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RESEARCH ARTICLE

COMMUNITY ECOLOGY OF METAZOAN PARASITES OF FRESHWATER FISHES OF RIVER GODAVARI, RAJAHMUNDRY, ANDHRA PRADESH, INDIA

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ABSTRACT

The current survey is the primary documentation of the metazoan parasite fauna of freshwater fishes of River Godavari, Andhra Pradesh state. The study was conducted for a period of four years i.e. 2005 to 2009. The Prevalence, mean intensity and mean abundance of metazoan parasitic infection and different community characteristics, along with the qualitative correlation of metazoan parasites among species and families of the 20 freshwater fishes belonging to thirteen families of River Godavari, Rajahmundry, Andhra Pradesh were determined. Metazoan parasite fauna of this geographical area is much diversified with 62 species of parasites belonging to 7 major taxa: eight species of monogeneans, 28 digenea of which 20 adult digeneans and 8 larval trematodes, 7 cestodes, 11 copepods, 6 acanthocephalans, 1 nematode and 1 Isopod. Prevalence of infection ranged from 77.5% (*M. armatus*) to 4.4% (*Sperata seenghala*) and mean intensity from 89.3 (*M. armatus*) to 1.0 (*Sperata seenghala*). The infra and component communities of parasites were somewhat distinctive/ peculiar. The dominance pattern of the major taxa was in the order Digenea > Copepoda > Monogenea > Cestoda > Acanthocephalans > Nematoda = Isopod. Richest parasite fauna (n=12) was observed in *Mastacembelus armatus* followed by *Clarias batrachus* (n=10). The parasite fauna of *C.batrachus* and *M.armatus* was the most heterogenous with four and six parasitic groups respectively and that of *L.rohita*, the most homogenous with only two parasitic groups. The diversity of parasite fauna was the greatest in *Mastacembelus armatus* and least in *Cyprinus carpio, Heteropneutus fossilis, Notopterus notopterus, Nandus nandus, Sperata seenghala* and *M. pancalus*. The parasite faunas of *M.vittatus* and *M.cavasius* were very similar as both the hosts shared 5 species in common; *C.punctatus* and *C.batrachus* shared only two species in common. However, in spite of taxonomic nearness and the similarity of habits and habitats of 4 species of cyprinids (*C.catla*, *C.mrigiala*, *L.rohita* and *C.carpio*), their parasite fauna were qualitatively dissimilar of the 5 species of parasites encountered in them only 2 species was shared by the 2 host species. Similarly, *M.armatus* and *M.aculeatus* showed dissimilar parasite fauna with only 3 species shared in common by the two hosts. The cyprinid, *Cyprinus carpio* had its own characterstic component community of parasites consisting of only one species which was not shared by the the other three cyprinids. Similarly, the two mastacembelid species, *M.armatus* and *M.panclaus* had their own characterstic component communities and their parasitic communities were quite dissimilar. The richest parasite fauna was that of the family Mastacembelidae (n=17) followed by Bagridae and Clariidae and the poorest of Heteropneustidae, Nandidae and Notopteridae. The most homogenous parasite fauna was that of Clariidae and the most heterogenous parasite fauna was that of Cyprinidae. The results specify that the freshwater fishes of River Godavari also harbour a rich and diverse metazoan parasite fauna but not as rich and diverse as that of the marine counterparts from this area. The results also put forward that carnivorous/omnivorous fish species harbour richer and more heterogeneous component communities of parasites than herbivorous species implying the role of the feeding habits as a major deciding factor for the parasite fauna of fishes.

Key words: Godavari River, Freshwater fish parasites, Dominance index, Evenness index, Jaccard index, Richness index, Shannon diversity index, Species overlap, Parasite community ecology

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INTRODUCTION

Fishes are the most numerous vertebrates living on this earth and constitute slightly more than one-half of total number of approximately 54,711 recognized living vertebrate species, of which an estimated 27,977 species are described as valid species of fishes (Nelson, 2006). Of this about 48% survive in freshwaters that represent just 0.01% of the earth's water.

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Freshwater fish diversity is erratically distributed on this planet. Fishes are one of the crucial factors in building the economy of many nations as they have been an unwavering item in the diet of many people. Biodiversity is very crucial for stabilization of ecosystem and safeguard of overall environmental quality for understanding intrinsic significance of all species on the earth (Ehrlich and Wilson, 1991). Fish biodiversity of river essentially signifies the icthyo-faunal diversity and their abundance. River conserves a rich variety of fish species which support to the commercial fisheries. India is one of the mega biodiversity countries in the world and

occupies the ninth position in terms of freshwater mega biodiversity (Miltermeier *et al.,* 1997). The Indian fish population represents 11.72% of species, 23.96% of genera, 57% of families and 80% of the global fishes. Of the so far listed 2200 species, 73 (3.32%) fit in to the cold freshwater regime, 544 (24.73%) to the warm fresh waters realm, 143 (6.50%) to the brackish waters and 1440 (65.45%) to the marine ecosystem. Globally, there are about 450 families of freshwater fishes and roughly 40 are represented in India (warm freshwater species). About 25 of these families contain commercially important species. The most important warm water species are: *Bagarius bagarius, Catla catla, Channa marulius, C. punctatus, C. striatus, Cirrhinus mrigala, Clarias batrachus, Heteropneustes fossilis, Labeo bata, L. calbasu, L. rohita, Aorichthys seenghala, Notopterus chitala, N. notopterus, Pangasius pangasius, Rita rita, Wallago attu.* Cyprinids (family: Cyprinidae), Live fish (family: Anabantidae, Clariidae, Channidae, Heteropneustidae), Cat fish (family: Bagridae, Silurdae, Schilbeidae), Clupeids (family: Clupeidae), Mullets (family: Mugilidae), featherbacks (family: Notopteridae), Loaches (family: Cobitidae), Eels (family: Mastacembelidae), Glass fishes (family: Chandidae) and Gobies (family: Gobiidae) are the major groups of fresh water fishes found in India. However, an important segment of the freshwater fish production in India is still based on the yield from wild population (Sarkar *et al.,* 2008). Parasites are a major threat to both freshwater and marine fishes of tropical regions (Iyaji and Eyo, 2008; Bichi and Dawaki, 2010 and Ekanem *et al.,* 2011). They represent themselves as a key restraining factor to the growth of farmed fish (Jalali, 1997 and Bichi and Yelwa, 2010). They play a crucial role in depreciation of nutrients (Hassan *et al.,* 2010 and Landfear, 2011); discrepancy of host biology and behaviour (Lafferty, 2008; Poulin, 2010 and Hart, 2011); declining the host immunity and induce blindness in host (Klein, 2003, Echi *et al.,* 2009a, b and Moore, 2013); attenuation of growth and fecundity, escalating mortality and morbidity (Chylinski *et al.,* 2009) and they also cause mechanical damage based on number and site of infection (Iwanowicz, 2011; Siquier *et al.,* 2009). Moreover, parasites may also regulate host population dynamics and influence community structure (Marcogliese, 2004; Hatcher *et al.,* 2006); Wood *et al.,* 2007; Vignon and Sasal, 2010 and Stenkewitz *et al.,* 2016).

Parasitology is an ever ending thrust area in the fishery research. The host-parasite relations are quite exceptional as among the two organisms, it is only the parasites that are benefited while the host suffers. Several parasitologists of national and international status contributed the commendable information on the ecological aspects of freshwater fishes (Dogiel, 1964; Holmes,1973; Kennedy, 1976, 1990; William and Jones, 1994; Khalil and Polling, 1997; Madhavi and Sairam, 2000; Nelson and Dick, 2002; Johnson *et al.,* 2004; Dhole *et al.,* 2010; Alves and Luque 2001Takemoto *et al.,* 2005, Avenant-Oldewage and Knight, 2008; Mwita and Nkwengulila, 2008; Khalil *et al.,* 2014; Omeji *et al.,* 2014; Gudivada *et al.,* 2017).

River Godavari is highly distinguished for its energetic environment, rich nutrients, high productivity and potential field to carry fishery research (Selvaraj, 2000). Preceding surveys from River Godavari have focused mainly on Icthyo faunal diversity and taxonomy (Babu Rao, 1976; Dutta and Reddy, 1979; Murthy, 2002; Rajyalakshmi and Narayana Rao, 1969; Reddy and Reddy, 1981; Krishna Prasad *et al.,* 2012, Laxmiappa *et al.,* 2015). At present, very few records of parasitic helminths in the study area were documented (Vankara *et al.,* 2011; Vankara and Chikkam, 2009, 2010, 2015; Pawar *et al.,* 2016). The present study was an attempt to carry out the community characteristics of the metazoan parasite fauna of 20 species of freshwater fish of River Godavari, Rajahmundry, Andhra Pradesh which would definitely add an informative data in the field of fishery research.

Study Area

Godavari River is known for its lively environment, enriched by the nutrients proved to be a highly productive and prospective field to accomplish fishery research and fishing operations. The catchment area of the river has been estimated as 290,600 square kilometers. It is the second longest river in India and about 1,450 km (900 miles) long rising at Trimbakeshwar, near Nasik in Maharashtra around 380 km distance from the Arabian Sea, but flows southeast across south-central India through the states of Madhya Pradesh, Karnataka, Orissa and Andhra Pradesh, and joins Bay of Bengal. The river splits into two streams forming a very fertile delta at Rajahmundry (80 km from the coast). It is a seasonal river which widens during monsoons and dries during the summers. Godavari River has many tributaries such as Indravati River, Manjira, Bindusara and Sarbari and some important urban centers on its banks such as Bhadrachalam, Rajahmundry and Narsapur (AP flood situation report, 2005, Godavari basin report, 2014 and Dakshina Ganga, 2015) (Fig.1).

MATERIALS AND METHODS

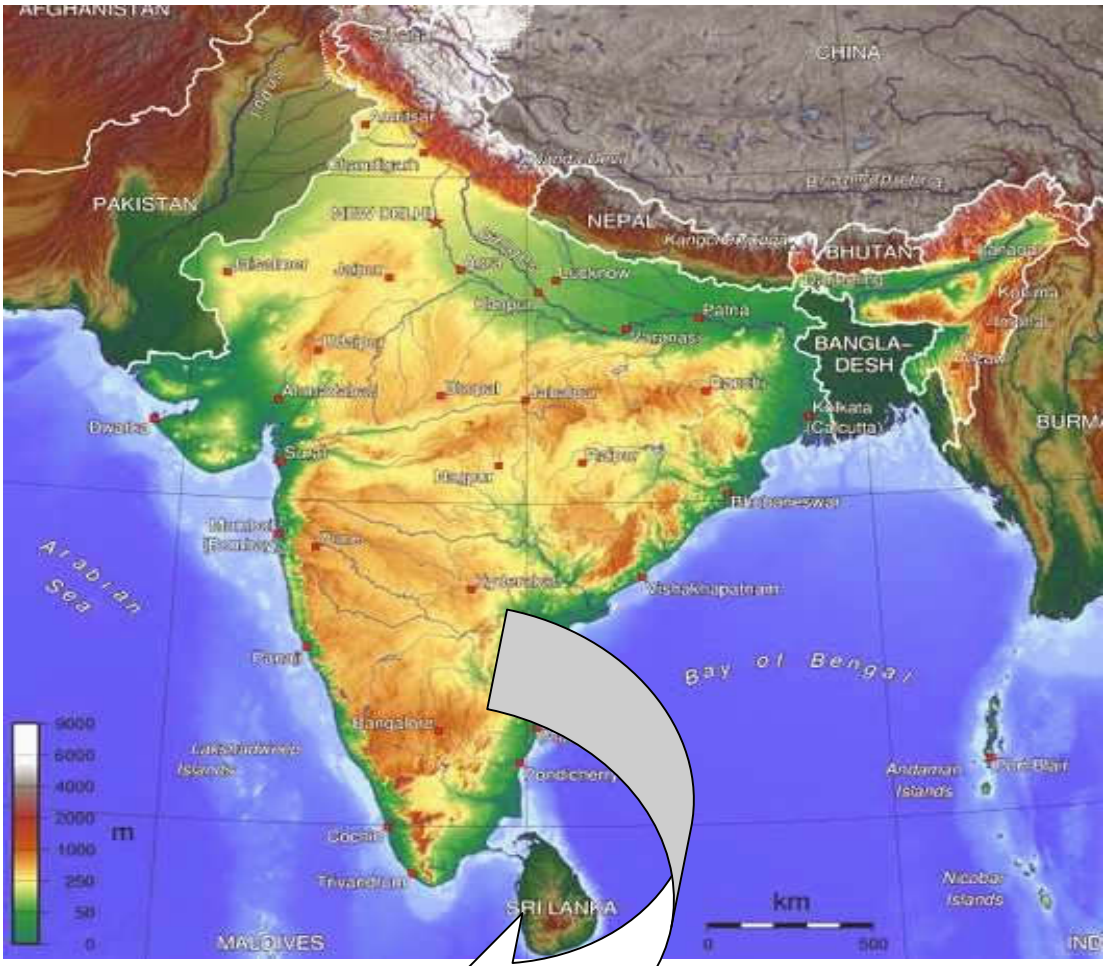
Fish Collection and Identification:

Fishes were collected from the River Godavari and various fish markets in and around the river in different seasons by using different types of 'Nets and Gears' with the help of local fishermen. Fishes caught were thoroughly washed, photographed in fresh condition and preserved in 9-10% formalin solution (Jayaram, 1999). For larger fishes an incision on the abdomen was done and the gut contents were removed before preservation. The collections were made once in a month from 2005 to 2009. The fishes were identified with help of standard books (Talwar and Jhingran, 1991, Jayaram, 1999 and Nath and Dey, 2000).

Parasitofauna analysis

External surface of the fish was keenly examined using a hand lens for ectoparasitic species and crustaceans. Smear of scrapings from the skin, fins and gills were also examined for ectoparasites. The fish were sectioned and the alimentary canal, liver, kidney, swim bladder and spleen examined for endoparasites. The excised gastrointestinal tract was carefully sectioned into portions such as oesophagus, intestine and rectum and each portion was then cut open, washed in Petri dish with 0.1% sodium chloride solution and examined thoroughly for the endoparasites namely, digeneans, cestodes, nematodes and acanthocephalans. These endoparasites were collected and preserved in A.F.A (Alcohol-85 ml, Formalin-10 ml and Acetic acid-5 ml) which acts as an idyllic fixative for the whole mount preparations and processed for further studies.

Fig. 1a: Geographical map of India showing Godavari river flowing Andhra Pradesh state



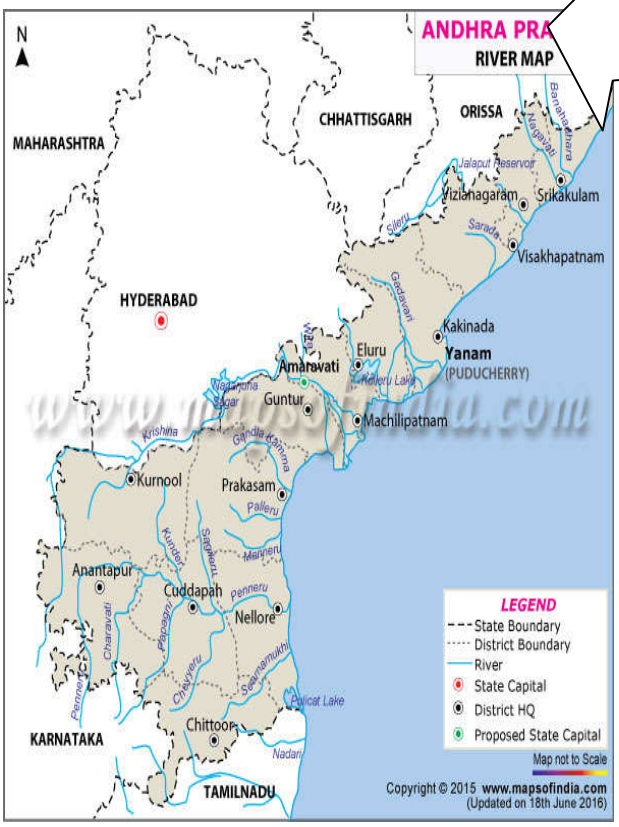


Fig. 1b. Andhra Pradesh River map

Fig. 1c. River Godavari

Table 1. List of host fish species and families examined and number of fish infected during the study period, May 2007 - June 2009 from River Godavari, Rajahmundry

Name of the host	No. of fish examined	No. of fish infected	Families
1.Anabas oligolepis (Bleeker)	102	25	Anabantidae
2. *Sperata seenghala* (Skyes)	68	3	Bagridae
3. *Mystus vittatus* (Bloch)	116	70	Bagridae
4. *Mystus cavasius* (Bloch)	94	64	Bagridae
5. *Belone (Xenentodon) cancila* (Ham)	185	143	Belonidae
6. *Clarias batrachus* (Linnaeus)	108	70	Clariidae
7. *Barbus Sp.*	85	26	Cyprinidae
8. *Catla catla* (Hamilton)	198	58	Cyprinidae
9. *Cyprinus carpio* (Linnaeus)	65	10	Cyprinidae
10. *Labeo rohita* (Hamilton)	82	30	Cyprinidae
11. *Glossogobius giurus* (Hamilton)	99	30	Gobiidae
12. *Heteropneustus fossilis* (Bloch)	85	20	Heteropneustidae
13. *Macrognathus aculeatus* (Bloch)	561	386	Mastacembelidae
14. *Mastacembelus armatus* (Lacepede)	494	383	Mastacembelidae
15. *Mastacembelus pancalus* (Hamilton)	206	103	Mastacembelidae
16. *Nandus nandus* (Hamilton)	87	10	Nandidae
17. *Notopterus notopterus* (Pallas)	58	3	Notopteridae
18. *Channa punctatus* (Bloch)	252	132	Channidae
19. *Wallago attu* (Schneider)	35	20	Siluridae
20. *Bagarius bagarius* (Hamilton)	34	13	Sisoridae
Total	3014	1599	

Trematode cysts from the muscle were manually teased to release the metacercariae, which were fixed in hot alcohol-formal-acetate (AFA) and preserved in 70% ethyl alcohol. Digenean trematode metacercariae were stained in Haematoxylin and Eosin (Paperna, 1996). Figures were drawn with the aid of drawing tube attachment and measurements were taken with the aid of an ocular micrometer. Measurements are given in millimetres unless otherwise mentioned. Microphotographs were taken and scale is provided accordingly. Voucher specimens of fish and parasites were deposited in the Department of Zoology, Andhra University, Andhra pradesh, India.

Data analysis

Different biostatistical factors like prevalence, mean intensity, mean abundance, dominance value, proportion and dominance index were calculated for total parasites, parasitic groups and also for individual parasitic genus were applied for qualitative and quantitative analysis of the data. Various biostatistical books by Sundara Rao and Richard (1996), Daniel (1998), Sokal and Rohlf (2000) and formulae from Leong and Holmes (1981) were followed for statistical analysis.

1. Prevalence of infection (P) = Percentage of fish infected
2. Mean intensity of infection (MI) = average number of parasite 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 parasite from all host fishes, calculated as Total MI × 100/(Σ 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. Dominance index (DI) = $\Sigma\ (DV_i/100)^2$
10. Evenness Index (EI) = (Homogeneity = Relative Diversity) = $H/\log_e$, where H = Shannon Index of Diversity
11. Shannon Index of Diversity = SI = H = $\{(n\log_e n)-(\Sigma f_i \log_e f_i)\}$, where $n = \Sigma f_i$; f_i = DV of parasite taxa in a host species/family
12. Jaccard Index of species overlap (J) = {(100c)/(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, infected and the total number of fish examined and infected in each species are shown in Table 1. The list of parasites and their distribution in host fishes and families are presented in Tables 2, 3 and 4. The overall nature of metazoan parasitic infection in different species and families of freshwater fishes is given in Tables 5 and 6 respectively. The community characteristics of the parasite fauna in different species and families of fishes are presented in Tables 7 and 8 respectively. Parasite species overlap (= similarity of the parasite fauna) in different species and families of fishes is given in Tables 9 and 10 respectively. Metazoan parasites occurred in all the 20 species of fishes. Of the 3014 fishes examined, 53.1% harboured metazoan parasites and the average number of parasites was 15.7 per fish. Prevalence of infection was the highest in *M. armatus* (77.5%) and the lowest in *Sperata seenghala* (4.4%). 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 *M. armatus* (89.3) and the lowest in *Sperata seenghala* (1.00); the former a predominantly carnivore (particularly larvivore) and the latter a predatory. As with prevalence, MI was also slightly higher in the carnivorous species than in the herbivorous. Proportion of metazoan parasites registered the maximum in *M. armatus* (0.54) and *M. aculeatus* (0.160) and the least in *S.seenghala* (0.006), *Glossogobius giurus* (0.0068) and *Bagarius bagarius* (0.0069) (Table-5). Of the 20 species of fishes infected, digeneans (88.2%) dominated the parasitic communities of these fishes, followed by monogeneans (6.92%), Copepods (2.25%), cestodes 91.54) and rest of the other groups showed less than 1 %.

Table 2. List of parasites collected

Name of fish	Name of the parasites	No. of Parasites Collected
1. *Anabas oligolepis* (Bleeker)	*Neascus* Type-I	2
	Allocreadium handiai Pande, 1937	8
	Trianchoratus kearni Agrawal & Bhatnagar,1994	38
2. *Bagarius bagarius* (Hamilton)	*Phyllodistomum tripathii* Motwani & Srivastava,1959	10
	Proteocephalus vitellaris Verma, 1926	5
3. *Barbus Sp.*	Metacercaria *Clinostomum gideoni* Bhalerao, 1942	24
	Lernaea cyprinacea Linnaeus, 1758	9
4. *Belone cancila*(Ham)	*Neascus* type-I	145
	Prosorhynchoides karvei (Dies, 1885) Nicoll, 1914	355
	Phyllodistomum tripathii Motwani & Srivastava,1959	174
	Xenentocleidus xenentodoni (Jain, 1959) Tripathi *et al*., 2006	20
5. *Catla catla* (Hamilton)	*Paradactylogyrus catalius* Thapar, 1948	67
	Lernaea cyprinacea Linnaeus, 1758	3
6. *Channa punctatus* (Bloch)	*Genarchopsis goppo* Ozaki, 1925	188
	Allocreadium handiai Pande, 1937	65
	Metacercaria *Euclinostomum heterostomum* (Rud., 1809) Travassos,1928	7
	Senga visakhapatnamensis Ramadevi & Rao, 1974	12
	Pallisentis ophiocephali (Thapar, 1930) Bayliss, 1933	133
	Lamproglena chinensis Yu, 1937	2
	Lernaea bengalensis Gnanamuthu, 1951	38
7. *Clarias batrachus* (Linnaeus)	*Allocreadium handiai* Pande, 1937	25
	*Orientocreadium batrachoides*Tubangui, 1931	79
	Emoletpalea proteopora Thomas, 1958	2
	Phyllodistomum batrachii n. sp.	2
	Astiotrema reniferum (Looss, 1898) Stossich, 1904	2
	Lytocestus indicus (Moghe, 1925) Yamaguti, 1959	25
	Lytocestus birmanicus Lynsdale, 1956	4
	Lytocestus longicollis Rama Devi, 1973	3
	Juvenile-Centrorhynchus batrachus Das,1952	1
	Lamproglena chinensis Yu, 1937	5
8. *Cyprinus carpio* (Linnaeus)	*Asymphylodora tincae* Modeer, 1970	13
9. *Glossogobius giurus* (Hamilton)	*Phyllodistomum parorchium* Jaiswal, 1957	3
	Tetracotyle glossogobi Chakrabarti, 1970	3
	Opecoelus beliyai (Pande, 1937) AkenÓva, 2007	22
	Allocreadium fasciatusi kakaji, 1959	2
	Copepodid-VI *of Lernaea sp.*	3
	Pallisentis ophiocephali (Thapar, 1930) Bayliss, 1933	1
10. *Heteropneustus fossilis* (Bloch)	*Clinostomum dasi* Bhalerao, 1942	33
11.*Labeo rohita* (Hamilton)	*Paradactylogyrus catalius* Thapar, 1948	120
	Argulus siamensis Wilson, 1914	85
12. *Mystus vittatus* (Bloch)	*Haplorchoides macrones* (Dayal, 1949) Yamaguti, 1958	88
	Metacercaria *Isoparorchis hypselobagri* Billet, 1898.	13
	Bifurcohaptor indicus Jain, 1958	33
	Thaparocleidus tengra (Tripathii, 1959) Lim, 1996	107
	Raosentis podderi Datta, 1947	19
	Raosentis thapari Rai,1967	13
	Raosentis godavarensis Anu prasanna & Vijayalakshmi, 2009	3
	Argulus striatus Cunnington, 1913	7
13. *Mystus cavasius* (Bloch)	*Haplorchoides macrones* (Dayal, 1949) Yamaguti, 1958	67
	Bifurcohaptor indicus Jain, 1958	33
	Thaparocleidus tengra (Tripathii, 1959) Lim, 1996	83
	Raosentis podderi Datta, 1947	98
	Raosentis thapari Rai,1967	77
	Lamproglena hospetensis Manohar *et al*., 1992	41
14. *Macrognathus aculeatus* (Bloch)	Metacercaria *Clinostomum mastacembeli* Jaiswal, 1959	816
	Allocreadium aculeatum (Pershad, 1937) Caira and Boega, 2005	4836
	Metacercaria *Ascocotyle nana* Looss, 1899	452
	Metacercaria *Tetracotyle* type-I	1105
	Mastacembelocleidus bam (Tripathi, 1959) Kritsky *et al*., 2004	2251
	Lernaea cyprinacea mastacembeli Hu, 1949	722
	Camallanus unispiculus Khera, 1956	2
	Alitropus typus Milne-Edwards, 1841	43
15. *Mastacembelus armatus* (Lacepede)	*Allogomtiotrema armati* Tiwari, 1959	88
	Genarchopsis faruquis Gupta, 1951	391
	Opecoelus mehrii (Harshey, 1937) AkenÓva, 2007	616
	Metacercaria *Tetracotyle* type-I	31333
	Metacercaria *Ascocotyle nana* Looss, 1899	257
	Phyllodistomum tripathi Motwani & Srivastava,1959	174
	Circumonchobothrium shindei Shinde and Chincholikar, 1977	536
	Plerocercoid of Senga lucknowensis Johri, 1956	147
	Mastacembelocleidus heteranchoratus (Kulkarni, 1959) Kritsky *et al*., 2004	469
	Camallanus unispiculus Khera, 1956	68
	Pallisentis colisai Sarkar, 1954	7
	Neoergasilus indicus n. sp.	110
16.*Mastacembelus pancalus* (Hamilton)	Metacercaria *Clinostomum mastacembeli* Jaiswal , 1959	360
17. *Nandus nandus* (Hamilton)	*Transversotrema patialense* (Soparkar,1924) Crusz & Sathanathan, 1960	15
18. *Notopterus notopterus* (Pallas)	*Lernaea notopteri n. sp.*	4
19. *Sperata seenghala* (Skyes)	*Neoergasilus indicus* n.sp.	3
20. *Wallago attu* (Schneider)	*Isoparorchis hypselobagri* Billet, 1898	8
	Bychowskyella wallagonia (Jain,1959) Gussev, 1961	56
	Ergasilus malnadensis Venkateshappa, Seenappa & Manohar, 1998	35

Table 3. Distribution of metazoan parasites in 20 species of freshwater fishes of River Godavari, Andhra pradesh (√-Present)

Parasite species/ Group	FISH SPECIES																			
	A. oligolepis	*B. bagarius*	*Barbus sp.*	*B. cancila*	*C.catla*	*C.punctatus*	*C.batrachus*	*C.carpio*	*G.giurus*	*H.fossilis*	*L.rohita*	*M.vittatus*	*M.cavasius*	*M.aculeatus*	*M.armatus*	*M.pancalus*	*N.nandus*	*N.notopterus*	*S.seenghala*	*W.attu*
MONOGENEA																				
Tricanhoratus kearni	√											√	√							
Bifurcohaptor indicus												√	√							
Thaparocledius tengra																				
Bychowskyella wallagonia																				√
Xenentocleidus xenentodoni				√																
Mastacembelocleidus bam														√						
M.heteranchoratus															√					
Paradactylogyrus catalius					√						√									
DIGENEA																				
Allocreadium handiai	√					√	√													
A.fasciatus									√											
A.aculeatum														√						
Orientocreadium batrachoides							√													
Prosorhynchoides karvei				√																
Emoleptalea proteopora							√													
Metacercaria Clinostomum dasi			√							√										
Metacercaria C. mastacembeli														√		√				
Metacercaria C.gideoni																				
Metacercaria Euclinostomum heterostomum						√														
Haplorchoides macrones												√	√							
Metacercaria Neascus-I	√			√																
Phyllodistomum parorchium									√											
P.tripathii		√		√											√					
P.batrachii n.sp.							√													
Genarchopsis goppo						√														
Genarchopsis faruquis															√					
Metacercaria Ascocotyle nana														√	√					
Isoparorchis hypselobagri																				√
Metacercaria I.hypselobagri												√								
Asymphylodora tincae								√												
Opecoelus beliyai									√											
O.mehrii															√					
Allogomtiotrema armati																				
Astiotrema reniferum							√													
Metacercaria Tetracotyle glossogobi									√											
Metacercaria Tetracotyle-I														√	√					
Transversotrema patialense																	√			
CESTODA																				
Lytocestus indicus							√													
L.birmanicus							√													
L.longicollis							√													
Circumonchobothrium shindei															√					
Plerocercoid of Circumonchobothrium sp.															√					
Senga visakhapatnamensis						√														
Plerocercoid of Senga lucknowensis															√					
Proteocephalus vitellaris		√																		
NEMATODA																				
Camallanus unispiculus														√	√					
ACANTHOCEPHALA																				
Pallisentis ophicephali						√			√											
P.colisai															√					
Raosentis podderi												√	√							
R. thapari												√	√							
R.godaveraensis n.sp												√								
Juvenile *Centrorhynchus batrachus*							√													
COPEPODA																				
Ergasilus malnadensis																				√
Neoergasilus indicus															√				√	
Lamproglena chinensis						√	√													
L.hospetensis													√							
Lernaea bengalensis						√														
L.cyprinicacea			√		√															
L.cyprinacea mastacembeli														√						
L.notopteri																		√		
Lernaea Copepodid-VI									√											
Argulus siamensis											√									
A.striatus												√								
ISOPODA																				
Alitropus typus														√						

Table 4. Distribution of metazoan parasites in 13 families of freshwater fishes of River Godavari, Andhra pradesh (√-present)

	Anabantidae	Bagriidae	Sisoridae	Cyprinidae	Belonidae	Ophiocephalidae	Clariidae	Gobidae	Heteropneustidae	Mastacembelidae	Nandidae	Notopteridae	Siluridae
MONOGENEA													
Tricanhoratus kearni	√												
Bifurcohaptor indicus		√											
Thaparocledius tengra		√											
Bychowskyella wallagonia													√
Xenentocleidus xenentodoni					√								
Mastacembelocleidus bam										√			
M.heteranchoratus										√			
Paradactylogyrus catalius				√									
DIGENEA													
Allocreadium handiai	√					√	√						
A.fasciatus								√					
A.aculeatum										√			
Orientocreadium batrachoides							√						
Prosorhynchoides karvei					√								
Emoleptalea proteopora							√						
Metacercaria Clinostomum dasi									√				
Metacercaria C. mastacembeli										√			
Metacercaria C.gideoni				√									
Metacercaria Euclinostomum heterostomum						√							
Haplorchoides macrones		√											
Metacercaria Neascus-I	√				√								
Phyllodistomum parorchium								√					
P.tripathii			√		√								
P.batrachii n.sp.							√						
Genarchopsis goppo						√							
Genarchopsis faruquis										√			
Metacercaria Ascocotyle nana										√			
Isoparorchis hypselobagri													√
Metacercaria I.hypselobagri		√											
Asymphylodora tincae				√									
Opecoelus beliyai								√					
O.mehrii										√			
Allogomtiotrema armati										√			
Astiotrema reniferum							√						
Metacercaria Tetracotyle glossogobi								√					
Metacercaria Tetracotyle-I										√			
Transversotrema patialense											√		
CESTODA													
Lytocestus indicus							√						
L.birmanicus							√						
L.longicollis							√						
Circumonchobothrium shindei										√			
Plerocercoid of Circumonchobothrium sp.										√			
Senga visakhapatnamensis						√				√			
Plerocercoid of Senga lucknowensis													
Proteocephalus vitellaris			√										
NEMATODA													
Camallanus unispiculus										√			
ACANTHOCEPHALA													
Pallisentis ophicephali						√		√					
P.colisai										√			
Raosentis podderi		√											
R. thapari		√											
R.godaveraensis n.sp		√											
Juvenile *Centrorhynchus batrachus*							√						
COPEPODA													
Ergasilus malnadensis													√
Neoergasilus indicus		√											
Lamproglena chinensis						√	√						
L.hospetensis		√											
Lernaea bengalensis						√							
L.cyprinicacea				√									
L.cyprinacea mastacembeli										√			
L.notopteri												√	
Lernaea Copepodid-VI								√					
Argulus siamensis				√									
A.striatus		√											
ISOPODA													
Alitropus typus										√			

Table-5. Prevalence (P= %), Mean Intensity (MI), Abundance (A), Dominance value (DV) and proportion of metazoan parasites in different species of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

Fish species/Family	Number examined	Number infected	Number of parasites	Total	Monogenes	Digenes	Larval Digenetic trematode	Cestodes	Plerocercoids	Acantho-cephala	Copepods	Copepodids	Nematodes	Isopods	Proportion
Family: Anabantidae															
Anabas oligolepis	102	25	48	P 24.5	23.5	5.88	1.96								0.012
				MI 1.9	1.5	1.3	1								
				A 0.47	0.37	0.07	0.01								
				DV 0.102	79.1	16.7	4.16								
Family: Bagridae															
Sperata seenghala	68	3	3	P 4.4							4.4				0.0060
				MI 1.0							1.0				
				A 0.04							0.04				
				DV 0.01							0.01				
Mystus vittatus	116	70	283	P 60.3	33.6	28.4	5.17			12.9	6.03				0.024
				MI 4.0	3.58	2.7	2.16			2.33	1				
				A 2.44	1.20	0.75	0.11			0.30	0.06				
				DV 0.60	49.5	31.0	4.59			12.36	2.47				
Mystus cavasius	94	64	399	P 68.1	32.9	28.7				36.2	18.1				0.037
				MI 6.2	3.74	2.5				5.14	2.4				
				A 4.24	1.23	0.71				1.86	0.44				
				DV 0.84	29.1	16.79				43.8	10.3				
Family: Belonidae															
Belone (Xenentodon) cancila	185	143	694	P 77.3	7.5	82.7	49.2								0.029
				MI 4.85	1.4	3.45	1.6								
				A 3.75	0.11	2.85	0.78								
				DV 1.47	2.88	76.2	20.9								
Family: Clariidae															
Calrias batrachus	108	70	148	P 64.8		68.5		23.1		0.92	4.6				0.012
				MI 2.11		1.49		1.28		1	1				
				A 1.37		1.01		0.29		0.009	0.04				
				DV 0.31		74.3		21.6		0.67	4.62				
Fam: Cyprinidae															
Barbus sp.	85	26	33	P 30.6			22.35				9.41				0.0078
				MI 1.3			1.26				1.13				
				A 0.39			0.28				0.11				
				DV 0.07			72.7				27.3				
Catla catla	198	58	70	P 29.3	27.8						1.52				0.0073
				MI 1.2	1.22						1				
				A 0.35	0.34						0.015				
				DV 0.15	95.7						4.28				
Cyprinus carpio	65	10	13	P 15.4		15.4									0.0078
				MI 1.3		1.3									
				A 0.2		0.2									
				DV 0.02		0.02									
Labeo rohita	82	30	205	P 36.6	20.7						35.3				0.0413
				MI 6.83	7.05						2.93				
				A 2.5	1.5						1.03				
				DV 0.43	58.5						41.5				
Family: Gobiidae															
Glossogobius giurus	99	30	34	P 30.3		23.2	3.03			1		3.03			0.0068
				MI 1.13		1.17	1			1		1			
				A 0.34		0.27	0.03			0.01		0.03			
				DV 0.072		79.4	8.82			2.94		8.82			
Family: Heteropneustidae															
Heteropneustus fossilis	85	20	33	P 23.5			23.5								0.0102
				MI 1.7			1.7								
				A 0.39			0.39								
				DV 0.07			0.07								
Family: Mastacembelidae															
Macrognathus aculeatus	561	386	10227	P 68.8	43.3	29.9	45.9				22.9		0.35	5.16	0.160
				MI 26.5	9.26	28.8	9.2				5.6		1.0	1.48	
				A 18.23	4.0	8.6	4.22				1.28		0.003	0.07	
				DV 21.61	0.22	0.47	0.23				0.07		0.0002	0.004	
Mastacembelus armatus	494	383	34196	P 77.5	14.9	41.2	51.8	37.2	8.3	0.8	8.3		6.07		0.54
				MI 89.3	6.34	6.22	123.4	2.91	3.5	1.75	2.68		2.3		
				A 69.22	0.94	2.56	63.9	1.08	0.29	0.014	0.22		0.14		
				DV 72.26	1.37	3.71	92.3	1.56	0.42	0.02	0.32		0.001		
Mastacembelus pancalus	206	103	360	P 50			50								0.021
				MI 3.49			3.49								
				A 1.75			1.75								
				DV 0.76			0.76								

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Family: Nandidae												
Nandus nandus	87	10	15	P 11.5		11.5						0.009
				MI 1.5		1.5						
				A 0.17		0.17						
				DV 0.03		0.03						
Family: Notopteridae												
Notopterus notopterus	58	3	4	P 5.2						5.2		0.0078
				MI 1.3						1.3		
				A 0.07						0.07		
				DV 0.008						0.008		
Family: Ophiocephidae												
Channa punctatus	252	132	445	P 52.4		50	2.7	4.36		21.0	12.30	0.0204
				MI 3.37		2	1	1.09		2.5	1.3	
				A 1.77		1.0	0.02	0.05		0.53	0.156	
				DV 0.94		56.8	1.6	2.7		29.8	8.9	
Family: Siluridae												
Wallago attu	35	20	99	P 57.1	45.7	17.1					31.4	0.0302
				MI 5.0	3.5	1.3					3.2	
				A 2.83	1.6	0.2					1.0	
				DV 0.21	56.6	8.1					35.4	
Family: Sisoridae												
Bagarius bagarius	34	13	15	P 38.2							38.2	0.0069
				MI 1.15							1.15	
				A 0.44							0.44	
				DV 0.032							0.032	
TOTAL	3014	1599	47324	P 41.3	12.49	20.12	12.78	3.23	8.3	3.64	9.88	3.03
				MI 8.3	1.88	2.69	7.29	0.26	3.5	0.68	1.28	1
				A 5.49	0.56	0.92	3.57	0.071	0.29	0.136	0.245	0.03
				DV 4.9	18.65	18.2	10.31	1.29	0.42	4.48	6.76	8.82

The dominance pattern of the major taxa of metazoan parasites in freshwater fishes of this region was in the order, Digenea >Copepoda Monogenea>Cestoda>Acanthocephala>Nematoda =Isopoda (Table 3). Results of the family-wise comparison of parasitic infection (Table 6) showed that the highest prevalence of metazoan parasitic infection was in Belonidae (77.3%) and the lowest in Notopteridae (5.7%). Prevalences of infection in the other 11 families were Ananbatidae (24.5%), Bagridae (41.4%), Clariidae (64.8%), Cyprinidae (28.8%), Gobiidae (30.3%), Heteropneustiidae (23.5%), Mastacembelidae (68.6%), Nandidae (11.4%), Ophiocephalidae (52.4%), Siluridae (57.1) and Sisoridae (38.2%). The highest MI was noted in Mastacembelidae (51.5) and the lowest in Gobiidae (1.13) and Sisoridae (1.15). In the other families MI varied between 1.5 and 4.95. The highest proportion of metazoan parasites was recorded in Mastacembelidae (0.62) followed by Nandidae (0.078), Bagridae (0.063), Siluridae (0.059) and Belonidae (0.058). The lowest proportion was noted in Gobiidae (1.13) and rest of the families ranged from 0.015-0.040.

Community structure of metazoan parasite fauna in different species of fishes

Each host species had a characteristic assemblage or community of parasites, which differed in several respects among the host species (Table-7). Of the 20 host species, *M. armatus* harboured the maximum of 12 parasite species and in rest of the host fishes, the number of parasite species varied between one to ten. Six fish species- *Sperata seenghala, Cyprinus carpio, Heteropneustus fossilis, Mastacembelus pancalus, Nandus nandus* and *Notopterus notopterus* harboured only single parasite species each. Most of the host species harboured two parasitic taxa i.e., *L.rohita* and *C.catla* (Monogenea, Copepoda) *A.oligolepis* (Digenea, Monogenea), *B.bagarius, barbus sp.*, and *B.cancila* (Copepoda, Digenea). The parasite fauna of *G.giurus* (Copepoda, Digenea and Acanthocephala) and *W. attu* (copepod, Digenea and Monogenea) was constituted by three major taxa of parasites.

Similarly, only *C. Punctatus, C.batrachus, M.vittatus* and *M.cavasius* showed infection with 4 parasitic taxa, *M. aculeatus* with 5 and *M. armtaus* with 6 parasitic groups respectively. None of the fish was infected by all the seven parasitic groups. *C.catla* (0.9) and *M.armatus* (0.85) showed the highest DIs whereas other hosts showed DI between 0.64-0.00003. The parasite fauna was the richest in *Clarias batrachus* (RI=1.8), which harboured 10 species of parasites belonging to four genera, closely followed by *G.giurus* (RI=1.42), *M.vittatus* (RI=1.24) and *M.armatus* (RI=1.05) with six, eight and twelve species of parasites represented by five, three and six major taxa respectively. The least rich parasite fauna was that of 5 species i.e., *S.seenghala*, *C.carpio*, *H.fossilis*, *M.pancalus*, *N.nandus* and *N.notopterus* which were represented by only one species of parasite. Of the 20 species of fish, only 11 species of fish potrayed the distribution of fish of which, the parasite fauna of *M.aculeatus* was the most unevenly distributed or the most heterogenous (EI=0.74) and that of *Barbus sp.* (RI=1.0) was the most homogenous followed by *C.batrachus* (RI= 0.97), *M. armatus* (RI=0.93). The eveness index of the other 7 fishes ranged between 0.92-0.83 (Table-7).

The dominance index was the highest for *Catla catla* (0.9) which harboured only 2 species of parasites, followed by *M.armatus* (0.85) which harboured the maximum number of 12 species of parasites and digeneans form the very dominant component of its parasite community (96.1%). DIs was comparatively high in *A.oligolepis* (0.6487), *G.giurus* (0.646), *B.cancila* (0.625), *Barbus sp.* (0.602) and *C.batrachus* (0.6007). Monogenenans subjugated the parasite fauna of *A.oligolepis* whereas digeneans conquered the parasite communities of *G.giurus*, *B.cancila*, *Barbus sp.* and *C.batrachus* correspondingly. *M.cavasius* (0.31), *M.vittatus* (0.36) and *M.aculeatus* (0.00003) showed relatively lower values of DI and the parasite fauna of these fish species were comparatively homogenous. Diversity of parasite fauna was the greatest for *M.aculeatus* (H=0.78) with 8 species of parasites belonging to 5 major taxa was homogenously distributed to some extent (EI=0.74).

Table 6. Prevalence (P= %), Mean Intensity (MI), Abundance (A), Dominance value (DV) and proportion of metazoan parasites in different families of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

Fish species/Family	Number examined	Number infected	Number of parasites	Total	Monogenea	Digenea	Larval Digenetic trematode	Cestodes	Plero-cercoids	Acantho-cephala	Copepods	Copepodids	Nematodes	Isopods	Proportion
Family: Anabantidae	102	25	48	P 24.5	23.5	5.88	1.96								0.023
				MI 1.92	1.5	1.3	1								
				A 0.47	0.37	0.07	0.01								
				DV 0.102	79.1	16.7	4.16								
Family: Bagridae	282	117	615	P 41.4	34.5	28.5	5.17			24.5	12.1				0.063
				MI 5.25	3.66	2.6	2.16			3.73	1.7				
				A 2.18	1.22	0.73	0.11			1.08	0.25				
				DV 0.013	39.3	23.9	4.59			28.1	6.4				
Family: Belonidae	185	143	694	P 77.3	7.5	82.7	49.2								0.058
				MI 4.85	1.4	3.45	1.6								
				A 3.75	0.11	2.85	0.78								
				DV 1.47	2.88	76.2	20.9								
Family: Clariidae	108	70	148	P 64.8		68.5		23.1		0.92	4.6				0.025
				MI 2.11		1.49		1.28		1	1				
				A 1.37		1.01		0.29		0.009	0.04				
				DV 0.31		74.3		21.6		0.67	4.62				
Fam: Cyprinidae	430	134	321	P 28.83	24.3	15.4	22.4				15.41				0.030
				MI 2.5	4.15	1.3	1.26				1.68				
				A 0.74	0.92	0.2	0.28				0.38				
				DV 0.68	77.1	0.02	72.7				24.4				
Family: Gobiidae	99	30	34	P 30.3		23.2	3.03			1		3.03			0.013
				MI 1.13		1.17	1			1		1			
				A 0.34		0.27	0.03			0.01		0.03			
				DV 0.072		79.4	8.82			2.94		8.82			
Family: Heteropneustidae	85	20	33	P 23.5			23.5								0.019
				MI 1.65			1.7								
				A 0.39			0.39								
				DV 0.07			0.07								
Family: Mastacembelidae	1261	866	44594	P 68.6	29.1	35.5	49.2	37.2	8.3	0.8	15.6		3.21	5.16	0.62
				MI 51.5	7.8	17.5	45.4	2.91	3.5	1.75	4.14		1.65	1.48	
				A 35.4	2.47	5.6	23.3	1.08	0.29	0.014	0.75		0.072	0.07	
				DV 94.7	0.79	2.09	31.1	1.56	0.42	0.02	0.195		0.0006	0.004	
Family: Nandidae	87	10	15	P 11.4		11.5									0.078
				MI 1.5		1.5									
				A 0.17		0.17									
				DV 0.03		0.03									
Family: Notopteridae	58	3	4	P 5.17							5.2				0.015
				MI 1.33							1.3				
				A 6.9							0.07				
				DV 0.008							0.008				
Family: Ophiocephidae	252	132	445	P 52.4		50	2.7	4.36		21.0	12.30				0.040
				MI 3.37		2	1	1.09		2.5	1.3				
				A 1.77		1.0	0.02	0.05		0.53	0.156				
				DV 0.94		56.8	1.6	2.7		29.8	8.9				
Family: Siluridae	35	20	99	P 57.1	45.7	17.1					31.4				0.059
				MI 4.95	3.5	1.3					3.2				
				A 2.82	1.6	0.2					1.0				
				DV 0.002	56.6	8.1					35.4				
Family: Sisoridae	34	13	15	P 38.2							38.2				0.013
				MI 1.15							1.15				
				A 0.44							0.44				
				DV 0.032							0.032				
TOTAL	3014	1599	47324	P 51.7	27.4	31.2	19.65	21.5	8.3	9.6	16.8	3.03	3.21	5.16	
				MI 7.9	3.67	3.4	6.9	1.8	3.5	1.9	1.9	1	1.65	1.48	
				A 5.5	1.11	1.21	3.2	0.47	0.29	0.3	1.5	0.03	0.072	0.07	
				DV 4.9	42.6	33.8	18	8.6	0.42	12.3	9.9	8.82	0.0006	0.004	

However, *C.batrachus* (H=0.76, EI=0.97), *M.cavasius* (H=0.75, EI=0.92) and *M.armatus* (H=0.71, EI=0.93) showed parasitisation with 10, 6 and 12 species of parasites belonging to four, four and six major taxa respectively. However, the diversity of the parasite fauna of *L.rohita* (H=0.57) was the lowest in which two species of parasites belonging to two major taxa were encountered and of these monogeneans (DV=90.2%) were highly dominant over the copepods. The diversity of parasite fauna of the other fishes ranged between 0.72-0.62.

Qualitative similarity of the parasite fauna of the host fishes (Table 9) showed that there was relatively high similarity between the parasite fauna of *M.vittatus* and *M.cavasius* (JI) = 55.5). Of the 14 species of parasites encountered in *M.vittatus* and *M.cavasius* five parasitic species were shared by the two hosts. Those of *M.aculeatus*-*M.armatus* (JI=17.6) which shared 3 species; *C.batrachus*-*C.punctatus* (JI=13.3) which shared 2 species; *C.catla*-*Barbus sp.* (JI = 33.3), *C.catla*-*L.rohita* (JI=33.3), *B.cancila*-*B.bagarius* (JI=25), *B.cancila*-*A.oligolepis* (JI=16.6), *M.aculeatus*-*M.pancalus* (JI=12.5),

Table 7. Community characteristics of metazoan parasites of 20 species of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

Parameters	Fish Families/species																				Grand Total
	Anabantidae	Bagridae			Belonidae	Clariidae	Cyprinidae				Gobiidae	Heteropneustidae	Mastacembelidae			Nandidae	Notopteridae	Ophiocephalidae	Siluridae	Sisoridae	
	Ao	*Ss*	*Mv*	*Mc*	*Bc*	*Cb*	*B.sp*	*Cc*	*Cy.c*	*Lr*	*Gg*	*Hf*	*M.ac*	*M.ar*	*M.p*	*Nn*	*Nnot*	*Cp*	*Wa*	*Bb*	
Number examined	102	68	116	94	185	108	85	198	65	82	99	85	561	494	206	87	58	252	35	34	3014
Number infected	25	3	70	64	143	70	26	58	10	30	30	20	386	383	103	10	3	132	20	13	1599
Total no. of parasites (N)	48	3	283	399	694	148	33	70	13	205	34	33	10227	34196	360	15	4	445	99	15	47324
No. of species of parasites (S)	3	1	8	6	4	10	2	2	1	2	6	1	8	12	1	1	1	7	3	2	
No. of taxa of parasites (K)	2	1	5	4	2	4	2	2	1	2	3	1	5	6	1	1	1	4	3	2	
Prevalence (%)	24.5	4.4	60.3	68.1	77.3	64.8	30.6	29.3	15.4	36.6	30.3	23.5	68.8	77.5	50	11.5	5.2	52.4	57.1	38.2	
Mean Intensity (MI)	1.9	1.0	4.0	6.2	4.85	2.11	1.3	1.2	1.3	6.83	1.13	1.7	26.5	89.3	3.49	1.5	1.3	3.37	5.0	1.15	
Abundance (A)	0.47	0.04	2.44	4.24	3.75	1.37	0.39	0.35	0.2	2.5	0.34	0.39	18.23	69.2	1.75	0.17	0.07	1.77	2.83	0.44	
Proportion of parasites	0.012	0.006	0.024	0.037	0.029	0.012	0.007	0.007	0.007	0.0413	0.0068	0.0102	0.160	0.54	0.021	0.0091	0.0078	0.0204	0.0302	0.0069	
Dominance index(DI)	0.6487	0.0000	0.36	0.31	0.6255	0.6007	0.602	0.9	0.00	0.5144	0.646	0.00	0.00003	0.8517	0.0	0.00000	0.0000	0.4189	0.4462	0.00	
Richness Index on S (RI)	0.5166	0	1.24	0.835	0.458	1.80	0.28	0.24	0	0.18	1.42	0	0.75	1.05	0	0	0	0.98	0.43	0.37	
Richness Index on K (RI)	0.258	0	0.73	0.501	0.152	0.60	0.28	0.24	0	0.18	0.56	0	0.43	0.47	0	0	0	0.49	0.43	0.37	
Evenness Index on S (EI)	0.866	0	0.84	0.92	0.88	0.97	1	0	0	0.835	0	0	0.74	0.93	0	0	0	0.868	0.88	0	
Shannon Index (H)	0.64	0	0.64	0.75	0.723	0.76	0.69	0	0	0.579	0	0	0.78	0.71	0	0	0	0.62	0.71	0	

Table 8. Community characteristics of metazoan parasites of 13 families of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

Parameters	Anabantidae	Bagridae	Belonidae	Clariidae	Cyprinidae	Gobiidae	Heterpneustidae	Mastacembelidae	Nandidae	Notopteridae	Ophiocephalidae	Siluridae	Sisoridae	TOTAL
Number examined	102	282	185	108	430	99	85	1261	87	58	252	35	34	
Number infected	25	117	143	70	134	30	20	866	10	3	132	20	13	
Total no. of parasites(N)	48	615	694	148	321	34	33	44594	15	4	445	99	15	
No. of species of parasites (S)	3	10	4	10	5	6	1	17	1	1	7	3	2	
No. of taxa of parasites (K)	2	4	2	4	3	3	1	7	1	1	4	3	2	
Prevalence (%)	24.5	41.4	77.3	64.8	28.8	30.3	23.5	68.6	11.4	5.17	52.4	57.1	38.2	
Mean Intensity(MI)	1.92	5.25	4.85	2.11	2.5	1.13	1.65	51.5	1.5	1.33	3.37	4.95	1.15	
Abundance (A)	0.47	2.18	3.75	1.37	0.74	0.34	0.39	35.4	0.17	6.9	1.77	2.82	0.44	
Proportion of parasites	0.023	0.063	0.058	0.025	0.030	0.013	0.019	0.62	0.078	0.015	0.040	0.059	0.013	
Dominance index(DI)	0.6487	0.2956	0.6255	0.6007	1.1824	0.6463	0.00000	0.0974	0.00000	0.000000	0.4189	0.4462	0.00000	
Richness Index on S (RI)	0.516	1.4	0.45	1.8	0.69	1.42	0	1.49	0	0	0.98	0.43	0.37	
Richness Index on K (RI)	0.25	0.46	0.15	0.60	0.35	0.57	0	0.56	0	0	0.49	0.43	0.37	
Evenness Index on S (EI)	0.866	0.588	0.88	0.973	0.458	0	0	0.55	0	0	0.868	0.88	0	
Shannon Index (H)	0.640	0.46	0.72	0.762	0.317	0	0	0.49	0	0	0.62	0.71	0	

Table 9. Parasite species overlap in different species of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

Fish Family	*S*	Ao	*Ss*	*Mv*	*Mc*	*Bc*	*Cb*	*B.sp.*	*Cc*	*Ccarp*	*Lr*	*Gg*	*Hf*	*Mac*	*Ma*	*Mp*	*Nnand*	*Nnot*	*Cp*	*Wa*	*Bb*
Ao	3	-	0	0	0	1 16.6	1 8.33	0	0	0	0	0	0	0	0	0	0	0	1 11.1	0	0
Ss	1	0	-	0	0	0	0	0	0	0	0	0	0	0	1 8.33	0	0	0	0	0	0
Mv	8	0	0	-	5 7.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mc	6	0	0	5 7.69	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bc	4	0	0	0	0	-	0	0	0	0	0	0	0	0	1 6.66	0	0	0	0	0	0
Cb	10	1 8.33	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	1 6.25	0	0
B.sp.	2	0	0	0	0	0	0	-	1 33.3	0	0	0	0	0	0	0	0	0	0	0	0
Cc	2	0	0	0	0	0	0	1 33.3	-	0	0	0	0	0	0	0	0	0	0	0	0
Ccarp	1	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Lr	2	0	0	0	0	0	0	0	1 33.3	0	-	0	0	0	0	0	0	0	0	0	0
Gg	6	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	1 8.33	0	0
Hf	1	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
Mac	8	0	0	0	0	0	0	0	0	0	0	0	0	-	3 17.6	0	0	0	0	0	0
Ma	12	0	0	0	0	0	0	0	0	0	0	0	0	3 17.6	-	0	0	0	0	0	0
Mp	1	0	0	0	0	0	0	0	0	0	0	0	0	1 12.5	0	-	0	0	0	0	0
Nnand	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0
Nnot	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
Cp	7	0	0	0	0	0	2 13.3	0	0	0	0	1 8.33		0	0	0	0	0	-	0	0
Wa	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bb	1	0	0	0	0	1 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-

Table 10. Parasite species overlap in different families of freshwater fishes of River Godavari, Rajahmundry, Andhra Pradesh

FISH FAMILY	No.of species of parasites (S)	Anabantidae	Bagriidae	Belonidae	Clariidae	Cyprinidae	Gobiidae	Heteropneustidae	Mastacembelidae	Nandidae	Notopteridae	Ophiocpehalidae	Siluridae	Sisoridae
Anabantidae	3	-	0	1 16.6	1 8.33	0	0	0	0	0	0	1 10.0	0	0
Bagridae	10	0	-	0	0	0	0	0	0	0	0	0	0	0
Belonidae	4	1 16.6	0	-	0	0	0	0	1 50.0	0	0	0	0	0
Clariidae	10	1 8.33	0	0	-	0	0	0	0	0	0	2 13.3	0	0
Cyprinidae	5	0	0	0	0	-	0	0	0	0	0	0	0	0
Gobiidae	6	0	0	0	0	0	-	0	0	0	0	1 8.33	0	0
Heteropneustidae	1	0	0	0	0	0	0	-	0	0	0	0	0	0
Mastacembelidae	17	0	0	1 50.0	0	0	0	0	-	0	0	0	0	0
Nandidae	1	0	0	0	0	0	0	0	0	-	0	0	0	0
Notopteridae	1	0	0	0	0	0	0	0	0	0	-	0	0	0
Ophiocephidae	7	1 10.0	0	0	2 13.33	0	1 8.33	0	0	0	0	-	0	0
Siluridae	3	0	0	0	0	0	0	0	0	0	0	0	-	0
Sisoridae	2	0	0	0	0	0	0	0	0	0	0	0	0	-

Anabas oligolepis-C.punctatus (JI=11.1), *A.oligolepis-C.batrachus, G.giurus-C.punctatus*, *S.seenghala-M.armatus* (JI=8.33), *M.armatus-B.cancila* (JI=6.66) and *C.punctatus-C.batrachus* (JI=6.25) which shared only one species.

Community ecology of metazoan parasite fauna in different families of fishes

The highest prevalence of metazoan parasitic infection was in Belonidae (77.3%) and the lowest in Nandidae (11.4%). However, the highest number of species of parasites was recorded in Mastacembelidae (17 belonging to all the seven major taxa) and the lowest in Heteropneustidae, Nandidae and Notopteridae (1). Bagridae and Clariidae harboured ten species of parasites and Ophiocephalidae harboured 7 species of parasites belonging to four major taxa, Cyprinidae was infected with five species belonging to three major taxa, Gobiidae with 6 species belonging to three major taxa, Belonidae with 4 species of parasites belonging to 2 major taxa, Anabantidae and Siluridae with 3 species and Sisoridae

with 2 species belonging to two major taxa. In Mastacembelidae the parasite fauna was predominated by larval digeneans (two species) but at the same time showed the most varied fauna of parasites (7 major taxa). Mean intensity recorded the highest in Mastacembelidae (51.5) followed by Bagridae (5.25), Siluridae (4.95) and Belonidae (4.85) and lowest in Gobiidae (1.13). In the other families MI varied between 1.15 and 3.37 (Table 5). The richest parasite fauna was that of Clariidae (RI= 1.8) followed by Mastacembelidae (RI= 1.49) and Bagridae (1.4) (Table-8). Clariidae showed only 10 parasite species representing four major taxa, but Mastacembelidae harboured 17 species of parasites representing 7 major taxa and Bagridae showed 10 parasitic species representing 4 major taxa. RI was 0.98 in Ophiocephalidae (7 species representing 4 major taxa) and Sisoridae showed least RI of 0.37 as Heteropneustidae, Nandidae and Notopteridae harboured only one parasite species each and there is no parasite diversity in these families. Dominance index recorded high for Cyprinidae (1.18), Anabantidae (0.6487), Gobiidae (0.646) Belonidae (0.6255) and Clariidae (0.6007). In these cases Monogenea (DV = 58.3%), Monogenea (DV = 79.2%), Digenea (DV = 88.2%), Digenea (DV = 97.1%) and Digenea (74.3%) respectively dominated over the other taxa of parasites (Table 8).

The parasite fauna of Clariidae was the most homogeneous (EI = 0.973) followed by Siluridae (0.88), Belonidae (0.88), Ophiocephalidae (0.868), Anabantidae (0.866) and of Cyprinidae, the most heterogeneous (EI = 0.458). Diversity of parasite fauna was the greatest in Clariidae (H = 0.762) followed by Belonidae (0.72) and Siluridae (0.72) and were dominated by digeneans. The lowest diversity index was recorded for Cyprinidae (H = 0.317) and were dominated by monogeneans. In both cases the parasite assemblages were very heterogeneous (EI = 0.973, 0.72, 0.72 and 0.458 respectively). That of Gobiidae, Heteropneustidae, Nandidae, Notopteridae and Sisoridae was nil (H = 0) (Table 8). Analysis of parasite species overlap in different host families (Table-10) showed that only the parasite species of Mastacembelidae and Belonidae (Jaccard's index=50.0) were qualitatively very less similar. Of the 21 species of parasites recorded from these two host families, only one species was shared by both the fish families (Table-10). Similarly, there was a parasite species overlap between Anabantidae-Belonidae (JI=16.6), Anabantidae-Clariidae (JI=8.33), Anabantidae-Ophiocephalidae (JI=10.0), Gobidae-Ophiocephalidae (JI=8.33) which only one parasite species each but Clariidae and Ophiocephaldae (JI=13.33) shared two parasite species in common. Rest all the families did not show any parasite species overlap.

DISCUSSION

Overall nature of parasitic infections

Prevalence and mean intensity were higher in carnivorus/omnivorus species/families when interspecific and interfamilial comparisons of metazoan parasitic fauna were conducted indicating the importance of feeding habit in determining the parasitic fauna in them. Carnivorous fishes are more prone to parasitic infections due to their high possibility of acquiring parasites, particularly heteroxenous forms than the herbivorous forms, which because of the restriction in food, do not have chances of acquiring more infections nor more varied fauna of parasites.

Community ecology of metazoan parasite fauna

Kennedy *et al.,* (1986) envisaged that 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 its marine counterparts. But the present study partly concur with these two contentions as rich species diversity (n=62) was encountered from the 20 species of fishes but slightly lesser than their marine counterpart from the same geographical area (Madhavi, 2011; Mani *et al.,* 2012; 2013; Madhavi and Triveni Lakshmi, 2012 and Kritsky *et al.,* 2012). In this perspective, it is to be noted that the component community (=local parasite fauna) is prejudiced by several factors and there could be even temporal differences in the nature of compound communities (Holmes, 1990). Parasitic communities of freshwater fishes are basically stochastic assemblages determined by events like chance introduction, colonization and extermination of parasites in a given area (Esch *et al.,* 1988; Hartvigsen and Kennedy, 1993; Kennedy, 1993 and Beevi and Radhakrishnan, 2012). Carnivorous fishes of the family Mastacembelidae, Clariidae, Bagriidae, Ophiocephalidae and Gobiidae harboured richer parasite faunas than predominantly herbivorous ones. Moreover, distribution of parasite species was somewhat homogenous than in herbivorous. Diversity index of parasite species was also comparatively higher in carnivorous forms than in herbivores. Marine fish generally have rich parasitic helminth communities than their freshwater counterparts (Homles, 1990; Rohde, 1992 and Thoney, 1993). In conventionality with this statement Radhakrishnan and Nair (1980), Biju Kumar (1996a) and Madhavi (2011) also found that the parasitic communities of marine fishes were proportionately predominated by helminths. The present results also however, showed helminth parasite fauna is very dominant (96.9% of helminths) which includes monogeneans, digeneans, cestodes and nematodes. In the present study of the 62 parasites met with 44 (71%) were helminths.

Qualitative similarity of parasite fauna

Qualitative similarity of the parasite fauna has been noticeable for the two bagrids, *M. vittatus* and *M.cavasius*, also between *M. aculeatus* and *M. armatus* support the fact that the feeding habits of the host species plays a very crucial role in determining the parasite fauna of the host. However, there has been no similarity between Bagrids *S.seenghala* and *M.vittatus, M.cavasius*. Similarly, very less similarlity is observed for the parasite faunas of *C.punctatus* and *Clarias batrachus* and *M.aramtus* and *B.cancila*. The parasite fauna of closely related species, *M.armatus* and *M.pancalus* was quite dissimilar and the reason for the dissimilarity lies beyond the knowledge. The similar situation was reported by Biju Kumar (1996b) who noticed the dissimilarlity in the parasite fauna of very closely related species, *Etroplus suratensis* and *E.maculatus*. Thus, the essential stochastic nature of the component communities of freshwater fishes might also have contributed to this conclusion.

Conclusion

The metazoan parasite fauna of the freshwater fishes of River Godavari is very rich and diverse which might be due to chance introduction, colonization and extermination of parasites in a given area. The parasite invasion into the

freshwater system might have increased due to the increased pollution in the river. A large number of parasite species and parasite number act as crucial factor in assessing the pollution in the river. The role of parasites as good bio-indicators can be accessed from the study.

Conflict of interest

The authors declare that they have no conflict of interest related to the work.

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Significance Statement: This study discovers the fact that the parasitic community structure of the 20 freshwater fish species Godavari River, Rajahmundry, Andhra Pradesh, India showed rich species diversity. This study has provided a database on host-parasite relationship which would definitely help the imminent young researchers to analyze the parasitic community structure of other freshwater fishes in a very sophisticated manner.

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