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ON THE METAZOAN PARASITES ASSOCIATED WITH FISHES ALONG THE SOUTHWEST COAST OF INDIA

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Abstract

Two thousand one hundred and ninety teleosts belonging to 11 species and forty eight elasmobranchs of two species, collected from major landing centres along the south-west coast of India, were examined for metazoan parasites. Of the teleosts 83.65% and of the elasmobranchs 93.75% were found infected with different metazoan parasites. The parasites include 3 species of monogenetic trematodes, 10 of digenetic trematodes, 6 of adult cestodes, a number of larval cestodes belonging to the orders Pseudophyllidea, Tetraphyllidea and Trypanorhyncha and two of uncertain identity, one species of acanthocephalan, 6 genera of nematodes, 17 species of copepods and 4 of isopods. Of the parasites obtained *Neogonapodasmius hemirhamphi* n. gen., n. sp. (Digenea), *Lernaeenicus epinepheli* n. sp., and *Paeonodes mugilis* n. sp. (Copepoda) and *Codonophilus hemirhamphi* n. sp. (Isopoda) are new finds. Except the monogeneans, copepods and isopods, all others are reported for the first time from the southwest coast of India. The incidence and intensity of infestation and the nature and extent of damage by each group of parasites, as well as the importance of a detailed study of parasites and similar associates in massive fish culture programmes are discussed.

Introduction

Despite the fact that parasitological and pathological studies on fishes have, all over the world, gained much momentum in recent years, in India such studies are yet to pick up pace. Taxonomic studies on fish parasites, especially metazoan parasites, in our country, like elsewhere, had an early beginning. Nevertheless, even from this angle the fishes of the southwest coast of India have received only little attention. The studies by the eminent carcinologist Prof. N. Krishna Pillai and his team of research workers during the past few decades on copepods,* and to a lesser extent on isopods (Pillai, 1958), as well as the works of Sivasankara Pillai (1968) and Unnithan (1957, 1961, 1962, 1964 a, b, c, 1965, 1966 a, b, 1967) on monogenetic trematodes are, in fact, valuable contributions to the systematics of metazoan parasites of fishes from this coast. It is, however, lamentable that even the systematics of other groups of metazoan parasites of the fishes of this coast remains a virgin field as yet, not to speak of the ecological aspects though the pioneering effort in studying the host-parasite relationships of copepod parasites and their marine fish hosts have come from Natarajan (1975). This lacuna in information prompted the present study to add information on the varied spectrum of metazoan parasites and their nature of infestation of fishes of the southwest coast of India.

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* Pillai, N. K. Copepod Parasites of Marine Fishes. Fauna of India (In Press).

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MATERIAL AND METHODS

The fishes examined were collected from landings at the four major landing centres Shankumughom, Valiyathurai, Kovalam and Vizhinjam along the southwest coast of India. As far as possible, fishes collected were examined on the day of collection itself. However, when the collection included too many fishes, some of them were deep-frozen and examined subsequently, using conventional parasitological methods.

In the laboratory, the standard length, total weight and the sex of each fish were noted and then they were examined for parasites on the skin, fins, gills and buccal cavity. Fishes were then cut open and all internal organs (except the CNS) were examined for internal metazoan parasites. The number, position of attachment and orientation of the parasites and external lesions at and around the point of attachment were recorded.

Monogeneans, digeneans and larval cestodes were sufficiently flattened between glass slides and fixed in 5% formalin. Adult cestodes were relaxed in tap water. The scolex, a few immature and mature proglottides were then properly flattened between glass slides and fixed in 5% formalin. Nematodes were killed and fixed by immersing in hot 70% alcohol and preserved in 80% glycerine—alcohol. Acanthocephalans were transferred to tap water to extrude the proboscis, flattened between glass slides and fixed in 5% formalin. Copepods and isopods were transferred to 10% aqueous sodium bicarbonate, cleaned off mucus and debris using a fine camel-hair brush, washed in tap water and preserved in 5% formalin.

All helminth parasites (except nematodes) were stained in alum carmine and made into permanent, balsm mounts. Copepods and isopods were identified straight away without staining.

OBSERVATIONS

A list of the parasites collected, their hosts and the site of infection is given in Table 1. The results of the analyses of the incidence and intensity of different infections and the maximum number of different parasites in male and female fish are presented in Tables 2 to 5.

TABLE 1. *List of parsites collected with their host fish and the site of infection*

Parasite	Host fish	Site of infection
I. TREMATODA — MONOGENEA		
Amphibdella narcini	*Narcine timlei*	Gill
Megamicrocotyle chirocentrus	*Chirocentrus dorab*	Gill
Osphyobothrus bychowskyi	*Saurida tumbil*	Gill
II. TREMATODE — DIGENEA		
Acanthocolpus liodorus	*Chirocentrus dorab*	Intestine
A. tenuis	*C. dorab*	Intestine
Dihemistephanus lydiae	*Mola mola*	Intestine
Accacladium nematulum	*M. mola*	Intestine
Accacladocoelium macrocotyle	*M. mola*	Intestine
Lecithocladium excisiforme	*Parastromateus niger*	Stomach
Tubulovesicula sauridae	*S. tumbil*	Stomach

TABLE I (*Contd.*)

Parasite	Host fish	Site of infection
Lecithochirium polynemi	*Trichiurus savala*	Stomach
Tetrochetus coryphaenae	*Diodon hystrix*	Rectum
Neogonapodasmius hemirhamphi n. gen., n. sp.	*Hemirhampus xanthopterus*	Dorsal fin
III. CESTODA		
A. Adult cestodes		
Penetrocephalus ganapatii	*S. tumbil*	Intestine (Scolex in liver)
Bothriocephalus indicus	*S. tumbil*	Intestine
B. scorpii	*M. mola*	Intestine
Anthobothrium variabile	*Himantura bleekeri*	Spiral valve
Acanthobothrium indicum	*N. timlei*	Spiral valve
Tylocephalum dierama	*H. bleekeri*	Spiral valve
B. Larval cestodes		
P. ganapatii Plerocercoid	*S. tumbil*	wall of intestine, Mesentery
Pseudophyllidean plerocercoids	*T. savala*	Viscera, visceral organs, muscle
	S. tumbil	Viscera, visceral organs
	C. dorab	Viscera, muscle
Scolex pleuronectis	*T. savala*	Gall bladder, pyloric caeca
Nybelinia sp., Plerocercoid	*D. hystrix*	Wall of oesophagus
Eutetrarhynchus sp. (i)	*D. hystrix*	Mesentery, liver
Plerocercoid (ii)	*T. savala*	Viscera, visceral organs
	S. tumbil	Viscera, visceral organs
	C. dorab	Viscera, visceral organs
Gymnorhynchus gigas (i)	*D. hystrix*	Liver
Plerocercoid (ii)	*C. dorab*	Liver, pyloric caeca
Pterobothrium sp., Plerocercoid	*T. savala*	Pyloric caeca, kidney
	S. tumbil	Pyloric caeca
	C. dorab	Liver
C. Cestode larvae of uncertain identity		
Tetrarhynchus sp. of Southwell, 1930	*D. hystrix* *C. dorab*	Muscle
Unidentified	*Parastromateus niger*	Viscera, visceral organs

TABLE I (*Contd.*)

Parasite	Host fish	Site of infection
IV. ACANTHOCEPHALA		
Rhadinorhynchus pristis	*C. dorab*	Intestine
V. NEMATODA		
Lappetascaris sp. larva	*S. tumbil*	Spleen, intestinal wall
Terranova sp. larva	*T. savala*	Viscera, mesentery
	S. tumbil	Liver
	P. niger	Intestine
Anisakis sp. larva	*T. savala*	Viscera, mesentery, intestine
	S. tumbil	Spleen, intestinal wall
Raphidascaris sp. larva	*S. tumbil*	Viscera
Thynnascaris sp. larva, V Stage	*S. tumbil*	Intestine
Thynnascaris sp. larva, IV stage	*S. tumbil*	Viscera
	H. bleekeri	Spiral valve
Thynnascaris sp. larva III stage	*T. savala*	Viscera, mesentery
Paranisakiopsis sp. larva III stage	*T. savala*	Mesentery
Thynnascaris sp. adult	*D. hystrix*	Intestine
VI. COPEPODA		
Ergasilus sp.	*Mugil cunnesius*	Gill filaments
Taeniacanthus narcini	*N. timlei*	Gill filaments
Bomolochus hemirhamphi	*H. xanthopterus*	Gill filaments
Caligus uruguayensis	*T. savala*	Buccal cavity
Synestius caliginus	*P. niger*	Buccal cavity
Lernanthropus koenigii	*P. niger*	Gill filaments
L. gibbosus	*S. tumbil*	Gill filaments
Lernaeenicus hemirhamphi	*H. xanthopterus* *H. far*	Body
L. epinepheli n. sp.	*Epinepheles malabaricus*	Body
Peniculus trichiuri	*T. savala*	Body
Peniculisa wilsoni	*D. hystrix*	Fins
Paeonodes mugilis n. sp.	*M. cunnesius*	Gill arch
Thysanote appendiculata	*P. niger*	Gill arch
Pseudocharopinus dasyaticus	*H. bleekeri*	Body margin
P. narcinae	*N. timlei*	Gill arch
Isobranchia appendiculata	*C. dorab*	Gill arch
Brachiella trichiuri	*T. savala*	Gill arch
VII. ISOPODA		
Cymothoa eremita	*P. niger*	Buccal cavity
Codonophilus hemirhamphi n. sp.	*H. xanthopterus*	Buccal cavity
Irona far	*H. far*	Branchial chamber
Livoneca sp.	*Nemipterus japonicus*	Body

TABLE 2. *Percentage incidence of metazoan parasites*

Fish	Number of Fish Examined	Percentage Incidence of Infection									
		Total	Helminths						Crustaceans		
			Monogenea	Digenea	Cestoda	Nematoda	Acanthocephala	Total	Copepoda	Isopoda	Total
Diodon hystrix	563	80.99	..	66.79	58.79	4.80	..	80.99	28.24	..	18.24
Trichiurus savala	365	86.85	..	20.55	66.30	12.05	..	86.85	67.67	..	67.67
Mugil cunnesius	350	92.57	..	..	..	..	..	..	92.57	..	92.57
Saurida tumbil	270	99.63	49.63	0.74	97.41	89.63	..	99.63	50.37	..	50.37
Hemirhamphus far	307	85.34	..	..	..	..	..	..	30.29	53.09	62.21
H. xanthopterus	138	42.03	..	7.25	..	..	..	7.25	43.48	3.62	45.65
Parastromateus niger	100	52.00	..	2.00	40.00	24.00	..	52.00	82.00	32.00	95.00
Chirocentrus dorab	93	97.85	24.73	22.58	84.95	..	1.08	96.77	41.94	..	41.94
Epinepheles malabaricus	2	50.00	..	..	..	..	..	..	50.00	..	50.00
Nemipterus japonicus	1	100.00	..	..	..	..	..	..	..	100.00	100.00
Mola mola	1	100.00	..	100.00	100.00	..	..	100.00	..	..	..
Total (Teleosts)	2190	83.65	7.17	22.24	43.65	15.39	0.05	54.57	52.10	9.63	57.35
Narcine timlei	23	100.00	69.56	..	100.00	..	..	100.00	60.87	..	60.87
Himantura bleekeri	25	88.00	..	..	88.00	4.00	..	88.00	4.00	..	4.00
Total (Elasmobranchs)	48	93.75	33.33	..	93.75	2.08	..	93.75	31.25	..	31.25
Grand Total	2238	83.87	7.73	21.76	44.73	15.10	0.04	55.41	15.65	9.43	56.79

.. Zero value

TABLE 3. *Intensity of infection (=mean number of parasites per infected fish) of metazoan parasites*

Fish	Total	Intensity of Infection								
		Helminths						Crustaceans		
		Monogenea	Digenea	Cestoda	Nematoda	Acanthocephala	Total	Copepoda	Isopoda	Total
D. hystrix	24.75	..	7.56	13.30	4.04	..	16.12	24.74	..	24.74
T. savala	5.85	..	4.75	3.29	2.05	..	3.91	2.48	..	2.48
M. cunnesius	27.73	..	..	..	..	..	..	27.73	..	27.73
S. tumbil	28.74	5.99	1.00	4.23	23.03	..	27.84	1.76	..	1.76
H. far	1.98	..	..	..	..	..	..	1.72	2.20	2.71
H. xanthopterus	2.60	..	1.20	..	..	..	1.20	2.20	1.40	2.21
P. niger	293.58	..	1.50	362.65	1.71	..	279.81	8.22	1.00	7.54
C. dorab	5.43	1.70	8.38	2.66	..	3.00	4.76	1.69	..	1.69
E. malabaricus	2.00	..	..	..	..	..	..	2.00	..	2.00
N. japonicus	1.00	..	..	..	..	..	..	..	1.00	1.00
M. mola	254.00	..	220·00	34.00	..	..	254.00	..	..	..
Total (Teleosts)	25.40	5.36	7.41	22.03	17.25	3.00	26.22	12.98	1.93	12.11
N. timlei	30.35	3.25	..	26.30	..	..	28.57	2.93	..	2.93
H. bleekeri	3.27	..	..	3.14	2.00	..	3.23	1.00	..	1.00
Total (Elasmobranchs)	17.11	3.25	..	14.98	2.00	..	16.18	2.80	..	2.80
Grand Total	25.21	5.16	7.41	21.71	17.21	3.00	25.85	12.84	1.93	12.00

.. Zero value.

TABLE 4. *Incidence of infection of metazoan parasites in fishes of the southwest coast of India*

Number of species of fish examined		
Teleosts	Elasmo-brachs	Total
11	2	13

	Parasite	Number of species of Fish Inefected		
		Teleosts	Elasmobranchs	Total
HELMINTHS	Monogenea	2 (18.18)	1 (50.00)	3 (23.08)
	Digenea	7 (63.64)	..	7 (53.85)
	Cestoda	6 (54.55)	2 (100.00)	8 (61.54)
	Nematoda	4 (36.36)	1 (50.00)	5 (38.46)
	Acanthocephala	1 (9.09)	..	1 (7.69)
	Total	7 (63.64)	2 (100.00)	2 (69.23)
CRUSTACEANS	Copepoda	9 (81.82)	2 (100.00)	11 (84.62)
	Isopoda	4 (36.36)	..	4 (30.77)
	Total	10 (90.91)	2 (100.00)	12 (92.31)
	Grand Total	11 (100.00)	2 (100.00)	13 (100.00)

Numbers in parentheses denote percentages.
.. Zero value.

TABLE 5. *Maximum number of different metazoan parasites in infected male and female fish*

Fish	Total		Maximum Number of Parasites on infected Male and Female Fish																			
			Helminths												Crustaceans					
			Monogenea		Digenea		Cestoda		Nematoda		Acanth-cephala		Total		Copepoda		Isopoda		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
D. hystrix	130	142	..	..	22	21	42	46	16	17	..	..	61	63	83	90	..	..	83	90
T. savala	21	40	..	..	14	19	14	18	3	8	..	..	17	38	8	11	..	..	8	11
M. cunnesius	314	383	..	..	..	..	..	..	..	..	..	..	..	..	314	388	..	..	314	383
S. tumbil	100	109	22	24	..	2	17	19	94	99	..	..	97	105	3	4	..	..	3	4
H. far	7	7	..	..	..	..	..	..	..	..	..	..	..	..	4	6	5	6	7	7
H. xanthopterus	8	6	..	..	1	2	..	..	..	..	..	..	1	2	8	6	1	2	8	6
P. niger	2020	1874	..	..	0	2	2016	1858	2	5	..	..	2017	1861	10	12	1	1	10	13
C. dorab	16	16	3	5	12	10	5	7	..	..	0	3	15	13	4	3	..	..	4	3
E. malabaricus	—	2	—	..	—	..	—	—	—	..	—	..	—	..	..	2	..		..	2
N. japonicus	—	1	—	..	—	..	—	—	—	..	—	..	—	—	..	..	..	1	..	1
M. mola	—	254	—	..	—	220	—	34	—	—	—	..	—	254	—	..	—	..	—	..
N. timlei	88	104	8	8	..	..	83	88	..	..	..	..	85	31	4	15	..	..	4	15
H. bleekeri	9	12	..	..	..	..	8	10	..	2	..	..	8	12	1	..	..	..	1	..

.. Zero value — Data not available. M — Male F — Female.

A. *Infection of Teleosts*

Monogenea *:* Two (18.18%) of the eleven species of teleosts examined were infected with monogenetic trematodes. The parasites are *Osphyobothrus bychowskyi* on *Saurida tumbil* and *Megamicrocotyle chirocentrus* on *Chirocentrus dorab.* The percentage incidence of infection of *O. bychowskyi* was 49.63 and that of *M. chirocentrus* 24.73. Intensity of infection of the former was 5.99 and that of the latter 1.70.

Of the 2190 teleosts examined 157 (7.17%) were infected with monogenetic trematodes, from which 841 parasites (intensity of infection =5.36) were obtained. Maximum number of *O. bychowskyi* on a fish was found to be 22 on male and 24 on female whereas that of *M. chirocentrus* was 3 on male and 5 on female.

Specimens of *O. bychowskyi,* usually light pink in colour, are located between adjacent primary gill filaments so that the ventral surface of the parasite is in close apposition with the broad lateral margin of the gill filament. Typically, the posterior end of the parasite is directed towards the gill arch and the eight, peduncled anchors of the adhesive organ grip the secondary gill filaments (respiratory folds) on the broad margin of the primary gill filament.

Some specimens of *O. bychowskyi* attach themselves to the gill filament, with their anterior ends directed towards the gill arch. In such instances the outermost pair of anchors of the parasite curves round the narrow margins of the primary gill filament to grip the respiratory folds on the opposite side of the primary gill filament to which the parasite is attached.

Specimens of *Megamicrocotyle chirocentrus* have been found to attach themselves to the broad margin of the primary gill filament. The attachment is effected by grasping the respiratory folds by the opposible jaws of the anchors. Attachment is nearer to the outer, lateral border of the primary gill filament. The longer row of anchors lie more or less parallel to the lateral margin of the primary gill filament and the anterior end of the parasite is directed towards the gill arch. Though the body of the parasite is inclined to the plane of the anchors, the parasite is oriented with its long axis parallel, or nearly so, to the direction of the ventillating water current thereby imparting only minimum resistance to the water current.

Digenea : Seven (63.64%) of the eleven species of teleosts examined were infected with digenetic trematodes. Ten species of parasites were obtained from the infected fishes. *Mola mola* harboured three different species : *Dihemistephanus lydiae, Accacladium nematulum* and *Accaladocoelium macrocotyle* and *Chirocentrus dorab* two species : *Acanthocolpus tenuis* and *A. liodorus. Parastromateus niger, Saurida tumbil, Trichiurus savala, Diodon hystrix* and *Hemirhamphus xanthopterus* had one species of digenean in each.

The highest incidence of digenean infection (66.79%), (barring the case of *Mola mola*) was noted for *Tetrochetus coryphaenae* in *D. hystrix* while the lowest incidence (0.74%) was noted for *Tubulovesicula sauridae* in *S. tumbil.* Similarly, considering the intensity of infection, the highest (8.38) was noted for *Acanthocolpus* spp. in *C. dorab* and the lowest (1.00) for *T. sauridae.*

From the single specimen of *Mola mola,* as many as 220 digeneans were obtained of which 138 were *A. macrocotyle,* 59 *A. nematulm* and 23 *D. lydiae.*

Considering the incidence and intensity of infection in teleosts as a whole, 487 (22.24%) of the examined fishes were infected from which as many as 3610 specimens (intensity=22.03) of digeneans were obtained.

In *C. dorab* and in *M. mola* the digeneans were found in the intestine, whereas in *P. niger, S. tumbil* and *T. savala,* the parasites were confined to the stomach. In the case of *D. hystrix* they were noticed in the rectum while in *H. xanthopterus* the parasites were encysted on the fin.

Digenetic trematodes are almost exclusively endoparasites. However, those belonging to the family Transversotrematidae are ectoparasitic. Even in the latter case the parasites are seen embedded in the host tissue. The interesting observation in regard to the digenean *Neogonapodasmius hemirhampi* n. gen., n.sp.* is that the parasites are seen encysted on the membranous part of the fin, usually between the first and second fin rays of the first dorsal fin of *H. xanthopterus*. In *N. hemirhamphi* the sexes are entirely separate and there is pronounced sexual dimorphism. The male is always seen along with the female inside a single cyst whereas the female may encyst solitarily.

Cestoda: Six (54.55%) of the eleven species of teleosts were infected with cestodes. All infected teleosts, invariably, harboured larval forms (plerocercoids). In *S. tumbil* and *M. mola* the cestode fauna included adult cestodes as well. While the adults were exclusively found in the intestine, the plerocercoids were seen to invade the visceral cavity and almost all visceral organs, except perhaps the heart and spleen.

Of the 2190 teleosts examined 956 (43.65%) had cestode infection. In *S. tumbil* 97.41% and in *C. dorab* 84.95% of the fish examined were infected. The lowest incidence of cestode infection (40.0%) was noted in *P. niger*.

The average intensity of cestode infection was found to be 22.03. The highest (362.65) and the lowest (2.66) intensities of infection were recorded for *P. niger* and *C. dorab* respectively. Maximum numbers of cestodes in a male and female of these two species of fishes were 2016 and 1858 and 5 and 7 respectively.

Trypanorhynchan plerocercoids predominated the larval cestode fauna and all infected teleost species harboured one or the other type of trypanorhynchan plerocercoid. These were always seen in an encysted condition and always bound firmly to the host tissue or embedded in such vital organs as the liver.

Pseudophyllidean plerocercoids have been found in *T. savala*, *S. tumbil* and *C. dorab*. Almost invariably, these parasites were seen lying freely in the visceral cavity or loosely bound to the visceral wall or to the surface of visceral organs, by connective tissue elements.

The tetraphyllidean plerocercoid *Scolex pleuronectis*, has been seen to invade the gall bladder and pyloric caeca of *T. savala*. The trypanorhynchan plerocercoid *Nybelinia* sp. invading the wall of the oesophagus of *D. hystrix* is both host specific and tissue specific.

The adult cestodes encountered during the present study belonged to three species — *Penetrocephalus ganapatti*, *Bothriocephalus indicus* and *B. scorpii* — all members of the family *Bothriocephalidae*. *P. ganapatii* and *B. indicus*, both from the intestine of *S. tumbil*, resemble closely and the latter is always associated with the former. Though the maximum number of *B. indicus* in an infected fish was never found to go beyond two, that of *P. ganapatii* may be sometimes as high as seven. The scolex of *B. indicus* penetrates the intestinal wall and lies encysted in a pouch in the wall of the intestine. The scolex of *P. ganapatti* penetrates the intestinal wall and almost invariably proceeds to the liver, (or rarely to the pyloric caeca) penetrates the organ and gets embedded and encysted in it, along with a part of the neck immediately behind the scolex. Later the scolex degenerates. A part of the long neck of the parasite remains in the visceral cavity, ensheathed in a dirty yellowish tissue. Usually each

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* Systematics published elsewhere.

worm penetrates into and encysts individually in the liver. It is, however, not uncommon that one may come across two or three worms gaining entry into the liver simultaneously, their necks ensheathed together before they enter the liver.

Nematoda: Four (36.36%) of the eleven species of teleosts examined were infected with nematodes. Six genera of nematodes* were obtained from the infected fish. Except for the specimens from *D. hystrix*, belonging to the genus *Thynnascaris* (probably a new species) the rest of the nematode fauna of teleosts consisted of larvae. In *S. tumbil* members of five genera, *Anisakis, Lappetascaris, Raphidascaris, Thynnascaris* and *Terranova*, were noted. Representatives of the genera *Anisakis, Paranisakiopsis, Terranova* and *Thynnascaris* have been found in *T. savala*. *P. niger* harboured only *Terranova* sp. larva.

The highest incidence (89.63%) and the highest intensity (23.03) of nematode infection was noted in *S. tumbil*. The maximum number of parasites in an infected fish was also the highest in this fish — 94 in male and 99 in female. Incidence of nematode infection was the lowest (4.80%) in *D. hystrix*. Intensity of infection in this fish was 4.04 and the maximum number of parasites in male and female fish was 16 and 17 respectively. The lowest intensity of nematode infection (1.71) was noted in *P. niger*, in which case 24.0% of the fish examined were infected.

Acanthocephala: Three specimens of the acanthocephalan *Rhadinorhynchus pristis* were obtained from two specimens of *C. dorab*. The percentage incidence of infection was 1.08.

Considering helminth infection in teleosts as a whole, seven (63.64%) out of the 11 species examined were infected, while 1195 (54.57%) out of the 2190 teleosts had helminth infection. The percentage incidence of infection was the highest (99.63) in *S. tumbil* and the lowest (7.25) in *H. xanthopterus* — the former harbouring four different helminth species and the latter only one.

Intensity of helminth infection in teleosts was 26.22. It was the highest (279.81) in *P. niger* and the lowest (1.20) in *H. xanthopterus*. Similarly, the maximum number of helminth parasites in an infected male and female fish was the highest (2017 and 1861) in *P. niger* and the lowest (1 and 2) in *H. xanthopterus*.

Copepoda: Nine (81.82%) of the 11 species of teleost examined were infected with copepod parasites. Fourteen species of copepods were obtained from the infected fish. Both *P. niger* and *T. savala* harboured three different species of copepods whereas *M. cunnesius* and *H. xanthopterus* harboured two species. *D. hystrix, S. tumbil, C. dorab* and *E. malabaricus* had one species of copepod in each. All the parasites except *Lernaeenicus hemirhamphi* perhaps, are host specific and most of them show distinct preference as to the site of attachment on the host.

Of the 2190 teleosts examined 1141 (52.10%) had copepod infection. The intensity of infection was 12.98. The highest incidence (92.57%) and intensity (27.73) of infection were recorded in *M. cunnesius* whereas the lowest incidence (28.24%) was in *D. hystrix* and the lowest intensity (1.69) in *C. dorab*. Maximum number of copepod parasites in infected male and female fish was 314 and 383 in *M. cunnesius*. In *D. hystrix* it was 83 and 90 and in *C. dorab* 4 and 3.

Isopoda: Four (36.36%) out of the eleven species of teleosts were infected with isopod parasites. The highest incidence of infection

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* The nematode parasites were identified by Dr. Bjørn Berland, Zoologisk Laboratorium, University of Bergen, Norway. Detailed systematic account of the parasites is being published by him.

(53.09%) was recorded for *Irona* for in *Hemirhamphus far* and the lowest (3.62%) for *Codonophilus hemirhamphi* in *H. xanthopterus*. 42.0% of the specimens of *Parastromateus niger* examined were infected with *Cymothoa eremita* while the one specimen of *Nemipterus japonicus* harboured a specimen of *Livoneca* sp. on its body.

The intensity of isopod infection in teleosts was 1.93. The highest intensity of infection (2.2) was noted for *I. far*. The intensity of infection of *C. hemirhamphi* was 1.4 and that of *C. eremita* was 1.0. Maximum numbers of *I. far*, *C. hemirhampi* and *C. eremita* noted on infected male and female fish were as follows :

I. far	5, 6
C. hemirhamphi	1, 2
C. eremita	1, 1

The females and intermediate stages of the protandrous hermaphroditic isopod *Irona far* were found to inavde the floor of the branchial chamber of *H. far*. Male stages were found to invade the body wall on the lower side of the mouth and along the rim of the branchial chamber. *C. hemirhamphi* and *C. eremita* are typical parasites of the buccal cavity and *Livoneca* sp. was found on the body surface.

B. Infection of elasmobranchs

Along the southwest coast of India landings of elasmobranchs are very scanty both in number and in variety. 23 specimens of the electric ray *Narcine timlei*, and 25 specimens of the two-spined sting ray *Himantura bleekeri*, were examined to study the nature of infection with metazoan parasites. Of the 48 fish examined 45 (93.75%) were infected. While all the specimens of *N. timlei* were infected with metazoan parasites, the percentage incidence of infection in *H. bleekeri* was only 88.0%.

In *N. timlei* the helminth parasite fauna consisted of a monogenetic trematode (*Amphibdella narcine*) and an adult cestode (*Acanthobothrium indicum*). Incidence of infection of the former was 69.56% and that of the latter 100.0%. 60.87% of the specimens of *N. timlei* examined harboured a copepod parasite *Pseudocharopinus narcinae* on their gills. The intensity of metazoan infection in *N. timlei* was 30.35. The intensities of the monogenean, cestode and copepod parasites were 3.25, 26.30 and 2.93 respectively. Maximum number of metazoan parasites on infected fish was 88 in the male and 104 in the female. The maximum numbers of monogenean, cestode and copepod parasites noted in infected male and female fish were :

monogenean	8, 8
cestode	83, 88
copepod	4, 15

The metazoan parasite fauna of *Himantura bleekari* consisted of two species of adult cestodes (*Tylocephalum dierama*, and *Anthobothrium variabile*), one species of nematode (*Thynnascaris* sp. larva) and one species of copepod (*Pseudocharopinus dasyaticus*). The respective percentage incidence of infection of these parasites was 88.0, 4.0 and 4.0.

Average intensity of metazoan infection was 3.27 and the respective intensities of cestode, nematode and copepod parasites were 3.14, 2.0 and 1.0. Maximum numbers of these parasites in infected male and female fish were :

cestode	8, 10
nematode	0, 2
copepod	1, 0

The overall picture of metazoan parasitic infection of fishes along the southwest coast of India, forthcoming from the present study may be summarised as follows. All the thirteen species of fish examined were infected. Of the 2238 fishes examined as much as 1877 (83.87%) were infected. 55.41% had helminth infection and 56.79% had other crustacean infection. 51.65% were infectd with coepods and 9.43% with isopods.

Of the different types of helminth parasites, the highest incidence was recorded for cestodes (44.73%) followed by 21.76% for digenetic trematodes, 15.1% for nematodes, 7.73% for monogenetic trematodes and the lowest, 0.04% for acanthocephalans.

From the infected fish 47310 metazoan parasites were obtained, the intensity of infection being 25.21. Intensity of helminth infection was 25.85 while that of crustacean infection was 12.0. Intensities of infection of copepod and isopod parasites were 12.84 and 1.93 respectively.

Of the different helminth parasites, the highest intensity of infection (21.71) was recorded for cestodes, followed by nematodes (17.21), digenetic trematodes (7.41), monogenetic trematodes (5.16) and the lowest (3.0) for acanthocephalans.

C. Pathology of infections

Since multiple infection of the same host with different species of parasite was prevalent and since the number of absolutely uninfected fish for comparative studies was very few a correct assessment of the effect of different types of infections was not possible. However, local histopathological changes at and around the site of infection, owing to the mode of attachment of the parasite and/or their feeding activity could be assessed with accuracy.

The site of attachment of the three monogenetic trematodes is the gill filaments. Except for the damage to the tender respiratory folds owing to the grasping/gripping of these structures by the hard anchors of the parasites, accompanied by light to moderate hypertrophic changes of the gill epithelium, not much damage is attributable to these infections. Besides, no positive evidence of the parasites feeding on host blood is forthcoming from the present study.

Though known to be serious pathogens of fishes, all the digenetic trematodes encountered during the present study seem to be comparatively innocuous, perhaps with the single exception of *Tetrochetus coryphaenae* in *Diodon hystrix*. None of the parasites was found to resort to a permanent attachment to the host tissue. Even *Acanthocolpus liodorus* and *A. tenuis* in *Chirocentrus dorab* and *Lecithochirium polynemi* in *Trichiurus savala*, found in somewhat large numbers in their hosts, were seen lying freely in the lumen of the intestine and pyloric stomach of their respective hosts. Specimens of *Neogonapodasmius hemirhamphi* though invariably found encysted on the fin of their host, no serious damage to the latter is attributable to this infection also except, perhaps, reducing the locomotor efficiency of the affected fin.

At least a few specimens of *Tetrochetus coryphaenae* were found to permanently attach to the rectal wall of *Diodon hystrix*. The mode of attachment is seen to result in responsive fibro-plastic inflammatory changes in the rectal wall. The parasites, though sustain on the mucus secretion of the host, cause erosion of the rectal wall owing to the constant friction of their body on the delicate rectal papillae. While the direct damages caused by the infection are of not much serious concern to the host, aggregation of a large number of parasites in the rectal lumen is likely to cause distress and consequent general weakness owing partly to occlusion of the vent.

Direct tissue damage as a result of cestode infections in general, is one of a connective tissue reaction comprising proliferation of fibrous connective tissue and accumulation of inflammatory cells at and around the site of attack. This type of inflammatory reaction is, in fact, aimed at encapsulating the infecting elements in well-formed connective tissue cysts (especially evident in *Eutetrarhynchus* sp. plerocercoid infection of *Diodon hystrix*, where the plerocercoids are encysted in sturdy cysts even before they have a chance to invade any host organ) or at walling off the infecting elements thereby preventing them from inflicting serious damages to the host tissue (as is noted in *Nybelinia* sp. plerocercoid infection of the oesophagus of *D. hystrix.*)

The very fact that many of the pseudophyllidean plerocercoids invading the visceral cavity of the host are left alone by the host, there being apparently no host-reaction against these invaders, suggests that these parasites are not of much concern to the host when present in the visceral cavity. However, when these parasites once penetrate the host tissue, the host invariably encapsulates them in fibrous connective tissue cysts formed by the proliferation of connective tissue elements around the site of infection (as seen in the case of pseudophyllidean plerocercoid infection of the stomach/intestinal wall of *Saurida tumbil* and *Chirocentrus dorab*).

The tetraphyllidean plerocercoid *Scolex pleuronectis*, invading the gall bladder and pyloric caeca of *Trichiurus savala* is capable of inducing serious haematological and biochemical changes in the host, irrespective of the fact that direct tissue damages at the site of infection are rather meagre, by virtue of the fact that the organs invaded by the parasite are of supreme importance to the host in maintaining a normal healthy condition. The same holds good for *Gymnorhynchus gigas* plerocercoid infection of the liver of *Diodon hystrix*. The haematological changes in both cases are suggestive of the occurrence of anaemia (decreased total RBC count and decreased haemoglobin content and haematocrit) whereas the biochemical changes, in the basic energy reserves *viz.*, carbohydrate, fat and protein, simulate the changes — depletion — during starvation.

Among the adult cestodes encountered during the present study only *Penetrocephalus ganapatii* seems to be of any serious concern to the host. In *Bothriocephalus indicus* infection and in adult cestode infection of elasmobranchs the damage inflicted by the parasites are more of a localised nature, at and around the point of penetration of the scolices into the host tissue, where fibroplasia and infiltration of inflamatory cells occur.

In *P. ganapatii* infection the behaviour of the parasite is quite curious and beyond comprehension. The strobila of the parasite lies in the intestinal lumen while the scolex, after penetrating the intestinal wall traverses the visceral cavity and enters the liver where it gets encysted along with a part of the neck immediately behind the scolex. Invariably the encysted scolices degenerate. Why the strobila of the parasite remains in the intestinal lumen is understandable. But, the reason why the parasite should get its scolex lodged in the liver of the host simply to get degenerated, once inside this organ, is not yet clear.

Inside the liver the tissue damage accompanying *P. ganapatii* infection is typically a fibroplastic reaction leading to the encystment of the scolex and a part of the neck in a well-formed fibrous connective tissue cyst. In the intestine, where the strobila of the parasite is located, apparent tissue damage is not evident. Infection of a fish with as many as 4 to 7 parasites could occlude the intestinal lumen. Added to this, absorption of the digested food and certain essential nutritional requirements [like vitamin B_{12} as is known in tapeworm infection of higher vertebrates ; (Baker and Douglas, 1966)] of the host by the parasite leads to serious consequences the sum total of which manifests itself as an anaemic change coupled with depletion of the basic energy reserves of the host.

Majority of the nematodes lying freely in the intestinal lumen of the host fish does not apparently cause any serious tissue damage. However, when they once penetrate the host tissue (as is the case with *Lappetascaris* sp.

infection in *Saurida tumbil*) they induce inflammatory changes in the affected tissue leading to encapsulation of the invaders in connective tissue cysts. Perhaps, when the number of infecting elements is low, nematodes may not cause serious trouble to their host. But when the number is as high as 300 to 400 per infected fish (as has been noted in *S. tumbil* during the present study) measurable haematological (anaemia) and biochemical (depletion of basic energy reserves) changes are induced by the parasites.

In copepod infections, when the parsites invade the gill tissue, the damage is essentially the destruction of the delicate gill tissue. Since respiratory folds are the real respiratory structures, damage of these structures is of serious consequence to the host, because, in fact, such damages cause reduction of the total respiratory area. Over exertion on the part of the host to compensate for this loss leads to general fatigue and distress making them more susceptible to other infections. The wounds inflicted on the gill tissue by the parasites in their attempt to establish a strong foothold and/or because of their feeding are likely to become ' open gates ' (Kabata and Cousens, 1977) for secondary invaders, like fungi and some bacteria.

A consequence in gill infections by copepods is excessive mucus secretion by the host. This, in fact, is an effective defence mechanism of the host. However, as the region where it occurs is the gill, where necessarily a continuous flow of water is to be maintained, often this defence reaction turns against the wellbeing of the host itself by acting as a barrier to the respiratory current thereby lowering the respiratory efficiency of the gill. Besides, as mucus traps sand grains and debris there is every possibility of mechanical damage to the delicate gill tissue leading to further complications resulting from secondary infections.

In contrast, some of the copepods, like *Lernaeenicus hemirhamphi*, (which has progressed much along the path of parasitism) invading the body of *Hemirhamphus xanthopterus* and *H. far* are capable of inducing direct serious damages to the host. The cephalothorax of the parasite invariably penetrates a vital organ of the host having copious blood supply. That the parasite feeds on host blood is unequivocal (Natarajan and Nair, 1973). Coupled with this, the formation of an elaborate connective tissue cyst around the cephalothorax of the parasite, irrespective of the site where it is anchored, puts a good part, if not all, of the infected organ out of function. The anaemic changes and the depletion of energy reserves are, but unavoidable consequences of the infection.

Among the isopods encountered during the present study, both *Codonophilus hemirhamphi* and *Cymothoa eremita* are in fact, too large for the small buccal cavity of their host fish and hence, are sure to interfere with the feeding of the host. *Irona far* does not seem to inflict any serious direct damage to the host. However, the constant friction of the delicate gill filaments against the hard exoskeleton of the parasite, leads to erosion of the former and in turn, to reduction of respiratory surface area of the host, causing distress and consequent general weakness of the infected fish rendering them vulnerable to predation and/or other infections.

DISCUSSION

It is clear from the results of the present study that the metazoan parasite fauna of the fishes of the southwest coast of India is quite diversified ; the representatives of the major groups of metazoan parasites being represented in the thirteen species of fish examined. Copepoda formes the most diverse group represented by 17 different species and Acanthocephala the least, represented by a single species. Among trematodes, digeneans outnumber monogeneans both in number and in variety. The cestode fauna is constituted mainly by larval forms (plerocercoids), particularly in teleosts.

Considering the host fishes, the parasite fauna is seen to be the most diverse in *Saurida tumbil*: 13 different species of parasites being found in this host.

In the absence of sufficient information on the micro-ecology, specificity and the life-cycle of the parasites obtained, an attempt to draw positive conclusions on the observed differences in the parasite fauna of different hosts will prove itself premature and speculative at this stage. However, from the observations at least two facts emerge (i) that the metazoan parasite fauna of the fishes of this coast is rich both in number and in species and (ii) that it shows clear difference between teleosts and elasmobranchs, at least in regard to cestode parasites. In teleosts the cestode fauna is predominated by larval forms whereas in the latter it is mainly constituted by adults.

Considering the pathology of infection it may be generalised that in metazoan parasitic infections, histopathological changes in the host conform to a typical fibroplastic inflammatory reaction. The fibrous connective tissue of the host at and around the site of attack by the parasite proliferates either to encapasulate or to wall off the infecting element there by preventing it from causing serious damages. Concurrent with this encystment process, hypertrophy of mucous cells and infiltration of inflammatory cells at and round the site of infection also occur. This type of host reaction is especially evident when the parasites actually penetrate the host tissue.

It is also to be emphasised that majority, if not all, of metazoan parasites induces measurable changes in the peripheral blood and in the biochemical composition of the host. However, multiple infection of the same host by different species of parasites makes it a difficult job to find out which of the parasite species is the most harmful. Added to this is the fact that the occurrence of absolutely uninfected fish in nature is rather uncommon. These remain formidable barriers in the progress of fish pathology and one is more often compelled to label some of the parasites on a host as innocuous though it is unequivocal that 'every parasite living in or on a fish exerts some degree of harmful influence on its host' (Bauer, 1958).

The results of the present study on the haematological changes in infected fish do point to the fact that such studies are of diagnostic value as it is in the case of higher vertebrates in assessing the health of fishes. It has to be emphasised this connection that, future studies on the haematology of fish, in health and in disease, should pay due attention to all parameters that are analysed in clinical diagnosis of the diseases of higher vertebrates, and man, and not merely limit them to the enumeration of cell counts and haemoglobin content.

In parasitic diseases of fishes, it may be concluded from the present observations that, the sum total of the haematological changes in the diseased fish, is manifested as anaemia. Even in cases where the parasite is not a true blood feeder anaemic changes are evident suggesting that such changes can occur as a result of infection of such important organs as the liver (resulting in its malfunction) or because of the absorption by the parasite, of such essential factors as vitamin B_{12} etc., from the host's diet that will adversely affect haemopoiesis in general, or haemoglobin synthesis in particular, leading to anaemic changes.

The biochemical changes induced by parasites on the host fish are not only directly concerned with the well-being of the host itself, but are indirectly concerned with the reduction of the quality of fish as food for man. The general depletion of the basic energy reserves in infections is certain to weaken the affected fish rendering them more vulnerable to predation or to infections by other, more serious parasites. In both cases the ultimate result is the reduction of the quantity and quality of fish available to human consumption.

In conclusion, the importance of the studies of fish parasites and diseases has to be emphasised. All are aware of the fact that the people of our country are facing the threatening problem of protein-deficiency of diet. Only a meagre percentage of the population is privileged to have protein-rich food - not that the rest is denied of this facility, but that our annual production of animal protein for consumption, is far from satisfying the need of all. Besides, the cost of most of the common animal-protein sources like livestock, milk and egg is beyond the reach of the common man who is the real victim of protein-deficiency.

Fish is perhaps the cheapest, but the best animal protein available to man. However, our annual landings are insufficient to feed our protein-hungry people. The only solution to eradicate the mounting problem of protein-deficiency of the diet is to produce or make available as much protein-rich food as possible. Here aquaculture in general, and fish culture in particular, has a strategic role to play and culture fisheries has to become a major national effort. However, in such attempts a prerequisite is a detailed knowledge of the possible set backs including those from parasites and diseases. Even in the wild condition fish harbour a multitude of parasites, not to speak of when they are subjected to the 'stress of an unnatural environment' (Sindermann, 1970), in culture ponds, hatcheries and aquaria. It has been shown on many an occasion that massive fish culture programmes have met with catastrophies because of mass mortalities caused by parasites and diseases. Such a knowledge would enable the formulation of effective prophylactic/curative measures against information on fish parasites and diseases from a possible outbreak of parasites/diseases.

One more point to be clarified before concluding this paper is the question — why should we study the parasites/diseases of the fishes of our waters when we have extensive information on fish parasites and diseases from around the world? The fact that parasites and diseases common in one geographical area may be rare or absent altogether in another and that microhabitats within a host species of fish having cosmopolitan distribution may be occupied by different species of parasites, not only justify the need for local studies, but also demands it.

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