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Community ecology of the metazoan parasites of freshwater fishes of Kerala

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Abstract The prevalence and mean intensity of metazoan parasite infection, the community characteristics (richness index, dominance index, evenness index and Shannon index of diversity) and the qualitative similarity of the metazoan parasite fauna among the species and families of the fishes were determined of 13 fish species of freshwater fishes of Kerala belonging to seven families. The metazoan parasite fauna of this geographical area is very diverse; it consisted of 33 species of parasites belonging to seven major taxa: ten species of Monogenea, nine Digenea, two Cestoda, six Nematoda, three Acanthocephala, two Copepoda and one Isopoda. Prevalence of infection ranged from 32.9% (*Puntius vittatus*) to 87.1% (*Mystus oculatus*) and mean intensity from 3.8 (*Puntius vittatus*) to 27.6 (*Aplocheilus lineatus*). The infra- and component communities of parasites were somewhat characteristic. The dominance pattern of the major taxa was in the order Digenea > Nematoda > Monogenea = Acanthocephala > Cestoda = Copepoda > Isopoda. *Macropodus cupanus* harboured the richest fauna and *Puntius vittatus* had the least rich fauna. The parasite fauna of *A. lineatus* was the most heterogeneous and that of *M. cavasius*, the most homogeneous. The diversity of the parasite fauna was the greatest in *M. cavasius* and the least in *A. lineatus*. The parasite faunas of *A. lineatus* and *M. cupanus* and of *M. cavasius* and *M. oculatus* were similar. However, in spite of the taxonomic nearness and the similarity of the habits and habitats of the four species of cyprinids (*P. amphibius*, *P. filamentosus*, *P. sarana* and *P. vittatus*), their parasite fauna were qualitatively very dissimilar–of the seven species of parasites encountered in them only one was shared by the four host species. The cyprinid, *Rasbora daniconius*, had its own characteristic component community of parasites consisting of six species none of which was shared by the other four cyprinids. The richest parasite fauna was that of the family Cyprinidae followed by that of Channidae and the poorest of Belonidae. The most homogeneous parasite fauna was that of Bagridae and the most heterogeneous that of Cyprinodontidae. The parasite fauna of Cyprinodontidae and Belontidae were qualitatively very similar. The results indicate that the freshwater fishes of the southwest cost of India harbour a rich and diverse metazoan parasite fauna, which is as rich and diverse as that of the marine fishes of this area. The results also suggest that carnivorous/omnivorous fish species harbour richer and more heterogeneous component communities of parasites than herbivorous species implying that the feeding habits of fishes is a major factor deciding their parasite faunas.

Keywords Dominance index · Evenness index · Freshwater fish parasites · Jaccard index · Parasite community ecology · Richness index · Shannon index of diversity · Species overlap

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Introduction

Parasite fauna of marine fishes of the southwest coast of India is well studied (Natarajan 1975; Radhakrishnan and Nair 1980; Pillai 1985; Bijukumar 1996a, b; Santhosh

2001). But, no comparable information on freshwater fishes of the region is available. Marine fishes are generally supposed to harbour much more diverse and rich parasite fauna than freshwater fishes (Kinne 1985; Sindermann 1990; Rohde 1993). Parasite fauna of omnivorous/carnivorous fishes are reported to be richer and more diverse than that of herbivorous fishes (Moravec 1985; Zaman and Leong 1987a, b; Wierzbicka 1991). The present study was an attempt at bringing out the community characteristics of the metazoan parasite fauna of 13 species of freshwater fishes distributed in Kerala waters.

Materials and methods

Fortnightly collections of 13 species of fishes belonging to seven families were made by using cast nets, from Vellayani Lake, Killiayar River and Chackai canal, Trivandrum, Kerala (8°2′; 8°9′ N lat.; 76°6′; 77°4′ E long.) during the year 1990. Fresh fishes were examined by total parasitological dissection (Fernando et al. 1972; Kennedy 1979). The taxonomic positions, the location and the number of parasite in each fish and each location were recorded of parasites encountered in each fish. From the data community characteristics of the parasite fauna were determined based on the measures as suggested by Leong and Holmes (1981).

1. Prevalence of infection (P) = percentage of fish infected.
2. Mean intensity of infection (MI) = average number of parasites per infected fish.
3. Abundance (A) = percentage of each taxon of parasite per host species.
4. Proportion (P) = total No. of parasites in a host species (100 infected fishes)/total number of parasites from all host fishes, calculated as Total MI × 100/($\sum$Total MI × 100)
5. Dominance Value (DV) = No. of parasites in each major taxon in a host species or family/Total No. of parasites in that host species or family × 100).
6. Total number of parasites (N)
7. Number of species (S) and number of major taxonomic group (major taxa = K) of parasites.
8. Richness Index (RI) = $(S-1)/\log_e N$
9. Dominace Index (DI) = $\sum (DV_i/100)^2$
10. Evenness Index (EI) = (Homogeneity = Relative Diversity) = $H/\log_e$, where H = Shannon Index of Diversity
11. Shannon Index of Diversity = SI = H = $\{(n \log_e n) - (\sum f_i \log_e f_i)\}$, where, $n = \sum f_i$; f_i = DV of parasite taxa in a host species/family.
12. Jaccard Index of species overlap (J) = $\{(100\,c)/(a + b) - c\}$, where, a = No. of species of parasites in host A; b = No. of species of parasites in host B; c = No. of species of parasites shared by hosts A and B.

Results

The different species and families of fishes examined and the total number of fish examined in each species are shown in Table 1. The list of parasites and their distribution in host fishes are presented in Tables 2 and 3. The overall nature of metazoan parasitic infection in different species and families of freshwater fishes is given in Tables 4 and 5, respectively. The community characteristics of the parasite fauna in different species and families of fishes are presented in Tables 6 and 7, respectively. Parasite species overlap (= similarity of the parasite fauna) in different species and families fishes is given in Tables 8 and 9, respectively.

Metazoan parasites occurred in all the 13 species. Of the 2,634 fishes examined, 62.5% harboured metazoan parasites and the average number of parasites was 11.4 per fish. Prevalence of infection was the highest in *M. oculatus* (87.1%) and the lowest in *P. vittatus* (32.9%). On the whole, in the carnivorous and omnivorous fishes prevalence of infection was comparatively higher than in the predominantly herbivorous species. The highest MI of metazoan parasites was noted in *A. lineatus* (27.6) and the lowest in *P. vittatus* (3.8); the former a predominantly carnivore (particularly larvivore) and the latter a herbivore. As with prevalence, MI was also was slightly higher in the carnivorous species than in the herbivorous. Proportion of metazoan parasites registered the maximum in *A. lineatus* (0.2157) and the lowest in *P. vittatus* (0.0301) (Table 4).

Of the 13 species of fishes examined 84.6% harboured digeneans, whereas only 7.7% harboured isopods. The percentage occurrence of the other major taxa of metazoan parasites was, Monogenea = 53.8%, Cestoda and Copepoda = 15.4% each, Nematoda = 61.5% and Acanthocephala = 38.5%. The dominance pattern of the major taxa of metazoan parasites in freshwater fishes of this region was in the order, Digenea > Nematoda > Monogenea > Acanthocephala > Cestoda = Copepoda > Isopoda (Table 2). The most dominant group of parasites was Digenea (DV = 52.7%) and the least were Cestoda and Isopoda (DV = 0.03%) (Tables 2, 3, 4).

Results of the family-wise comparison of parasitic infection (Table 5) showed that the highest prevalence of metazoan parasitic infection was in Heteropneustidae (81.1%) and the lowest in Cyprinidae (50.5%). Prevalences of infection in the other six families were, Bagridae = 77.7%, Cyprinodontidae = 73.8%, Belonidae = 67.0%, Channnidae = 62.9% and Belontidae = 60.6%. The highest MI was noted in

Table 1 Species and families of freshwater fishes examined and the total number of fish examined in each species

Name of Host	Number examined	Family
Puntius amphibius (Valenciennes)	339	Cyprinidae
Puntius filamentosus (Valenciennes)	191	
Puntius sarana (Hamilton)	76	
Puntius vittatus Day	213	
Rasbora daniconius (Hamilton)	317	
Aplocheilus lineatus (Valenciennes)	240	Cyprinodontidae
Mystus cavasius (Hamilton)	174	Bagridae
Mystus oculatus (Valenciennes)	202	
Macropodus cupanus Cuvier	216	Belontidae
Heteropneustes fossilis (Bloch)	244	Heteropneustidae
Xenentodon cancila (Hamilton)	212	Belonidae
Channa gachua Hamilton	106	Channidae
Channa striata (Bloch)	104	
Total	2,634	

Cyprinodontidae (27.6) and the lowest in Belonidae (5.1). In the other families MI varied between 6.6 and 16.3. The highest proportion of metazoan parasites was recorded in Cyprinodontidae (0.3492) followed by Bagridae (0.2064) and Cyprinidae (0.1120). The lowest proportion was noted in Belonidae (0.0644). In Belontidae it was 0.0841, in Channidae, 0.0868 and in Heteropneustidae, 0.0972.

Community ecology of metazoan parasite fauna in different species of fishes

The results are shown in Table 6. Each host species had a characteristic assemblage or community of parasites, which differed in several respects among the host species. Of the 13 host species, three (*R. daniconius, M. cupanus* and *C. striatus*) harboured six parasite species each and *P. vittatus* harboured only one. In the other hosts species, the number of parasite species varied between two and five. In *M. oculatus* and *C. striatus* the parasite fauna was constituted by five major taxa of parasites (Monogenea, Digenea, Cestoda, Nematoda and Acanthocephala in the former and Digenea, Nematoda, Acanthocephala, Copepoda and Isopida in the latter).

The parasite fauna was the richest in *Macropodus cupanus* (RI = 0.7694), which harboured six species of parasites belonging to three genera, closely followed by *C. striata* (RI = 0.7535) and *R. daniconius* (RI = 0.7303) both with six species of parasites represented by five major taxa in the former and three in the latter. The least rich fauna was that of *P. vittatus* in which only one species of parasite (*Clinostomum* sp. metacercaria) was encountered. The parasite fauna of *A. lineatus* was the most unevenly distributed or the most heterogeneous (EI = 0.1449) and that of *M. cavasius* was the most homogeneous (EI = 0.8516) followed by that of *P. filamentosus* (EI = 0.7759).

Barring, *P. vittatus*, which harboured only one species of parasite, dominance index was the highest (0.9312) for the parasite fauna of *A. lineatus* in which digeneans were a very dominant component constituting 96.4% of the total number of parasites in this fish. DIs were comparatively high in *H. fossilis* (0.9201), *Xenentodon cancila* (0.8734) and *M. cupanus* (0.8447). In *H. fossilis* nematodes and in *M. cupanus* digeneans dominated in the parasite fauna. In *C. striata, M. oculatus* and *M. cavasius* DI recorded comparatively low values (0.3921, 0.3773 and 0.3525, respectively) and in these species the parasite faunas were comparatively homogeneous.

Diversity of parasite fauna was the greatest for *M. cavasius* (H = 1.1806). In this species the parasite fauna represented by four species of parasites belonging to four major taxa was somewhat homogeneously distributed (EI = 0.8516). Diversity of the parasite fauna was the lowest in *A. lineatus* (H = 0.1592) in which five species of parasites belonging to three major taxa were encountered and of these digeneans were highly dominant (DV = 96.4%) over the other groups. In *H. fossilis* also diversity of parasite fauna was comparatively low (H = 0.1916); in this species the parasite fauna was represented by four species belonging to three major taxa, of which nematodes were very dominant (DV = 95.9%).

Qualitative similarity of the parasite fauna of the host fishes (Table 8) showed that there was relatively high similarity between the parasite fauna of *A. lineatus* and *M. cupanus* (Jaccard index = 83.3) as also between those of *M. cavasius* and *M. oculatus* (Jaccard index = 80.0). Of the six species of parasites encountered in *A. lineatus* and *M. cupanus* five were shared by the two hosts. Similarly, out of the five species of parasites harboured by *M. cavasius* and *M. oculatus*, four were shared by them. Only relatively lesser similarity was noted in the parasite fauna of the cyprinids; even though seven species of parasites were encountered in them only one species was shared by them.

Community ecology of metazoan parasite fauna in different families of fishes

The highest prevalence of metazoan parasitic infection was in Heteropneustidae (81.1%) and the lowest in Cyprinidae (50.5%). However, the highest number of species of parasites was recorded in Cyprinidae (13 belonging to four major taxa) and the lowest in Belonidae (2). Channidae harboured nine species of parasites belonging to six major taxa and Belontidae, six species belonging to three major taxa. In Cyprinidae the parasite fauna was predominated by

Table 2 Distribution of metazoan parasites in 13 species of freshwater fishes of Kerala (*p* present)

Parasite species/group	Fish species												
	Puntius amphibius	*Puntius filamentosus*	*Puntius sarana*	*Puntius vittatus*	*Rasbora daniconius*	*Aplocheilus lineatus*	*Mystus cavasius*	*Mystus oculatus*	*Macropodus cupanus*	*Heteropneustes fossilis*	*Xenentodon cancila*	*Channa gachua*	*Channa striatus*
Monogena													
Ddactylogyrus cauveryi Tripathi			p										
D. daniconius Razia Beevi and Radhakrishnan					p								
D. arwetrabus Razia Beevi and Radhakrishnan			p										
Dactylogyroides macracanthus Tripathi		p											
D. gussevii Razia Beevi and Radhakrishnan	p												
Ancyrocephalus acqualis forma travencoriensis Razia Beevi and Radhakrishnan					p								
Neomuraytrema tengra Tripathi							p	p					
Haliotrema sp.											p		
Diplozoon indicum Dayal		p											
Neodiplozoon barbi Tripathi					p								
Digenea													
Clinostomum sp. 1 metacercaria	p	p	p	p									
Clinostomum sp. 2 metacercaria									p				
Clinostomum sp. 3 metacercaria												p	
Euclinostomum heterostomum Rudolphi												p	
Diplostomum metacercaria					p								
Neodiplostomum sp. Metacercaria						p			p				
Masenia fossilis Gupta										p			
Eumasenia moradabadensis Srivastava							p	p					
Acanthostomum sp.					p	p			p				
Cestoda													
Senga malayana Fernando and Furtado													p
Neogryporhynchus sp. Plerocercus								p					

Table 2 continued

Parasite species/group	Fish species												
	Puntius amphibius	*Puntius filamentosus*	*Puntius sarana*	*Puntius vittatus*	*Rasbora daniconius*	*Aplocheilus lineatus*	*Mystus cavasius*	*Mystus oculatus*	*Macropodus cupanus*	*Heteropneustes fossilis*	*Xenentodon cancila*	*Channa gachua*	*Channa striatus*
Nematoda													
Paracamallanus furtadoi Petter										p			
Paracamallanus sp.													p
Procamallanus sp.						p			p	p		p	
Spirocamallanus sp.							p	p					
Philometra lateolabracis (Yamaguti)											p		
Pseudocapillaria indica Moravec et al.												p	
Acantho-cephala													
Pallisentis nagpurensis Bhalerao					p	p			p	p			p
Arythmorhynchus platysomi George and Nadakkal						p			p				p
Copepoda													
Lamproglena krishnai Thomas and Hameed													p
Lernaea bengalensis Gnanamuthu	p												
Isopoda													
Alytropus typus M. Edwards													p

Table 3 Distribution of metazoan parasites in 7 families of freshwater fishes of Kerala (*p* present)

Parasite species/group	Fish family						
	Cyprinidae	Cyprinodontidae	Bagridae	Belontidae	Heteropneustidae	Belonidae	Channidae
Monogenea							
Ddactylogyrus cauveryi Tripathi	p						
D. daniconius Razia Beevi and Radhakrishnan	p						
D. arwetrabus Razia Beevi and Radhakrishnan	p						
Dactylogyroides macracanthus Tripathi	p						
D. gussevii Razia Beevi and Radhakrishnan	p						
Ancyrocephalus acqualis forma travencoriensis Razia Beevi and Radhakrishnan	p						
Neomuraytrema tengra Tripathit			p				
Haliotrema sp.						p	
Diplozoon indicum Dayal	p						
Neodiplozoon barbi Tripathi	p						
Digenea							
Clinostomum sp. 1 metacercaria	p						
Clinostomum sp. 2 metacercaria				p			
Clinostomum sp. 3 metacercaria							p
Euclinostomum heterostomum Rudolphi							p
Diplostomum metacercaria	p						
Neodiplostomum sp. Metacercaria		p		p			
Masenia fossilis Gupta					p		
Eumasenia moradabadensis Srivastava			p				
Acanthostomum sp.	p	p		p			
Cestoda							
Senga malayana Fernando and Furtado							p
Neogryporhynchus sp. Plerocercus			p				
Nematoda							
Paracamallanus furtadoi Petter					p		
Paracamallanus sp.							p
Procamallanus sp.		p		p	p		p
Spirocamallanus sp.			p				
Philometra lateolabracis (Yamaguti)						p	
Pseudocapillaria indica Moravec et al.							p
Acantho-cephala							
Pallisentis nagpurensis Bhalerao	p	p		p	p		p
Arythmorhynchus platysomi George and Nadakkal		p		p			p
Copepoda							
Lamproglena krishnai Thomas and Hameed							p
Lernaea bengalensis Gnanamuthu	p						
Isopoda							
Alytropus typus M. Edwards							p

monogeneans (eight species), whereas the most assorted fauna of parasites was in Channidae. Mean intensity recorded the highest in Cyprinodontidae (27.6) followed by Bagridae (16.3). Belontidae recorded the lowest MI (5.1). In the other families MI varied between 6.9 and 8.9 (Table 5).

Table 4 Prevalence (P = %), *MI* mean intensity, *A* abundance, *DV* dominance value and proportion of metazoan parasites in different species of freshwater fishes of Kerala

Fish species/Family	Number examined	Number infected	Number of parasites		Total	Monogenea	Digenea	Cestoda	Nematoda	Acantho-cephala	Copepoda	Isopoda	Proportion
Puntius amphibius	339	194	2,311	P	57.2	12.4	47.5				8.6		
				MI	11.9	9.2	11.7				1.4		0.0932
				A	6.8	1.1	5.6				0.1		
				DV	12.3	16.8	81.5				1.73		
P. filamentosus	191	81	446	P	42.4	33.5	24.1						
				MI	5.5	5.4	2.2						0.0431
				A	2.3	1.8	0.5						
				DV	2.4	77.1	22.9						
P. sarana	76	36	236	P	47.4	10.5	44.7						
				MI	6.6	5.6	5.6						0.0513
				A	3.1	0.6	2.5						
				DV	1.3	19.1	80.9						
P. vittatus	213	70	269	P	32.9	0.0	32.86						
				MI	3.8		3.84						0.0301
				A	1.3	0.0	1.26						
				DV	1.4	0.0	100.0						
Rasbora daniconius	317	193	1,816	P	60.9	17.7	51.4			9.8			
				MI	9.4	5.7	8.9			1.6			0.0736
				A	5.7	1.0	4.6			0.2			
				DV	9.7	17.6	79.7			2.7			
Aplocheilus lineatus	240	177	4,882	P	73.8		69.2		1.7	18.3			
				MI	27.6		28.4		1.5	3.8			0.2157
				A	20.3		19.6		0.0	0.7			
				DV	26.1		96.4		0.1	3.4			
Mystus cavasius	174	116	955	P	66.7	36.2	14.4		33.3	30.5			
				MI	8.2	7.7	2.4		3.8	3.7			0.0644
				A	5.5	2.8	0.3		1.3	1.1			
				DV	5.1	50.5	6.3		22.8	20.4			
M. oculatus	202	176	3,805	P	87.1	60.4	27.2	1.5	45.0	61.4			
				MI	21.6	17.1	6.0	1.7	6.0	6.8			0.1691
				A	18.8	10.3	1.6	0.0	2.7	4.2			
				DV	20.3	54.8	8.6	0.1	14.3	22.1			

Table 4 continued

Fish species/Family	Number examined	Number infected	Number of parasites		Total	Monogenea	Digenea	Cestoda	Nematoda	Acantho-cephala	Copepoda	Isopoda	Proportion
Macropodus cupanus	216	131	870	P	60.6		54.2		8.8	12.0			
				MI	6.6		6.8		1.7	1.5			0.0519
				A	4.0		3.7		0.1	0.2			
				DV	4.6		91.7		3.68	4.60			
Heteropneustes fossilis	244	198	1,521	P	81.1		1.6		79.9	8.2			
				MI	7.7		2.8		7.5	2.6			0.0601
				A	6.2		0.0		6.0	0.2			
				DV	8.1		0.7		95.9	3.4			
Xenentodon cancila	212	142	722	P	67.0	54.7			21.2				
				MI	5.1	5.8			1.1				0.0398
				A	3.4	3.2			0.2				
				DV	3.9	93.2			6.8				
Channa gachua	106	69	425	P	65.1		21.7		54.7				
				MI	6.2		3.7		5.9				0.0482
				A	4.0		0.8		3.2				
				DV	2.3		19.8		80.2				
C. striatus	104	63	480	P	60.6			1.0	24.0	44.2	33.7	2.88	
				MI	7.6			1.0	4.6	5.6	2.9	1.67	0.0596
				A	4.6			0.01	1.1	2.5	1.0	0.05	
				DV	2.6			0.2	24.0	54.0	20.8	1.04	
Total	2,634	1,646	1,8738	P	62.5	17.9	32.8	0.2	18.8	13.1	2.4	0.1	
				MI	11.4	9.2	11.4	1.5	5.6	4.7	2.2	1.7	
				A	7.1	1.6	3.8	0.002	1.0	0.6	0.1	0.002	
				DV		23.1	52.7	0.03	14.8	8.6	0.7	0.03	

Table 5 Prevalence (P = %), *MI* mean intensity, *A* abundance, *DV* dominance value and proportion of metazoan parasites in different families of freshwater fishes of Kerala

Fish species/family	Number examined	Number infected	Number of parasites		Total	Monogenea	Digenea	Cestoda	Nematoda	Acantho-cephala	Copepoda	Isopoda	Proportion
Cyprinidae	1136	574	5,078	P	50.5	15.0	41.7			2.7	2.6		
				MI	8.8	6.4	8.2			1.6	1.4		0.1120
				A	4.5	1.0	3.4			0.0	0.0		
				DV	27.1	21.6	76.7			0.96	0.8		
Cyprinodontidae	240	177	4,882	P	73.8								
				MI	27.6								0.3492
				A	20.3								
				DV	26.1								
Bagridae	376	292	4,760	P	77.7	49.2	21.3	0.8	39.6	47.1			
				MI	16.3	13.9	4.9	1.7	5.1	5.8			0.2064
				A	12.7	6.8	1.0	0.0	2.0	2.8			
				DV	25.4	53.9	8.2	0.1	16.0	21.7			
Belontidae	216	131	870	P	60.6								
				MI	6.6								0.0841
				A	4.0								
				DV	4.6								
Heteropneustidae	244	198	1,521	P	81.1								
				MI	7.7								0.0972
				A	6.2								
				DV	8.1								
Belonidae	212	142	722	P	67.0								
				MI	5.1								0.0644
				A	3.4								
				DV	3.9								
Channidae	210	132	905	P	62.9		11.0	0.5	39.52	21.9	16.7	1.4	
				MI	6.9		3.7	1.0	5.5	5.6	2.9	1.7	0.0868
				A	4.3		0.4	0.0	2.2	1.2	0.5	0.0	
				DV	4.8		9.3	0.1	50.4	28.6	11.0	0.6	
Total	2,634	1,646	18,738	P	62.5	17.9	32.8	0.2	18.8	13.1	2.4	0.1	
				MI	11.4	9.2	11.4	1.5	5.6	4.7	2.2	1.7	
				A	7.1	1.6	3.8	0.002	1.0	0.6	0.1	0.0	
				DV		23.1	52.7	0.03	14.8	8.6	0.7	0.0	

Table 6 Community characteristics of metazoan parasites of 13 species of freshwater fishes of Kerala

Parameters	Fish families/species																Grand total
	Cyprinidae						Cyprinodontidae	Bagridae			Belontidae	Heteropneustinidae	Belonidae	Channidae			
	Pa	Pf	Ps	Pv	Rd	Total	Al	Mc	Mo	Total	Mcu	Hf	Xc	Cg	Cs	Total	
Number examined	339	191	76	213	317	1136	240	174	202	376	216	244	212	106	104	210	2634
Number infected	194	81	36	70	193	574	177	116	176	292	131	198	142	69	63	132	1646
Total no. of parasites (N)	2,311	446	236	269	1816	5078	4882	955	3805	4760	870	1521	722	425	480	905	6513
No. of species of parasites (S)	3	3	3	1	6	14	5	4	5	5	6	4	2	4	6	10	33
No. of taxa of parasites (K)	3	2	2	1	3	4	3	4	5	5	3	3	2	2	5	6	7
Prevalence (%)	57.2	42.4	47.4	32.9	60.9	50.5	73.8	66.7	87.1	77.7	60.6	81.1	67.0	65.1	60.6	62.9	62.5
Mean intensity (MI)	11.9	5.5	6.6	3.8	9.4	8.8	27.6	8.2	21.6	16.3	6.6	7.7	5.1	6.2	7.6	6.9	4.0
Abundance (A)	6.8	2.3	3.1	1.3	5.7	4.5	20.3	5.5	18.8	12.7	4.0	6.2	3.4	4.0	4.6	4.3	2.5
Proportion of parasites	0.0932	0.0431	0.0513	0.0301	0.0736	0.1120	0.2157	0.0644	0.1691	0.1275	0.0519	0.0601	0.0398	0.0482	0.0596	0.0868	
Dominance index (DI)	0.6924	0.6472	0.6914	1.0000	0.6674	0.6345	0.9312	0.3525	0.3773	0.3707	0.8448	0.9201	0.8735	0.6828	0.3921	0.3566	
Richness index on S (RI)	0.2824	0.3169	0.3083	0	0.7303	1.9158	0.5049	0.4469	0.5209	0.5408	0.7694	0.4515	0.1605	0.4671	0.7535	1.3781	
Richness index on K (RI)	0.2824	0.1584	0.1542	0	0.2921	0.4421	0.2525	0.4469	0.5209	0.5408	0.3078	0.3010	0.1605	0.1557	0.6028	0.7656	
Evenness index on S (EI)	0.4885	0.7759	0.7029	0	0.5311	0.4456	0.1449	0.8516	0.7217	0.7270	0.3116	0.1744	0.3579	0.7172	0.6601	0.6718	
Shannon index (H)	0.5367	0.5378	0.4872	0	0.5834	0.6177	0.1592	1.1806	1.1615	1.1700	0.3423	0.1916	0.2481	0.4971	1.0624	1.2037	

Pa P. amphibius ,Pf *P. filamentosus,* Ps *P. sarana,* Pv *P. vittatus,* Rd *R. daniconius,* Al *A. lineatus,* Mc *M. cavasius,* Mo *M. oculatus,* Mcu *M. cupanus*, Hf *H. fossilis,* Xc *X. cancila,* Cg *C. gachua,* Cs *C. striata*

The richest parasite fauna was that of Cyprinidae (RI = 1.9158) followed by that of Channidae (RI = 1.3781) (Table 7). In Cyprinidae 13 species of parasites representing four major taxa and in Channidae nine species representing six major taxa occurred. RI was 0.7694 in Belontidae (six species in three major taxa) and it was the lowest (0.1605) in Belonidae (two species belonging to two major taxa). Dominance index recorded high for Cyprinodontidae (0.9312), Heteropneustidae (0.9201), Belonidae (0.8735) and Belontidae (0.8448). In these cases Digenea (DV = 96.4%), Nematoda (DV = 95.7%), Monogenea (DV = 93.2%) and Digenea (DV = 91.7%) respectively dominated over the other taxa of parasites. The parasite fauna of Bagridae was the most homogeneous (EI = 0.7270) and of Cyprinodontidae, the most heterogeneous (EI = 0.1449). Diversity of parasite fauna war the greatest in Channidae (H = 1.2037). That of Bagridae was also high (H = 1.1700). Both host families had somewhat homogeneous parasite faunas, that of Bagridae being more evenly distributed than of Channidae and in both none of the parasite taxa being overly dominant. The lowest diversity index was recorded for Cyprinodontidae (H = 0.1592). That of Heteropneustidae was also low (H = 0.1916). In both cases the parasite assemblages were very heterogeneous (EI = 0.1449 and 0.1744, respectively) and they were dominated by Digenea (DI = 0.9312) and Nematoda (DI = 0.9201), respectively (Table 7).

Analysis of parasite species overlap in different host families (Table 9) showed that the parasite species were qualitatively very similar in Cyprinodontidae and Belontidae (Jaccard index = 83.3). Of the 11 species of parasites recorded from these two host families, five were shared by them.

Discussion

Overall nature of parasitic infections

Interspecific and interfamilial comparisons of metazoan parasitic fauna revealed that both prevalence and mean intensity were higher in carnivorous/omnivorous species/families indicating that feeding habit of the host is significant factor in determining the nature of parasitic faunas in them. As noted by Bibby (1972), Rampus (1975), Evans (1977), Lian and Leong (1979), Moravec (1985), Zaman and Leong (1987a, b) and Wierzbicka (1991), carnivorous/omnivorous species of fishes are more prone to parasitic infections as they stand higher chances of acquiring parasites, particularly heteroxenous forms than the herbivorous forms, which because of the restriction in food, do not have the chances of acquiring more infections nor more varied fauna of parasites.

Community ecology of metazoan parasite fauna

Kennedy et al. (1986) are of the view that compared to the parasite fauna of birds and mammals, that of freshwater fishes is poor and less diverse and that species richness and mean intensity of parasites of freshwater fishes is less than that of marine fishes. The present results corroborate both these contentions as only 33 species of metazoan parasites were encountered in 13 species of freshwater fishes as against 65 species from 13 species of marine fishes (Radhakrishnan and Nair 1980) and 50 from eight species of mullets (Santhosh 2001) from the same geographical area. Yet, such a generalisation may not always hold good as Bijukumar (1996a) found only 50 species of metazoan

Table 7 Community characteristics of metazoan parasites of seven families of freshwater fishes of Kerala

Parameters	Cyprinidae	Cyprino-dontidae	Bagridae	Belontidae	Heteropneu-stidae	Belonidae	Channidae	Total
Number examined	1136	240	376	216	244	212	210	2,634
Number infected	574	177	292	131	198	142	132	1,646
Total No. of parasites (N)	5,078	4,882	4,760	870	1,521	722	905	6,513
No. of species of parasites (S)	14	5	5	6	4	2	10	33
No. of taxa of parasites (K)	4	3	5	3	3	2	6	7
Prevalence (%)	50.5	73.8	77.7	60.6	81.1	67.0	62.9	62.5
Mean intensity (MI)	8.8	27.6	16.3	6.6	7.7	5.1	6.9	4.0
Abundance (A)	4.5	20.3	12.7	4.0	6.2	3.4	4.3	2.5
Proportion of parasites	0.1120	0.3492	0.2064	0.0841	0.0972	0.0644	0.0868	
Dominance index (DI)	0.6345	0.9312	0.3707	0.8448	0.9201	0.8735	0.3566	
Richness index on S (RI)	1.9158	0.5049	0.5408	0.7694	0.4515	0.1605	1.3781	
Richness index on K (RI)	0.4421	0.2525	0.5408	0.3078	0.3010	0.1605	0.7656	
Evenness index on S (EI)	0.4456	0.1449	0.7270	0.3116	0.1744	0.3579	0.6718	
Shannon index K(H)	0.6177	0.1592	1.1700	0.3423	0.1916	0.2481	1.2037	

Table 8 Parasite species overlap in different species of freshwater fishes of Kerala

Fish species		S	Pf	Ps	Pv	Rd	Al	Mc	Mo	Mcu	Hf	Xc	Cg	Cs
Puntius amphibius	(Pa)	3	1	1	1	0	0	0	0	0	0	0	0	0
			20.0	**20.0**	**33.3**									
P. filamentosus	(Pf)	3		1	1	0	0	0	0	0	0	0	0	0
				20.0	**33.3**									
P. sarana	(Ps)	3			1	0	0	0	0	0	0	0	0	0
					33.3									
P. vittatus	(Pv)	1				0	0	0	0	0	0	0	0	0
Rasbora daniconius	(Rd)	6					2	0	0	2	1	0	0	1
							22.2			**20.0**	**11.1**			**9.1**
Aplocheilus lineatus	(Al)	5						0	0	5	2	0	1	2
										83.3	**28.6**		**12.5**	**22.2**
Mystus cavasius	(Mc)	4							4	0	0	0	0	0
									80.0					
M. oculatus	(Mo)	5								0	0	0	0	0
Macropodus cupanus	(Mcu)	6								0	2	0	1	0
											25.0		**11.1**	
Heteropneustes fossilis	(Hf)	4									0	0	1	1
													14.3	**11.1**
Xenentodon cancila	(Xc)	2										0	0	0
Channa gachua	(Cg)	4											0	0
C. striata	(Cs)	6												0

Bold values are indicate results

Table 9 Parasite species overlap in different families of freshwater fishes of Kerala

Fish family		S	Cyp	Cyd	Bag	Bet	Het	Ben	Cha
Cyprinidae	(Cyp)	13		2	0	2	1	0	1
				12.5		**11.8**	**6.2**		**4.5**
Cyprinodontidae	(Cyd)	5			0	5	2	0	3
						83.3	**28.6**		**25.0**
Bagridae	(Bag)	5					0	0	0
Belontidae	(Bet)	6					2	0	3
							25.0		**23.1**
Heteropneustidae	(Het)	4							2
									16.7
Belonidae	(Ben)	2							
Channidae	(Cha)	10							

Bold values are indicate results

parasites in 21 species of marine flatfishes of the same region. It is to be noted in this context that the compound community of parasites (= local parasite fauna) is influenced by several factors and there could be even temporal differences in the nature of the compound communities (Holmes 1990). Further, there is evidence to show that the parasite communities of freshwater fishes are basically stochastic assemblages determined by events like chance introduction, colonization and extinction of parasites in a given region (Esch et al. 1988; Hartvigsen and Kennedy 1993; Kennedy 1993).

Carnivorous forms such as *Channa* spp., *M. cupanus*, *Mystus* spp. and *H. fossilis* harboured richer parasite faunas than the predominantly herbivorous forms. Moreover, the distribution of parasite species was somewhat more homogeneous in carnivorous forms than in herbivorous. Diversity index of parasite species was also comparatively higher in carnivorous forms than in herbivores. But results obtained for *R. daniconius*, a herbivore and *X. cancila* a carnivore, betray the general conclusions drawn above, the reasons for which remain elusive. However, since many other factors other than the feeding habit of the hosts are involved in deciding the nature of the parasite fauna of fishes, the results obtained for *R. daniconius* and *X. cancila* do not overrule the significant relation between feeding habit and nature parasite fauna of fishes.

Marine fishes generally have rich parasitic helminth communities (Holmes 1990; Rohde 1993; Thoney 1993). In conformity with this Radhakrishnan and Nair (1980) found that about 58% of the parasites in the marine fishes they examined were helminths and Bijukumar (1996a) found 75% of the parasites in flatfishes to be helminths. However, in mullets of Kerala waters the proportion of helminth parasites is only 42% (Santhosh 2001). The present results however show that in freshwater fishes also

helminth parasite fauna is very dominant possibly even more than that in marine fishes; in the present study of the 33 parasites met with 30 (about 91%) were helminths.

Qualitative similarity of parasite fauna

Qualitative similarity of the parasite fauna has been very marked for the two herbivorous species, *A. lineatus* and *M. cupanus* and for the two bagrids, *M. cavasius* and *M. oculatus*, lending support to the fact that the feeding habit of the host species is a very significant factor in deciding the parasite fauna of the hosts. However, there has been no similarity between the parasite fauna of the channids, *C. striata* and *C. gachua*. Similarly, only very little similarity was recorded for the parasite faunas of the four cyprinids, *P. amphibius, P. filamentosus, P. sarana and P. vittatus*, and none of the parasites of the cyprinid, *R. daniconius* was shared by the other four. The reasons for the observed dissimilarity of the parasite fauna of closely allied hosts species is beyond comprehension. Bijukumar (1996b), who also reported on a similar situation in respect of *Etroplus suratensis* and *E. maculatus*, two closely allied Asian cichlids, in which also the metazoan parasite communities differed considerably in spite of the phylogenetic closeness of the two, their similar habits and habitats, attributed it to the interspecific differences inherent in parasitism. The fundamental stochastic nature of the component parasite communities of freshwater fishes might also have contributed to this end.

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