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Clupeid fish hosts a *Peniculus* sp. (Pennellidae, Siphonostomatoida, Copepoda)—First report on new host and season dependent prevalence

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Abstract
Pennellid copepod *Peniculus fistula fistula* (Nordmann, 1832) (Synonym: *Peniculus fistula* Nordmann, 1832, Aphia ID: 745880), a worldwide distributed species, has been recovered from at least 19 teleost families. The present paper reports for the first time from the Malabar coast (South India), not only the existence of a new host family, Clupeidae, hosting this parasitic copepod species (*P. fistula fistula*) but also their season dependent hosting. A total of 123 marine fish species, belonging to 77 genera and 38 families surveyed along the Malabar coast, only the clupeid, *Anadontostoma chacunda* (Hamilton, 1822) was shown to be infected by this copepod species; all the recovered (copepod) parasites were invariably found attached at the mid portion of the caudal fin lobes and lying parallel to the host body, indicating the strict site-specific parasitisation. There is a discrete seasonality in the prevalence ($P<0.05$) as the sign of infection was noticed during the period from September to May with relatively high prevalence during winter months (November–January). During the monsoon months (June–August), the host fish was found completely free from *Peniculus* infection. Interestingly, all the 229 recovered specimens (*P. fistula fistula*) were gravid females having paired uniserrate egg sacs with the length more than its own body length.

Key words: clupeid fish, *Peniculus fistula fistula*, host specificity, seasonality, prevalence

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1 Introduction

Copepods are known to be one of the most recognized crustaceans that parasitize on fishes. More than 2 000 species of copepods are known to infect the marine and the freshwater fishes. They are found all over the external body surface of the host as well as in more sheltered microhabitats (Arnal and Morand, 2001; Nagasawa, 2015; Youssef et al., 2016; Abdel-Gaber et al., 2017). These parasitic copepods draw considerable attention of researchers worldwide, on account of their economical, ecological and evolutionary impacts (Bunkley-Williams and Williams, 2009). Pennellidae, one of the major families of parasitic copepods, comprises 140 species belonging to 20 genera and most of them appears to be mesoparasites of marine fishes and aquatic mammals (Boxshall and Halsey, 2004; Ho et al., 2007; Uyeno and Nagasawa, 2010; Ismail et al., 2013; Moon and Choi, 2014). Among them (Pennellidae) *Peniculus* forms the largest of all genera, comprising 14 valid species (Maran et al., 2012). Their members are highly transformed ectoparasites which generally prefer to infect the body surface and fin rays of actinopterygian fishes (Ismail et al., 2013; Moon and Choi, 2014). The fishes, *Terapon jarbua* (Terapontidae) and *Daysciaena albida* (Sciaenidae) from Indian waters host *P. teraponi* and *P. sciaenae* respectively (Gnanamuthu, 1951). *Peniculus ostraciontis* was found to parasitize the fins of rock fish, *Sebastes schlegeli* (Sebastidae) along the Korean coast, humpback turretfish, *Ostacion gibbosum* (Ostraciidae) and *Lactophrys* sp. (Ostraciidae) along the Japan coast (Choi et al., 1996). *Peniculus truncatus* infects the dorsal fin of Korean rock fishes such as *Sebastes schledge* and *S. oblongus* (Maran et al., 2012). *Peniculus minuticaudae*is shown to infect four species of Monocanthid fishes *Stephanolepis cirrhifer, Thamnaconus modestus, Aluterus monoceros* and *Paramonocanthus japonicas* and a Chaetodontid fish *Roa modesta* from Japan (Alexander, 1983; Okawachi et al., 2012). *Peniculus fistula fistula* von Nordmann, 1832 (Synonym-*Peniculus fistula* von Nordmann, 1832) which appears as more or less widely distributed parasitic copepod being recovered from at least 19 teleost families (Vidjak et al., 2008; Bunkley-Williams and Williams, 2009). However, surveying through the literature, not even a single report showing the instance of clupeid fish being parasitized by any species of *Peniculus*. It is at this context, the present paper reports for the first time from the Malabar coast (South India), not only the existence of a new host family, Clupeidae, host-

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ing the *Peniculus* sp. (*P. fistula fistula*) but also their season dependent hosting of this parasite.

2 Materials and methods

The present study was conducted during the period from June 2013 to May 2017. Marine fishes were collected afresh from the fishing boat harbored at Ayyikkara (11°51′N, 75°22′E), Azhikkal (11°56′00″N, 75°18′00″E) and Chombala (11°39′N, 75°33′E). Immediately after collection before brought to the laboratory, the fish body parts (body surface, buccal cavity, lateral line region, fins, branchial cavity, gill filaments, inner wall of the operculum and cornea) were closely examined for the presence of parasitic copepod infection using hand lens. Some of the recovered *Peniculus* sp. were immediately removed from the host body and preserved in 70% ethanol (after Ramakrishna, 1980) for the purpose of identification and documentation. In some cases, the infected host fish along with the parasite (without removing from their host) was also brought to the laboratory in order to have a close examination of the site of infection. Using a dissection microscope and a stereo microscope Leica- S6D, the identification was performed according to Kabata (1979), Pillai (1985) and Vidjak et al. (2008). Photography of the host fish and the parasite was done using both Olympus (μTOUGH-3000) and camera attached with stereo microscope Leica-S6D. Prevalence (P), intensity (I) and abundance (A) of parasitic infection were calculated according to Bush et al. (1997). Host nomenclature and fish taxonomy were done according to Fish Base (Froese and Pauly, 2017). Voucher specimens of *P. fistula fistula* (accession No. PF-01F, PF-02F, PF-03F) were deposited in the Parasitic Crustacean Museum, Crustacean Biology Research Laboratory, Sree Narayana College, Kannur, Kerala, India. The periods of June–August (monsoon), September–October (post-monsoon), November–January (winter), February–May (summer) were considered when analyzed the parasitic occurrence of *P. fistula fistula* on its host fish on a seasonal basis.

Data analysis was performed using the software Parasitology 3 for calculating the parasitological indices. Seasonal variation in the prevalence of the parasite was analyzed by adopting one-way ANOVA followed by pairwise *t*-test. Significance level was set at $P<0.05$. PAST software (version 2.17c) (Hammer et al., 2001) was used for these statistical analyses.

3 Results

Out of 123 marine fish species belonging to 77 genera and 38 fish families surveyed (Table 1), *Peniculus fistula fistula* was recovered only from a clupeid fish species *Anadontostoma chacunda* commonly called as Chacunda gizzard shad (Table 1, Fig. 1), signifying its holoxenous host specificity as far as the Malabar coast is concerned. Among the 2 708 fish specimens of *A. chacunda* observed, for the period of four years extending from June 2013 to May 2017, 132 members were shown to have the infection with *P. fistula fistula* (Table 1, Fig. 1) and a total of 229 members of this copepod species were collected from the infected fishes, with average annual prevalence, intensity and mean abundance being 4.06%±1.09%, 1.28±0.30, 0.292±0.42 respectively (Table 2, Fig. 2). All the recovered parasites were adult females bearing egg sacs which were longer than its own body length (the egg sac-body length ratio being 1.5:1.0) (Fig. 1). The parasites prefer to attach exactly at the mid portion of both upper and lower lobes of host fish caudal fin using their modified antennae (Table 2, Fig. 1).

Present study also recorded a statistically significant variation (P=0.000 1) in the season wise occurrence of *P. fistula fistula* on its host fish (*A. chacunda*) (Fig. 3). Further, significant proportion of them showed infection during winter months (November–January), with average prevalence (13.02%±2.54%) and peak value during December (17.68%) followed by January (12.54%). However, the average prevalence (3.51%±1.19%) during the summer months (February–May), showed significant decline compared to that of winter months (P=0.005). During the monsoon months of June, July and August, the host fish population was found entirely free (P=0%) from this copepod infection and a narrow increase was recorded in prevalence during the post-monsoon season (1.17%±1.07%) (Fig. 3).

This observation was validated further with result of pairwise comparison of prevalence of all four seasons using *t*-test. Result of the *t*-test showed significant variation in prevalence between winter and monsoon (P=0.002), winter and post-monsoon (P=0.0006), and summer and winter (P=0.005) (Fig. 4). Monthly variation was also seen in the mean intensity which showed its peak value during November–December months (Fig. 3).

When compared the total length of infected fish (*A. chacunda*) with both body length of the parasite (*P. fistula fistula*) (without egg sac) and its egg sac length, it was found that the size of the parasites infected on the small fishes was smaller compared to that of the parasites on the large fish. This was further confirmed by the correlation analysis between host fish total length and parasite length (R^2 = 0.771 5) (Fig. 5). A significant correlation was also observed between the fish total length and copepod egg sac length (R^2=0.808 4) (Fig. 5) as well as copepod length and its egg sac length (R^2=0.792 5) (Fig. 6).

4 Discussion

Clupeids, one of the most abundant edible fish groups distributed worldwide, appear as potential hosts for diverse parasitic copepod families including Pennellidae, Bomolochidae, Lernaeopodidae (Pillai, 1985; WoRMS, 2017; Rijin et al., 2019). For instance, the pennellid genus, *Lernaeenicus* comprising 32 valid species, shows much host preference to the clupeid fishes; the heavy infection by *Lernaeenicus sprattae* was reported on clupeid fishes such as *Sprattus sprattus* (European sprat), *Sardina pilchardus* (European sprat) and *Clupea herengus* (Atlantic herring) from North European waters (WoRMS, 2017). Different species of *Peniculus* (*P. teraponi*, *P. sciaenae, P. truncatus*, *P. minuticaudae*is, *P. ostraciontis, P. fistula fistula*) have also been recovered from a variety of non-clupeid fishes (Bunkley-Williams and Williams, 2009; Ismail et al., 2013; Moon and Choi, 2014). The present *Peniculus* sp., *P. fistula fistula* infects the members of 19 fish families including Mugilidae, Lampridae, Antherinidae, Belonidae, Carangidae, Coryphaenidae, Sparidae, etc. (Bunkley-Williams and Williams, 2009). However, no report has ever recorded clupeids as the host fishes for any of the *Peniculus* sp. The present study reports for the first time, the parasitic occurrence of a *Peniculus* sp. (*P. fistula fistula*) on a clupeid fish, *Anadontostoma chacunda* from the Malabar coast. This finding also appears to be a new host record for *P. fistula fistula*, from geographical stand points. Though 123 teleost marine fish species from diverse genera and families, were closely observed, only the clupeid fish *A. chacunda* was shown to have infected with this *Peniculus* sp. which signifies its holoxenous host specificity.

The fishes such as *Mugil cephalus* (Family Mugilidae) and *Coryphaena hippurus* (Family Coryphaenidae), were previously reported as potential hosts for this *Peniculus* sp. from the Aegean Sea coastal waters of Turkey (Öktener, 2008; Vidjak et al., 2008). Though these two fishes (*M. cephalus* and *C. hippurus*) were observed throughout the present study period, no sign of parasitic

Table 1. List of fishes surveyed for the presence of parasitic copepod, *P. fistula fistula*

Sl No.	Fish family	Name of the fish	NFO	IPff
1	Acanthuridae	*Acanthurus mata* (Cuvier, 1829)	13	–
2	Ambassidae	*Ambassis ambassis* (Lacepède, 1802)	168	–
3	Ariidae	*Arius caelatus* (Valenciennes, 1840)	15	–
4	Belonidae	*Ablennes hians* (Valenciennes, 1846)	24	–
		Platybelone argalus (Lesueur, 1821)	144	–
		Strongylura incisa (Valenciennes, 1846)	14	–
		Strongylura leiura (Bleeker, 1850)	188	–
		Strongylura strongylura (van Hasselt, 1823)	166	–
5	Carangidae	*Alectis ciliaris* (Bloch, 1787)	10	–
		Alepes djedaba (Forsskål, 1775)	528	–
		Alepes kleini (Bloch, 1793)	110	–
		Atule mate (Cuvier, 1833)	20	–
		Carangoides chrysophrys (Cuvier, 1833)	10	–
		Carangoides coeruleopinnatus (Rüppell, 1830)	2	–
		Carangoides malabaricus (Bloch & Schneider, 1801)	80	–
		Carangoides telamparoides (Bleeker, 1852)	19	–
		Caranx sexfasciatus (Quoy & Gaimard, 1825)	10	–
		Decapterus macrosoma (Bleeker, 1851)	19	–
		Decapterus russelli (Rüppell, 1830)	122	–
		Megalaspis cordyla (Linnaeus, 1758)	427	–
		Parastromateus niger (Bloch, 1795)	387	–
		Scomberoides tol (Cuvier, 1832)	198	–
		Selar crumenophthalmus (Bloch, 1793)	42	–
		Seriola dumerilli (Risso, 1810)	17	–
		Trachinotus blochii (Lacepede, 1801)	11	–
6	Carcharhinidae	*Scoliodon laticaudus* (Müller & Henle, 1838)	10	–
7	Chirocentridae	*Chirocentrus nudus* (Swainson, 1839)	35	–
8	Cichlidae	*Etroplus suratensis* (Bloch, 1790)	19	–
9	Clupeidae	*Amblygaster sirm* (Walbaum, 1792)	169	–
		Anodontostoma chacunda (Hamilton, 1822)	829	+
		Escualosa thoracata (Valenciennes, 1847)	1 107	–
		Hilsa kelee (Cuvier, 1829)	113	–
		Sardinella fimbriata (Valenciennes, 1847)	587	–
		Sardinella gibbosa (Bleeker, 1849)	148	–
		Sardinella longiceps (Valenciennes, 1847)	727	–
		Tenualosa ilisha (Hamilton, 1822)	225	–
		Tenualosa toli (Valenciennes, 1847)	811	–
10	Congridae	*Uroconger lepturus* (Richardson,1845)	10	–
11	Coryphaenidae	*Coryphaena hippurus* (Linnaeus, 1758)	87	–
12	Cynoglossidae	*Cynoglossus cynoglossus* (Hamilton, 1822)	125	–
		Cynoglossus dubius (Day, 1873)	17	–
		Cynoglossus puncticeps (Richardson, 1846)	23	–
13	Dussumieridae	*Dussumeiria acuta* (Valenciennes, 1847)	44	–
		Dussumeiria elopsoides (Bleeker, 1849)	16	–
14	Engraulidae	*Coilia dussumieri* (Valenciennes, 1848)	189	–
		Stolephorus baganensis (Hardenberg, 1933)	50	–
		Stolephoruschinensis (Günther, 1880)	50	–
		Stolephoruscommersonnii (Lacepède,1803)	76	–
		Stolephorus indicus (van Hasselt, 1823)	231	–
		Stolephorus macrops, Hardenberg, 1933	256	–
		Stolephorus tri (Bleeker, 1852)	680	–
		Thryssa dussumieri (Valenciennes, 1848)	17	–
		Thryssa hamiltonii (Gray, 1835)	10	–
		Thryssa malabarica (Bloch, 1795)	544	–
		Thryssa mystax (Bloch & Schneider, 1801)	149	–
		Thryssa setirostris (Broussonet, 1782)	234	–

to be continued

Continued from Table 1

Sl No.	Fish family	Name of the fish	NFO	IPff
		Thryssa vitrirostris (Gilchrist & Thompson, 1908)	10	–
15	Exocoetidae	*Exocoetus volitans* (Linnaeus, 1758)	17	–
16	Gerreidae	*Gerres erythrourus* (Bloch, 1791)	11	–
		Gerres filamentous (Cuvier, 1829)	10	–
17	Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)	198	–
		Hemiramphus lutkei (Valenciennes, 1847)	156	–
		Hyporhamphus limbatus (Valenciennes, 1847)	202	–
		Rhynchorhamphus malabaricus (Collette, 1976)	150	–
18	Hemiscylliidae	*Chiloscyllium griseum* (Müller & Henle, 1838)	14	–
19	Leiognathidae	*Equulites elongatus* (Günther, 1874)	15	–
		Equulites leuciscus (Günther, 1860)	20	–
		Eubleekeria splendens (Cuvier, 1829)	39	–
		Gazza minuta (Bloch, 1795)	48	–
		Leiognathus brevirostris (Valenciennes, 1835)	86	–
		Leiognathus daura (Cuvier, 1829)	112	–
		Leiognathus dussumieri (Valenciennes, 1835)	102	–
		Leiognathus equulus (Forsskål, 1775)	480	–
		Leiognathus fasciatus (Lacepède, 1803)	29	–
		Leiognathus lineolatus (Valenciennes, 1835)	45	–
		Leiognathus longispinis (Valenciennes, 1835)	35	–
		Nuchequula blochii (Valenciennes, 1835)	13	–
		Photopectoralis bindus (Valenciennes, 1835)	16	–
		Secutor insidiator (Bloch, 1787)	113	–
		Secutor ruconius (Hamilton, 1822)	138	–
20	Lethrinidae	*Lethrinus lentjan* (Lacepède, 1802)	17	–
21	Lutjanidae	*Lutjanus lutjanus* (Bloch, 1790)	11	–
22	Megalopidae	*Megalops cyprinoides* (Broussonet, 1782)	10	–
23	Menidae	*Mene maculata* (Bloch & Schneider, 1801)	145	–
24	Mugilidae	*Liza abu* (Heckel, 1843)	21	–
		Liza argentea (Quoy & Gaimard, 1825)	10	–
		Liza parsia (Hamilton, 1822)	11	–
		Moolgarda seheli (Forsskål, 1775)	18	–
		Mugil cephalus (Linnaeus, 1758)	59	–
25	Nemipteridae	*Nemipterus japonicus* (Bloch, 1791)	142	–
26	Priacanthidae	*Priacanthus hamrur* (Forsskal, 1775)	311	–
27	Pristigasteridae	*Opisthopterus tardoore* (Cuvier, 1829)	297	–
		Pellona ditchela (Valenciennes, 1847)	156	–
28	Polynemidae	*Leptomelanosoma indicum* (Shaw, 1804)	32	–
29	Sciaenidae	*Chrysochir aureus* (Richardson, 1846)	40	–
		Johnius dussumieri (Cuvier, 1830)	11	–
		Johnius glaucus (Day, 1876)	27	–
		Johnius trachycephalus (Bleeker, 1851)	114	–
		Miichthys miiuy (Basilewsky, 1855)	25	–
		Nibea maculata (Bloch & Schneider, 1801)	16	–
		Otolithoides biauritus (Cantor, 1849)	28	–
		Otolithes ruber (Bloch & Schneider, 1801)	259	–
30	Scombridae	*Euthynnus affinis* (Cantor, 1849)	87	–
		Rastrelliger kanagurta (Cuvier, 1816)	475	–
		Scomberomorus commerson (Lacepède, 1800)	211	–
31	Serranidae	*Epinepheluscostae* (Steindachner, 1878)	10	–
		Epinephelus aeneus (Geoffroy Saint-Hilaire, 1817)	13	–
		Epinephelus diacanthus (Valenciennes, 1828)	68	–
		Epinephelus chirostigma (Valenciennes, 1828)	8	–
32	Sillaginidae	*Sillago maculata* (Quay & Giamard, 1824)	27	–
		Sillago sihama (Forsskål, 1775)	14	–

to be continued

Continued from Table 1

Sl No.	Fish family	Name of the fish	NFO	IPff
33	Sparidae	*Acanthopogrus latus* (Houuttuyn, 1782)	38	–
34	Sphyraenidae	*Sphyraena barracuda* (Edwards, 1771)	47	–
		Sphyraena jello (Cuvier, 1829)	53	–
		Sphyraena obtusata (Cuvier, 1829)	77	–
35	Stromatidae	*Pampus argenteus* (Euphrasen, 1788)	93	–
36	Synodontidae	*Saurida tumbil* (Bloch, 1795)	66	–
		Saurida undosquamis (Richardson, 1848)	79	–
37	Terapontidae	*Terapon jarbua* (Forsskål, 1775)	41	–
38	Trichiuridae	*Eupleurogrammus glossodon* (Bleeker, 1860)	10	–
		Eupleurogrammus muticus (Gray, 1831)	14	–
		Lepturacanthus savala (Cuvier, 1829)	45	–
		Trichiurus lepturus (Linnaeus, 1758)	27	–

Note: NFO represents number of fishes observed, IPff infected with *Peniculus fistula fistula*, +_ presence of *P. fistula fistula*, and - absence of *P. fistula fistula*.

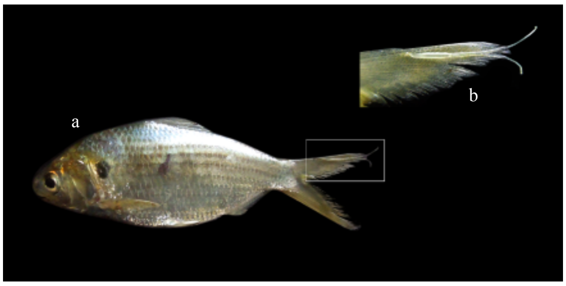

Fig. 1. *Anadontostoma chacunda* with *Peniculus fistula fistula* on its tail fin. a. *A. chacunda* infected with *P. fistula fistula*, and b. enlarged view of site of infection of *P. fistula fistula*.

infection by *P. fistula fistula* was found; the study reflects the impact of geographical difference for its host fish selection. This assumption was also confirmed by the fact that, though present host fish (*A. chacunda*) and previously reported host fishes (*M. cephalus* and *C. hippurus*) of *P. fistula fistula*, are largely available from the Cochin coast (one of the major coasts in Kerala and approximately 260 km away from the present study area), all these three fish species are found to be free from the infection by this *Peniculus* species (Drisya et al., unpublished data).

Present study also underlines the role of host fish age on parasite growth as evidenced from the present study on correlation between fish length (*A. chacunda*) and parasite length (R^2=0.771 5) as well as fish length and egg sac length (R^2=0.808 4). This observation supports the recent study on cymothoid isopod *Norileca indica* parasitizing the scombrid fish, *Rastrelliger kanagurta* from the Malabar coast (Helna, 2016).

All the recovered parasites were not only the adult females but they invariably bear long egg sacs containing 200–350 eggs undergoing embryogenesis. There is also a positive correlation (R^2=0.793) between the length of the parasite body and the egg sac length. No male, pre-adults or larvae of parasites were recovered from the host fish. During our recent survey, all the members of *Peniculus scombri* recovered from Indian Mackerel, *Rastrelliger kanagurta* were also ovigerous females bearing egg sacs. In this context, the questions, whether the parasitic association with its specific host fish is a requisite for the reproductive life of *Peniculus* species and which host factor is mandatory for their successful breeding, need to be answered in the future research.

Table 2. Parasitic indices (mean±standard deviation) and site of infection of *P. fistula fistula* on *A. chacunda*

Name of the copepod	Host fish	Prevalence/%	Intensity (No.)	Site of infection
P. fistula fistula	*A. chacunda*	4.06±1.09	1.28±0.30	upper and lower lobes of caudal fin

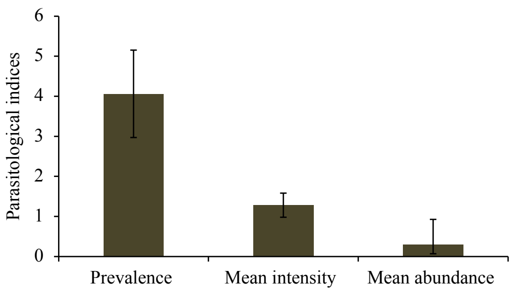

Fig. 2. Parasitological indices (mean±SD) of parasitic copepod *P. fistula fistula* on *A. chacunda.*

The prevalence shown by *P. fistula fistula* towards host fishes appears to be quite different from the previous reports. The infection of *P. fistula fistula* on the gar fish *Belone belone* (Belonidae) in the Adriatic Sea has been reported with a prevalence of 22.3% and a mean intensity of 1.64; the numbers of parasite per host fish was 1–7 (Vidjak et al., 2008). The prevalence and mean intensity of this parasite (*P. fistula fistula*) on another host fish, *Pagrus pagrus* (Sparidae) was 7.14% and 1.0% respectively (Ramdane and Trilles, 2007). Castro-Romero et al. (2016) reported the host species–dependent prevalence of this parasite (*P. fistula fistula)*, ranging 4%–70% on nine species of host fishes, each from different non-clupeid family from Chilean waters. The present recorded annual average prevalence shown by *P. fistula fistula* and its host fish (*A. chacunda*) is quite less (4.06%±1.09%), just because of the presence of discrete seasonality in the prevalence.

Recent studies report the seasonal dependent variation in the copepod infection rate and suggest the possible impact of ecological parameters. The present study also reveals the discrete seasonality for the occurrence of *P. fistula fistula*; the winter season extending from November to January exhibits the highest preval-

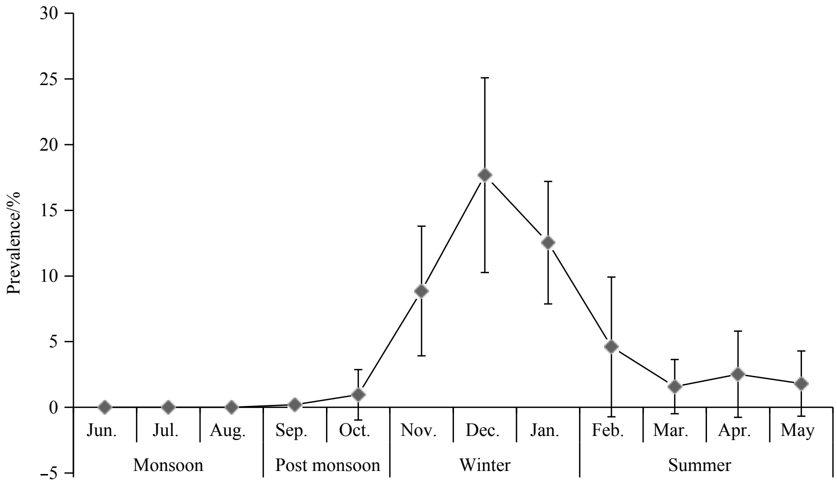

Fig. 3. Season dependent variation in prevalence (mean±SD) of parasitic copepod *P. fistula fistula* on its host fish, *A. chacunda.*

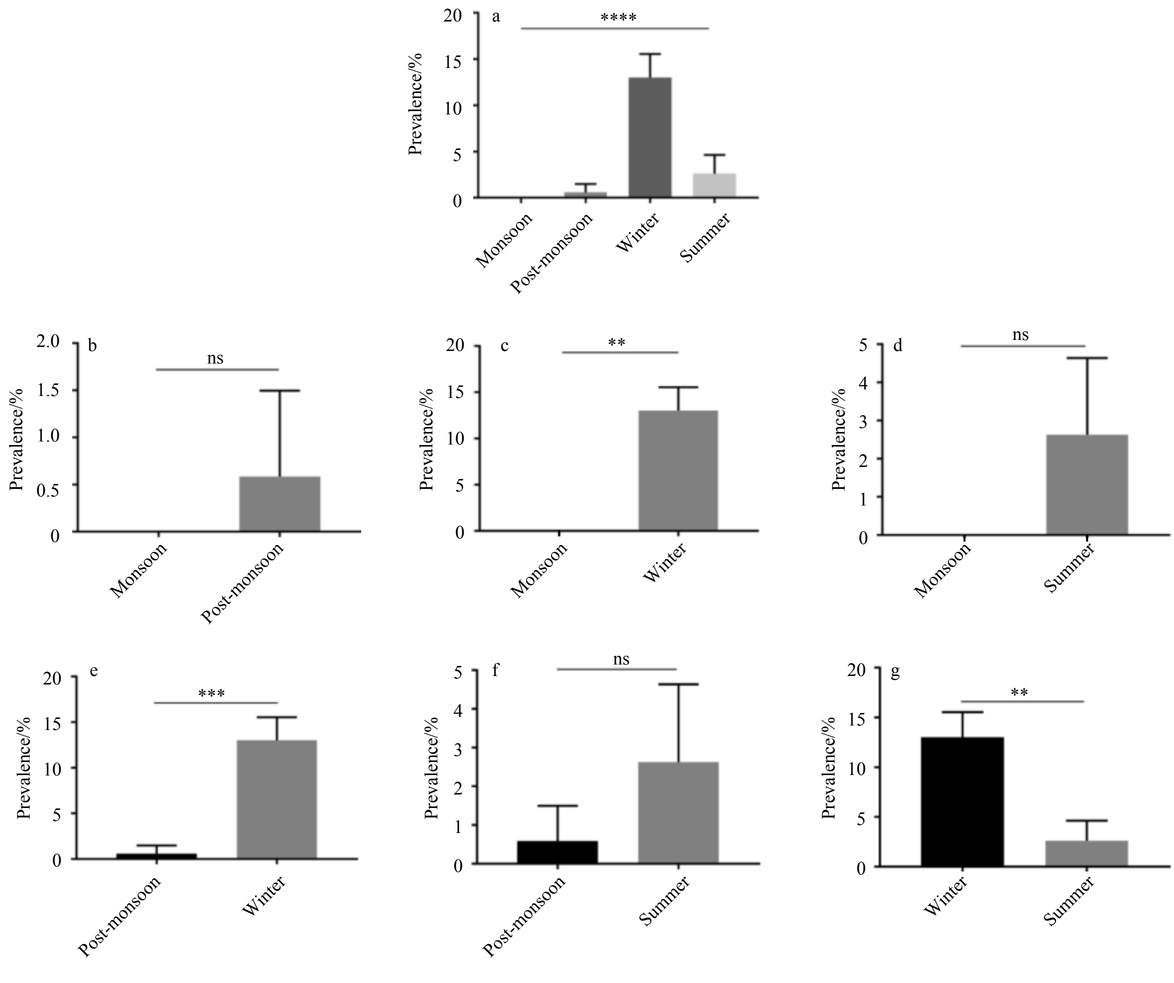

Fig. 4. Statistical analysis for testing significance in season dependent variation in prevalence (mean±SD) of *P. fistula fistula* on its host fish, *A. chacunda*. a. Overall seasonal comparison and b–g. inter seasonal comparison of prevalence; b. monsoon vs. post-monsoon, c. monsoon vs. winter, d. monsoon vs. summer, e. post-monsoon vs. winter, f. post-monsoon vs. summer, and g. winter vs. summer. ns represents no significance, and number of * indicate increase in the significance of seasonal variation in prevalence.

ence (13.02%±2.54%) followed by summer season (February–May) with a very significantly low prevalence (3.51%±1.19%). During the post-monsoon (Sepember–October), recorded prevalence is <1.2 and no infection was recorded during monsoon (June–August). This observation was further confirmed by the Pairwise *t*-test performed between seasons (winter and monsoon (P=0.002), winter and post-monsoon (P=0.000 6), and summer and winter (P=0.005)). However, *Caligus cybii* infecting the

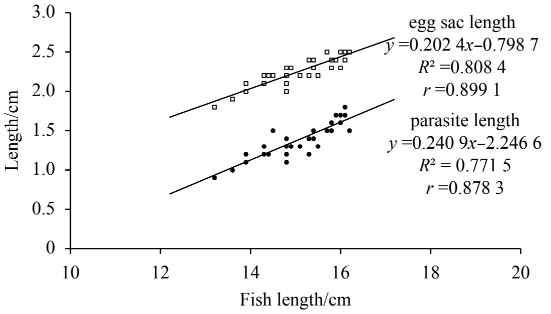

Fig. 5. Correlation analysis of fish length (cm) with parasite length and egg sac length (cm).

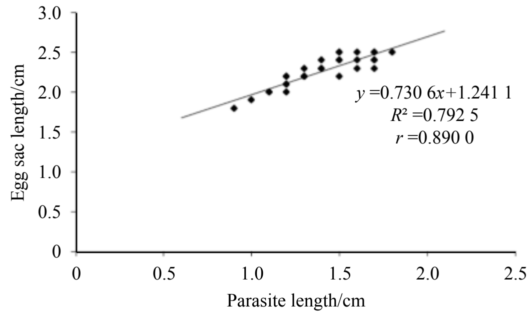

Fig. 6. Correlation analysis of parasite length (cm) and egg sac length (cm).

scombrid fish *Scomberomorus commerson* from Malabar coast exhibits a maximum prevalence during summer months followed by winter and monsoon/post-monsoon months (Helna et al., 2016, 2018). Contrary to this, *Cybicola armatus* infecting the same host (*S. commerson*) from the same locality (Malabar coast) exhibits more or less uniform but high (>90%) prevalence throughout the year suggesting that there could also be certain factors (host/parasite/environment) influencing the infection pattern of each copepod species.

The site-specific parasitisation and microhabitat preference shown by *P. fistula fistula* is that all members are invariably attach exactly the mid portion of upper and lower lobes of caudal fin of the host fish (*A. chacunda*) using their modified antennae (Fig. 1). Since the camouflaged parasite is always lying on the caudal fin lobe parallel to their host body, their presence could barely be detected at a first glance (Fig. 1). Contrary to this, according to the previous study on its (*P. fistula fistula*) infection on another host fish, *Belone belone*, no specific site of attachment and micro habitat preference was reported as it was seen clinging to all types of fins except the pelvic fin; the pectoral fin forms the major site of infection (Vidjak et al., 2008). The ventral fin of *C. hippurus* from the Aegean Sea coastal waters of Turkey forms the major site of attachment for *P. fistula fistula* (Öktener, 2008). The aforesaid information clearly indicate that site specificity and micro habitat preference of *P. fistula fistula* is host dependent.

During the present study, the tissue damage caused on the host fish by the infection with *P. fistula fistula* was not morphologically visible. The fins seem to be a less preferred site for parasite attachment of the copepods compared to the gills and other predominant infection sites such as body surface, buccal cavity, mucus membrane of opercular fold, thus agreeing with the previous report by Lester and Hayward (2006). However, the gravity of tissue damage (due to parasitisation by *P. fistula fistula*) may be assessed only through the studies on the host response at physiological and immunological levels.

5 Conclusions

In conclusion, the clupeid fish, *Anadontostoma chacunda* forms host for a *Peniculus* sp. (*P. fistula fistula*), the information adds new host family (Clupeidae) for this widely distributed pennellid copepod. However, question is to be addressed why the majority of clupeids are free from *Peniculus* infection, even though they are potential hosts for various parasitic copepods even in the Pennellidae family. The present study also indicates the geographical variation in the host preference for the parasitic infection by *P. fistula fistula* as *Mugil cephalus* and *Coryphaena hippurus*, the previously reported hosts were found exclusively free from *P. fistula fistula* infection from Malabar coast, though they are available round the year. Since this Pennellid copepod exhibits a discrete seasonality for infecting the host fish, *A. chacunda*, the apparent influence of ecological parameters for its parasitic occurrence is suggested. Hence the future study needs to be focused to the complete life cycle stages with the mode of living coupled with the analysis of ecological parameters. Though the tissue damage on the host fish due to parasitisation by *P. fistula fistula* was not visible morphologically, the question of physiological and immunological host response against the *Peniculus* infection is also to be addressed in the future research to understand the gravity of infection.

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References

Abdel-Gaber R, El Deeb N, Maher S, et al. 2017. Diversity and host distribution of the external gill parasite *Lamproglena monodi* (Copepoda: Lernaeidae) among Tilapia species in Egypt: light and scanning electron microscopic studies. The Egyptian Journal of Experimental Biology (Zoology), 13(1): 23–30

Alexander P D. 1983. *Peniculus haemuloni*, a new species of copepod (Siphonostomatoida: Pennellidae) parasitic on *Haemulon steindachneri* from Ubatuba, Brazil. Bulletin of the British Museum (Natural History), 45: 381–385, doi: 10.5962/bhl.part.28007

Arnal C, Morand S. 2001. Importance of ectoparasites and mucus in cleaning interactions in the Mediterranean cleaner wrasse *Symphodus melanocercus*. Marine Biology, 138(4): 777–784, doi: 10.1007/s002270000494

Boxshall G A, Halsey S H. 2004. An Introduction to Copepod Diversity. London: Ray Society

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, doi: 10.1080/10641260903216012

Bush A O, Lafferty K D, Lotz J M, et al. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. The Journal of Parasitology, 83(4): 575–583

Castro-Romero R, Montes M M, Martorelli S R, et al. 2016. Integrative taxonomy of *Peniculus*, *Metapeniculus*, and *Trifur* (Siphonostomatoida: Pennellidae), copepod parasites of marine fishes from Chile: species delimitation analyses using DNA barcoding and morphological evidence. Systematics and Biodiversity, 14(5): 466–483, doi: 10.1080/14772000.2016.1158213

Choi S D, Suh H L, Hong S Y. 1996. Two species of parasitic copepods (*Neobrachiella incurva* and *Peniculus ostraciontis*) from the marine fishes, *Halichoeres poecilopterus* and *Sebastes schlegeli*, of the South Coast of Korea. Journal of Aquaculture, 9: 117–123

Froese R, Pauly D. 2017. FishBase. World Wide Web electronic publication. http://www.Fishbase.org [2017–10]

Gnanamuthu C P. 1951. Copepods parasitic on south Indian fishes. Ann Mag Nat Hist, 12(4): 77–86

Hammer Ø, Harper D A T, Ryan P D. 2001. PAST: paleontological Statistics software package for education and data analysis. Palaeontologia Electronica, 4(1): 4

Helna A K. 2016. Studies on growth and reproduction of parasitic crust aceans infesting scombrid fishes along the Malabar Coast [dissertation]. Kannur, Kerala: Kannur University

Helna A K, Sudha K, Aneesh P T, et al. 2016. A case of persisting massive infection of *Scomberomorus commerson*, a commercially exploited scombrid fish, with *Cybicola armatus* (Copepoda: Siphonostomatoida: Pseudocycnidae). Acta Parasitologica, 61(4): 836–848, doi: 10.1515/ap-2016-0116

Helna A K, Sudha K, Aneesh P T, et al. 2018. *Caligus cybii* (Caligidae, Copepoda) parasitising the commercially exploited seer fish, *Scomberomorus commerson*, from the Malabar Coast (India)-occurrence and adaptations. Turkish Journal of Fisheries and Aquatic Sciences, 18(3): 445–455, doi: 10.4194/1303-2712-v18_3_10

Ho J S, Nagasawa K, Kim I H. 2007. *Sarcotretes longirostris* N. sp. (Copepoda: Pennellidae) parasitic on bluefin driftfish (*Psenes pellucidus*) from the stomachs of short-finned pilot whales caught off Japan. Journal of Crustacean Biology, 27(1): 116–120, doi: 10.1651/S-2751.1

Ismail N, Ohtsuka S, Maran B A V, et al. 2013. Complete life cycle of a pennellid *Peniculus minuticaudae* Shiino, 1956 (Copepoda: Siphonostomatoida) infecting cultured threadsail filefish, *Stephanolepis cirrhifer*. Parasite, 20: 42, doi: 10.1051/parasite/2013041

Kabata Z. 1979. Parasitic Copepoda of British Fishes. London, UK: The Ray Society, 468

Lester R J G, Hayward C J. 2006. Phylum arthropoda. In: Woo P T K, ed. Fish Diseases and Disorders, Volume 1: Protozoan and Metazoan Infections. 2nd ed. Cambridge: CAB International, 466–565

Maran B V A, Moon S Y, Oh S Y, et al. 2012. Redescription of two Pennellids (Copepoda, Siphonostomatoida) from Korea with a key to species of *Peniculus* von Nordmann, 1832. ZooKeys, (243): 1–14, doi: 10.3897/zookeys.243.3668

Moon S Y, Choi S H. 2014. Description of two species of *Peniculus* von Nordmann, 1832 (Copepoda: Siphonostomatoida: Pennellidae) parasitic on commercial fishes from Korea, including a new species. Systematic Parasitology, 88(2): 185–193, doi: 10.1007/s11230-014-9493-4

Nagasawa K. 2015. Parasitic copepods of marine fish cultured in Japan: a review. Journal of Natural History, 49(45–48): 2891–2903, doi: 10.1080/00222933.2015.1022615

Okawachi H, Uyeno D, Ogino K, et al. 2012. Redescription of *Peniculus minuticaudae* Shiino, 1956 (Copepoda: Pennellidae) from aquarium-held marine fishes in Japan, with notes on its occurrence and life cycle in captivity. Zoosymposia, 8: 56–68, doi: 10.11646/zoosymposia.8.1.9

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, doi: 10.1080/10641260802046668

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

Ramakrishna G. 1980. Techniques of collection and preservation of parasitic crustaceans. In: Proceedings of Workshop-Techniques in Parasitology. Kolkatha: Zoological Survey of India, 109–113

Ramdane Z, Trilles J P. 2007. Parasitic copepods (Crustacea: Copepoda) from Algerian marine fishes. Zootaxa, 3: 49–68

Rijin K, Sudha K, Vineesh P J, et al. 2019. Seasonal variation in the occurrence of parasitic isopods and copepods (Crustacea) infecting the clupeidaen fishes of Malabar Coast, India. Turkish Journal of Fisheries and Aquatic Sciences, 19(3): 241–249, doi: 10.4194/1303-2712-v19_03_07

Uyeno D, Nagasawa K. 2010. Three new species of the family Pennellidae (Copepoda: Siphonostomatoida) from gobiid fishes (Actinopterygii: Perciformes) in coastal waters of the western Pacific Ocean. Zootaxa, 2687(1): 29–44, doi: 10.11646/zootaxa.2687.1.2

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

WoRMS Editorial Board. 2017. World Register of Marine Species; [accessed2017 Aug 14]. http://www.marinespecies.org [2017–03]

Youssef F, Benmansour B, Hassine O K B, et al. 2016. Some parasitic copepods of selected Teleost and Chondrichthyan fishes from the Tunisian gulfs. African Journal of Microbiology Research, 10(35): 1467–1476, doi: 10.5897/AJMR2015.7820