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Research Article
Community Ecology of Metazoan Parasites in Two Species of *Mystus* from River Godavari, Andhra Pradesh, India

[1]Anu Prasanna Vankara and [2]Vijayalakshmi Chikkam

[1]Department of Animal Sciences, Yogi Vemana University, Kadapa, 516003 YSR District, Andhra Pradesh, India
[2]Department of Zoology, Andhra University, 530003 Visakhapatnam, India

Abstract

Background and Objective: Fishes of the genus *Mystus* are the members of Bagridae family which occupy an important place in Godavari fishery. Two commonly available species, *Mystus vittatus* Bloch, 1800 and *Mystus cavasius* Hamilton, 1822 of River Godavari, Rajahmundry Andhra Pradesh serve as significant hosts for metazoa\n parasites. The present study was aimed to ascertain the population dynamics, community characteristics and the faunal similarity of the two bagridae fishes, *Mystus vittatus* (n = 116) and *Mystus cavasius* (n = 94) at both infra and component community level during the 2008-2009. **Materials and Methods:** Standard statistical analyses were conducted to study the parasitic communities of both the fishes. Jaccard's similarity coefficient was used to observe the faunal similarity of both the fishes. Various parameters such as Shannon-wiener index (H'), evenness (E) and Simpson's diversity indices were applied to the fully sampled metazoan infracommunities of both fishes. Mean-variance ratio described the distribution patterns of the parasites within the host. The correlation coefficient (R) explained the correlation between the standard length of host and parasitic abundance for all parasites. The Mann-Whitney U-test was applied to both the fishes to observe the influence of host sex on the overall parasitic abundance. Jaccard's interspecific association was used to find out the interspecific association between each pair of parasite species within a same host. **Results:** A total of nine metazoan parasites were obtained from both the fishes during the research study. The present investigation includes five species, i.e., *Haplorchoides macrones*, *Bifurcohaptor indicus*, *Thaparocleidus tengra*, *Raosentis podderi* and *Raosentis thapari* that are common to both the species. On the other hand, Metacercaria *Isoparorchis hypselobagri*, *Raosentis godavarensis* and *Argulus striatus* occurred specifically in *Mystus vittatus* and *Lamproglena hospetensis* occur exclusively from *Mystus cavasius*. There were no core and secondary species in the parasitic communities of both the fishes. Host length and rate of parasitisation showed very less correlation. There was no influence of sex on the parasitisation. Over-dispersed distribution is the generalized pattern of distribution of macroparasites and all the parasites showed over-dispersed distribution patterns except *Argulus striatus*, which displayed a random distribution pattern. The higher JI values indicate that there is very less competition among species as they occupy different niches within the same host. **Conclusion:** Though, the faunal similarity of both the fishes was high but the parasitic communities of these fishes are less diverse, depauperate and non-interactive.

Key words: Parasite ecology, community structure, *Mystus vittatus*, *Mystus cavasius*, Godavari

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Corresponding Author: Anu Prasanna Vankara, Department of Animal Sciences, Yogi Vemana University, Kadapa, 516003 YSR District, Andhra Pradesh, India Tel: 07032825689

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

River Godavari is highly renowned as for its vibrant environment, affluent nutrients, high productivity and potential field to carry out fishery research[1]. The genus *Mystus* Scolpoli, 1771 is the representative of the family Bagridae native to Asia and consists of 45 recognized species. Two species, *Mystus vittatus* Bloch, 1800 and *Mystus cavasius* Hamilton, 1822 are of common occurrence in the River Godavari[2-4]. *Mystus*, commonly known as Eti Jella, is one of the popular commercial fish highly relished in Southern India as delicious proteinaceous food and forms an important inland fishery in Indian subcontinent. *Mystus vittatus*, the striped dwarf catfish, is a species of catfish that grows upto a length of 21 cm and found in brackish water systems with marginal vegetation in lakes and swamps with a mud substrate of Asian countries like India, Pakistan, Sri Lanka, Nepal, Bangladesh and probably Myanmar. *Mystus cavasius*, the Gangetic mystus, is a species of catfish that grows to a length of 40 cm and found in Indian Subcontinent countries such as, India, Pakistan, Sri Lanka, Nepal and Myanmar. The pectoral spine of this species may be noxious and cause agonizing wounds. Both the population are known to be declining in recent past, due to their indiscriminate catching, pet trading and habitat destruction. Most of the work on the silurid fishes was concentrated on its breeding and culture techniques, embryonic and larval development, fecundity and sex ratio[5-12]. Parasites occupy a very decisive place in animal kingdom for their invasive adoption and harmful activities to host[13,14]. Every parasite residing in or on a fish impose some degree of detrimental effect on its host. Heavily infected fish shows an intermittent or inhibited growth. Extensive research conducted on parasitic infection in various freshwater fishes such as *Clarias batrachus*, *Channa punctatus*, *Rita rita*, *Anabas testudineus* and carps from all over the world[15-27]. Conversely, only a few surveys on parasite community structure of freshwater fishes were executed globally[28-35]. The silurid fishes of the genus *Mystus* serves as better hosts for the metazoan parasites. However, very less amount of work has been concentrated on the parasitic fauna of *Mystus* due to the poor diagnosis of the genus[36,37]. The composition of parasite community in a fish is influenced by many environmental factors such as the location of the habitat, season of the year, physio-chemical factors of water and fauna present in and around the habit. All these factors can add to the emergence of new species and may amplify the parasite species richness[38-43]. Also the diet, age, abundance of fish length, sex and interdependence of members of the parasite fauna within the fish and season are some other factors which directly persuade parasitic fauna of the host[44-48]. The community structure of parasites in a host is shaped by many factors such as the parasitic interaction in various trophic levels, food webs, competition and biodiversity around them. The ecological studies on the metazoan parasites of fish are incredibly scarce in Indian Sub-continent especially in Andhra Pradesh. There are no comparative studies on the parasitic community structure of the two *Mystus* species. A meticulous attempt was made to ascertain the parasite diversity of *M. vittatus* and *M. cavasius* at component and infra-community structural levels and to calculate the possible effect of host standard length and sex on its parasitic abundance.

MATERIALS AND METHODS

Study area: Godavari is the second longest river in India and often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. The river is about 1,450 km (900 miles) long. It rises at Trimbakeshwar, near Nashik and Mumbai 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. At Rajahmundry, 80 km from the coast, the river splits into two streams, thus forming a very fertile delta. It is a seasonal river, widened during the monsoons and dried during the summers. Godavari river water is brownish. Some of its tributaries include Indravati river, Manjira, Bindusara and Sarbari[49-51]. Some important urban centers of Andhra Pradesh on its banks include Bhadrachalam, Rajahmundry and Narsapur (Fig. 1a-c). Godavari River is known for its lively environment, enriched with 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 km^2.

The present study was designed to investigate the parasites of the *Mystus vittatus* and *Mystus cavasius* collected from the River Godavari, Rajahmundry Andhra Pradesh from local fish markets during 2008-2009. A total of 116 *Mystus vittatus* and 94 *Mystus cavasius* transported to the laboratory to screen the presence of parasites. Morphometric characters such as length, weight and sex of each fish was noted cautiously and all the organs were examined separately under the stereo zoom microscope (LM-52-3621 Elegant) and specific characters were observed under the Lynx Trinocular microscope (N-800 M). A conventional technique was followed to prepare permanent slides of the collected[52].

Fig. 1(a-c): Centers of Andhra Pradesh, (a) Geographical map of India showing Godavari river flowing Andhra Pradesh state, (b) Andhra Pradesh River map and (c) River Godavari

Statistical analysis: Monthly population dynamics of the parasites were calculated by employing standard statistical computations (prevalence, mean intensity, mean abundance, index of infection and standard deviation) using various statistical softwares. To study the seasonal impact, each annual cycle was classified into three seasons as follows:

Winter (November-February), summer (March-June) and rainy (July-October). The seasonal influence on the incidence of infection was analyzed by Chi-square test[53]. The structure of the component and infra communities of *Mystus vittatus* and *Mystus cavasius* was described following the terminologies of Margolis *et al.*[54] and Bush *et al.*[55]. Parasite infracommunities were expressed by means of statistical computations i.e., prevalence, abundance and intensity, however component of communities are described in terms of species richness, mean abundance, mean intensity and community similarity such as diversity, dominance and evenness indices. Species classification was done according to Bush and Holmes[56], as central/core species (if prevalence >66.6%), secondary species (prevalence between 33.3-66.6%) and satellite species (prevalence <33.3%) of the total number of fish analyzed. Dispersion index (DI) evaluated the dispersion pattern of parasite species. The distribution of parasites was classified as aggregated (DI>1.96), regular (DI<-1.96) and random (DI<1.96). The parasite diversity of the sample was calculated using Simpson diversity index (λ) and for infinite population, Shannon's index of diversity (H') was employed[57]. For evenness, Shannon-based evenness (E) was calculated. Host size is considered as the decisive factor in determining the parasitic communities in any host. Pearson linear correlation coefficient (r) determines the possible correlation between host standard length with prevalence and abundance of each parasite species respectively[53]. The existence of an association among species for measuring degree of association was done by Jaccard's index (JI) whose value ranged between 0-1 and as the value approached to 1, indicated the high association among species. Mann-Whitney U-test was used as an indication to scrutinize the influence of host sex on the parasitic abundance. Community structure of parasites has been determined as a function of host habitats, sizes and sexes.

All the statistical tests were conducted using excel in SPSS, IBM 21.0, MS-Office and statistical significance level adopted was $p \leq 0.05$.

RESULTS AND DISCUSSION

Nine metazoan parasites were obtained from both the fishes during the present investigation, i.e., *Haplorchoides macrones*, *Bifurcohaptor indicus*, *Thaparocleidus tengra*, *Raosentis podderi* and *R. thapari*, *Metacercaria Isoparorchis hypselobagri*, *Raosentis godavarensis*, *Argulus striatus Lamproglena hospetensis*, whose monthly population dynamics and seasonal influence were carefully studied with a prime focus on their individual community structure (Table 1).

Monthly population dynamics of the metazoan parasites in *M. vittatus* and *M. cavasius* and the seasonal influence on parasitization: In the present study, the prevalence was 100% in the months of February, August, September and October, moderate in April, June, July and December and least in the rest of the month for *M. vittatus* while *M. cavasius* showed the highest prevalence in the months January and July and least prevalence in the months of March and April (Fig. 2a-d). Remaining months depicted the moderate to high prevalence's (Fig. 2a). Mean intensity and mean abundance were high in the months of July and August and higher index of infection was observed in August for *M. vittatus* (Fig. 2b-d). Similarly, *M. cavasius* showed high mean intensity, mean abundance and index of infection values in September and October (Fig. 2b-d). The season is also one of the main factors in structuring the parasitic community in the fish population[58-60]. Prevalence, mean intensity, mean abundance and index of infection were high in the rainy season, followed

Table 1: Metazoan parasites of *Mystus vittatus* Bloch, 1800 and *Mystus cavasius* Hamilton, 1822

Name of the hosts	Name of the parasites	Number of parasites collected
Mystus vittatus Bloch, 1800	*Haplorchoides macrones* (Dayal, 1949; Yamaguti, 1958)	88
	Metacercaria *Isoparorchis hypselobagri* (Billet, 1898)	13
	Bifurcohaptor indicus (Jain, 1958)	33
	Thaparocleidus tengra (Tripathi, 1959; Lim, 1996)	107
	Raosentis podderi (Datta, 1947)	19
	Raosentis thapari (Rai, 1967)	13
	Raosentis godavarensis (Anuprasanna and Vijayalakshmi, 2009)	3
	Argulus striatus (Cunnington, 1913)	7
Mystus cavasius Hamilton, 1822	*Haplorchoides macrones* (Dayal, 1949; Yamaguti, 1958)	67
	Bifurcohaptor indicus (Jain, 1958)	33
	Thaparocleidus tengra (Tripathi, 1959; Lim, 1996)	83
	Raosentis podderi (Datta, 1947)	98
	Raosentis thapari (Rai, 1967)	77
	Lamproglena hospetensis (Manohar, Seenappa and Venkateshappa, 1992)	41

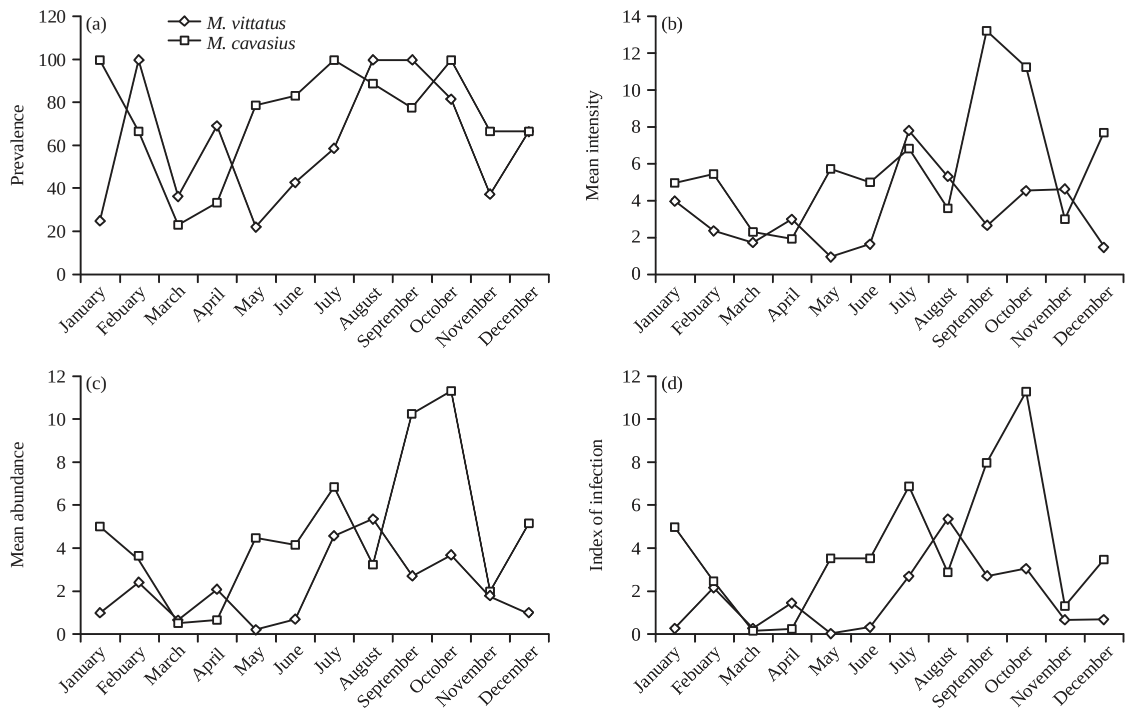

Fig. 2(a-d): Monthly population dynamics of total parasites of *M. vittatus* and *M. cavasius*, (a) Prevalence, (b) Mean intensity, (c) Mean abundance and (d) Intensity of infection

by winter season and least in summer season for both the fishes. However, the insignificant Chi-square values $\chi^2 = 2.64$, $p = 0.267$ for *M. vittatus* and $\chi^2 = 2.45$, $p = 0.292$ for *M. cavasius* at $p<0.05$ showed no influence of seasons on the parasitization (Table 2).

Component community structure of *M. vittatus* and *M. cavasius*: Of the nine metazoan parasites obtained from both the fishes 5 species i.e., *H. macrones*, *B. indicus*, *T. tengra*, *R. podderi* and *R. thapari* are common to both the species whereas *Metacercaria I. hypselobagri*, *R. godavarensis* and *A. striatus* occurred specifically in *Mystus vittatus* and *L. hospetensis* from *M. cavasius* (Table 1, 3, 4). Monogeneans (49.5%) predominated the parasitic community of *M. vittatus* followed by the digeneans (35.6%) whereas in *M. cavasius*, acanthocephalans (43.8%) conquered the parasitic community followed by the monogeneans (29.1%) (Table 5). Of the 116 hosts, 59 hosts (50.8%) of *M. vittatus* showed infection with any single parasitic group, 9 hosts (7.75%) were infected with any two parasitic groups and only 2 hosts (1.72%) showed infection with the 3 parasitic groups and none of the hosts showed infection with all the 4 parasitic groups (Table 6). On the other hand, of the 94 hosts, 39 hosts (41.4%) of *M. cavasius* showed infection with any single parasitic group, 20 hosts (21.2%) were infected with any two parasitic groups and only 5 hosts (5.3%) showed infection with 3 parasitic groups and none of the hosts showed infection with all the 4 parasitic groups (Table 6). Analysis on infestation with endo and ectoparasites shows that infestation with ecto helminth community (56.5%) was slightly more than endoparasitic community (43.5%) in *M. vittatus* whereas *M. cavasius* showed more endoparasitic infection (60.6%) than ectoparasites (39.3%). Alimentary gut, especially esophagus, stomach and intestine are the ideal locale of the endoparasites whereas gills and skin being much-preferred habitats of ectoparasites and parasites retain a commensalistic relationship with its host and do not create any nuisance although present in abundant number[61]. The number of parasites present in skin, gills, stomach and intestine of *M. vittatus* and *M. cavasius* was enumerated. Gills showed the maximum infection of 49.5% monogeneans, followed by the intestine (43.5%), swim bladder (4.5%) and skin (2.4%) in *M. vittatus* however, *M. cavasius* showed high infection in intestine (60%) rather than gills (39%) (Fig. 3a-b). The present study is in concurrence with the views of a few scientists, who predicted that endoparasites choose frequently intestine as its favorite locale due to the presence of digested food or due to its greater surface area and ectoparasites preferably choose gills as their favorite site[22,62-64]. Various factors such as length of the host, age, sex, alteration in diet, in the quantity of food

Table 2: Influence of seasons on parasitization of *M. vittatus* and *M. cavasius*

Seasons	*Mystus vittatus* (n = 116) Fishes examined (a)	Number of infected fishes (b)	Total parasites©	Prevalence (%)	Mean intensity	Mean abundance	Index of infection	*Mystus cavasius* (n = 94) Fishes examined (a)	Number of infected fishes (b)	Total parasites©	Prevalence (%)	Mean intensity	Mean abundance	Index of infection
2008-2009														
Winter	30	20	53	66.7	2.65	1.76	1.17	39	19	87	48.7	4.58	2.23	1.09
Summer	40	18	41	45	2.3	1.03	0.46	37	32	219	86.5	6.84	5.91	5.12
Rainy	46	37	189	80.4	5.11	4.1	3.30	18	13	93	72.2	7.15	5.16	4.18
Chi-square value*	$\chi^2 = 2.64$, p = 0.267							$\chi^2 = 2.45$, p =0.292						

*Result is not significant at p<0.05

Table 3: Diversity parameters and distribution patterns of parasitic species of *Mystus vittatus* (n=116)

Name of the parasite	Infected fishes	Number of parasites	Prevalence	Mean intensity	Mean abundance	Index of infection	Range	Dispersion index	Location	Nature of infection*	Nature of species**
Haplorchoides macrones	33	88	28.4	2.66	0.75	0.210	1-6	0.310	Intestine	Frequent	Satellite
Isoparorchis hypselobagri	6	13	5.17	2.16	0.11	0.006	1-3	0.040	Swim bladder	Rare	Satellite
Bifurcohaptor indicus	16	33	13.8	2.06	0.28	0.039	1-6	0.110	Gills	Frequent	Satellite
Thaparocleidus tengra	23	107	19.8	4.65	0.92	0.182	1-10	0.370	Gills	Frequent	Satellite
Raosentis podderi	8	19	6.89	2.38	0.16	0.011	1-4	0.067	Intestine	Rare	Satellite
R. thapari	5	13	4.31	2.60	0.112	0.004	2-4	0.040	Intestine	Rare	Satellite
R. godavarensis	2	3	1.72	1.50	0.02	0.0004	1-2	0.010	Intestine	Sporadic	Satellite
Argulus striatus	7	7	6.03	1.00	0.06	0.003	0-1	0.020	Skin	Rare	Satellite

*Common: 30-50%, Frequent: 10-30%, Rare: 4-10%, Sporadic: <4%, **Core sp.: >66%, Secondary sp.: Between 66-33%, Satellite sp.: <33%

Table 4: Diversity parameters and distribution patterns of parasitic species of *Mystus cavasius* (n = 94)

Name of the parasite	Infected fishes	Number of parasites	Prevalence	Mean intensity	Mean abundance	Index of infection	Range	Dispersion index	Location	Nature of infection*	Nature of species**
Haplorchoides macrones	27	67	28.47	2.48	0.71	0.204	1-10	0.16	Intestine	Frequent	Satellite
Bifurcohaptor indicus	14	33	14.8	2.35	0.35	0.052	1-7	0.08	Gills	Frequent	Satellite
Thaparocleidus tengra	17	83	18.08	4.88	0.88	0.159	1-11	0.20	Gills	Frequent	Satellite
R. podderi	18	98	19.14	5.44	1.04	0.199	1-24	0.24	Intestine	Frequent	Satellite
R. thapari	16	77	17.02	4.8	0.81	0.139	1-16	0.19	Intestine	Frequent	Satellite
Lamproglena hospetensis	17	41	18.08	2.4	0.43	0.078	1-10	0.102	Gills	Frequent	Satellite

*Common: 30-50%, Frequent: 10-30%, Rare: 4-10%, Sporadic: <4%, **Core sp.: >66%, Secondary sp.: Between 66-33%, Satellite sp.: <33%

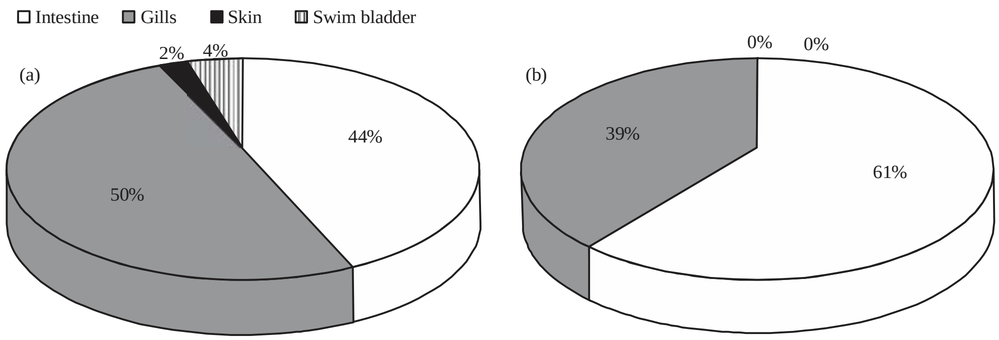

Fig. 3(a-b): Percentage of infection in different organs of *M. vittatus* and *M. cavasius*

Table 5: Number of parasites obtained, dominance index and mean total parasites of different parasitic groups in *M. vittatus* and *M. cavasius*

	M. vittatus			*M. cavasius*		
Parasite groups	Number of parasites	Dispersion index	MTP	Number of parasites	Dispersion index	MTP
Digeneans	101	0.36	0.87	67	0.17	0.71
Monogeneans	140	0.49	1.21	116	0.29	1.23
Acanthocephalans	35	0.12	0.30	175	0.44	1.86
Copepods	7	0.02	0.06	41	0.10	0.44

Table 6: Frequency distribution of number of parasitic groups per individual in *M. vittatus* and *M. cavasius*

	M. vittatus (n = 116)*		*M. cavasius* (n = 94)**	
Number of parasitic groups	Number of infected fishes	Frequency (%)	Number of infected fishes	Frequency (%)
1	59	50.8	39	41.4
2	9	7.75	20	21.2
3	2	1.72	5	5.30
4	0	0.00	0	0.00

*n = 116, Σx = 3, X = 3/116 = 0.025, Range = 1-3, **n = 94, Σx = 3, X = 3/94 = 0.031, Range = 1-3

ingested, variation in immunological competence and changes in the possibility of contact with intermediate hosts might discriminate the prevalence and intensity of the parasite community.

Infracommunities of *M. vittatus* and *M. cavasius*: A total of 70 (60.3%) *M. vittatus* and 64 (68.1%) *M. cavasius* parasitized with at least one or more parasite species. A sum of 283 individual parasites was collected with a mean of 2 parasites/fish in *M. vittatus* whereas a total of 399 individual parasites were collected with a mean of 4 parasites/fish in *M. cavasius.* Forty-six hosts (39.6%) showed infection with one parasite species and 19 (16.3%), 4 (3.44%) and 1 (0.86%) showed multiple infections with 2, 3 and 4 parasite species, respectively in *M. vittatus* (Table 7). Likewise, 32 (34.04%), 22 (23.4%), 8 (8.51%), 1 (1.1%) and 1 (1.1%) *M. cavasius* fish depicted multiple infections with 1, 2, 3, 4 and 5 parasite species, respectively (Table 7). The lower values of Shannon's H' index (0.64±0.45) and Simpson index (0.16) for *M. vittatus* and H' index (0.75±0.54) and Simpson index (0.29) for *M. cavasius* indicates less diversification of parasitic community. On the other hand, the slightly higher value of Shannon based evenness (E = 0.84±0.59) for *M. vittatus* and (E = 0.75±0.54) for *M. cavasius* suggests that community structures show consistent distribution of all parasite species (Table 8). Among the eight parasites obtained from *M. vittatus*, *H. macrones* (28.44%), *T. tengra* (19.8%) and *B. indicus* (13.8%) are frequently occurring species. Similarly, *R. podderi* (6.89%), *A. striatus* (6.03%), *Metacercaria I. hypselobagri* (5.17%) and *R. thapari* (4.31%) occur rarely with prevalence ranging between 4-10% and *R. godavarensis* was the sporadically occurring species. While all the six parasites of *M. cavasius* were frequently occurring with *H. macrones* (28.47%) and *R. podderi* (19.14%) showing a high prevalence (Table 3, 4). All the nine species are satellite species and there are no core and secondary species in both the hosts. Berger-Parkers dominance index was calculated for each species of parasite in the host. The monogenea, *T. tengra* (37.8%) was most prevalent in the parasite community of *M. vittatus* but occupied the position of satellite species. Likewise, *R. podderi* (24.5%) occurred in high numbers but occupied the position of satellite species in the parasitic

Table 7: Frequency distribution of number of parasitic species per individual in *M. vittatus* and *M. cavasius*

Number of parasitic species	*M. vittatus* (n = 116)*		*M. cavasius* (n = 94)**	
	Number of infected fishes	Frequency (%)	Number of infected fishes	Frequency (%)
1	46	39.6	32	34.04
2	19	16.3	22	23.40
3	4	3.44	8	8.51
4	1	0.86	1	1.06
5	0	0.00	1	1.06
6	0	0.00	0	0.00

*n = 116, Σx = 4, X = 4/116 = 0.034, Range = 1-4, **n = 94, Σx = 5, X = 5/94 = 0.053, Range = 1-5

Table 8: Diversity parameters of metazoan parasite communities of *M. vittatus* and *M. cavasius*

Host	Sample size	Mean No. of parasite species	Simpson's diversity index	Shannon's diversity index (H')	Shannon-based evenness (E)	Number of core species
M. vittatus	116 (70)	0.45±0.32	0.16	0.638±0.45	0.844±0.59	-
M. cavasius	94(64)	0.6±0.42	0.29	0.75±0.54	0.92±0.65	-

community of *M. cavasius*. Of the total 9 metazoan parasites from both the fishes 5 species i.e., *H. macrones*, *B. indicus*, *T. tengra*, *R. podderi* and *R. thapari* are common to both the hosts and presented a strong similarity in the species richness of both the fishes which was evidenced by a Jaccard's similarity coefficient (S_J = 55%). The ratio of variance to mean values gave the index of dispersion (DI). All the parasites, expect *R. godavarensis* and *A. striatus* exhibited over-dispersed (aggregated) distribution in *M. vittatus*. Similarly, all parasites of *M. cavasius* exhibited over-dispersed distribution (Table 9). The aggregated distribution of the parasite population is one of the universal features of metazoan parasite infection[65-67]. The present study is in harmony with the views of Anderson and Gordon[68] which suggested that the aggregated pattern might be due to varied behavioral changes of the host, susceptibility sand capability of host immunological response.

Infection with respect to host standard length: The relationship between host length and might be due to the incidence and association between parasite diversity and body length of sample[46,69-75]. According to Pearson's correlation coefficient, a less positive correlation (r = 0.359 for *M. vittatus* and r = 0.395 for *M. cavasius*) exists between host length and parasitic abundance. Middle-aged fishes are more susceptible to parasite infection than the younger and older ones.

Infection in relation host sex: Prevalence of parasites with respect to host sex varies. Male hosts showed more infection than females[71,76-78] while a few scientists were of the opinion that females are more infected than males[79-81]. The present study is in harmony with the views of Jarkovsky *et al.*[82], who suggested that there are no significant differences in infection rates of male and female hosts. In the present survey of 116 *M. vittatus*, 51 being males, 65 being females, of which 31 (60.7%) male and 39 (60%) female fishes were infected with at least one parasite. Similarly, of the 94 *M. cavasius*, 48 being males and 46 being females, of which 34 (70.8%) male and 30 (65.2%) female fishes were infected with at least one parasite. The impact of host sex on the overall prevalence of infection was analyzed by Chi-square test and Mann-Whitney U-test for each host species sex wise individually. Based on a benchmark of 0.05 alpha, the estimated χ^2-value = 0.0018, p = 0.966 for *M. vittatus* and χ^2-value = 0.0648, p = 0.799 for *M. cavasius* suggested that there was no statistically significant association between the parasite abundance of males and females of both the fishes. The insignificant values with respect to sex from Z (U)-test for *M. vittatus* (Z = -0.13, p = 0.896) and for *M. cavasius* (Z = 0.17, p = 0.865) at $p<0.05$ showed that the ecological relationship of both males and females might be similar (Table 10, 11). However, individual parasitization showed consistent results which suggest that host sex has no role to play in the parasitization except *Metacercaria I. hypselobagri* in *M. vittatus* which showed infection in males.

Co-existence of two species within a same host is referred it as interspecific association. Jaccard's index (JI) can monitor this type of association between each pair of parasite species. Hubalek[83], suggested that sharing of same biotic and abiotic environments, different habitat preference and reciprocated affinity for each other might be the inspiring factors for the existence of association between different species. The above results depicted that there is very diminutive competition among species of ectoparasite and endoparasite in the host species as they share different niches within the hosts. Only, *T. tengra* and *B. indicus* (0.64) in *M. vittatus* and *R. podderi* and *R. thapari* (0.916) in *M. cavasius* showed higher values,

Table 9: Mean (X), variance (s^2) and dispersion index (s^2/X) of parasite species in *M. vittatus* and *M. cavasius*

	M. vittatus 2008-2009 (n =116)				*M. cavasius* 2008-2009 (n = 94)			
Name of the parasite	Number of parasites collected	Mean (X)	Variance (s^2)	Dispersion index	Number of parasites collected	Mean (X)	Variance (s^2)	Dispersion index
H. macrones	88	0.79	2.18	2.78	67	0.712	2.44	3.43
I. hypselobagri	13	0.11	0.26	2.29	-	-	-	-
B. indicus	33	0.28	0.80	2.81	33	0.35	1.22	3.48
T. tengra	107	0.92	4.68	5.07	83	0.88	6.64	7.55
R. podderi	19	0.16	0.45	2.77	98	1.04	13.5	12.98
R. thapari	13	0.11	0.31	2.76	77	0.82	6.99	8.53
R. godavarensis	03	0.03	0.04	1.71	-	-	-	-
A. striatus	07	0.06	0.06	0.95	-	-	-	-
L. hospetensis	-	-	-	-	41	0.43	1.92	4.48

Table 10: Diversity parameters of parasitic species in males and females and values of Mann-Whitney U-test to evaluate rate of host sex and parasitic abundance in *Mystus vittatus*

	Host name										
	Mystus vittatus (N_m = 51, N_f = 65)								Mann-Whitney U test (Z)		
Parasite	N_{mi}	P_m	MI_m	MA_m	N_{fi}	P_f	MI_f	MA_f	Z (U)	p_1	p_2
H. macrones	13	25.49	3.23	0.82	20	30.70	2.30	0.707	0.30	0.38	0.76
I. hypselobagri	6	11.76	2.16	0.25	0	0.00	0.00	0.00	-1.08	0.14	0.28
B. indicus	7	13.72	1.57	0.215	9	13.84	2.44	0.33	0.06	0.47	0.95
T. tengra	9	17.64	5.66	1.00	14	21.53	4.00	0.86	0.25	0.40	0.80
R. podderi	3	5.88	2.30	0.13	5	7.69	2.40	0.18	0.17	0.43	0.86
R. thapari	2	3.92	3.00	0.117	3	4.61	2.33	0.107	0.06	0.47	0.95
R. godavarensis	0	0.00	0.00	0.00	2	3.07	1.50	0.046	0.28	0.38	0.78
A. striatus	3	5.88	1.00	0.05	4	6.15	1.00	0.062	0.02	0.49	0.98

N_m: Number of males examined, N_f: Number of females examined, N_{mi}: Number of males infected, N_{fi}: Number of females infected, P_m and P_f: Prevalence of males and females respectively, MI_m and MI_f: Mean intensity of males and females, MA_m and MA_f: Mean abundance of males and females respectively, p_1, p_2: Significance level

Table 11: Diversity parameters of parasitic species in males and females and values of Mann-Whitney U-test to evaluate rate of host sex and parasitic abundance in *Mystus cavasius*

	Host name										
	Mystus cavasius (N_m = 48, N_f = 46)								Mann-Whitney U test (Z)		
Parasite	N_{mi}	P_m	MI_m	MA_m	N_{fi}	P_f	MI_f	MA_f	Z (U)	p_1	p_2
H. macrones	14	29.16	0.071	0.77	13	28.26	2.3	0.65	0.10	0.46	0.92
B. indicus	10	20.83	1.90	0.39	4	08.69	3.5	0.30	0.93	0.17	0.35
T. tengra	8	16.66	6.13	1.02	9	19.56	3.7	0.74	-0.17	0.43	0.86
R. podderi	12	25.00	4.41	1.10	6	13.04	7.5	0.98	1.01	0.15	0.31
R. thapari	10	20.83	3.20	0.66	6	13.04	7.5	0.98	0.56	0.28	0.57
L. hospetensis	7	14.58	2.14	0.31	10	21.70	2.6	0.56	-0.59	0.27	0.55

N_m: Number of males examined, N_f: Number of females examined, N_{mi}: Number of males infected, N_{fi}: Number of females infected, P_m and P_f: Prevalence of males and females respectively, MI_m and MI_f: Mean intensity of males and females, MA_m and MA_f: Mean abundance of males and females respectively, p_1, p_2: Significance level

Table 12: Values of Jaccard's Index (JI) to estimate interspecific association between each pair of parasite species of *M. vittatus*

Name of parasites	*H. macrones*	*I. hyselobagri*	*B. indicus*	*T. tengra*	*R. podderi*	*R. thapari*	*R. godavarensis*	*A. striatus*
H. macrones	-	0.027	0.044	0.2	0.025	NA	NA	0.026
I. hyselobagri	0.027	-	NA	NA	NA	NA	NA	NA
B. indicus	0.044	NA	-	0.64	0.045	0.05	0.063	NA
T. tengra	0.2	NA	0.64	-	0.074	0.038	NA	0.035
R. podderi	0.025	NA	0.045	0.074	-	0.42	0.33	NA
R. thapari	NA	NA	0.05	0.038	0.42	-	0.2	NA
R. godavarensis	NA	NA	0.063	NA	0.33	0.2	-	NA
A. striatus	0.026	NA	NA	0.035	NA	NA	NA	-

Table 13: Values of Jaccard's index (JI) to estimate interspecific association between each pair of parasite species of *M.cavasius*

Name of parasites	*H. macrones*	*B. indicus*	*T. tengra*	*R. podderi*	*R. thapari*	*L. hospetensis*
H. macrones	-	0.121	0.19	0.33	0.296	0.182
B. indicus	0.121	-	0.173	0.071	0.076	0.0344
T. tengra	0.19	0.173	-	0.103	0.068	NA
R. podderi	0.33	0.071	0.103	-	0.916	0.038
R. thapari	0.296	0.076	0.068	0.916	-	0.032
L. hospetensis	0.182	0.0344	NA	0.038	0.032	-

suggesting that these parasites share a common niche i.e., gills within the host (Table 12, 13). Hence, the present ecological study put forward that parasitic communities of *M. vittatus* and *M. cavasius* show maximum similarity in their species composition less diverse, conventional, depauperate and non-interactive and holds good with the views of Holmes[84], who suggested that freshwater counterparts are less diverse than the marine ones.

CONCLUSION

Comparative study of the parasite fauna of two fish species of the genus *Mystus* from the River Godavari revealed a strong similarity in their species richness. The parasitic community of *M. vittatus* was predominated by monogeneans followed by the digeneans whereas acanthocephalans conquered the parasitic community in *M. cavasius* followed by the monogeneans. The fully sampled metazoan infracommunities of both the fishes showed less but consistent diversity of parasitic species and there were no core and secondary species. Host size and sex has very less to no influence on the parasitization, respectively. All the parasites showed over-dispersed distribution patterns except *A. striatus*, which displayed a random distribution pattern. Only monogeneans in *M. vittatus* and acanthocephalans in *M. cavasius* showed high JI values which might be due to the sharing the common niches. Hence, the present ecological study puts forward that parasitic communities of *M. vittatus* and *M. cavasius* show maximum similarity in their species composition but are less diverse, conventional, depauperate and non-interactive.

SIGNIFICANCE STATEMENTS

This study discovers the fact that the parasitic community structure of the two freshwater fish species of the genus *Mystus* showed less species diversity and strong similarity of species composition compared to their marine counterparts. This study help the future researchers to analyze the parasitic community structure of other freshwater fishes.

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