Occurrence of parasitic copepods in Carangid fishes from Parangipettai, Southeast coast of India

Ganapathy Rameshkumar · Samuthirapandian Ravichandran ·
B. A. Venmathi Maran

Received: 8 January 2013 / Accepted: 18 January 2013 / Published online: 3 February 2013
© Indian Society for Parasitology 2013

Abstract In the present study, 68 fishes were infested out of 544 specimens examined from six different species of Carangid fishes which were collected from Parangipettai coastal waters. Eight species of parasitic copepods were found on gill filaments, body surface and nasal capsule regions. The maximum prevalence was recorded in *Carangoides malabaricus* (22.5 %) and minimum was noticed in (2.4 %) *Selaroides leptolepis*. The intensity of infection ranged from 1 to 1.2. Thus, considerable variation in the respiratory area was observed owing to the attachment of parasites in the infected fishes. *Caligus* sp. and *C. epidemicus* parasites were attached to body surface and only one *Sphyrriid* sp. parasites were found in nasal capsule region. It is very difficult to estimate the actual harm to fish caused by the presence of parasites; if this is uneasy in cultured fish, it is almost impossible in feral fish populations. It should also be emphasized that the presence of a parasite does not necessarily imply manifestation of a disease. In aquaculture, some parasites are able to reproduce rapidly and heavily infect a large proportion of fish which may lead to diseases with significant economic consequences.

Keywords Copepod parasites · Mode of attachment · Respiratory surface area · Gill rack count · Parangipettai

Introduction

The diversity of parasitic copepods reported from deep mesopelagic and bathypelagic fish hosts is extremely low. Parasitic copepods are commonly found in cultured and wild marine fishes (Vinoth et al. 2010; Rameshkumar and Ravichandran 2013; Jones et al. 2012). In the aquaculture industry throughout the world, these parasitic copepods, particularly the family Caligidae, are important as pathogens causing heavy mortality or acting as disease inducers, by creating a portal for entry of bacterial or other pathogens (Johnson et al. 2004).

The gills are a favorite site for the attachment of several parasitic copepods. They damage the gills by feeding on the delicate tissue of the gill lamellae or on the blood circulating within the lamellae, leading to a loss of respiratory surface area (Lester and Hayward 2006). There is extensive gill damage and severe haemorrhage, with inflammation and exsanguination associated with the attachment and feeding of the copepod (Lester and Hayward 2006). This, nowadays, has become a major problem in identification and treatment of parasites and diseases in the rapidly developing mariculture industry (Roza et al. 2002). More recently (Vinoth et al. 2010) recorded 12 species of parasitic copepods from the gill region of Sea bass in Vellar estuarine waters. But no detailed study on the infestation of copepods parasites in Carangid fishes of Parangipettai waters. The present study is the investigation on occurrence and infestation of copepod from Carangid species from Parangipettai coast.

Material and methods

During a routine observation of the Carangid fishery in the Parangipettai (11° 29' N; 79° 46' E) an interesting

G. Rameshkumar (✉) · S. Ravichandran
Centre of Advanced Study in Marine Biology, Faculty of Marine
Science, Annamalai University, Parangipettai 608 502,
Tamil Nadu, India
e-mail: grkumarcas@gmail.com

B. A. Venmathi Maran (✉)
Marine Ecosystem Research Division, KIOST, Ansan,
Seoul 425-600, Korea

incidence of parasitisation in Carangid fishes was observed. Fishes were thoroughly checked for parasitic infection in the body surface, fins, head, gill filaments, oral cavities and other tissue also examined. Each fish was examined microscopically for the presence of parasitic crustaceans based on a method described by (Kabata 1985; Ravichandran et al. 2007). The collection and preservation methodology for crustacean parasites was followed by Pritchard and Kruse (1982). Copepod identification was based on morphological features according to Yamaguti (1963), Kabata (1979), Pillai (1985), Sirikanchana (2003), Ho and Kim (2004). Prevalence and mean intensity of each parasitic species were determined as in Margolis et al. (1982).

Respiratory surface area

The influence of infestation in respiratory surface area of the gill arch of infected and uninfected fish were carefully dissected out and blotted to remove the moisture. The imprint drawing of each gill arch on millimeter graph was used to calculate the surface area of the gill arch. The surface area of each tracing was determined by counting the number of small squares and the total area was obtained. The value was taken and doubled to consider the total functioning of the gill arch. The total surface area of the gill arch of both infected and uninfected fish was compared and then area was considered as reduction of respiratory area due to infestation.

Gill rack count

The average gill rack count of the 1st, 2nd and 3rd gill arch of infested fishes were taken. The data collected were tabulated and variation in the gill raker count as a function of infestation was recounted.

Results

Infestation of fishes

In the present study, 68 fishes were infested out of 544 specimens examined from six different species of Carangid fishes which were collected from Parangipettai coastal waters (Table 1). Eight species of parasitic copepods were found on gill filaments, body surface and nasal capsule regions. These eight species belong to three genera Bomolochidae, Caligidae and Sphyrriidae. *Caligus* sp. (26) was found in highest number followed by *C. epidemicus* (17), *Holobomolochus chilensis* (13), *Parabomolochus bellones* (10) and *Bomolochus* sp. (8) which infested 23, 16, 11, 7, 8 species of Carangid fishes respectively (Table 2). While *Nothobomolochus* sp., *P. cuneatus* and *Sphyrriid* sp.

were found in minimum (1) of Carangid fishes. The prevalence and intensity of copepod parasites on Carangid fishes are presented in Table 3. Maximum prevalence was recorded in *C. malabaricus* (22.5 %) and minimum of (2.4) was noticed in *Selaroides leptolepis* (Fig. 1).

Mode of attachment of parasitic copepods

The distribution of copepod parasites in different species of Carangid fishes was reported. Maximum infection was recorded in *C. malabaricus* in the gill region and minimum was recorded in *Carangoides* sp. (gill region) and *S. leptolepis* in the nasal capsule.

Respiratory surface

Variation in the respiratory surface area of fish owing to the infestation of copepod parasites (*Caligus* sp., *C. epidemicus*, *Bomolochus* sp., *H. chilensis*, *P. bellones*, *P. cuneatus*, *N. sp.* and *Sphyrriid* sp.) were studied (Fig. 2). Detailed study of respiratory surface area due to the infestation of copepods in Carangid fishes was carried out (Table 4). The maximum numbers of copepods (38) was noticed in the first gill arch and minimum numbers of copepods (5) was found in the fourth gill arch and 16 numbers of copepods were found in the second gill arch and seven numbers of copepods were found in the third gill arch. Thus, considerable variation in the respiratory area was observed owing to the attachment of parasites in the infected fishes. *Caligus* sp. and *C. epidemicus* parasites were attached body surface (10) and only one *Sphyrriid* sp. parasites were found in nasal capsule region.

The infested fish had extremely pale gills, indicating the gill rakers were seriously lost, apical damage and out off gill lamellae were deployed. Some secondary gill lamellae were fused or thickened. Gill lamellae of the first and second arches of gill were found to be eroded due to parasites and the damage was found to be concentrated towards posterior position. Several damage have observed in the host of fishes, gill damage was major effect when a large section of filaments was destroyed and gill arch broken.

Discussion

Caligus fortis was first reported by Kabata (1965) from the nostrils of a yellow spotted trevally *C. fulvoguttatus* (Forsskal) reported as *C. emburyi* (Whitley) by Kabata (1965) caught off Green Island, Queensland. It was subsequently found in the nasal cavities of an unidentified jack (*Caranx* sp.) collected from Trivandrum, India by Prabha

Table 1 Parasitic copepods in carangid fishes

S. No.	Name of the host	No. of fishes infested	Copepods	No. of parasites collected
1.	<i>Carangoides malabaricus</i>	23	<i>Caligus</i> sp.	26
		5	<i>Caligus epidemicus</i>	5
		7	<i>Parabomolochus bellones</i>	10
		1	<i>Parabomolochus cuneatus</i>	1
2.	<i>Alepes</i> sp.	8	<i>Bomolochus</i> sp.	8
3.	<i>Gnathanodon speciosus</i>	11	<i>Holobomolochus chilensis</i>	13
4.	<i>Carangoides</i> sp.	1	<i>Nothobomolochus</i> sp.	1
5.	<i>Selaroides leptolepis</i>	1	<i>Sphyrriid</i> sp.	1
6.	<i>Parastromateus niger</i>	11	<i>Caligus epidemicus</i>	12

Table 2 Attachment site of parasites in carangid fishes

Host	Parasites	Site of attachment
<i>Carangoides malabaricus</i>	<i>Caligus</i> sp.	Gill, body surface
	<i>Caligus epidemicus</i>	Gill, body surface
	<i>Parabomolochus bellones</i>	Gill
	<i>Parabomolochus cuneatus</i>	Gill
<i>Alepes</i> sp.	<i>Bomolochus</i> sp.	Gill
<i>Gnathanodon speciosus</i>	<i>Holobomolochus chilensis</i>	Gill
<i>Carangoides</i> sp.	<i>Nothobomolochus</i> sp.	Gill
<i>Selaroides leptolepis</i>	<i>Sphyrriid</i> sp.	Nasal capsule
<i>Parastromateus niger</i>	<i>Caligus epidemicus</i>	Gill, body surface

Table 3 Occurrence of copepod parasites in carangid fishes

Name of host	No. of fish examined	No. fish infested	No. of parasites (%)	Prevalence (%)	Mean intensity
<i>Carangoides malabaricus</i>	160	36	42	22.5	1.2
<i>Alepes</i> sp.	94	8	8	8.5	1
<i>Gnathanodon speciosus</i>	124	11	13	8.9	1.2
<i>Carangoides</i> sp.	36	1	1	2.8	1
<i>Selaroides leptolepis</i>	42	1	1	2.4	1
<i>Parastromateus niger</i>	88	11	12	12.5	1.1
Total	544	68	77	12.5	1.1

Fig. 1 Prevalence and mean intensity of copepod parasites in carangid fishes

and Pillai (1986). In this study, *Sphyrriid* sp. was found in the Nasal capsule of *S. leptolepis*.

Caligus robustus was circumglobal in distribution, occurring on the carangid fishes in the tropical and sub-tropical oceans (Cressey 1991). However, it seems to be rare off Taiwan. *C. robustus* has a broader distribution than *C. fortis*. It has been reported from off Sri Lanka by Bassett-Smith (1898) and Kirtisinghe (1964), from Jamaica by Wilson (1913), from off Mauritania by Brian (1924), from the Gulf of Mexico by Bere (1936) and Causey (1953), from off India by Pillai (1985), and from off Borneo, the Celebes and the Philippines by Cressey (1991). The present study has reported the infestation of parasitic copepods on gills and Nasal capsule of Carangid fishes from Parangipettai coastal

Fig. 2 Copepods collected from carangid fishes **Table 4** Infestation and site of attachment of copepod parasites

Name of Species	Gill arch (%)				Nasal capsule	Body surface	Total
	I-Gill	II-Gill	III-Gill	IV-Gill			
<i>Carangoides malabaricus</i>	19	9	4	2	–	8	42
<i>Alepes</i> sp.	5	1	1	1	–	–	8
<i>Gnathanodon speciosus</i>	7	4	1	1	–	–	13
<i>Carangoides</i> sp.	1	–	–	–	–	–	1
<i>Selaroides leptolepis</i>	–	–	–	–	1	–	1
<i>Parastromateus niger</i>	6	2	1	1	–	2	12

environments. Parasitic copepods especially *C. epidemicus* having a broader distribution than *Caligus* spp. were reported in the Parangipettai waters.

According to Boxshall and Halsey (2004), Caligid, Ergasilid, and Lernanthropid copepods are known as common parasites of shallow water fish. Copepods of the

family Ergasilidae are mostly known as freshwater parasites, and only few species are known from the brackish water or marine environment (Boxshall and Halsey 2004). The other collected copepod families (Bomolochidae, Caligidae, Lernanthropidae, Lernaepodidae, Pennellidae, Siphonostomatoida and Tetraodontidae,) are mainly or exclusively known as marine fish parasites (Hallett and Roubal 1995; Boxshall and Halsey 2004; El-Rashidy and Boxshall 2012; Ho and Lin 2012; Ozak et al. 2012) *Sinergasilus polycolpus* and *Sinergasilus major* are over distributed on their respective hosts. Other parasitic copepods, such as Caligid copepods (Hallett and Roubal 1995) have been reported to be over disposed in their host populations. In this study, *C. epidemicus* were found in maximum number of *C.malabaricus* and *P.niger* fishes. Three species of parasitic copepods, one each from the Siphonostomatoid families Lernanthropidae and Lernaepodidae and one from the Cyclopoid family Bomolochidae, are redescribed based on material collected from the gills of four fish species belonging to the family Clupeidae caught from coastal waters off Alexandria, Egypt (El-Rashidy and Boxshall 2010).

Caligidae currently accommodates 33 genera, 445 species, more than 75 % are members of *Caligus* (239 spp.) and *Lepeophtheirus* (107 spp.) (Ho 2000). *Caligus* spp. is dominant on marine teleost fishes (Kabata 1979). In the present study, Caligidae has been found on body and gills of Carangid fishes. Many fish genera in this study had same parasites as found in India (Pillai 1985). Many factors have been suggested to influence the aggregation of parasite burdens (Quinnell et al. 1995). However, host resistance and behaviour are considered as important in generating variable parasite burdens (Tanguay and Scott 1992), and host susceptibility is proposed to explain the higher infection levels of *E. brianii* in bream *Abramis brama* and tench *Tinca tinca* (Alston and Lewis 1994). *C.malabaricus* was infested with 4 copepod species and showed the highest percentage parasitic infestation followed by other Carangid species of parasitic infestation, respectively.

Within the present study two species of Caligidae copepods were recorded from Parangipettai; five of them belonging to Bomolochidae and one species probably represents a Sphyrriidae genus. Yuniar et al. (2007) reported *Mugil cephalus*, *Scatophagus argus*, *Eleutheronema tetradactylum*, and *Johnius coitor* had a species-rich copepod fauna. Six parasitic copepods were recorded from *M. cephalus*. Even though this fish species has a wide distribution and has been well studied for copepod parasites (e.g., Paperna and Overstreet 1981; El-Rashidy and Boxshall 1999), several copepods from the study represent new host records. Parasitic copepod *Pseudocycnus appendiculatus* at their gill filaments and this report documents a new record of the Andaman Sea, Thailand

Purivirojkul et al. 2011). Six species of copepods belonging to the Lernanthropidae were found parasitic on the gill filaments of six species of marine fishes of Taiwan (Ho et al. 2011). A new species of *Ergasilus boleophthalmi* parasitic on the gills of two gobiid fishes *Boleophthalmus dussumieri* and *Bathygobius fuscus* from Shatt Al-Basrah Canal, Iraq, was described (Thamir et al. 2011). In the present study eight species of parasitic copepods were recorded from Carangid fishes.

A parasitic copepods study of Algerian teleost fish, report 25 copepod species belonging to eight families harvested from the gills of 14 fish species (Boualleg et al. 2011). *C. elongatus* has been recorded from more than 100 host species, both teleosts and even elasmobranchs, belonging to 47 families (Williams and Williams 1996). Yuniar et al. (2007) reported, seven out of eight fish species were infested with *Caligus* spp. The results of the present study also agree with the earlier works. In the present study it is reported that eight out of six fish species were infested belonging to three genera of copepods. According to Moller and Anders (1986), pranzia stages were recorded to infest a high number of different fish species. Most copepods from Segara Anakan were host-specific, with 19 species infesting only a single host fish species (Yuniar et al. 2007). The present study result also shows that *C. epidemicus* have the character of broad host specificity. It infects two different Carangid fish species but the host specificity of *Bomolochus* sp., *H. chilensis*, *Nothobomolochus* sp. and *Sphyrriid* sp. was very narrow. Both the species are found to infest only the host fishes of *Alepes* sp., *Gnathanodon speciosus*, *Caligus* sp. and *S. leptolepis*. Host parasite relation is the outcome of the interaction of three factors: the host, the parasite and the environment (Moller 1985).

Prevalence and intensity of parasitic copepods on fish can vary with habitat, season, and host size (Hudson et al. 1994). The prevalence of infection in Saginaw Bay was not as high as in the Alabama ponds, where 100 % of the fishes were infected (Hayden and Rogers 1998). Mugridge et al. (1982) found 50–250 parasites/fish in British ponds and suggested that the reduced growth rate of roach may be caused by *Neoergasilus japonicus*. Ponyi and Molnar (1969) noted severe infections of *N. japonicus* in Hungary but provided no details on the intensity or effects. Effects of a parasitic copepod on the larval growth of the Chilean triplefin *H. chilensis* (Trypterygiidae) based on the microstructure of the sagittal otoliths (Palacios-Fuentes et al. 2012). There are reports that the low prevalence of *L. branchialis* in offshore areas might be attributed to the fact that infected fish remain close to shore (Sproston and Hartley 1941; Kabata 1958). In this study it is reported that the prevalence was maximum in *C. malabaricus* and minimum was noticed in *S. leptolepis* and mean intensity of parasitic copepods on fish vary from 1 to 1.2.

First gill arch preference has been previously reported for microcotylids (El Hafidi et al. 1998), as well as naobranchiids (Roubal, 1999), and it is known that abiotic factors affect the abundance of some monogeneans and copepods (Barker and Cone, 2000). Although less oxygenated and less ventilated than the posterior arches (Hughes and Morgan 1973), gill arch I is where the current flow is minimal (Paling, 1967) and thus, where monogeneans may be the least precariously attached as suggested by El Hafidi et al. (1998). The parasitic copepod *Haemobaphes diceraus* was found localized on the isthmus of two specimens of the walleye pollock *Theragra chalcogramma*. In both cases, the parasite directly penetrated the heart, without entering the blood vessels (Yu and Poltev 2010). In the present case, maximum reduction in respiratory surface area was noticed in the first gill compared to other gill arches. The explanation should be considered with caution, since specimens of *Metamicrocotyla macracantha* can secure them by coiling around gill filaments (Baker et al. 2005). Further, some other microcotylids do not exhibit such a preference for the first arch (Lyndon and Vidal-Martinez 1994; Geets et al. 1997). A preference for gill arch I among naobranchiids has neither been investigated nor explained in previous studies. Kabata (1988) reported the adult naobranchiids display a secure mode of attachment, by firmly embracing the individual gill filaments using their modified second maxillae, it is not excluded that larvae are precariously attached when they first settle on the gills. In the present investigation highest number of copepods was attached in gill filament. These parasitic copepods with neutral interactions have occurred in the first two arches and have decreased in the third and fourth gill arches.

Fish parasites are an integral part of water ecosystem and they are common in natural and cultured populations of fish. In natural conditions, most parasites do not tend to severely injure their hosts and cause mortalities which affect the population size at detectable levels. It is very difficult to estimate the actual harm to fish caused by the presence of parasites; if this is uneasy in cultured fish, it is almost impossible in feral fish populations. It should also be emphasized that the presence of a parasite does not necessarily imply manifestation of a disease. Diseases caused by parasites are much more frequently manifested in cultured fish, which suffer from artificial conditions and numerous stress factors that influence their ability to effectively protect themselves against parasitic infections. In aquaculture, some parasites are able to reproduce rapidly and heavily infect a large proportion of fish which may lead to diseases with significant economic consequences.

Acknowledgments Authors are thankful to Department of Science and Technology (Grant No:SR/FF/LS-088/2007) and Ministry of Environment & Forest, Government of India (Grant No:22-18/2008-

CS-I) for providing financial support and Director of Centre of Advanced Study in Marine Biology for providing facilities and encouragement.

References

- Alston S, Lewis JW (1994) The ergasilid parasites Copepoda: *Poecilostomatoida* of British freshwater fish. In: Pike AW, Lewis JW (eds) Parasitic diseases of fish. Samara Publishing, Dyfed, pp 171–188
- Baker TG, Viricel A, Meraziz L, de Buron I (2005) Size variation of aduelpolyopisthocotylid *Metamicrocotyla macracantha* (Monogenea) in relation to host size. *Comp Parasitol* 72(2):179–182
- Barker DE, Cone DK (2000) Occurrence of *Ergasilus celestis* (Copepoda) and *Pseudodactylogyrus anguillae* wild eels (*Anguilla rostrata*) in relation to stream flow, pH and temperature and recommendations for controlling their transmission among captive eels. *Aquaculture* 187(3–4):261–274
- Bassett-Smith PW (1898) Some new or rare parasitic copepods found on fish in the Indo-Tropic Region. *Ann Mag Nat Hist* 7(1):357–372
- Bere R (1936) Parasitic copepods from Gulf of Mexico fish. *Amer Mid Natu* 17:577–625
- Boualleg C, Kaouachi N, Seridi M, Ternango S, Bensouilah MA (2011) Copepod parasites of gills of 14 teleost fish species caught in the Gulf of Annaba (Algeria). *Afri J Microbiol Res* 5(25):4253–4259
- Boxshall GA, Halsey SH (2004) An introduction to Copepod diversity. Roy Society, London, pp 1–966
- Brian A (1924) Parasitologia Mauritanica, mate'rieux pour la faune parasitologiqueen Mauritanie Arthropoda (1er partie), Copepoda. *Bulletin du Comite' d'E' tudes Historiques et Scientifiques de l'Afrique Occidental Francaise* 9:364–427
- Causey D (1953) Parasitic Copepoda of texas coastal fishes. *Publ Inst Mar Sci Univ Texas* 3:6–16
- Cressey RF (1991) Parasitic copepods from the Gulf of Mexico and Caribbean sea, III: Caligus. *Smith Contri Zoo* 497:1–53
- El Hafidi F, Berrada-Rkhami O, Benazzou T, Gabrion C (1998) Microhabitat distribution and coexistence of Microcotylidae (Monogenea) on the gills of the striped mullet *Mugil cephalus*: chance of competition. *Parasitol Res* 84:315–320
- El-Rashidy H, Boxshall GA (1999) Ergasilid copepods (*Poecilostomatoida*) from the gills of primitive Mugilidae (grey mullets). *Syst Parasitol* 42:161–186
- El-Rashidy H, Boxshall GA (2010) Parasitic copepods on immigrant and native clupeid fishes caught in Egyptian coastal waters off Alexandria. *Syst Parasitol* 76(1):19–38
- El-Rashidy H, Boxshall GA (2012) A new Copepod (Siphonostomatoida: Lernanthropidae) parasitic on a Red Sea immigrant dragonet (Actinopterygii: Callionymidae), with a review of records of parasitic copepods from dragonets. *Syst Parasitol* 81(2):87–96
- Geets A, Coene H, Ollevier F (1997) Ectoparasites of the white spotted rabbitfish, *Siganus sutor* (Valenciennes, 1835) off the Kenyan Coast: distribution within the host population and site selection on the gills. *Parasitology* 115:69–79
- Hallett SL, Roubal FR (1995) Experiments on the infection dynamics of *Caligus epidermicus* Copepoda: Caligidae on the small marine fish *Ambassis marianus* gunther. *J Fish Dis* 18:59–66
- Hayden KJ, Rogers WA (1998) *Neoergasilus japonicus* (Poe-cilostomatoida: Ergasilidae), a parasitic copepod new to North America. *J Parasitol* 84:88–93
- Ho JS (2000) The major problem of cage aquaculture in Asia relating to sea lice. In: Liao I, Lin C (eds) Cage aquaculture in Asia. Proceeding of the First International Symposium on Cage

- Aquaculture in Asia, Asian Fisheries Society, Manila and World Aquaculture Society, Southeast Asian chapter, Bangkok, pp 13–19
- Ho JS, Kim IH (2004) Lernanthropid copepods (Siphonostomatoidea) parasitic on fishes of the Gulf of Thailand. *Syst Parasitol* 58:17–21
- Ho JS, Lin CH (2012) *Cirracanthus longus* sp. nov. (Taeniacanthidae), a Copepod parasitic on seabats (Ogcocephalidae: Halieutae) from Taiwan, with a key to 23 Taeniacanthid species known from Taiwan. *Zool Stud* 51(4):548–555
- Ho JS, Liu WC, Lin CL (2011) Six species of the Lernanthropidae (Crustacea: Copepoda) parasitic on marine fishes of Taiwan, with a key to 18 species of the family known from Taiwan. *Zool Stud* 50(5):611–635
- Hudson PL, Bowenii CA, Stedman RM (1994) New records of *Ergasilus* (Copepoda: Ergasilidae) in the Laurentian great lakes, including a lakewide review of records and host associations. *Can Journ Zoo* 72:1002–1009
- Hughes G, Morgan M (1973) The structure of fish gills in relation to their respiratory function. *Biol Rev* 48:419–475
- Johnson SC, Treasurer JW, Bravo S, Nagasawa K, Kabata Z (2004) A review of the impact of parasitic copepods in marine aquaculture. *Zool Stud* 43:229–243
- Jones SR, Prosperi-Porta G, Kim E (2012) The diversity of microsporidia in parasitic copepods (Caligidae: Siphonostomatoidea) in the Northeast Pacific Ocean with description of *Facilispora margolisi* n. g., n. sp. and a new family Facilisporidae n. fam. *J Eukaryot Microbiol* 59(3):206–217
- Kabata Z (1958) *Lernaecocera obtusa* n. sp.: its bi-ology and its effects on the haddock marine research. *Dept Agric Fish* 3:1–26
- Kabata Z (1965) Copepoda parasitic on Australian fishes. IV. Genus *Caligus* (Caligidae). *Ann Mag Nat Hist* 13(8):109–126
- Kabata Z (1979) Parasitic copepods of British fishes. Ray Society, London, pp 1–468
- Kabata Z (1985) Parasites and disease of fish cultured in tropics. Taylor and Francis, UK, USA, pp 242–246
- Kabata Z (1988) Copepoda and Brachiura. In: Guide to the Parasites of Fishes of Canada. Part II-Crustacea, L. Margolis and Z. Kabata (Eds.). *Fish Aqu Sci* 101:3–127
- Kirtisinghe P (1964) A review of the parasitic copepods of fish recorded from ceylon with descriptions of additional forms. *Bull. Fish Res Sta Ceylon* 17:45–132
- Lester RJG, Hayward CJ (2006) Phylum Arthropoda. In: Woo PTK (ed) *Fish diseases and disorders vol 1: Protozoan and Metazoan infections*, 2nd edition. CAB international, London, pp 466–565
- Lyndon AR, Vidal-Martinez VM (1994) The microhabitat and morphology of *Grubea cochlear* on the gills of mackerel from Lyme Bay, southern England. *J Mar Biol Ass UK* 74:731–734
- Margolis L, Esch G, Holmes JC, Kuris AM, Schad GA (1982) The use of ecological terms in parasitology. *J Parasitol* 68(1):131–133
- Moller H (1985) Fish disease in coastal waters: indicator of marine pollution. *Ani Res Dev* 22:106–115
- Moller H, Anders K (1986) Diseases and parasites of marine fishes. Verlag Moller, German Federal Republic, p 365
- Mugridge RER, Stallybrass HG, Hollman A (1982) *Neoergasilus japonicus* (Crustacea: Ergasilidae). a parasitic copepod new to Britain. *J. Zoo London* 197:551–557
- Ozak AA, Demirkale I, Yanar A (2012) First record of two species of parasitic copepods on immigrant Pufferfishes (Tetraodontiformes: Tetraodontidae) caught in the Eastern Mediterranean Sea. *Turk J Fish Aquat Sci* 12:1–2. doi:10.4194/1303-2712-v12_3_17
- Palacios-Fuentes P, Landaeta MF, Muñoz G, Plaza G, Ojeda FP (2012) The effects of a parasitic copepod on the recent larval growth of a fish inhabiting rocky coasts. *Parasitol Res* 111(4):1661–1671
- Paling ER (1967) A method of estimating the relative volume of water flowing over the different gills of freshwater fish. *J Exp Biol* 48:533–544
- Paperna I, Overstreet RM (1981) Parasites and diseases of mullets (Mugilidae). Aquaculture of grey mullets. In: Oren OH (eds) *International biological program* 26. Cambridge University Press, USA, pp 411–493
- Pillai NK (1985) The fauna of India: Copepod parasites of marine fishes. *Zoo Sur India* p 900
- Ponyi M, Molnar K (1969) Studies on the parasite fauna of fish in Hungary, part 5. Parasitic copepods *Parasitol Hung* 2(2):137–148
- Prabha C, Pillai NK (1986) Additions to the copepods parasitic on the marine fishes of India. 4. on twenty-six species of Caligidae. *Rec Zoo Sur India* 79:1–139
- Pritchard MH, Kruse OW (1982) The collection and preservation of animal parasites. University of Nebraska Press, USA, p 318
- Purivirojkul W, Chaidee P, Thapanand-Chaidee T (2011) New record of *Pseudocycnus appendiculatus* Heller, 1868 parasites of yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) in the Andaman Sea, Thailand. *Walailak J Sci & Tech* 8(1):81–85
- Quinnell RJ, Graffen A, Woolhouse EJ (1995) Changes in parasite aggregation with age: a discrete infection model. *Parasitology* 111:635–644
- Rameshkumar G, Ravichandran S (2013) *Lernaenicus sprattae* (Crustacea: Copepoda) on *Hemiramphus far*. *Mid East J Sci Res* 13(2):183–186
- Ravichandran S, Ajith Kumar TT, Ronald Ross P, Muthulingam M (2007) Histopathology of the infestation of parasitic isopod *Joryma tartoor* of the host fish *Parastromates niger*. *Res J Parasitol* 2(1):68–71
- Roubal F (1999) Extent of gill pathology in the toadfish *Tetractenosis hamiltoni* caused by *Naobranchia variabilis* (Copepoda: Naobranchiidae). *Dis Aqu Org* 35:203–211
- Roza D, Johnny F, Kawahara S, Hanafi A (2002) Penyakit pada budidaya ikan kerapu dan upaya penanggulangannya. Kumpulan Makalah Seminar Pengembangan Teknologi Budidaya Kerapu, Balai Budidaya Laut Lampung p, pp 75–86
- Sirikanchana P (2003) Parasites of aquatic animals. Sky Word Advertising Ltd, Bangkok 270
- Sproston NG, Hartley PHT (1941) The ecology of some parasitic copepods of gadoids and other fishes. *J Mar Biol Ass UK* 25:361–392
- Tanguay GV, Scott ME (1992) Factors generating aggregation of *Elgimosomoides polygyrus* Nematoda in laboratory mice. *Parasitology* 104:519–529
- Thamir K, Adday, Atheer H, Ali (2011) *Ergasilus boleophthalmi* sp. n. (Copepoda: Ergasilidae) parasitic on gobiid fishes from Shatt Al-Basrah Canal, South of Iraq. *Wiadomooci Parazytologiczne* 57(3):137–142
- Vinoth R, Ajith Kumar TT, Ravichandran S, Gopi M, Rameshkumar G (2010) Infestation of Copepod parasites in the food fishes of Vellar estuary, Southeast coast of India. *Act Parasitol Glob* 1(1):1–5
- Williams EH Jr, Williams LB (1996) Parasites off shore, big game sport fishes of Puerto Rico and the Western North Atlantic. Puerto Rico Department of Natural and Environmental Resources/Department of Biology, University of Puerto Rico, San Juan, Puerto Rico/Mayaguez, Puerto Rico, p 384
- Wilson CB (1913) Crustacean parasites of West Indian fishes and land crabs, with descriptions of new genera and species. *Proc Unit States Nat Mus* 44:189–277
- Yamaguti S (1963) Parasitic Copepoda and Branchiura of fishes. Interscience publishers, A Division of John Wiley & Sons, New York, p 1104
- Yu N, Poltev (2010) An unusual localization of the parasitic Copepod *Haemobaphes diceraus* Wilson, 1917 (Copepoda: Pennellidae) on the walleye pollock *Theragra chalcogramma*. *Rus J Mar Biol* 36(2):154–156
- Yuniar A, Palm HW, Walter T (2007) Crustacean fish parasites from Segara Anakan Lagoon, Java, Indonesia. *Parasit Res* 100:1193–1204