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Diversity, host specificity, speciation and ecological equivalence in some dactylogyrid monogenoideans of freshwater fish

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ABSTRACT

Objective: To observe their specificity, speciation and ecological equivalence by using previous and present records, from freshwater fish from Tanakpur to Sultanpur areas, during 2009 & 2010. **Methods:** Data is gathered from the published records to compare it with the present records and entered into a computer database. The taxonomy of monogenoideans follows and those of fish follows. The worms were gently scrapped from the gills of fish and counted manually. They were studied mostly live, under a phase contrast microscope (Olympus CX 41 U-DA 4E 03365 Japan) or fixed in 3% formalin, after being relaxed in lukewarm water. **Results:** These monogenoids have perfect ecological equivalence, as their macro habitat is geologically connected. They exhibit specificity at different taxonomic levels of the parasites and the hosts. Sympatric speciation of parasites and their host is evident in the present study. **Conclusions:** The monogenoidean fauna, in this region, has its species integrity in the past sixty to sixty five years. From this important body of study, it seems likely that host specificity among monogenoids from the fresh water fish is more widely spread than previously thought. Seasonal variations, probable controlling factor of infection, determine the intensity.

1. Introduction

Monogenoidean diversity in Indian subcontinent has not been documented completely. In the last few decades, 43 genera and 196 species have been described under the family, Dactylogyridae. With an aim to evaluate records (previous and present) of the monogenoids in a region (Figure 1) whose macro habitat is geologically connected, *i.e.* from Tanakpur, Pilibhit, Rumnagar, Madho Tanda, Lucknow to Sultanpur, (Coordinates: U.P. 26.8 ° North 80.91 ° East, Uttarakhand-28.43′ North to31 ° 27′ North and its longitudinal extent is 77 ° 34′ East to 02′ East), the present analysis was conducted over a period of two years (2009 & 2010).

The data given in Table 1 is based on natural infection. Analysis of the available data, on monogenoidean diversity (or species richness) at taxonomic levels provides useful information on their distribution pattern. Species diversity, as an indicator of health and stability of ecosystems is an important aspect towards proper management of aquaculture systems and wild life. Diversity broadly undertakes species richness or number of species and species evenness (*i.e.* how the data is distributed amongst the species).

Attention has been paid on finding the minor differences, if any, in the morphological characters of monogenoids as a consequence of change of host and its locality. Twenty five dactylogyrid species, belonging to nine genera *viz.*, *Dactylogyrus* Deising, 1850; *Bifurcohaptor* Jain, 1958; Dactylogyroides Gusev, 1963; *Heteronchocleidus* Price, 1964; *Cornudiscoides* Kulkarni, 1969; *Mastacembelocleidus* Kritsky *et al*, 2004; *Spicocleidus* Agrawal *et al*, 2005 (a recent addition); *Chandacleidus* Agrawal *et al*, 2006 (sp. recently added); *Xenentocleidus* Tripathi *et al*, 2007 were collected from fourteen fish species. Monogenoids are useful model for the study of co-evolution. Therefore, a brief comment on speciation is also presented here.

2. Material and methods

Data is gathered from the published records to compare it with the present records and entered into a computer database to generate a tabular form. A literature search

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showed that the current research on dactylogyrid monogenoideans in India is solely dependant on morphology. The taxonomy of monogenoideans follows[1] and those of fish follows[2].

Data for each species include the currently recognized scientific name, including author(s) and date. Type host, type locality including city, in India, references for all the records are included. An attempt had also been made to establish relationship between seasonal fluctuations and species richness. The monogenoids for the purpose of study were gently scrapped from the gills (site of infection) of the sacrificed fish and counted manually. The worms were studied mostly live, under a phase contrast microscope (Olympus CX 41 U-DA 4E 03365 Japan) or fixed in 3% formalin after being relaxed in lukewarm water.

The monogenoideans exhibit ecological equivalence throughout the region *i.e.* from Pilibhit, Madho Tanda, Rumnagar, Lucknow upto Sultanpur, though some records are new. Few monogenoids are specialists (four in the present study) while others could be generalist in nature. Strict host-specificity (Table 2) is possessed by *M. indicus*, only host being *W. attu*, *H. lucknowensis*, *C. fasciatus*, being its single host and *X. xenentodoni* (monotypic), *S. namae* (monotypic), infecting only *X. cancila* and *C. nama* respectively (also confirmed by previous and present records).

In *B. indicus*, *B. asiatica*, Dactylogyroides tripathii, *D. dorsali*, *D. longicirrus*, *M. heteronchorus*, *M. bam* and *C. lucknowensis*, however, the specificity is at generic level of the hosts species *i.e. Mystus*, *Ompok*, *Puntius*, *Mastacembelus* and *Chanda*, as is evident from records (past and present). Similarly, the species of the genus *Cornudiscoides* (three species recorded in the present study) infect different species of *Mystus* only. *B. indica* has even wider host specificity, infecting more than two siluriforms. *Dactylogyrus angularis*, *D. brevitignus*, *D. longiacus*, *D. subtilis*, and two undescribed species inhabit *Puntius sophore* (multiple infections). Three undescribed species were also found infecting two species of *Puntius*. Co-existence within monogenoidean community was observed.

The species richness, estimated per fish species is about three. However, speciation in host is accompanied by the speciation of monogenoid (Table 3). Seasonal variations also affect the occurrence. Maximum infection in terms of number and species richness is observed in May. The incidence of infestation shows two peaks, *i.e.* in summer (May) and winter (November) (Figure 2). In October recruitment begins, maximum number being in November which declines in December.

The number increases during March and reaches its peak in May. However, they maintain their adequate rate of infestation during winter months as well, which seems rare in monsoon months. Sometimes, epithelial outgrowths on the gill lamellae, were observed, on which the parasites were unable to survive.

3. Results

Geographically, Pilibhit, Madho Tanda, Tanakpur and Rumnagar are situated to the west of Lucknow and Sultanpur is situated to its east, a whole geographical belt has some how geological connections of the regions concerned. The river Gomti originates from about 3 km east of Pilibhit town, near Madho Tanda, of the same district at a height of 200 metres.

The river drains the area lying between river Ramganga and Sharda in the upper reaches and Ganga and Ghaghra at the lower reaches. In addition, bio-geographical distribution of fish, the environmental factors like macro and micro-environments affect survival ability of parasites, resulting in similarities among the pattern of occurrence of monogenoids. Organisms that occupy similar ecological niches in different geographical regions are ecological equivalents. Species occupying equivalent niches tend to be closely related taxonomically in regions which are contiguous.

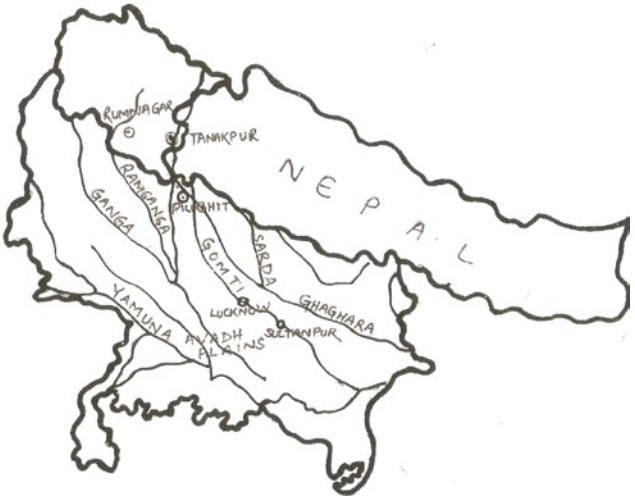

Figure 1. Map of Uttar Pradesh and adjoining regions showing interconnected waterbodies.

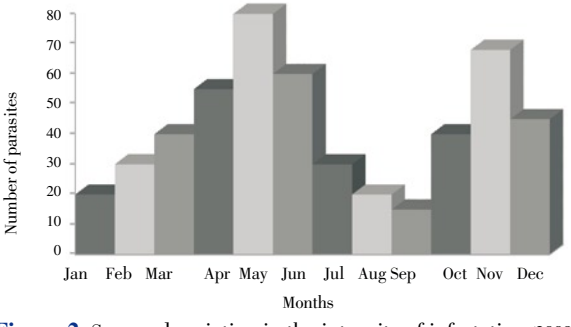

Figure 2. Seasonal variation in the intensity of infestation (2009 & 2010).

From this important body of study, it seems likely that host

Table 1
Comparative records of previously and presently studied species of some Monogenoidea.

		Previous Record		Present Record	
S.N	Parasites	Hosts	Localities	Hosts	Localities
1	*Mizelleusindicus* Jain,1957	*Wallagoattu* (Bloch and Schneider,1801)	Gomti River, Lucknow, Bhavanisagar reservoir,Raipur, Hyderabad, Meerut, Sultanpur, River Saryu, Faizabad,River Rapti, Gorakhpur,Deoria	*W. attu* (Bloch and Schneider,1801)	River Gomti, Water Bodies of Pilibhit, Chuka Bifurcation, Rum Nagar
2	*Bifurcohaptorindicus* Jain,1958	*Mystusvittatus* (Bloch,1794), *M. tengara* (Hamilton,1822), *M. bleekeri* (Day, 1877), *M. keletius* (Valenciennes, 1840), *Hemibagrusnemurus* (Valenciennes, 1840)	River Gomti, Lucknow, Hyderabad	*M. tengara* (Hamilton,1822)	River Gomti,Lucknow, River Dehwa, Pilibhit, River Sharda, Tanakpur
3	*Bychowskyellaasiatica* (Jain,1959) Gussev,1961	*Ompokpabda* (Hamilton,1822), *O. bimaculatus* (Bloch,1794)	River Gomti, Lucknow, River Ganges,Kanpur River Yamuna, Allahabad	*O. pabda* (Hamilton,1822)	River Gomti, Lucknow, Water bodies of Pilibhit, River Sharda, Tanakpur
4	*B. indica*(Jain, 1959) Gussev, 1961	*W. attu*(Bloch and Schneider,1801), *O. pabda* (Hamilton,1822), *Eutropiicthysvacha*(Hamilton,1822), *Clupisomagarua* (Hamilton,1822)	River Gomti, Lucknow,River Sai near Lucknow, River Yamuna, Allahabad, River Rapti, Gorakhpur	*Eutropiicthysvacha* (Hamilton,1822)	River Gomti, Lucknow,River Dehwa, Pilibhit,Chuka Bifurcation, Rum Nagar
5	*Dactylogyroidestripathii* (Tripathi, 1959, Yamaguti,1963) Gussev 1963	*Puntiusticto* (Hamilton,1822) *P. sophore* (Hamilton,1822)	River Gomti, Lucknow, Tungbhadra Dam,Raipur	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur, BhagharJheel, Barabanki, River Sai near Lucknow, Water bodies of Pilibhit
6	*Cornudiscoidesproximus* Gussev,1976	*M. vittatus* (Bloch,1794), *M. tengara* (Hamilton,1822)	River Gomti& Water bodies near Lucknow, Deoria, Sultanpur	*M. tengara* (Hamilton,1822)	River Gomti, Lucknow, River Dehwa, Pilibhit, River Sharda, Tanakpur
7	*Dactylogyroideslongicirrus* (Tripathi, 1959) Gussev, 1976	*P. sophore* (Hamilton,1822), *P. ticto* (Hamilton, 1822)	River Gomti,Lucknow Tungbhadra Dam,Raipur	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur, BhagharJheel, Barabanki, River Sai near Lucknow, Water bodies of Pilibhit
8	*Dactylogyrusangularis* Gussev,1976	*P. sophore* (Hamilton,1822)	River Gomti& Water Bodies near Lucknow	*P. sophore* (Hamilton,1822)	River Gomti,Lucknow,BhagharJheel, Barabanki
9	*D. brevitignus* Gussev,1976	*P. sophore* (Hamilton,1822)	River Gomti&Water Bodies near Lucknow	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur, BhagharJheel, Barabanki,River Sai near Lucknow,Water bodies of Pilibhit
10	*D. longiacus* Gussev,1976	*P. sophore* (Hamilton,1822)	River Gomti& Water Bodies near Lucknow	*P. sophore* (Hamilton,1822)	River Gomti,Lucknow , River Sai near Lucknow
11	*D. subtilis* Gussev,1976	*P. sophore* (Hamilton,1822)	River Gomti,Lucknow, Water Bodies near Lucknow	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow, BhagharJheel, Barabanki
12	*Cornudiscoidesvittati* Dubey *et al*,1992	*M. vittatus* (Bloch,1794)	River Gomti,Lucknow, Water Bodies near Raipur	*M. vittatus* (Bloch,1794)	River Gomti, Lucknow,Water bodies of Pilibhit, ChukaBifurcation,Rum Nagar,River Sharda, Tanakpur
13	*Heteronchocleiduslucknowensis* Agrawal and Bhatnagar,1997	*Colisafasciatus* (Bloch and Schneider,1801)	River Gomti, Lucknow	*C. fasciatus* (Bloch and Schneider 1801)	Water bodies of Pilibhit, Chuka Bifurcation, Rum Nagar
14	*Dactylogyroidesdorsali* (Gussev,1976) Agrawal *et al*, 2002	*Puntiusdorsalis* (Jerdon,1849)	River Gomti, Lucknow, Water bodies near Lucknow	*Puntiuschola* (Hamilton, 1822)	River Gomti, Lucknow, River Gomti, Sultanpur, Water bodies of Pilibhit,RiverSharda , Tanakpur
15	*Mastacembelocleidusheteronchorus* (Kulkarni,1969) Kritsky *et al*, 2004	*Mastacembelusarmatus* (Laceped,1800),	River Gomti, Lucknow, Hyderabad	*M. armatus* (Laceped,1800)	River Gomti, Lucknow,ChukaBifurcation,RumNagar,RiverSharda,Tanakpur
16	*M. bam* (Tripathi,1959) Kritsky *et al*, 2004	*M. armatus* (Laceped,1800) *Macrognathusaculeatus* (Bloch, 1786) *M. pancalus* (Hamilton,1822)	River Gomti, Lucknow,Tungbhadra Dam	*M. pancalus* (Hamilton,1822)	River Gomti, Lucknow, ChukaBifurcation,RumNagar,Water bodies of Pilibhit
17	*Chandacleiduslucknowensis* Agrawal *et al*,2006	*Chandanama* (Hamilton,1822), *C. baculis* (Hamilton)	River Sai near Lucknow	*C. nama* (Hamilton,1822)	Chuka Bifurcation, Rum Nagar,River Sharda,Tanakpur,River Dehwa, Pilibhit
18	Spicocleidusnamae Agrawal *et al*.2006	*C. nama* (Hamilton,1822)	River Sai near Lucknow	*C. nama* (Hamilton,1822)	Chuka Bifurcation, Rum Nagar,River Sharda,Tanakpur
19	*Xenentocleidusxenentodoni* (Jain,1961) Tripathi *et al*, 2007	*Xenentodoncancilla* (Hamilton,1822)	River Gomti, Lucknow, River Sai, Lucknow	*X. cancilla* (Hamilton,1822)	River Gomti, Lucknow, Chuka Bifurcation, River Sharda, Rum Nagar,Water bodies of Pilibhit
20	*Cornudiscoides n* spp	X	X	*Mystusbleekeri* (Day,1877)	River Gomti, Lucknow
21	*Dactylogyrussps 1*	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur
22	*Dactylogyrussps 2*	*P. chola* (Hamilton, 1822)	River Gomti, Lucknow	*P. chola* (Hamilton, 1822)	Water Bodies of Lucknow,BhagharJheel,Barabanki,
23	*Dactylogyrussps 3*	*P. ticto* (Hamilton,1822)	River Gomti, Lucknow	*P. ticto* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur,BhagharJheel,Barabanki
24	*Dactylogyrussps 4*	*P. ticto* (Hamilton,1822)	River Gomti, Lucknow	*P. ticto* (Hamilton,1822)	River Gomti, Lucknow, River Gomti, Sultanpur
25	*Dactylogyrussps 5*	*P. sophore* (Hamilton,1822)	River Gomti, Lucknow	*P. sophore* (Hamilton,1822)	River Gomti, Sultanpur,BhagharJheel, Barabanki, River Sai near Lucknow

Table 2
Host-species relationship of Monogenoidea.

Strict host species specific	Wider host species specific	Host genus specific	Host order specific
Mizelleusindicus *Heteronchodeidusslucknowensis* *Xenentodeidusxenentodoni* *Spicocleidusnamae*	*Dactylogyrusangularis* *D. brevitignus* *D. longiacus* *D. subtilis* & 5 undescribed species of *Dactylogyrus*	*Bifurcohaptorindicus*, *Bychowskyellaasiatica*, *Dactylogyroidestripathii*, *Dactylogyroidesdorsali*, *Dactylogyroideslongicirrus*, *Mastacembelocleidusheteronchorus* *M. bam, handacleidusslucknowensis*, *Cornudiscoidesproximus*, *Cornudiscoidesvittati* & one unknown spp. of Cornudiscoides	*Bychowskyellaindica*

Table 3
Sympatric speciation of host with it's parasite.

S.No.	Host genus	Monogenoids
1.	*Chanda* (2 species) 1. *Chanda nama* 2. *C. baculis*	2 species *Chandacleidusslucknowensis, Spicocleidusnamae* *C. lucknowensis*
2.	*Clupisoma* (1 species) 1. *Clupisomagarua*	1 species *Bychowskyellaasiatica*
3.	*Colisa* (1 species) 1.*Colisa fasciatus*	1 species *Heteronchocleidusslucknowensis*
4.	*Eutropiicthys* (1 species) 1.*Eutropiicthys vacha*	1 species *B. indica*
5.	*Macrognathus* (2 species) 1.*Macrognathus aculeatus* 2.*M. pancalus*	2 species *Mastacembelocleidus bam M. bam*
6.	*Mastacembelus* (1species) 1.*Mastacembelus armatus*	1 species *M. heteronchorus*
7.	*Mystus* (4 species) 1.*Mystus bleekeri* 2.*M. keletius* 3.*M. tengara* 4.*M. vittatus*	4 species *Bifurcohaptorindicus, Cornudiscoides* new species *B. indicus* *B. indicus, C. proximus* *B. indicus, C. proximus, C. vittati*
8.	*Ompok* (1 species) 1.*Ompok pabda*	2 species *Bychowskyellaasiatica, B. indica*
9.	*Puntius* (4 species) 1.*Puntius chola* 2.*P. dorsalis* 3.*P. sophore* 4.*P. ticto*	12 species *Dactylogyroidesdorsali*, 1 new species of Dactylogyrus *D. dorsal* *D. tripathii, D. longicirrus,* *Dactylogyrusangularis, D. brevitignus, D. longiacus,* *D. subtilis*, 2 new species of Dactylogyrus *D. tripathii, D. longicirrus*, 2 new species of *Dactylogyrus*
10.	*Wallago* (1 species) 1.*Wallago attu*	2 species *B. indica, Mizelleusindicus*
11.	*Xenentodon* (1 species) 1.*Xenentodon cancilla*	1 species *Xenentocleidusxenentodoni*

specificity among monogenoids from the fresh water fish is more widely spread than previously thought. The majority of these ectoparasites are restricted either to a particular host sp., genus, family or even order, although some have broader host amplitude (Table 3). The host response mechanism together with the parasite population growth on a fish establishes and determines the host specificity [3]. Four monogenoids are strictly host specific (follow the rule framed by Tripathi *et al*[4] for the genus *Quadriacanthus*: each host species may have more than one parasite species but no parasite species will usually infest more than one host species).

Repetitive occurrence of parasites on their respective hosts confirms our conception that a particular parasite species is limited to a single host species. Narrow host specificity usually indicates an old and intimate relationship, implying that co-evolution has taken place between the host species and its parasites.

Wider specificity is, however, observed in 9 species of *Dactylogyrus* (of which 5 are undescribed) and the generic level specificity is possessed by 11 species. Order level specificity is shown by *Bychowskyella indica* (Table 2).

4. Discussion

Monogenoideans have come up as a highly successful group, as indicated by their high diversity. The co-speciation of *Dactylogyrus*, Dactylogyroides and

Cornudiscoides on various species of *Puntius* and *Mystus*, indicates the sympatric speciation where parasite phylogeny mirrors host phylogeny (Fahrenholz's rule). In the present study, it is evident that more the number of host's species, more are the parasite species However, the number of parasite taxa is higher than the number of their hosts, as indicated in Table 3. Species co-existence within host is reinforced probably by reproductive isolation. Wide specificity could be due to the ability of host species to exchange parasites, which is in turn dependent on the ability of these parasites to adapt to the conditions found in the new hosts. The number of hosts ranges on the basis of availability of favorable conditions shown by the host and the environment

The reason behind variation (Figure 2) in the intensity of infection during different months of the year can be temperature conditions[5]. July-September, the breeding season of the host seems to correspond with the duration of rare occurrence of its parasites, as the fish is under hormonal stress, due to release of corticosteroids into blood, starvation and relatively warmer temperature of water. Decline in the intensity, during the monsoon months may be attributed to the reason that they cannot withstand the heavy rains and get washed away[6,7]. however, have all held that the decrease in incidence and intensity in monsoons was most likely on account of formation of epithelial outgrowths on the gill lamellae on which the parasites were unable to survive (we also found similar cases sometimes).

It should be noted that this survey is not complete and that an intensive survey is still needed because rapid environmental deterioration can be a hindrance towards determination of monogenoidean fauna along with its sensitive host *i.e.*, fish. However, Jain *et al*[8-14] have described numerous Indian monogenoideans, that have escaped their extinction during the long course of evolution. The persisting presence of even ancient monogenoids, during the present study has proved that in spite of exposure to constant environmental pressures during life cycle stages, they are conserved till date.

Conflict of interest statement

We declare that we have no conflict of interest.

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