3		*Agarna malayi*/ Cymothoidae	*T. toli*	14.38±1.34	1.31±0.15	Branchial cavity-Floor
4	Copepod	*Clavellisa hilsae* / Lernaeopodidae	*S. fimbriata*	7.13±1.22	4.03±0.21	Gill racker/ gill filaments
5		*Peniculus fistula fistula*/ Pennellidae	*A. chacunda*	2.88±0.47	1.21±0.02	Caudal fin - upper/lower lobe
6		*Pseudorbitacolax varunae*/ Bomolochidae	*A. chacunda*	20.29±3.03	1.02±0.01	inner operculum - Upper region
7		*Naobranchia cygniformis* / Lernaeopodidae	*A. chacunda*	0.40±0.56	1.00±0.00	inner operculum - lower region

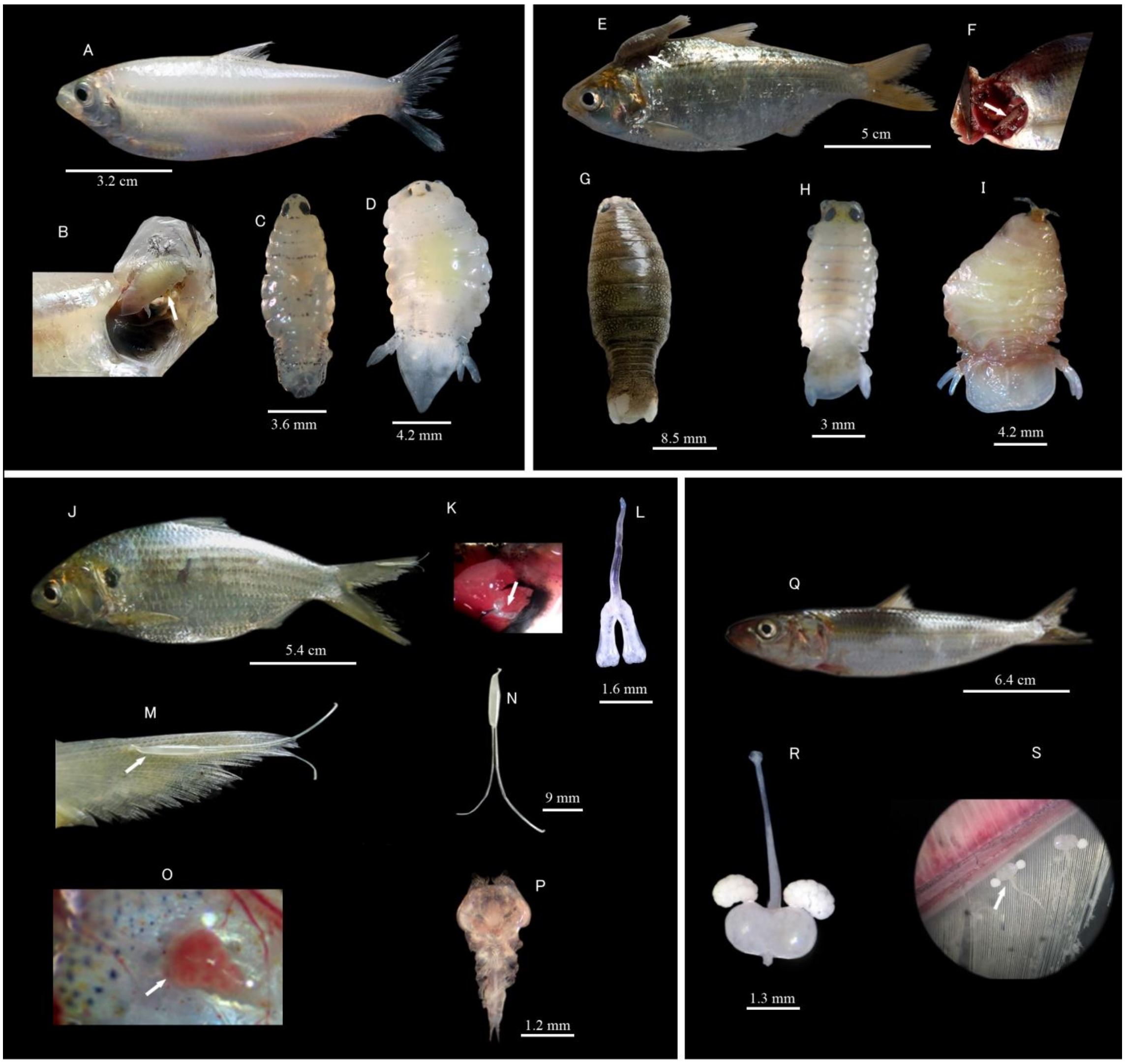

Figure 1. Parasitic isopods and copepods and their respective Clupeidaen host fish.
A) *E. thoracata*, B) Site of attachment of *J. brachysoma* on the host, *E. thoracata* C) *J. brachysoma*- ♂, D) *J. brachysoma*- ♀, E) *T. toli* and site of attachment of *A. leptosoma*on the host,*T. toli*, F) Site of attachment of *A. malayi*on the host, *T. toli*, G) *A. Leptosoma*- ♀, H) *A. malayi*- ♂, I) *A. malayi*- ♀, J) *A. chacunda,* K) Site of attachment of *N. cygniformis*on the host , *A. chacunda,* L) *N. cygniformis*- ♀. M) Tail fin of host, *A. chacunda* showing infestation with *P. fistula fistula* N) *P. fistula fistula*- ♀. O) *P. varunae* - ♀attached theinner operculum of *A. chacunda* P) *P. varunae*- ♀, Q) *S. fimbriata,* R) *C. hilsae*-♀, S) Gill of *S. fimbriata* showing infestation with *C. hilsae.*

site of infection for *A. leptosoma,* on the other hand, *A. malayi is* found attached the floor of the branchial cavity of the host fish (Figure 1). Both body surface and branchial cavity of host fish (*T. toli*) where parasite found attached were heavily damaged (Figure 1).

A. chacunda, a small genus of gizzard shads usually distributed in the Indo-Pacific region showed infection with three parasitic copepod species belong to three different genera such as Bomolochidae, Lernaeopodidae, and Pennellidae (Table 2; figure 1). The bomolochid, *P. varunae* exhibited greater prevalence (P= 20.29±3.03) and intensity (I= 1.02±0.01) (Table 2; Figure 3 & 4) compared to other copepod species. It preferred upper region of inner operculum of host fish (*A. chacunda*), for site of infection (Figure 1). Most of the recovered members were females possessing egg sacs containing eggs undergoing embryogenesis. All members of pennellid species, *P. fistula fistula* recovered from *A. chacunda* were also females attached to either lobe of caudal fin lying parallel to the host body (Figure 1); prevalence and intensity being 2.88±0.47 and 1.21±0.02 respectively (Table 2; Figure 2 & 3). *A. chacunda* also showed infection with lernaeopodid, *N. cygniformis* (Hesse, 1863), but with relatively less prevalence (0.04±0.56) and intensity (1.00) (Table 2, Figure 2 & 3) and site of infection being the lower region of inner operculum of host fish. Selection of different niche by the different copepod parasites on the same host body likely avoids competition among them for space and food. Fringe scale sardinella (*S. fimbriata*) showed infection by the copepod *C. hilsae* (Figure 1) with prevalence and intensity respectively 7.13±1.22 and 4.03±0.21 and the site of attachment being both gill filaments and gill rakers (Table 2; Figure 2 & 3).

Seasonal Variation in Prevalence

Season dependent variation was noticed in the intensity and prevalence of parasitic isopods and copepods recovered from clupeids (F=2.788; P=0.022) during the present study period. Irrespective of the individual parasite species,

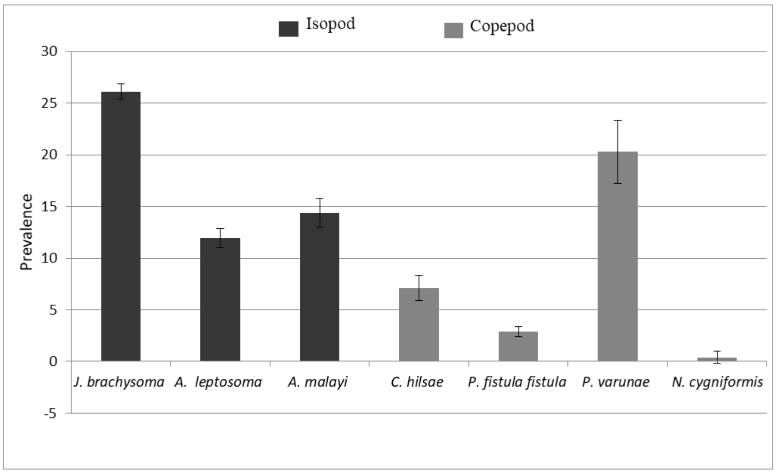

Figure 2. Prevalence (Mean± SD) of parasitic isopods and copepods recovered from the Clupeidaen fishes.

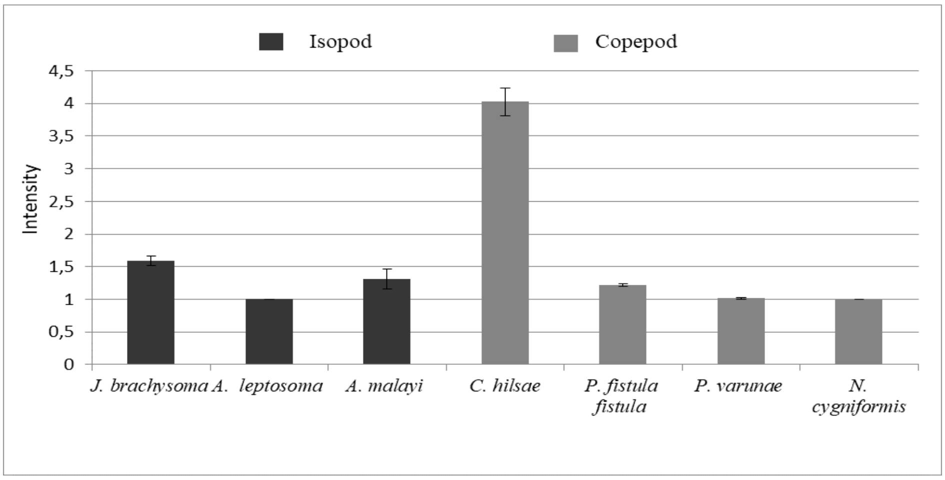

Figure 3. Intensity (Mean± SD) of parasitic isopods and copepods recovered from their Clupeidaen fishes.

isopods shows greater prevalence during the pre- monsoon (Feb-May) and least in monsoon (June- Sept). Among isopods higher prevalence was found in *J. brachysoma (*Figure 4) with a sequence of pre- monsoon (P= 32.68±2.90) > post- monsoon (P=26.29±0.99) > monsoon (P=17.02±0.81) (Figure 4). The prevalence shown by *A. leptosoma* during pre- monsoon, monsoon and post- monsoon was 14.76±2.27, 8.97±0.56 and 13.86±4.25 respectively (Figure 4). Contrary to this pattern, parasitic copepods such as *C. hilsae, P. fistula fistula* and *N. cygniformis* showed greater prevalence during post- monsoon season (Figure 4) while the seasonal pattern of prevalence shown by *P. varunae* was resembled to that of isopods. During monsoon, prevalence shown by all isopod and copepod species recovered during the present study was least (Figure 4).

Tukey's pairwise comparison between the prevalence of the recovered isopods and copepods revealed no pairwise variation in the prevalence with respect to seasons (P>0.05) (Table 3) except between *A. malayi* and *N. cygniformis* (P<0.05). Season wise analysis reveals that prevalence shown by the isopods J. *brachysoma* and *A. malayi* between monsoon & post- monsoon, monsoon & pre- monsoon and post- monsoon & pre- monsoon is statistically significant (*P*<0.05) (Table 4). Statistically significant seasonal variation in prevalence shown by the copepods, *C. hilsae* and *P. fistula fistula*, between post- monsoon & pre- monsoon and monsoon & post- monsoon was also recorded (P<0.05) (Table 4). Prevalence of *P. varunae* also showed notable variation between monsoon & pre- monsoon and post- monsoon & pre- monsoon (P<0.05) (Table 4).

Shannon diversity index of each parasite (both isopod and copepod) with respect to seasons was also recorded; highest Shannon diversity for all three isopods was during pre- monsoon followed by post- monsoon and monsoon (Figure 5). Maximum Shannon diversity was recorded in the case of *J. brachysoma* when compared to other two isopod species throughout the study period (Figure 5). Among the copepods, *P. varunae* showed high Shannon diversity when compared to other copepod species irrespective of the seasons. *C. hilsae, and P. fistula fistula*, on the other hand, showed greater diversity index during post- monsoon and then it gradually declined towards the pre- monsoon and the lowest value was observed in the monsoon (Figure 6).Interestingly, in the case of *N. cygnyformis*, no diversity index was observed with respect to seasons as it remained at the base line throughout the study period

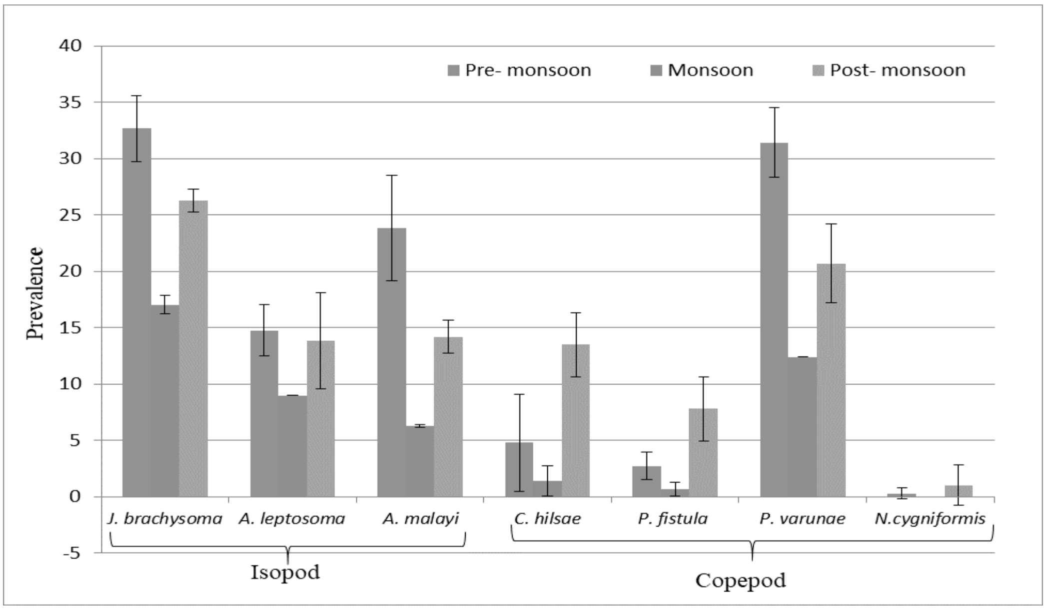

Figure.4. Seasonal variation in Prevalence (Mean± SD) of parasitic isopods and copepods recovered from Clupeidaen fishes.

Table 3. Tukey's pairwise comparisons between prevalence of parasitic isopods and copepods . (Significant *P* value is given in bold)

	J. brachysoma	*A. leptosoma*	*A. malayi*	*C. hilsae*	*P. fistula fistula*	*P. varunae*	*N. cygniformis*
J. brachysoma		1	1	0.9088	0.6796	0.5579	0.05274
A. leptosoma	0.174		1	0.9451	0.7533	0.6369	0.07058
A. malayi	0.2112	0.3852		0.8489	0.5846	0.4631	0.0365
C. hilsae	1.625	1.451	1.836		0.9993	0.9947	0.4758
P. fistula fistula	2.271	2.097	2.482	0.6457		1	0.7612
P. varunae	2.54	2.366	2.752	0.9156	0.2699		0.8581
N. cygniformis	4.348	4.174	4.559	2.723	2.077	1.807	

(Figure 6).

Seasonal Variation in Intensity

Intensity of infestation signifies the degree of survival of parasite on the host species. Intensity in isopods (except *A. leptosoma* in which the intensity was 1.00 irrespective of the season) is at its peak during pre- monsoon season followed by post- monsoon and monsoon (Figure 7). In the case of copepods, high rate of intensity was during post- monsoon and least in monsoon (Figure 7). However, results of one-way ANOVA test showed no significant variation in intensity when we consider overall data (F= 1.022; P= 0.387) on both isopods and copepods together; but, there exists significant variation in the intensity when the parasite

Table 4. Significance of variation in prevalence of individual parasitic isopods and copepods with different seasons- *P* value, *F* value and Tukey value. (Significant *P* value is given in bold).

Sl No	Name of the parasite	F value	P value	Seasons	Pre-monsoon	Monsoon	Post-monsoon
				Pre-monsoon		14.8	6.052
1	*J. brachysoma*	55.49	0.000135	Monsoon	0.000312		0.002149
				Post-monsoon	0.01247	8.764	
				Pre-monsoon		10.69	5.853
2	*A. malayi*	28.66	0.000851	Monsoon	0.000861		0.03272
				Post-monsoon	0.01449	4.839	
				Pre-monsoon		1.886	4.871
3	*C. hilsae*	12.16	0.007751	Monsoon	0.4293		0.00747
				Post-monsoon	0.03841	6.758	
				Pre-monsoon		1.953	4.829
4	*P. fistula fistula*	12.19	0.007707	Monsoon	0.4073		0.007345
				Post-monsoon	0.033	6.782	
				Pre-monsoon		9.58	5.393
5	*P. varunae*	23.06	0.001525	Monsoon	0.001412		0.0573
				Post-monsoon	0.02077	4.187	

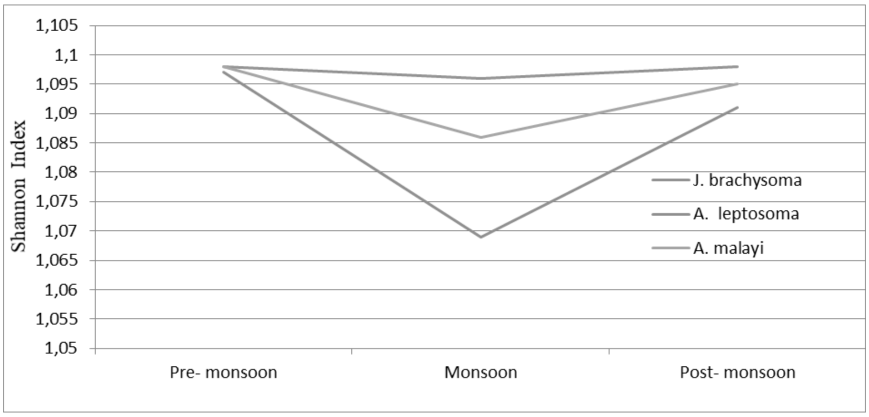

Figure 5. Shannon diversity index for parasitic isopods infesting the clupeid fishes with respect to seasons.

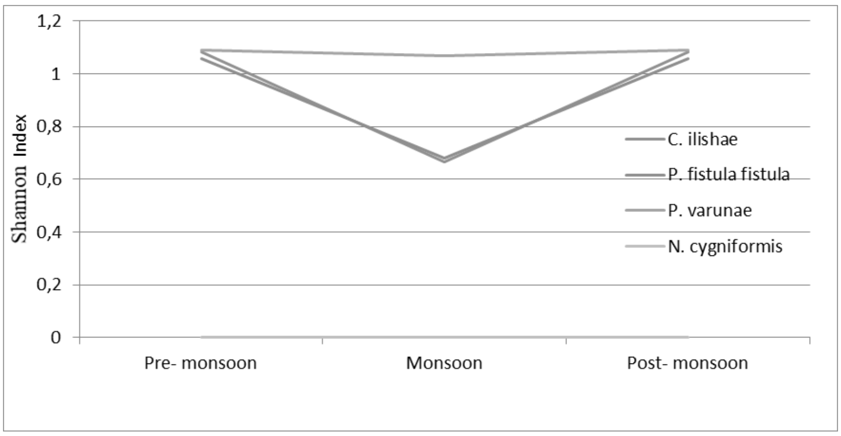

Figure 6. Shannon diversity index for parasitic copepods infesting the clupeid fishes with respect to seasons.

species is considered individually with respect to seasons. For instance, isopods, *J. brachysoma* and *A. malayi* exhibit significant variation in intensity (*J. brachysoma*, *F*= 7.327, *P*= 0.02452; *A. malayi* *F*= 18.74, *P*= 0.002627) which is more predominant between pre-monsoon & monsoon and monsoon & post- monsoon (Table 5).

Discussion

Clupeid fishes from the Malabar coast appear to be potential host for both isopods and copepods. The white sardine, *Escualosa thoracata* hosts *Joryma brachysoma* and *Tenualosa toli* hosts *Anilocra leptosoma* and *Agarna malayi.* Among the recovered isopods, *J. brachysoma* shows highest prevalence (P= 26.11+ 0.073) and intensity (I=1.59 + 0.07). Infection by *J. brachysoma* has also been reported from the Indian fishes such as *Rastrelliger kanagurta, Ilisha melastoma*, *Pellona brachysoma* (Ravichandran & Ajith Kumar, 2008; Ravichandran, Rameshkumar & Kumaravel, 2009; Rameshkumar, Ravichandran & Trilles, 2011). According to the recent report (Panakkool-Thamban *et al*., 2013), *E. thoracata* from the Malabar coast is also under the heavy infection with another isopod *Nerocila loveni.* Panakkool-Thamban *et al*., (2016) previously reported the presence of parasitic isopod *A. malayi* on the same host, *T. toli* with a prevalence of 16.19 and an intensity of 1.89 which is akin to the data (P= 14.38±1.34 and I= 1.31±0.15) obtained from the present study. Among the recovered isopods, *Anilocra leptosoma* shows least prevalence and intensity throughout the study period.

The gizzard shad, *A. chacunda* is potential to host three different species of copepods (*P. fistula fistula, P. varunae* and *N. cygniformis*), but not simultaneously; at a time fish hosts maximum of two species and most instances the combination is with *P. varunae* and *P. fistula fistula. P. varunae* shows maximum prevalence (P= 20.29 + 3.03), but their intensity is relatively less comparing to *P. fistula fistula.* Reports are available on *P. fistula fistula* infecting the Coryphaenid (Order Perciformes) fish, *Coryphaena hippurus* from the Aegean Sea coastal waters of Turkey **(**Öktener, (2008). Vidjak, Zorica, and Sinovčić (2008) reported that garfish, *Belone belone* (in the eastern Adriatic Sea) infected with *P. fistula fistula*. Bunkley-Williams and Williams Jr. (2009) listed 34 host fishes in 2 super orders, 6 orders, and 19 families of fishes for this parasite (*P. fistula fistula*) signifying their non host specific parasitisation. Among the presently recovered parasitic copepods *N. cygniformis* shows least prevalence. Presence of this parasite has also been reported from the cow-eyed sparid fish, *Boops boops* in the southern and northern mediterranean (Ramdane, Trilles, Mahe, & Amara, 2013).

During the present study, *S. fimbriata* is shown to have the parasitisation with only the copepod *C. hilsae*.

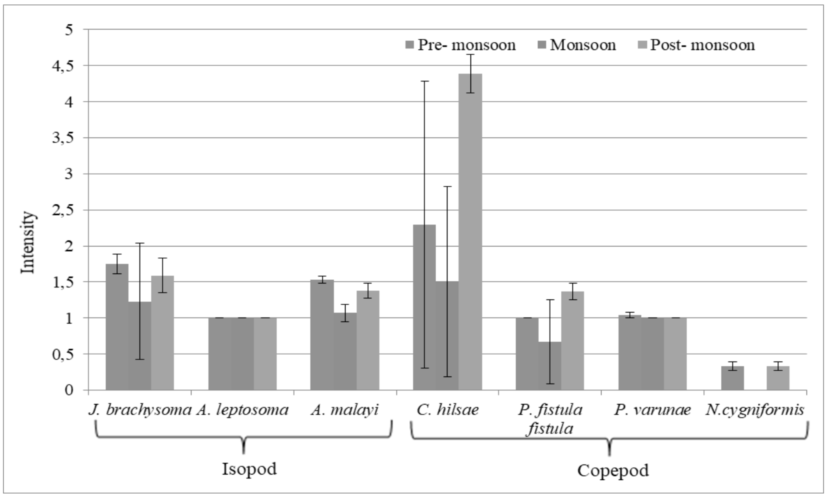

Figure 7. Seasonal variation in intensity (Mean± SD) in the infestation of parasitic isopods and copepods with respect to seasons.

Table 5. Significance of variation in intensity of individual parasitic crustacean with different seasons- *P* value, F value and Tukey value. (Significant *P* value is given in bold)

Sl No	Name of the parasite	F value	P value	Seasons	Pre-monsoon	Monsoon	Post-monsoon
				Pre-monsoon		5.28	1.637
1	*J. brachysoma*	7.327	0.02452	Monsoon	0.023		0.09
				Post-monsoon	0.517	3.65	
				Pre-monsoon		8.45	2.57
2	*A. malayi*	18.74	0.002627	Monsoon	0.0025		0.0142
				Post-monsoon	0.24	5.87	

But according to the previous reports, this clupeid fish (*S. fimbriata)* distributed at the Malabar coast and Karachi (Pakistan) also harbours another copepod, *Pumiliopes squamosus* (Aneesh, 2014) and an isopod, *Joryma sawayah* (Ghani, 2003).

Parasitic crustaceans usually exhibit strict site specificity apparently for avoiding the inter-parasitic competition for space and food (Rijin & Sudha, 2017). In present study, all the members of *J. brachysoma* and *A. malayi* were found specifically attached the branchial chamber of their respective host fish, *E. thoracata* and *T.toli*. On the other hand, *A. leptosoma* prefers the body surface of its host fish, *T. toli.* All presently recovered copepod parasites also occupy their own niche on their host body; *C. hilsae* prefers gill for infection, but their microhabitats are restricted to anterior gill rakers and gill filaments. Other microhabitats for parasitic copepods inculde anterio-posterior axis of the gill, gill arches and external/ internal gill filament. (Rijin & Sudha, 2017). The direction and speed of ventilation, water-currents and certain intrinsic factors of the parasite themselves may determine their microhabitat restriction on the gills (Ramasamy, Ramalingam, Hanna & Halton, 1985).

Present study reveals that prevalence and intensity of recovered parasitic isopods and copepods vary with seasons. In the case of isopods, invariably, pre- monsoon (Feb- May) is the period of maximum prevalence and by the onset of the monsoon season, (June- Sept) the prevalence generally showed a downward trend, however, during the post- monsoon season (Oct- Jan) the prevalence gradually increased. This observation supports the previous reports in four species of parasitic isopod representing the genus *Nerocila* infecting commercially exploited marine fishes of the families Engraulidae, Clupeidae and Ambassidae, from the Malabar coast of India (Panakkool-Thamban *et al*., 2013). The prevalence and intensity shown by *J. brachysoma* on *R. kanagurta* showed considerable monthly variation with maximum in January and minimum in July (Ravichandran *et al*., 2009). The prevalence could be dependent on environmental parameters like rainfall, salinity and temperature. Low prevalence during the monsoon period is apparently due to the weak salinity (27–29 ppt), resulting from the heavy rain fall, inducing an unfavorable environment for the parasitic infection while the gradual increase of salinity (30–35 ppt) during the post- monsoon season seems to facilitate the parasitic infestation (Panakkool-Thamban *et al*., 2013). Present study also supports this information.

Conclusion

Present study could demonstrate the diverse pattern of seasonal variation in the prevalence and intensity of parasitic isopods and copepods infection on the Clupeidaen fishes along the Malabar coast using statistical tools; all three recovered isopod and one copepod species are with their highest prevalence during pre- monsoon period and least in monsoon period. But, post- monsoon season is the favorable period for infection by the remaining three recovered copepod species. This signifies the role apparently played by environmental factors like salinity, temperature and rainfall in the pattern of parasitisation by the isopod and copepods on clupeidaen fishes. So the future research may be focused in such way to demonstrate the role of extrinsic factors by considering primarily the parameters like salinity, rainfall and temperature, the gathered information would be useful to adopt the strategies for the management of crustacean parasitism in culture fisheries.

Acknowledgements

Authors gratefully acknowledge Kerala State Council for Science, Technology and Environment, Govt. of Kerala (No. (T) 093/SRS/2011/CSTE, dated 25.06.2011) for financial support to carry out this work.

Kannur University Junior Research Fellowship offered to KR is also gratefully acknowledged.

References

Altizer, S., Dobson, A., Hosseini, P., Hudson, P., Pascual, M., & Rohani, P. (2006). Seasonality and the dynamics of infectious diseases. *Ecology letters*, *9*(4), 467-484. https://doi.org/10.1111/j.1461-0248.2005.00879.x

Aneesh, P. T. (2014). *Studies on Parsitic Crustaceans Infesting on Fishes of Malabar* (Ph D Thesis). Kannur University, Kannur, India.

Athanassopoulou, F., Bouboulis, D., & Martinsen, B. (2001). In vitro treatments of deltamethrin against the isopod parasite Ceratothoa oestroides, a pathogen of sea bass *Dicentrarchus labrax* L. *Bulletin- European Association of Fish Pathologists*, *21*, 26–29.

Barber, I. & Poulin, R., 2002. Interactions between fish, parasites and disease. P.J.B. Hart and J.D. Reynolds (eds.), *Handbook of fish biology and fisheries* Oxford Blackwell Publishing. pp. 359-389.

Başusta, N., Mutlu, E., & Deval, M. C. (2017). Parasitic isopods (*Anilocra frontalis* (Milne Edwards, 1830) and *Ceratothoa capri* (Trilles, 1964)) from the Antalya Bay (Turkey) with new host records. *Turkish Journal of Science & Technology*, *12*(1), 11-15.

Bush, A. O., Lafferty, K. D., Lotz, J. M., & Shostak, A. W. (1997). Parasitology meets ecology on its own terms. Margolis *et al*. revised. *Journal of Parasitology, 83*, 575–583.

Carr, J., & Whoriskey, F. (2004). Sea lice infestation rates on wild and escaped farmed Atlantic salmon (*Salmo salar* L.) entering the Magaguadavic River, New Brunswick. *Aquaculture Research*, *35*(8), 723-729. https://doi.org/10.1111/j.1365-2109.2004.01094.x

Fogelman, R. M., Kuris, A. M., & Grutter, A. S. (2009). Parasitic castration of a vertebrate: effect of the cymothoid isopod, *Anilocra apogonae*, on the five-lined cardinal fish, *Cheilodipterus quinquelineatus*. *International*

Journal for Parasitology, *39*(5), 577-583. https://doi.org/10.1016/j.ijpara.2008.10.013

Froese, R., & Pauly, D. (2013). Fish Base. World Wide Web electronic publication. Available from: http://www.Fishbase.org, Version (January 2016). Accessed 3 Feb 2016.

Ghani, N. A. (2003). Isopod parasites of marine fishes of Pakistan. In *Proeedings of Pakistan Congress of Zoology*, Vol. *23*, 217-221.

Hammer, O., Harper, D. A., & Paul, D. Ryan (2001). PAST Palaeontological Statistics, software package for education and data analysis. *Palaeontologia electronica*, *4*(1), 9.

Johnson, S. C., Bravo, S., Nagasawa, K., Kabata, Z., Hwang, J. S., Ho, J. S., & Shih, C. T. (2004). A review of the impact of parasitic copepods on marine aquaculture*. Zoological Studies*, *43*(2), 229-243.

Lafferty, K. D., & Kuris, A. M. (1993). Mass mortality of abalone *Haliotis cracherodii* on the California Channel Islands: tests of epidemiological hypotheses. *Marine Ecology Progress Series*, 239-248.

Leonardos, I., & Trilles, J. P. (2003). Host-parasite relationships: occurrence and effect of the parasitic isopod *Mothocya epimerica* on sand smelt *Atherina boyeri* in the Mesolongi and Etolikon Lagoons (W. Greece). *Diseases of Aquatic Organisms*, *54*(3), 243-251. https://doi.org/10.3354/dao054243

Öktener, A. (2008). *Peniculus fistula* von Nordmann, 1832 (Copepoda: Pennelidae) Parasitic on Coryphaena hippurus Linnaeus, 1758 (Teleostei: Coryphaenidae). *Reviews in Fisheries Science*, *16*(4), 445-448. https://doi.org/10.1080/10641260802046668

Panakkool-Thamban, A., Kappalli, S., Keethadath, A., Gopinathan, A., & Jean-Paul, T. (2013). Seasonal fluctuation of the prevalence of cymothoids representing the genus *Nerocila* (Crustacea, Isopoda), parasitizing commercially exploited marine fishes from the Malabar Coast, India. *Acta parasitologica*, *58*(1), 80-90. https://doi.org/10.2478/s11686-013-0112-3

Panakkool-Thamban, A., Kottarathil, H. A., & Kappalli, S. (2016). Branchial cymothoids infesting the marine food fishes of Malabar coast. *Journal of Parasitic Diseases*, *40*(4), 1270-1277. https://doi.org/10.1007/s12639-015-0666-0

Pillai, N. K. (1985). *The Fauna of India*: *Copepod Parasites of Marine Fishes*. Zoological Survey of India, India. 900.

Ramasamy, P., Ramalingam, K., Hanna, R. E. B., & Halton, D. W. (1985). Microhabitats of gill parasites (Monogenea and Copepoda) of teleosts (*Scomberoides spp*.). *International Journal for Parasitology*, *15*(4), 385-397. https://doi.org/10.1016/0020-7519(85)90023-2

Ramdane, Z., Trilles, J. P., Mahe, K., & Amara, R. (2013). Metazoan ectoparasites of two teleost fish, *Boops boops* L. and *Mullus barbatus barbatus* L. from Algerian coast: diversity, parasitological index and impact of parasitism. *Cybium*, *37*(1-2), 59-66.

Rameshkumar, G., & Ravichandran, S. (2014) Problems caused by isopod parasites in commercial fishes. *Journal of Parasitic Diseases*, *38*(1), 138-141. http://dx.doi.org/10.1007/s12639-012-0210-4

Rameshkumar, G., Ravichandran, S., & Trilles, J. P. (2011). Cymothoidae (Crustacea, Isopoda) from Indian fishes. *Acta Parasitologica*, *56*(1), 78-91. https://doi.org/10.2478/s11686-011-0002-5

Ravichandran, S., & Ajith Kumar, T. T. (2008). Secondary microbial infection in *Ilisha melastoma* due to isopod fish parasites. *Journal of Fisheries and Aquatic Science*, *3*(1), 92-96. https://doi.org/10.3923/jfas.2008.92.96

Ravichandran, S., Rameshkumar, G., & Kumaravel, K. (2009). Variation in the morphological features of isopod fish parasites. *World Journal of Fish and Marine Sciences*, *1*(2), 137-140.

Rijin K. and Sudha K. (2017) A Report On Parasitic Crustacean Infection on Clupeid and Carangid Fishes Along The Malabar Coast. In proceedings of 29th Kerala Science Congress (pp. 821-825). Marthoma College, Thiruvalla, India.

Smit, N. J., Bruce, N. L., & Hadfield, K. A. (2014). Global diversity of fish parasitic isopod crustaceans of the family Cymothoidae. *International Journal for Parasitology: Parasites and Wildlife*. *3*(2), 188-197. https://doi.org/10.1016/j.ijppaw.2014.03.004

Trilles, J. P., & Oktener, A. (2004). *Livoneca sinuata* (Crustacea; Isopoda; Cymothoidae) on *Loligo vulgaris* from Turkey, and unusual cymothoid associations. *Diseases of Aquatic Organisms*, *61*, 235–240. https://doi.org/10.3354/dao061235

Vidjak, O., Zorica, B., & Sinovčić, G. (2008). First record of parasitic copepod *Peniculus fistula* von Nordmann, 1832 (Siphonostomatoida: Pennellidae) from garfish *Belone belone* (Linnaeus, 1761) in the Adriatic Sea. *Cahiers de biologie marine*, *49*, 209-213.

Bunkley-Williams, L., & Williams Jr, E. H. (2009). Hosts and distribution of *Peniculus fistula* Von Nordman, 1832. *Reviews in Fisheries Science*, *17*(4), 538-540. https://doi.org/10.1080/10641260903216012

Williams Jr, E. H., & Bunkley-Williams, L. (2000). On the generic placement of '*Livoneca sp.'*: a critique of Colorni *et al*. (1997). *Diseases of Aquatic Organisms*, *40*, 233–234. http://dx.doi.org/10.3354/dao040233

Yu, H., & Li, X. (2003). Study on the Cymothoidae from Chinese waters. *Studia Marina Sinica*, *45*, 223-238.