A review of Monogenean diversity in India: Pathogens of fish diseases

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1. Introduction

The earth has its variety of life and biological diversity which is commonly referred as biodiversity. Generally, in recent past, interest in biodiversity has grown rapidly. Biodiversity, defined as the number and variety of organisms living within a specific geographical region and is essential for stability of ecosystems, protection of environment and understanding the intrinsic value of various species on earth[1]. Parasites, which are estimated to constitute more than half of the biodiversity[2] are the core of biodiversity surveys and ecosystem function. Parasites use to represent a neglected component of diversity because of they are small, hidden on or within their hosts and need more careful observation to be identified with accuracy. The diversity and ecology of many groups of parasites is poorly known[3,4]. In the present study, an attempt to evaluate the state of art known about the monogenean fauna parasitic in freshwater fishes of India. The available information indicates the rich diversity of these parasites in India for that an integrated approach is necessary which should start with morphological characterization followed by molecular characterization of monogenean parasites in all river system of India. So that subsequent comparison of monogenean fauna present in different river systems of India can be made.

ABSTRACT

The monogeneans parasitizing skin, fins, gills of fishes and are pathogenic to cultivated fish and a few have caused epizootic events. This paper presents a catalogue of known species of the class monogenea from the freshwater fishes of five major river systems of India. Data is gathered from all the published records of monogenean species from India and also from NCBI database for molecular studies, including the fish data gathered from Fishbase. Approximately 50 families of freshwater fishes have been reported from five Indian major river systems, having 159 nominal genera and 208 species have been reported. In all, the present study takes a broad look at monogenean diversity in the freshwater fishes of India. The available information indicates the rich diversity of these parasites in India for that an integrated approach is necessary which should start with morphological characterization followed by molecular characterization of monogenean parasites in all river system of India. So that subsequent comparison of monogenean fauna present in different river systems of India can be made.

KEYWORDS
Monogenea, Freshwater, Molecular biology, India

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after hatching these parasites fastly try to find a host fish and this is easy for them when the fishes are in captive and crowded conditions where they have no problem in findings the host. Monogeneans have a haptor at their posterior end, it has hooks that helps them to attached to their host. These parasites have a direct life cycle, which helps them to go directly from one host to another. This attempt, has also been made to estimate the extent of our current knowledge in comparison to a total, exhaustive inventory of the monogenean fauna. Diseases borned by the parasite are the most important factor which threatened the fishery industry worldwide[5] and India is not exception to this. Monogenean parasites infect freshwater fishes are one of the major group of parasites that often cause diseases worldwide[6]. Helminth parasites beside being important for causing fish diseases but also because they are an essential and integral component of global biodiversity[3]. As parasites of fish including monogeneans, according to a rough estimate about 30000 helminth species have been documented worldwide. Monogeneans are the most ubiquitous and abundant group of parasites in the aquatic environment and predominantly ectoparasitic on gills and skin of fishes[7]. During course of their evolution, however a few species become endoparasitic by inhabiting the palleal cavity of cephalopods, urinary bladder and rectum of amphibians and reptiles, eye and nasal cavities of amphibious mammals[8]. These helminthes use to feed on blood and/or epithelial cells and mucus of fish causing direct piscine loss due to morbidity and mortality[9,10]. This becomes more severe when they invade younger fishes in intensive culture conditions[11].

Moreover, monogenean infection also lead to indirect damage, making the fishes more susceptible to secondary infections by degrade and break the epithelium and mucous layer[12]. As far as economic affects of monogenean infestation is concern, it includes decrease or rejection of edible fish products leading to subsequent loss of interest in the aquaculture practice[13]. During heavy infections of monogeneans it was found that the fish died which may significant damage and mortality. Some symptoms of heavily infected fish are: rubbing on objects in tank; erratic swimming, hanging near water surface; gills flared, mouth open, irregular opercular beat; squirting water, or coughing in order to back-flush gills; not eating, decrease in weight; lethargic, cloudy eyes; damaged or frayed fins, scaleless, skin may vary in color where the parasites have fed; patches and open wounds may appear on skin.

Some skin and gill infections illustrate that situation, such as the ichthyophthiriosis produced by the ciliate *Ichthyophthirius multifilis*[14–16].

In India, studies related to biodiversity of helminthes (excluding monogeneans) were started from the middle of last century by workers who came to this subcontinent on medical or military deputation from foreign lands[17]. Consequently, diversity of helminthes parasites has been documented from different parts of the country by helminthologists including: GD Bhalerao, GS Thapar, MN Dafta, BS Chauhan, TD Soota, PD Gupta, HD Srivastava, CB Srivastava, SP Gupta, V Gupta, GB Shinde, G Premvati, NK Gupta, BL Kaw, SC Baugh, KC Pandey, Y Chaturvedi, M Hafeezullah, OH Baqui, RK Ghosh and MS Jayrajpur. Most of these workers studied and described new taxa, however, a few publications also dealt with ecological aspects, life cycle, pathology and control. As far as biodiversity studies related to Indian monogeneans is concerned, it begun in fourth decade of 19th century by workers like BS Chauhan, GS Thapar, SL Jain, RV Ummithan, SP Gupta, NK Gupta, GP Agarwal, K Ramalingam, YR Tripathi, AV Gussev, KC Pandey, N Agrawal and HS Singh. Recently, compiled a comprehensive account of known nominal species of monogeneans is to be about 300 which is far from complete[18].

Here we would like to provide additional information about known monogenean parasites harboring the freshwater fishes of India. The principle objective of this paper is found out the lacunae existing in biodiversity studies of freshwater monogeneans in Indian subcontinent. Beside this, the present study brings together all monogenean parasitizing freshwater fishes from the five major river systems of India and also to provide molecular biological data available on freshwater monogeneans from this subcontinent.

### 2. Five major river systems of India

There are five major river systems of India viz., Ganga, Brahmaputra, Indus, East coast and West coast. These rivers are long and are joined by many large and important tributaries. Besides this, many small seasonal and perennial rivers also use to contribute to these river systems separately (Figure 1).
2.1. Ganga River system

The Ganga and its major tributaries like Yamuna, Son and Gandak actually formulates the biggest cultivable plains of north and eastern India, known as the Gangetic plains. The Bhagirathi, which is considered the Ganga’s true source, starts from Gomukh Gangotri glaciers in the Himalayas and flows through the states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. Subsequently, it enters in Bangladesh and known as the Padma River.

2.2. Brahmaputra River system

Originates in China, near the sources of the Indus and the Sutlej, where it is known as the Yarlung Zangbo River or Tsangpo. It flows east, parallel to the Himalayas, reaches Namjagbarwa, turns south and enters India in Arunachal Pradesh, where it is known as Dihang. In Assam, it is called the Brahmaputra and just before entering Bangladesh it splits into two distributaries.

2.3. Indus River system

The Indus River originates in the northern slopes of Kailash range near Lake Mansarovar in Tibet. Although, most of the river’s course runs through neighbouring Pakistan, a portion of it does run through Indian territory and has five tributaries.

2.4. East coast

East coast river system includes Godavari, often referred to as the Vridhdh Dakshin Ganga. It arises at Tryambakeshwar, near Nasik and Mumbai in Maharashtra around 380 km distance from the Arabian Sea, and empties into the Bay of Bengal. It also includes the Krishna which originates at Mahabaleswar in Maharashtra and meets the sea in the Bay of Bengal at Hamasaladeevi in Andhra Pradesh. The Krishna River flows through the states of Maharashtra, Karnataka and Andhra Pradesh. East coast river system also has the Kaveri that headwaters are in the Western Ghats range of Karnataka state, and from Karnataka through Tamil Nadu and empties into the Bay of Bengal.

2.5. West Coast

The main water divide in peninsular rivers is formed by the Western Ghats, which run from north to south close to the western coast. Most of the major rivers of the peninsula such as the Narmada’ or Nerbudda is a river in central India and originates in Amarkantak. The Tapti is one of the major rivers of peninsular India rises in the eastern Satpura Range of southern Madhya Pradesh state, before emptying into the Gulf of Cambay of the Arabian Sea, in the State of Gujarat.

3. Host and parasites

From India, total 50 families of freshwater fishes from five major river systems are found having 159 nominal genera. From these genera, only 14 families which belong to 44 genera of freshwater monogeneans were reported (Table 1 and Figure 2). The present study takes a broad look at monogenean diversity in the fishes of five major river systems of India in order to determine the status of monogenean diversity. The study reveals that approximately 35.45% fishes have so far been investigated for monogenean infection in general and still 74% are remaining that are not screened. As far as investigations related to five different major river systems are concerned, the data is presented in the form of table and figure (Table 2). The data shows that in India, not a significant number of host species have been studied for monogeneans. The maximum screening has been made in Ganges river system i.e. 62.25% followed by East coast river system (34.37%), Indus river system (17.18%), Brahmaputra river system (16.50%) and West coast river system (4.16%) (Figure 3 and 4).

![Figure 2](image-url) Flow chart showed the total number of fish and parasites in five freshwater systems of India.

| Major river system | Total fish fauna | Screened fish | % Screened |
|--------------------|-----------------|---------------|------------|
| Ganga              | 151             | 94            | 62.25      |
| Brahmaputra        | 103             | 17            | 16.50      |
| Indus              | 64              | 11            | 17.18      |
| East coast         | 160             | 55            | 34.37      |
| West Coast         | 24              | 1             | 4.16       |

Table 2

Status of screened fishes in five major river systems of India.
Table 1
List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish Family       | Monogenea                    | Monogenea family         |
|----------------------|-------------------|------------------------------|--------------------------|
| I. Ganga River System|                   |                              |                          |
| Acanthocobitis botia | Balitoridae       | –                            | –                        |
| Ailia coila           | Schilbeidae       | –                            | –                        |
| Ailia punctata        | Schilbeidae       | –                            | –                        |
| Anabas testudineus    | Anabantidae       | Trianchoratus agrawali       | Dactylogyridae           |
|                      |                   | Trianchoratus kearni         | Dactylogyridae           |
| Anchoviella bataviensis| Engraulidae      | Engraulicola foreoposim      | Gastrocotylidae          |
| Anguilla bengalensis  | Anguillidae       | –                            | –                        |
| Anodontostoma chacunda| Clupeidae         | Neomazocraes anodontostomae  | Mazocraeidae             |
| Arius gagarides       | Ariidae           | –                            | –                        |
| Arius thunbergi       | Ariidae           | Chauhanellas alatus          | Dactylogyridae           |
| Aspidoparia morar     | Cyprinidae        | Labotrema aspidoparasi     | Diplectanidae            |
| Badis badis           | Nandidae          | –                            | –                        |
| Bagarius bagarius     | Sisoridae         | Bifurcohaptor giganticus     | Dactylogyridae           |
|                      |                   | Bychowskyella bagariusi     | Dactylogyridae           |
| Bagarius docmak       | Sisoridae         | Quadricanthus bagrae         | Dactylogyridae           |
| Bagarius dorsalis     | Sisoridae         | Dactylogyrides dorsali       | Dactylogyridae           |
| Bagarius yarrelli     | Sisoridae         | –                            | –                        |
| Barbus stigmaticemion | Cyprinidae        | Dactylogyrus gussevi         | Dactylogyridae           |
| Barilus barna         | Cyprinidae        | –                            | –                        |
| Barilus shacra        | Cyprinidae        | –                            | –                        |
| Barilus tileo         | Cyprinidae        | –                            | –                        |
| Botia Dario           | Cobitidae         | –                            | –                        |
| Botia lokiachata      | Cobitidae         | –                            | –                        |
| Calllichrous malabaricus| Siluridae        | Thaparocleidus devrai        | Dactylogyridae           |
| Carassius auratus     | Cyprinidae        | Dactylogyrus inexpectatus    | Dactylogyridae           |
| Carassius species     | Cyprinidae        | Pellucidhaptor kritskyia     | Dactylogyridae           |
| Catla catla           | Cyprinidae        | Dactylogyrus kalyanensis     | Dactylogyridae           |
|                      |                   | Diplozoon indicum            | Diplozoidae              |
|                      |                   | Dogielius catalus            | Dactylogyridae           |
|                      |                   | Gyrodactylus elegans indicus | Gyrodactylidae           |
|                      |                   | Paradactylogyrus catalius    | Dactylogyridae           |
|                      |                   | Singhiogyrus exota           | Dactylogyridae           |
| Chacca chacca         | Chacidae          | –                            | –                        |
| Chanda baculis        | Ambassidae        | Chandacleidus lucknowensis  | Dactylogyridae           |
|                      |                   | Chandacleidus sainensis     | Dactylogyridae           |
| Chanda nama           | Ambassidae        | Chandacleidus lucknowensis  | Dactylogyridae           |
|                      |                   | Chandacleidus recurvatus    | Dactylogyridae           |
|                      |                   | Spicoleidus namae            | Dactylogyridae           |
| Chanda ranga          | Ambassidae        | Chandacleidus recurvatus     | Dactylogyridae           |
| Channa gachua         | Ophiocephalidae   | Gyrodactylus raipuresi       | Gyrodactylidae           |
| Channa maralius       | Ophiocephalidae   | –                            | –                        |
| Channa orientalis     | Ophiocephalidae   | Gyrodactylus raipuresi       | Gyrodactylidae           |
| Channa punctata       | Ophiocephalidae   | Gyrodactylus hyderabadiensis| Gyrodactylidae           |
| Channa striatia       | Ophiocephalidae   | –                            | –                        |
| Chagunius chagunio    | Cyprinidae        | Dactylogyrus chagunionis     | Dactylogyridae           |
|                      |                   | Neodiplozoon barhi           | Diplozoidae              |
| Chitala chitala       | Notopteridae      | Notopteroidiscoides chitalai | Dactylogyridae           |
|                      |                   | Notopteroidiscoides cirri    | Dactylogyridae           |
|                      |                   | Notopteroidiscoides indicus  | Dactylogyridae           |
|                      |                   | Notopteroidiscoides currhahamulus| Dactylogyridae       |
|                      |                   | Notopteroidiscoides lucknowensis| Dactylogyridae      |
|                      |                   | Pseudodiplectanum lucknowensis| Diplectanidae           |
| Cirrhus ariza         | Cyprinidae        | Dactylogyrus anchocalancanthus| Dactylogyridae           |
|                      |                   | Dactylogyrus cirrhini        | Dactylogyridae           |
|                      |                   | Dactylogyrus crucitubus      | Dactylogyridae           |
|                      |                   | Gyrodactylus elegans indicus | Gyrodactylidae           |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish            | Fish family | Monogenea                  | Monogenea family   |
|-----------------|-------------|----------------------------|--------------------|
| *Cirrhinus cirrhosus* | Cyprinidae  | *Dactylogyrus chauhanus*   | Dactylogyridae     |
|                 |             | *Dactylogyrus mirigali*    | Dactylogyridae     |
|                 |             | *Dactylogyrus yogendrai*   | Dactylogyridae     |
|                 |             | *Gyrodactylus elegans indicus* | Gyrodactyliidae |
|                 |             | *Mazocraes singhi*         | Mazocraeidae       |
| *Clarias batrachus* | Claridae    | *Hamatompedancularia batrachi* | Dactylogyridae   |
|                 |             | *Quadricanths kohiensi*    | Dactylogyridae     |
| *Clarias fuscus*   | Claridae    | *Quadricanths kohiensi*    | Dactylogyridae     |
| *Clarias gariepinus* | Claridae    | *Quadricanths bagrae*      | Dactylogyridae     |
|                 |             | *Quadricanths clariaidis*  | Dactylogyridae     |
| *Clupisoma garna*   | Schilbeidae | *Bychowskyella gharui*     | Dactylogyridae     |
|                 |             | *Bychowskyella gusseri*    | Dactylogyridae     |
|                 |             | *Bychowskyella jaini*      | Dactylogyridae     |
|                 |             | *Bychowskyella pricei*     | Dactylogyridae     |
|                 |             | *Thaparocleidus indicus*   | Dactylogyridae     |
|                 |             | *Thaparocleidus seenghali* | Dactylogyridae     |
|                 |             | *Thaparocleidus vaginals*  | Dactylogyridae     |
| *Coius quadrispeciatus* | Coiidae  | –                           | –                  |
| *Colisa fasciatus*   | Belontiiidae| *Gyrodactyls chauhani*     | Gyrodactyliidae    |
|                 |             | *Gyrodactyls colisai*      | Gyrodactyliidae    |
|                 |             | *Heteronchocleidus buschkieli* | Dactylogyridae   |
|                 |             | *Heteronchocleidus colisai* | Dactylogyridae     |
|                 |             | *Heteronchocleidus gracilis* | Dactylogyridae    |
|                 |             | *Heteronchocleidus lucknowensis* | Dactylogyridae |
| *Colisa lalia*      | Belontiiidae| –                           | –                  |
| *Crossocheilus latius* | Cyprinidae | –                           | –                  |
| *Ctenopharyngodon idella* | Cyprinidae | *Dactylogyrus ctenopharyngodon* | Dactylogyridae |
| *Calura inconstans*   | Gasterosteidae | *Dactylogyrus eucalius*   | Dactylogyridae     |
| *Cyprinus carpio*    | Cyprinidae  | *Dactylogyrus anchoratus*  | Dactylogyridae     |
| *Danio sp.*          | Cyprinidae  | *Dactylogyrus aequippinnati* | Dactylogyridae |
| *Erethistes pusillus* | Erethistidae| –                           | –                  |
| *Esomus danricus*    | Cyprinidae  | *Ancyrocephalus chakrabartii* | Dactylogyridae |
| *Eutropiichthys marius* | Schilbeidae | –                           | –                  |
| *Eutropiichthys vachii* | Schilbeidae| *Bychowskyella gharui*     | Dactylogyridae     |
|                 |             | *Bychowskyella gomtia*     | Dactylogyridae     |
|                 |             | *Bychowskyella indica*     | Dactylogyridae     |
|                 |             | *Bychowskyella lucknowensis* | Dactylogyridae    |
|                 |             | *Bychowskyella vachii*     | Dactylogyridae     |
|                 |             | *Thaparocleidus indicus*   | Dactylogyridae     |
|                 |             | *Thaparocleidus pangasi*   | Dactylogyridae     |
|                 |             | *Thaparocleidus vaginals*  | Dactylogyridae     |
| *Gagata cenia*       | Sisoridae   | –                           | –                  |
| *Gagata gagata*      | Sisoridae   | –                           | –                  |
| *Gagata sexualis*    | Sisoridae   | –                           | –                  |
| *Gagata youssoufi*   | Sisoridae   | –                           | –                  |
| *Gangra viridescens* | Sisoridae   | –                           | –                  |
| *Garra gosyla*       | Cyprinidae  | *Labotrema rajendrai*      | Diplectanidae      |
| *Glossogobius giuris* | Sisoridae  | *Dactylogyrus gobii*       | Dactylogyridae     |
|                 |             | *Dactylogyrus glossogobii* | Dactylogyridae     |
|                 |             | *Dactylogyrus lali*        | Dactylogyridae     |
| *Gonialosa manminna*  | Clupeidae   | *Mazocraes gonialosa*      | Mazocraeidae       |
|                 |             | *Mazocraeoides gonialosa*  | Mazocraeidae       |
| *Glyptothorax lonah*  | Sisoridae   | –                           | –                  |
| *Glyptothorax stoliczkae* | Sisoridae | –                           | –                  |
| *Gudusia chapra*      | Clupeidae   | –                           | –                  |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea                  | Monogenea family                        |
|-----------------------|-------------|----------------------------|-----------------------------------------|
| Heteropneustes fossilis | Heteropneustidae | Bychowskyella fossilisi   | Dactylogyridae                          |
|                       |             | Gyrodactylus gussevi       | Gyrodactylidae                          |
|                       |             | Gyrodactylus neopnephotus malbergi | Gyrodactylidae                          |
| Ilisha megaloptera    | Clupeidae   | –                          | –                                       |
| Johnius coitor        | Sciaenidae  | Paramazocraes guptai      | Mazocraeidae                            |
| Johnius gangeticus   | Sciaenida   | –                          | –                                       |
| Johnius ruber         | Sciaenidae  | Bilaterocotyle mamaevi    | Allodiscocotylidae                      |
| Ilisha megaloptera    | Clupeidae   | –                          | –                                       |
| Labeo ariza           | Cyprinidae  | Dactylogyrus batae         | Dactylogyridae                          |
|                       |             | Dactylogyrus fotedari      | Dactylogyridae                          |
|                       |             | Dactylogyrus lohanii       | Dactylogyridae                          |
|                       |             | Dipladius catalius         | Dactylogyridae                          |
|                       |             | Gyrodactylus elegans indicus | Gyrodactylidae                          |
|                       |             | Paradactylogyrus catalius  | Dactylogyridae                          |
|                       |             | Thaparogyrus lucknowius    | Dactylogyridae                          |
| Labeo boga            | Cyprinidae  | –                          | –                                       |
| Labeo calbasu         | Cyprinidae  | Dactylogyrus batae         | Dactylogyridae                          |
|                       |             | Dactylogyrus vicinus       | Dactylogyridae                          |
|                       |             | Paradactylogyrus catalius  | Dactylogyridae                          |
| Labeo dero            | Cyprinidae  | –                          | –                                       |
| Labeo gonius          | Cyprinidae  | Dactylogyrus brevitubus    | Dactylogyridae                          |
|                       |             | Dactylogyrus batae         | Dactylogyridae                          |
|                       |             | DiplADIUS catalius         | Dactylogyridae                          |
|                       |             | Paradactylogyrus catalius  | Dactylogyridae                          |
| Labeo pangusia        | Cyprinidae  | –                          | –                                       |
| Labeo rohita          | Cyprinidae  | Dactylogyrus batae         | Dactylogyridae                          |
|                       |             | Dactylogyrus glossogobii   | Dactylogyridae                          |
|                       |             | Dactylogyrus batae         | Dactylogyridae                          |
|                       |             | Dactylogyrus lohanii       | Dactylogyridae                          |
|                       |             | Dactylogyrus speciosus     | Dactylogyridae                          |
|                       |             | Dactylogyrus yogendrai     | Dactylogyridae                          |
|                       |             | Gyrodactylus elegans indicus | Dactylogyridae                          |
|                       |             | Haplocleidus sachi         | Dactylogyridae                          |
|                       |             | Mazocrae mamaevi           | Mazocraeidae                            |
|                       |             | Paradactylogyrus catalius  | Dactylogyridae                          |
|                       |             | Parachactramyzocraes gorakhanati | Mazocraeidae                            |
| Lates calcarifer      | Latidae     | Laticola latesi            | Diplectanidae                           |
| Leognathus edentulus  | Leigonathiida | Actinocephalus leognathi       | Dactylogyridae                          |
| Lepidocephalus guntea | Cobitidae  | –                          | –                                       |
| Lutjanus johnii       | Lutjanidae  | Ancyrocephalus johnii      | Dactylogyridae                          |
| Macragnostus aculeatus| Mastacembalidae | Mastacembelocephalus bam    | Dactylogyridae                          |
|                       |             | Mastacembelocephalus indicus | Dactylogyridae                          |
| Macragnostus ponceanus| Mastacembalidae | Mastacembelocephalus bam    | Dactylogyridae                          |
| Mastacembalus armatus  | Mastacembalidae | Mastacembelocephalus heteranchorus | Dactylogyridae                          |
| Morulus calbasu       | Cyprinidae  | Dactylogyrus calbasu       | Dactylogyridae                          |
|                       |             | Dactylogyrus fotedari      | Dactylogyridae                          |
| Mystus bleekeri       | Bagridae    | Cornudiscoides bleekeri    | Dactylogyridae                          |
|                       |             | Cornudiscoides gominus     | Dactylogyridae                          |
|                       |             | Cornudiscoides gussevi     | Dactylogyridae                          |
|                       |             | Cornudiscoides susanae     | Dactylogyridae                          |
|                       |             | Cornudiscoides takarami    | Dactylogyridae                          |
|                       |             | Thaparocleidus pusillus    | Dactylogyridae                          |
| Mystus gulio          | Bagridae    | –                          | –                                       |
| Fish               | Fish family | Monogenea          | Monogenea family       |
|--------------------|-------------|--------------------|------------------------|
| Mystus keletius    | Bagridae    | Bifurcohaptor indicus | Dactylogyridae         |
| Mystus nemurus     | Bagridae    | Bifurcohaptor indicus | Dactylogyridae         |
| Mystus seenghala   | Bagridae    | Chauhanellus indicus | Dactylogyridae         |
| Mystus tengara     | Bagridae    | Bifurcohaptor indicus | Dactylogyridae         |
|                    |             | Cornudiscoides megalorchis | Dactylogyridae         |
|                    |             | Cornudiscoides proximus | Dactylogyridae         |
|                    |             | Hematopeduncularia orientalis | Dactylogyridae         |
|                    |             | Hematopeduncularia ritai | Dactylogyridae         |
|                    |             | Neocallistoma srivastavai | Calceostomatidae       |
| Mystus vittatus    | Bagridae    | Bifurcohaptor indicus | Dactylogyridae         |
|                    |             | Cornudiscoides agarwali | Dactylogyridae         |
|                    |             | Cornudiscoides gomtiai | Dactylogyridae         |
|                    |             | Cornudiscoides kulkarnii | Dactylogyridae        |
|                    |             | Cornudiscoides proximus | Dactylogyridae         |
|                    |             | Cornudiscoides susanii | Dactylogyridae         |
|                    |             | Cornudiscoides vittai | Dactylogyridae         |
|                    |             | Gyrodactylus mizellei | Gyrodactylidae         |
|                    |             | Thaparocleidus parvulus | Dactylogyridae         |
| Nandus nandus      | Nandidae    | Sandanonechus behuri | Dactylogyridae         |
| Nangra carcharhinoide | Sisoridae | Cornudiscoides geminus | Dactylogyridae         |
| Nangra nangra      | Sisoridae   | –                  | –                      |
| Naziritor chelynoide | Cyprinidae | –                  | –                      |
| Neolissochilus spinulosus | Cyprinidae | –                  | –                      |
| Notopterus chitala | Notopteridae | Malyanodiscoides indicus | Dactylogyridae         |
|                    |             | Notopterodiscoides curvishamalus | Dactylogyridae         |
|                    |             | Notopterodiscoides notopterus | Dactylogyridae         |
| Notopterus notopterus | Notopteridae | Malyanodiscoides indicus | Dactylogyridae         |
| Ompok bimaculatus  | Siluridae   | Bychoeskyella asiatica | Dactylogyridae         |
|                    |             | Bychoeskyella kanpuresis | Dactylogyridae         |
|                    |             | Thaparocleidus malabaricus | Dactylogyridae         |
| Ompok malabaricus  | Siluridae   | Thaparocleidus malabaricus | Dactylogyridae         |
| Ompok pabda        | Siluridae   | Rychoeskyella asiatica | Dactylogyridae         |
| Osteobrama cotio cotio | Cyprinidae | Dactylogyroides osteobramii | Dactylogyridae         |
| Osteobrama cotio canno | Cyprinidae | Dactylogyrus cotios | Dactylogyridae         |
| Otolithes argenteus | Sciaenidae | Diplectanidae tripathii | Diplectanidae         |
| Otolithoides pama  | Sciaenidae  | –                  | –                      |
| Oxygaster bacala   | Cyprinidae  | Dogielius indicus | Dactylogyridae         |
| Pampus cinereus    | Stromateidae | Bicotyle stromatea | Axinidae               |
| Pangasius pangasius | Panagasiidae | Thaparocleidus pangasi | Dactylogyridae         |
| Parambassis lal    | Ambassidae  | –                  | –                      |
| Pinnicallago kanpuresis | Siluridae | –                  | –                      |
| Platyecephalus indicus | Platyecephalidae | Haliotrema indicum | Dactylogyridae         |
| Poropuntius clavatus | Cyprinidae | –                  | –                      |
| Pristis microdon   | Pristidae   | –                  | –                      |
| Pseudechensis sulcata | Sisoridae | –                  | –                      |
| Psilorhynchus sucatio | Psilorhynchidae | –                  | –                      |
| Pterocryptis gangetica | Siluridae | –                  | –                      |
| Puntius chola      | Cyprinidae  | Dactylogyroides mahecoli | Dactylogyridae         |
| Puntius conchonias | Cyprinidae  | –                  | –                      |
| Puntius dorsalis   | Cyprinidae  | Dactylogyrus moorthyi | Dactylogyridae         |
|                    |             | Dactylogyroids dorsali | Dactylogyridae         |
| Puntius filamentous | Cyprinidae  | Dactylogyroids mahecoli | Dactylogyridae         |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea                          | Monogenea family |
|-----------------------|-------------|------------------------------------|------------------|
| Puntius guganio       | Cyprinidae  | –                                  | –                |
| Puntius sarana        | Cyprinidae  | Diplolozon indicum                 | Diplozoidea      |
| Puntius sophore       | Cyprinidae  | Dactylogyroides longicirrus        | Dactylogyridae   |
|                       |             | Dactylogyrus angularis             | Dactylogyridae   |
|                       |             | Dactylogyrus brevigignus           | Dactylogyridae   |
|                       |             | Dactylogyrus indicus               | Dactylogyridae   |
|                       |             | Dactylogyrus longiacus             | Dactylogyridae   |
|                       |             | Dactylogyrus orientalis            | Dactylogyridae   |
|                       |             | Dactylogyrus subtilis              | Dactylogyridae   |
|                       |             | Gyrodactylus punti                 | Gyrodactylidae   |
|                       |             | Gyrodactylus vivekanensis          | Gyrodactylidae   |
| Pseudotropius garua   | Cichlidae   | Thaparoleidus multispiralis        | Dactylogyridae   |
| Puntius ticto         | Cyprinidae  | Dactylogyroides longicirrus        | Dactylogyridae   |
|                       |             | Dactylogyroides tripathi           | Dactylogyridae   |
|                       |             | Dactylogyrus cauvery               | Dactylogyridae   |
|                       |             | Dactylogyrus subtilis              | Dactylogyridae   |
|                       |             | Gyrodactylus baughi                | Gyrodactylidae   |
|                       |             | Gyrodactylus punti                 | Gyrodactylidae   |
| Raiamas bala          | Cyprinidae  | Dactylogyrus boli                  | Dactylogyridae   |
|                       |             | Diplolozon indicum                 | Diplozoidea      |
| Rastrelliger kanagarata| Scombridae  | Pricea fotedari                    | Gotocotylidae    |
| Rhodosargus sarba     | Sparidae    | –                                  | –                |
| Rhinomugil corsula    | Mugilidae   | Yogendrotrema rajghatai            | Microcotylidae   |
| Rita gagra            | Bagridae    | Diplectanum gupta                  | Diplectanidae    |
| Rita rita             | Bagridae    | Bychowskyella raipurensis          | Dactylogyridae   |
|                       |             | Metahalotrema sircastasi           | Dactylogyridae   |
|                       |             | Thaparoleidus seenghali            | Dactylogyridae   |
| Salmostoma bactaila   | Cyprinidae  | Ancyrocephalus baughi              | Dactylogyridae   |
|                       |             | Ancyrocephalus ghoshi              | Dactylogyridae   |
|                       |             | Ancyrocephalus spiculus            | Dactylogyridae   |
|                       |             | Dactylogyrus anchoracanthus        | Dactylogyridae   |
|                       |             | Dactylogyrus partianchoris         | Dactylogyridae   |
|                       |             | Diplozoza indicum                  | Diplozoidea      |
|                       |             | Dogielius lucknowensis             | Dactylogyridae   |
| Salmostoma phulo      | Cyprinidae  | –                                  | –                |
| Salmostoma sardinella | Cyprinidae  | –                                  | –                |
| Schizotheraichthys progastus | Cyprinidae | –                                | –                |
| Sciaena coiter        | Sciaenidae  | Bilaterocotyle lucknowensis        | Allodiscocotylidae|
|                       |             | Bilaterocotyle mamoae              | Allodiscocotylidae|
|                       |             | Lobotrema kamari                   | Diplectanidae    |
|                       |             | Paramazocraes gupta                | Dactylogyridae   |
|                       |             | Paramazocraes yogenderai           | Dactylogyridae   |
| Securicula gora       | Cyprinidae  | Heteromazocraes mamoeri            | Mazocraeidae     |
| Setipinna brevifilis  | Engraulidae | –                                  | –                |
| Setipinna phusa       | Engraulidae | Heteromazocraes phasae             | Mazocraeidae     |
| Sicamugil cascasia    | Mugilidae   | –                                  | –                |
| Silonia silondia      | Schilbeidae | Bychowskyella cauvery              | Dactylogyridae   |
|                       |             | Neocalceostoma microformis         | Calceostomatidae |
|                       |             | Thaparoleidus multispiralis        | Dactylogyridae   |
|                       |             | Thaparoleidus siloniensis          | Dactylogyridae   |
| Sisor rhbadorphorus   | Sisoridae   | –                                  | –                |
| Sperata aor           | Bagridae    | Thaparoleidus speratai             | Dactylogyridae   |
|                       |             | Thaparoleidus speratai             | Dactylogyridae   |
| Sperata seenghala     | Bagridae    | Bifurcohaptor gigantius            | Dactylogyridae   |
|                       |             | Hamatopeduncularia sohani          | Dactylogyridae   |
|                       |             | Thaparoleidus seenghali            | Dactylogyridae   |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea                      | Monogenea family |
|-----------------------|-------------|--------------------------------|------------------|
| Tor tor               | Cyprinidae  | Thaparocleidus wallagonius     | Dactylogyridae   |
| Tenualosa ilisha      | Clupeidae   | Diplozoon indicum              | Diplozoidae      |
|                       |             | Leptomazocraea ilevelyni       | Mazocraeidae     |
|                       |             | Leptomazocraea lucknowensis    | Mazocraeidae     |
|                       |             | Mazocraea gussevi              | Mazocraeidae     |
|                       |             | Mazocraea multispiralis        | Mazocraeidae     |
|                       |             | Pseudomazocereoides indicus    | Mazocraeidae     |
| Tetrodon oblongus     | Tetrodontidae| Didelophora indica            | Diclidophoridae  |
| Wallago attu          | Siluridae   | Bychoeskyella tripatii         | Dactylogyridae   |
|                       |             | Thaparocleidus gomtius         | Dactylogyridae   |
|                       |             | Bychoeskyella wallagonia       | Dactylogyridae   |
|                       |             | Chaubanellas indicus           | Dactylogyridae   |
|                       |             | Cosmetocleithrum orientalis    | Dactylogyridae   |
|                       |             | Dactylogyrus kontii            | Dactylogyridae   |
|                       |             | Hamatopedanculilaria lucknowensis| Dactylogyridae |
|                       |             | Hamatopedanculilaria sohani    | Dactylogyridae   |
|                       |             | Hamatopedanculilaria wallagonius| Dactylogyridae  |
|                       |             | Hamatopedanculilaria yogendrai| Dactylogyridae   |
|                       |             | Mizelleus indicus              | Dactylogyridae   |
|                       |             | Mizellus indicus               | Dactylogyridae   |
|                       |             | Mizellus longicirrus           | Dactylogyridae   |
|                       |             | Neocalecostoma chauhani       | Calceostomatidae |
|                       |             | Neocalecostoma microformis     | Calceostomatidae |
|                       |             | Rhamnocercus srivastavaei      | Diplectanidae    |
|                       |             | Thaparocleidus indicus         | Dactylogyridae   |
|                       |             | Thaparocleidus longiphallus    | Dactylogyridae   |
|                       |             | Thaparocleidus wallagonius     | Dactylogyridae   |
| Xenentodon cancila    | Belonidae   | Xenentolecidus xenentodoni     | Dactylogyridae   |
| II. Brahmaputra River System |               |                                |                  |
| Acanthocobitis botia  | Balitoridae | –                               | –                |
| Acanthocobitis zonalternans | Balitoridae | –                               | –                |
| Ailia coila           | Schilbeidae | –                               | –                |
| Anabas testudineus    | Anabantidae | Trianchoratus kearnii          | Dactylogyridae   |
| Badis badis           | Nandidae    | –                               | –                |
| Badis bloxysrus       | Nandidae    | –                               | –                |
| Badis kanabos         | Nandidae    | –                               | –                |
| Bagarius bagarius     | Sisoridae   | –                               | –                |
| Barboes hexagonolepis | Cyprinidae  | –                               | –                |
| Barilius barna        | Cyprinidae  | –                               | –                |
| Barilius shacra       | Cyprinidae  | –                               | –                |
| Barilius tileo        | Cyprinidae  | –                               | –                |
| Bataio tengana        | Bagridae    | –                               | –                |
| Botia dario           | Cobitidae   | –                               | –                |
| Botia dayi            | Cobitidae   | –                               | –                |
| Catla catla           | Cyprinidae  | Dactylogyrus labei              | Dactylogyridae   |
| Chaca chaca           | Chacidae    | –                               | –                |
| Chagunias chagunio    | Cyprinidae  | –                               | –                |
| Channa barca          | Channidae   | –                               | –                |
| Channa stewartii      | Channidae   | –                               | –                |
| Chitala chitala       | Notopteridae| –                               | –                |
| Cirrhinus cirrhous    | Cyprinidae  | Dactylogyrus chauhanus          | Dactylogyridae   |
| Clarias batracus      | Claridae    | –                               | –                |
| Crossochelus latius   | Cyprinidae  | –                               | –                |
| Ctenopharyngodon idella| Cyprinidae  | Dactylogyrus lamellatus         | Dactylogyridae   |
| Cyprinus carpio       | Cyprinidae  | Dactylogyrus extensus           | Dactylogyridae   |
| Decario acuticephalus | Cyprinidae  | –                               | –                |
| Erethisites pusillus  | Erethistidae| –                               | –                |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea | Monogenea family |
|-----------------------|-------------|-----------|------------------|
| Exostoma labiatum     | Sisoridae   | –         | –                |
| Gagata gagata         | Sisoridae   | –         | –                |
| Gagata youssoufi      | Sisoridae   | –         | –                |
| Gangra viridescens    | Sisoridae   | –         | –                |
| Garra kempi           | Cyprinidae  | –         | –                |
| Garra lissorhynenus   | Cyprinidae  | –         | –                |
| Glyptosternon maculatum| Sisoridae     | –         | –                |
| Glyptothorax annandaei| Sisoridae     | –         | –                |
| Goaniaosa manmina     | Clupeidae   | –         | –                |
| Galudia charpa        | Clupeidae   | –         | –                |
| Labeo ariza           | Cyprinidae  | –         | –                |
| Labeo boga            | Cyprinidae  | Diplozoon cauveri | Diplzooidae |
| Labeo goinus          | Cyprinidae  | Dactylogyrus subtilis | Dactylogyridae |
| Labeo pangusia        | Cyprinidae  | Diplozoon cauveri | Diplzooidae |
| Lepidocephalus guinea | Cobitidae   | –         | –                |
| Lepidocephalus menoni | Cobitidae   | –         | –                |
| Mesonoemacheilus pulchellus | Belitoridae | – | – |
| Mystus aor            | Bagridae    | –         | –                |
| Mystus bleekeri       | Bagridae    | –         | –                |
| Mystus casius         | Bagridae    | –         | –                |
| Mystus menoda         | Bagridae    | –         | –                |
| Mystus senghaha       | Bagridae    | –         | –                |
| Mystus tengara        | Bagridae    | Bifurcohaptor indicus | Dactylogyridae |
| Mystus viatus         | Bagridae    | Bifurcohaptor indicus | Dactylogyridae |
| Neopomacentrarchus aculeatus | Mastacembelidae | Mastacembelocleidus ban | Dactylogyridae |
| Nandus nandus         | Nandidae    | Sundananchus behuri | Dactylogyridae |
| Nemacheilus elongatus | Balitoridae | –         | –                |
| Nemacheilus labeouis  | Balitoridae | –         | –                |
| Nemacheilus nagaensis | Balitoridae | –         | –                |
| Nemacheilus paronaceus| Balitoridae | –         | –                |
| Nemacheilus reticulospectatus | Balitoridae | – | – |
| Nemacheilus subfuscus | Balitoridae | –         | –                |
| Neocirrhichthys maydelli | Cobitidae | –         | –                |
| Notopterus notopterus  | Notopteridae | Notopterodiscoides notopterus | Dactylogyridae |
| Ompok bimaculatus     | Siluridae   | –         | –                |
| Ostobrama cotio cotio | Cyprinidae  | –         | –                |
| Otothoides pama       | Sciaenidae  | –         | –                |
| Oxygymnocypris stewartii | Cyprinidae | –         | –                |
| Pangasius pangasius   | Pangasidae  | –         | –                |
| Parachilognathus hodgari | Sisoridae | –         | –                |
| Parechiolofilis kamengensis | Sisoridae | –         | –                |
| Polynemus sexfilis    | Polynemidae | Pseudolamellodiscus polynemus | Diplectanidae |
| Prambassis lala       | Ambassidae  | –         | –                |
| Pristis microdon      | Pristidae   | –         | –                |
| Pseudecheneis sulcata | Sisoridae   | –         | –                |
| Psilorhynchus homaloptera | Psilorhynchidae | – | – |
| Ptychochristus dipogon | Cyprinidae | –         | –                |
| Puntius conchonius    | Cyprinidae  | –         | –                |
| Puntius gueganio      | Cyprinidae  | –         | –                |
| Puntius sophore       | Cyprinidae  | Dactylogyroides longicirrus | Dactylogyridae |
| Puntius ticto         | Cyprinidae  | Dactylogyroides tripathii | Dactylogyridae |
| Salmo trutta fario    | Salmonidae  | –         | –                |
| Salmostoma bacaila    | Cyprinidae  | –         | –                |
| Salmostoma phulo      | Cyprinidae  | –         | –                |
| Salmostoma sardinella | Cyprinidae  | –         | –                |
| Schistura beavani     | Balitoridae | –         | –                |
**Table 1, continued**

List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea | Monogenea family |
|-----------------------|-------------|-----------|------------------|
| Schistura manipurensis| Balitoridae |           |                  |
| Schistura prashadi    | Balitoridae |           |                  |
| Schizopygopsis youngusbandi | Cyprinidae |           |                  |
| Schizothoracichys progastus | Cyprinidae |           |                  |
| Schizothorax macropogon| Cyprinidae |           |                  |
| Schizothorax molesworthy| Cyprinidae |           |                  |
| Schizothorax oconnori | Cyprinidae |           |                  |
| Schizothorax walloni  | Cyprinidae |           |                  |
| Sicomagil cascasia    | Mugilidae   |           |                  |
| Sinalabeo dero        | Cyprinidae |           |                  |
| Sisor rabdophorus     | Sisoridae  |           |                  |
| Sperata aor           | Bagridae   |           |                  |
| Sperata seenghala     | Bagridae   |           |                  |
| Tor progeneius        | Cyprinidae |           |                  |
| Triphophya microps    | Balitoridae|           |                  |
| Triphophya stenura    | Balitoridae|           |                  |
| Triplophysa stewarti  | Balitoridae|           |                  |
| Triplophysa tibetana  | Balitoridae|           |                  |
| Wallago atta          | Siluridae  |           |                  |
| Xentodonton cancila   | Belonidae  | Xentoeideus xenentodoni |  Dactylogyridae |
| III. Indus River System |             |           |                  |
| Acanthocobitis botia  | Balitoridae|           |                  |
| Apidoparia morar      | Cyprinidae |           |                  |
| Bagarius yarrelli     | Sisoridae  |           |                  |
| Barbus chagunio       | Cyprinidae | Neodiplozoon barbi | Diplozoideae |
| Barilius pakistaniicus| Cyprinidae |           |                  |
| Barilius vagra        | Cyprinidae |           |                  |
| Carassius vulgaris    | Cyprinidae | Diplozon nipponicum | Diplozoideae |
| Chela cachias         | Cyprinidae |           |                  |
| Chitala chitala       | Notopteridae|           |                  |
| Crossocheilus diplochilus | Cyprinidae |           |                  |
| Cyprinus carpio       | Cyprinidae |           |                  |
| Cyprinus carpio speculatis | Cyprinidae | Diplozon nipponicum | Diplozoideae |
| Diphyurus maculates   | Cyprinidae |           |                  |
| Gagata cenia          | Sisoridae  |           |                  |
| Glyptosternon maculatum| Sisoridae |           |                  |
| Glyptosternon reticulatum | Sisoridae |           |                  |
| Glyptothorax kashmirensis | Sisoridae |           |                  |
| Glyptothorax pectinopterus | Sisoridae |           |                  |
| Glyptothorax telchita  | Sisoridae  |           |                  |
| Heteropneustes fossilis| Heteropneustidae |           |                  |
| Labeo ariza           | Cyprinidae |           |                  |
| Labeo dero            | Cyprinidae |           |                  |
| Lepidocephalus guntea | Cobitidae  |           |                  |
| Mystus cavasius       | Bagridae   |           |                  |
| Nangra nangra         | Sisoridae  |           |                  |
| Nangra robusta        | Sisoridae  |           |                  |
| Nemacheilus gracilis | Balitoridae|           |                  |
| Notopterus notopterus  | Notoptereidae|         |                  |
| Ptychocharus conorosiris | Cyprinidae |           |                  |
| Puntius conchonius    | Cyprinidae |           |                  |
| Racoma labiata        | Cyprinidae |           |                  |
| Raimas bola           | Cyprinidae | Dactylogyrus boli | Dactylogyridae |
| Salmotrutta ferio     | Salmonidae |           |                  |
| Schistura afasciata   | Balitoridae|           |                  |
| Schistura alepidota   | Balitoridae|           |                  |
| Schistura corica      | Balitoridae|           |                  |
**Table 1, continued**

List of monogeneans, their host from five major river systems of India.

| Fish                      | Fish family | Monogenea                     | Monogenea family |
|---------------------------|-------------|-------------------------------|-------------------|
| Schistura curtistigma     | Balitoridae | –                             | –                 |
| Schistura microlabra      | Balitoridae | –                             | –                 |
| Schistura prashari        | Balitoridae | –                             | –                 |
| Schizopygopsis stoliczkae | Cyprinidae  | –                             | –                 |
| Schizothoracichthys curvifrons | Cyprinidae | Diplozoon nipponicum          | Diplozoidae       |
| Schizothorax esocinus     | Cyprinidae  | Diplozoon nipponicum          | Diplozoidae       |
| Schizothorax longipinnis  | Cyprinidae  | –                             | –                 |
| Schizothorax macropogon   | Cyprinidae  | –                             | –                 |
| Schizothorax nasus        | Cyprinidae  | –                             | –                 |
| Schizothorax plagiosomum  | Cyprinidae  | Diplozoon nipponicum          | Diplozoidae       |
| Schizothorax richardsonii | Cyprinidae  | –                             | –                 |
| Sicalmagil cascasia       | Mugilidae   | –                             | –                 |
| Silionia silondia         | Schilbeidae | –                             | –                 |
| Sisor rablephorus         | Sisoridae   | –                             | –                 |
| Sperata aor               | Bagridae    | –                             | –                 |
| Sperata seenghala         | Bagridae    | Cornudiscoides geminus        | Dactylogyridae    |
| Terapon theraps           | Terapontidae| –                             | –                 |
| Tetradon oblongus         | Tetradontidae| Neodiciiclidophora simhai | Diclidophoridae  |
| Tor putitora              | Cyprinidae  | Dactylogyroides gussevia      | Dactylogyridae    |
| Triplophysa aliensis      | Balitoridae | –                             | –                 |
| Triplophysa gracilis      | Balitoridae | –                             | –                 |
| Triplophysa griffishi     | Balitoridae | –                             | –                 |
| Triplophysa marmorata     | Balitoridae | –                             | –                 |
| Triplophysa microps       | Balitoridae | –                             | –                 |
| Triplophysa stenura       | Balitoridae | –                             | –                 |
| Triplophysa stoliczkae    | Balitoridae | –                             | –                 |
| Triplophysa yasinensis    | Balitoridae | –                             | –                 |
| IV. East Coast River System |            |                                |                   |
| Amblypharyngodon mola     | Cyprinidae  | –                             | –                 |
| Anguilla bengalensis bengalensis | Anguillidae | –                             | –                 |
| Anodontostoma chacunda    | Clupeidae   | Neomazocraes anodontostomae   | Mazocraeidiae     |
| Aristichthys nobilis      | Cyprinidae  | –                             | –                 |
| Bagarius bagarius         | Sisoridae   | –                             | –                 |
| Balitora mysorensis       | Balitoridae | –                             | –                 |
| Barbodes boaricus         | Cyprinidae  | –                             | –                 |
| Barbodes carnaticus       | Cyprinidae  | –                             | –                 |
| Barbodes sarana           | Cyprinidae  | –                             | –                 |
| Barbodes wynaadensis      | Cyprinidae  | –                             | –                 |
| Barilius genatus          | Cyprinidae  | –                             | –                 |
| Callichthys malabaricus   | Siluridae   | Thaparoleidus devrajii        | Dactylogyridae    |
| Caranx kalla              | Carangidae  | Bilaterocotyle spindalis     | Allodiscocotylidae|
| Caranx rottileri           | Carangidae  | Chaunacotytle rottileri      | Allodiscocotylidae|
| Caranx sp.                | Carangidae  | Heteromicrocotyla multispina | Heteromicrocotylidae|
| Catla catla               | Cyprinidae  | Dactylogyrus spinatus         | Dactylogyridae    |
| Chanda nama               | Ambassidae  | –                             | –                 |
| Channa marilus            | Cyprinidae  | –                             | –                 |
| Channa orientalis         | Cyprinidae  | Metagyrodactylus minutus      | Dactylogyridae    |
| Channa striata            | Cyprinidae  | –                             | –                 |
| Chanas chanos             | Chaniidae   | –                             | –                 |
| Chorinemus chori [ ]      | Carangidae  | Tripathia chori [ ]           | Microcoelidae     |
| Cirrhinus ariza           | Cyprinidae  | Dactylogyrus anchoracanthus   | Dactylogyridae    |
| Cirrhinus cirrhousus      | Cyprinidae  | Dactylogyrus chauhanus        | Dactylogyridae    |
### Table 1, continued

List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family | Monogenea                  | Monogenea family     |
|-----------------------|-------------|----------------------------|----------------------|
| Cirrhinus fulungee    | Cyprinidae  | Diplozoon indicum          | Diplozoidae          |
| Cirrhinus macrops     | Cyprinidae  | –                          | –                    |
| Clarias batrachus     | Clariidae   | Dactylogyrus macrogaster   | Dactylogyridae       |
|                        |             | Quadriacanthus kobiensis   | Dactylogyridae       |
| Clarias dussamieri    | Clariidae   | –                          | –                    |
| Clupea harengus       | Clupeidae   | Dactylogyrus tetraradiatus | Dactylogyridae       |
| Clupisoma garua       | Schilbeidae | Bychowskyella caballeroi   | Dactylogyridae       |
| Ctenopharyngodon idellius | Cyprinidae | –                          | –                    |
| Cyprinus carpio carpio | Cyprinidae | –                          | –                    |
| Danio aequipinnattus  | Cyprinidae  | –                          | –                    |
| Danio rerio           | Cyprinidae  | –                          | –                    |
| Devario devario       | Cyprinidae  | –                          | –                    |
| Devario fraseri       | Cyprinidae  | –                          | –                    |
| Engraulis purava      | Engraulidae | Diclidophora caudospina    | Diclidophoridea      |
| Esomus danricus       | Cyprinidae  | –                          | –                    |
| Esomus thermoicos     | Cyprinidae  | –                          | –                    |
| Etheuronema tetractylum | Polynemidae | Diplectanidae             | Diplectanidae        |
| Etroplus suratensis   | Cichlidae   | Sclerocheiloides etropi    | Dactylogyridae       |
| Etroplus suratensis   | Cichlidae   | –                          | –                    |
| Gagata ichkeerla      | Sisoridae   | –                          | –                    |
| Garra gotyla stenorhyncha | Cyprinidae | –                          | –                    |
| Garra meccellandi     | Cyprinidae  | –                          | –                    |
| Garra mullya          | Cyprinidae  | –                          | –                    |
| Glossogobius giuris   | Gobiidae    | Dactylogyrus pharyngocephalus | Dactylogyridae    |
| Glyptothorax annandalei | Sisoridae | –                          | –                    |
| Glyptothorax lonah    | Sisoridae   | –                          | –                    |
| Glyptothorax madraspatanum | Sisoridae | –                          | –                    |
| Gudusia chapra        | Clupeidae   | –                          | –                    |
| Hemibagrus punctatus  | Bagridae    | –                          | –                    |
| Heteropneustes fossilis | Heteropneustidae | –                          | –                    |
| Hilsa sp.             | Clupeidae   | –                          | –                    |
| Hypophthalmichthys molitrix | Cyprinidae | Singhiogyrus singhi         | Dactylogyridae       |
| Hypostomus species    | Loricariidae| Hetrostomus heterotylos   | Dactylogyridae       |
| Hypoelobarius curmuca | Cyprinidae  | –                          | –                    |
| Hypoelobarius dolsoni | Cyprinidae  | –                          | –                    |
| Hypoelobarius dubius  | Cyprinidae  | Dactylogyrus brevicardus   | Dactylogyridae       |
|                        |             | Dactylogyrus cauveryi      | Dactylogyridae       |
|                        |             | Dactylogyrus dubii         | Dactylogyridae       |
|                        |             | Dactylogyrus magnicordus   | Dactylogyridae       |
| Hypoelobarius kolus   | Cyprinidae  | –                          | –                    |
| Hypoelobarius micropogon | Cyprinidae | –                          | –                    |
| Indoreonectes erezardi | Balitoridae | –                          | –                    |
| Labeo ariza           | Cyprinidae  | –                          | –                    |
| Labeo bata            | Cyprinidae  | –                          | –                    |
| Labeo boga            | Cyprinidae  | –                          | –                    |
| Labeo boggut          | Cyprinidae  | –                          | –                    |
| Labeo calbasu         | Cyprinidae  | –                          | –                    |
| Labeo fimbriatus      | Cyprinidae  | Dactylogyrus chitravanshii | Dactylogyridae       |
| Labeo kontius         | Cyprinidae  | Dactylogyrus kontii        | Dactylogyridae       |
| Labeo pangusia        | Cyprinidae  | –                          | –                    |
| Labeo porcellus       | Cyprinidae  | –                          | –                    |
| Labeo potail          | Cyprinidae  | –                          | –                    |
| Labeo rohita          | Cyprinidae  | Dactylogyrus yogendrai     | Dactylogyridae       |
| Lates calcarifer      | Latidae     | Diplectanum latesi         | Diplectanidae        |
|                        |             | Laticola latesi            | Diplectanidae        |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish                          | Fish family | Monogene | Monogenea family                  |
|-------------------------------|-------------|----------|-----------------------------------|
| *Lepidocephalus thermalis*    | Cobitidae   | –        | –                                 |
| *Longichistura bhimachari*    | Balitoridae | –        | –                                 |
| *Macronathus acutobranchus*   | Mastacembalidae | Dactylogyrus manairensis | Dactylogyridae                  |
| *Mastacembalus armatus*       | Mastacembalidae | Mastacembeloeleidus heteranchorus | Dactylogyridae                  |
| *Megalespis cordyla*          | Carangidae  | Tripathiana minuta | Microcotylidae                  |
| *Megaloops cyprinoides*       | Megalopidae | –        | –                                 |
| *Mesonemaechelus guentheri*   | Balitoridae | –        | –                                 |
| *Mesonemaechelus pallichias*  | Balitoridae | –        | –                                 |
| *Mystus caudatus*             | Bagridae    | –        | –                                 |
| *Mystus malabaricus*          | Bagridae    | –        | –                                 |
| *Mystus seenghala*            | Bagridae    | –        | –                                 |
| *Mystus tengara*              | Bagridae    | –        | –                                 |
| *Mystus vittatus*             | Bagridae    | –        | –                                 |
| *Nemacheilus kodaguensis*     | Balitoridae | –        | –                                 |
| *Nematolosa nasus*            | Clupeidae   | Mazocraeoides nematolosae | Mazocraeidae                  |
| *Notopterus notopterus*        | Notopteridae | –        | –                                 |
| *Ompok bimaculatus*           | Siluridae   | –        | –                                 |
| *Ompok pabda*                 | Siluridae   | Thaparolecidus octotylus | Dactylogyridae                  |
| *Oreochromis mossambicus*     | Cichlidae   | –        | –                                 |
| *Ostebrama belangeri*         | Cyprinidae  | –        | –                                 |
| *Ostebrama cotto canna*        | Cyprinidae  | –        | –                                 |
| *Ostebrama cotto peninsularis*| Cyprinidae  | –        | –                                 |
| *Ostebrama dayi*              | Cyprinidae  | –        | –                                 |
| *Osteochilichthys brevidorsalis* | Cyprinidae | –        | –                                 |
| *Osteochilus godaveriensis*   | Cyprinidae  | –        | –                                 |
| *Osteochilus nashii*          | Cyprinidae  | –        | –                                 |
| *Osteochilus thomasi*         | Cyprinidae  | –        | –                                 |
| *Oxygaster bacala*            | Cyprinidae  | –        | –                                 |
| *Pana pama*                   | Sciaenidae  | Microcotyle pamae | Microcotylidae                  |
| *Pangassius pangasius*        | Pangasiidae | –        | –                                 |
| *Parambassis ranga*           | Ambassidae  | –        | –                                 |
| *Parapsilorhynchus prateri*   | Cyprinidae  | –        | –                                 |
| *Parasilisoma labiosa*        | Cyprinidae  | Dactylogyrus pedunculatus | Dactylogyridae                  |
| *Platycephalus indicus*       | Platycephalidae | Haliotrema indicum | Dactylogyridae                  |
| *Polydactylus indicus*        | Polynemidae | Diplectanum polynemus | Diplectanidae                  |
| *Polyemosus indicus*          | Polynemidae | Microcotyle polyneme | Microcotylidae                  |
| *Proeutochthys taakree taakree* | Schilbeidae | –        | –                                 |
| *Pseudobobius javanicus*      | Gobidae     | –        | –                                 |
| *Pterocryptis wynaadensis*    | Siluridae   | –        | –                                 |
| *Puntius arulius*             | Cyprinidae  | –        | –                                 |
| *Puntius caueriensis*         | Cyprinidae  | –        | –                                 |
| *Puntius chola*               | Cyprinidae  | Dactylogyrus bibcinus | Dactylogyridae                  |
| *Puntius conchonius*          | Cyprinidae  | –        | –                                 |
| *Puntius dorsalis*            | Cyprinidae  | Dactylogyrus moorthyi | Dactylogyridae                  |
| *Puntius fasciatus*           | Cyprinidae  | –        | –                                 |
| *Puntius filamentosus*        | Cyprinidae  | Dactylogyroides mahecoli | Dactylogyridae                  |
| *Puntius melanostigma*        | Cyprinidae  | –        | –                                 |
| *Puntius narayani*            | Cyprinidae  | –        | –                                 |
| *Puntius parrah*              | Cyprinidae  | –        | –                                 |
| *Puntius sarana*              | Cyprinidae  | Dactylogyrus barbi | Dactylogyridae                  |
|                             |             | Dactylogyrus hyderabadensis | Dactylogyridae                  |
|                             |             | Dactylogyrus sarani | Dactylogyridae                  |
|                             |             | Dactylogyrus sphyronoides | Dactylogyridae                  |
Table 1, continued
List of monogeneans, their host from five major river systems of India.

| Fish          | Fish family | Monogenea                      | Monogenea family       |
|---------------|-------------|--------------------------------|------------------------|
| Puntius sophore| Cyprinidae  | _Dactylogyrus varicorhinoides_ | _Dactylogyridae_       |
| Puntius ticlo  | Cyprinidae  | _Dactylogyrus moorthyi_        | _Dactylogyridae_       |
| Puntius vittatus| Cyprinidae  | –                              | –                      |
| Rasbora caserii| Cyprinidae  | –                              | –                      |
| Rastrelliger kanagurata| Scrombriidae | _Pricea fotedari_ | Gotocotylidae |
| Raja kükurnee  | Bagridae    | –                              | –                      |
| Raja pavimenta | Bagridae    | _Diplectanum guptai_           | _Diplectanidae_        |
| Raja rita      | Bagridae    | _Bychowskyella raipurensis_    | _Dactylogyridae_       |
| Rohite ogilbi  | Cyprinidae  | –                              | –                      |
| Salmostoma acinae| Cyprinidae | –                              | –                      |
| Salmostoma bacaia| Cyprinidae | _Dactylogyrus circumphallus_   | _Dactylogyridae_       |
| Salmostoma balookee| Cyprinidae | –                              | –                      |
| Salmostoma belachi| Cyprinidae| –                              | –                      |
| Salmostoma horai| Cyprinidae  | –                              | –                      |
| Salmostoma nasculata| Cyprinidae| –                              | –                      |
| Salmostoma phulo| Cyprinidae  | –                              | –                      |
| Salmostoma untrahi| Cyprinidae| –                              | –                      |
| Saurida tambil | Synodontidae| –                              | –                      |
| Schistura semiarmata| Balitoridae| –                              | –                      |
| Sciaena belengeri| Sciaenidae | _Diplectanum umbrinum_         | _Diplectanidae_        |
| Sciaena glauca  | Sciaenidae  | _Diplectanum minutum_          | _Diplectanidae_        |
| Sciaena maculata| Sciaenidae  | _Diplectanum minutum_          | _Diplectanidae_        |
| Sciaena vogleri | Sciaenidae  | _Diplectanum orrisai_          | _Diplectanidae_        |
| Sillago silama  | Sillaginidae| _Diplectanum sillagonum_       | _Diplectanidae_        |
| Silonia childreni| Silboideae | –                              | –                      |
| Silonia silonda | Silboideae  | _Bychowskyella cauveryi_       | _Dactylogyridae_       |
| Sizilabeo dero  | Cyprinidae  | –                              | –                      |
| Sperata aor     | Bagridae    | _Ancylodiscoides microcanthus_  | _Dactylogyridae_       |
| Sperata seenghala| Bagridae   | –                              | –                      |
| Tenualosa ilisha| Clupeidae   | –                              | –                      |
| Thynnichthys sandhol| Cyprinidae| –                              | –                      |
| Tor khadree    | Cyprinidae  | –                              | –                      |
| Tor mussullah  | Cyprinidae  | –                              | –                      |
| Tor tor        | Cyprinidae  | _Dactylogyrus tori_            | _Dactylogyridae_       |
| Wallago attu   | Siluridae   | _Bychowskyella chauhani_       | _Dactylogyridae_       |
|               |             | _Bychowskyella singhi_         | _Dactylogyridae_       |
|               |             | _Mizellus indicus_             | _Dactylogyridae_       |
|               |             | _Mizellus longicirrus_         | _Dactylogyridae_       |
|               |             | _Thaparoleidus indicus_        | _Dactylogyridae_       |
|               |             | _Thaparoleidus sudhakari_      | _Dactylogyridae_       |
|               |             | _Thaparoleidus wallagonius_    | _Dactylogyridae_       |
| V. West Coast River System | | | |
| Catla catla    | Cyprinidae  | –                              | –                      |
| Channa species | Channidae   | –                              | –                      |
| Cirrhinus mirgala| Cyprinidae | –                              | –                      |
| Cirrhinus mirgala| Cyprinidae | –                              | –                      |
| Cirrhinus reba | Cyprinidae  | –                              | –                      |
| Clupisoma garua | Silboideae | –                              | –                      |
| Labeo bata     | Cyprinidae  | –                              | –                      |
| Labeo boggut   | Cyprinidae  | –                              | –                      |
| Labeo calbasu  | Cyprinidae  | –                              | –                      |
| Labeo jambiri  | Cyprinidae  | –                              | –                      |
| Labeo gonius   | Cyprinidae  | –                              | –                      |
| Mastacembelus species| Mastacembelidae| – | – |
| Mystus aor     | Bagridae    | –                              | –                      |

Minnows, Cyprinidae: Cyprinidae.
**Table 1, continued**

List of monogeneans, their host from five major river systems of India.

| Fish                  | Fish family   | Monogenea                       | Monogenea family     |
|-----------------------|---------------|---------------------------------|----------------------|
| Mystus cavasius       | Bagridae      | –                               | –                    |
| Mystus seenghala      | Bagridae      | –                               | –                    |
| Nematalosa nasus      | Clupeidae     | Mazocraeoides nematalosae       | Mazocraeidae         |
| Notopterus notopterus | Notopteridae  | –                               | –                    |
| Ompok binaculatus     | Siluridae     | –                               | –                    |
| Puntius sarana        | Cyprinidae    | –                               | –                    |
| Rūta pavimentata      | Bagridae      | –                               | –                    |
| Tor tor               | Cyprinidae    | –                               | –                    |
| Tor tor               | Cyprinidae    | –                               | –                    |
| Wallago attu          | Siluridae     | –                               | –                    |

References for these reports are not cited in the text, however, it can be checked from the comprehensive work of Pandey and Agrawal, 2008.

**Figure 3.** Status of screened fishes in river systems of India.

**Figure 4.** Showed the pyramid of river systems according to the parasites infection.

**Table 3**

List of molecular data of freshwater Indian monogeneans (References are not cited but the data can checked on the www.ncbi.nlm.nih.gov).

| Monogenea species       | Host          | Locality (River system) | Accession number |
|-------------------------|---------------|-------------------------|------------------|
| Bifurcohaptor indicus   | Mystus vittatus| Ganga                   | GU830881         |
| Bifurcohaptor indicus   | Mystus vittatus| Brahmaputra             | JX852710         |
| Cornudiscoides proximus | Mystus vittatus| Ganga                   | GQ925913         |
| Dactylogyroidea longicirrus | Puntius sophore | Ganga             | GU903482         |
| Dactylogyroidea longicirrus | Puntius sophore | Brahmaputra         | KX685371         |
| Dactylogyroidea tripathi | Puntius ticto      | Brahmaputra           | JX993982         |
| Dactylogyrus ilei       | Catla catla   | Brahmaputra            | JX566720         |
| Dactylogyrus ctenopharyngodonis | Ctenopharyngodon idella | Ganga | EU643633         |
| Dactylogyrus ctenopharyngodonis | Ctenopharyngodon idella | Brahmaputra | JQ926198, JQ926200 |
| Dactylogyrus lamellatus | Ctenopharyngodon idella | Brahmaputra | JQ926197, JQ926198 |
| Dactylogyrus eucalvis   | Catla inconstans| Ganga                   | EU643634         |
| Dactylogyrus inexpectatus | Carassius auratus | Ganga            | EU643632         |
| Dactylogyrus anchoratus | Cyprinus carpio| Ganga                   | AJ564111         |
| Dactylogyrus extensus   | Cyprinus carpio| Brahmaputra           | JQ926197, JQ926198 |
| Gyrodactylus colosi     | Colisa fasciata| Ganga                   | GQ925912         |
| Malayano discoides bhamali | Notopterus chitala | Ganga         | GU830882         |
| Mastacembelocleidus indicus | Macrurus aculeatus | Ganga     | GU830884         |
| Mastacembelocleidus ham  | Macrurus aculeatus| Brahmaputra | JX987076         |
| Notopterodiscoides notopterus | Notopterus notopterus | Brahmaputra | JX444912         |
| Sundananchus behuri     | Nandus nandus | Ganga                   | GU830883         |
| Sundananchus behuri     | Nandus nandus | Brahmaputra           | JX444913         |
| Thaparocleidus longiphallus | Wallago attu  | Ganga                   | JX980972         |
| Thaparocleidus parvulus | Mystus vittatus| Ganga                   | GU014844         |
| Thaparocleidus siloniensis | Silonia silondia | Ganga       | GU890973         |
| Thaparocleidus wallagonensis | Wallago attu  | Ganga                   | JX020351         |
| Trisnorhatus agrawali   | Anaba testudineus| Ganga            | GU830880         |
| Trisnorhatus karni      | Anaba testudineus| Brahmaputra | JX987077         |
| Xenentocleidus xenentodonii | Xenentodon cancila | Ganga     | JX535617         |
| Xenentocleidus xenentodonii | Xenentodon cancila | Brahmaputra | JX987075         |
Although, monogeneans are a diverse group, with several species currently described in India, in which only a few species have been molecularly sequenced (Table 3). Of course, molecular analysis of these tiny worms is necessary to investigate for species distinctions. This finding represents a known diversity of these fish pathogens and in this respect, additional molecular characterization can also fruitfully assist in inferring the phylogeny.

4. Discussion

Monogenea is one of the largest class that include more than 5000 known species; all of them are reported as parasitic[19,20]. Among the known species, 95% of the genera have been reported from fishes and remaining 5% have been reported from amphibious vertebrates. Approximately including freshwater and marine 112 genera belonging to 28 families on monogenoidea have been abstracted from India[18]. The demand for fish as a valuable protein source has increased all over the world, whereas, the catch of capture fishery came to a stand still[21,22]. However, metazoon parasites in general and monogeneans in particular cause greater losses on account of having direct life cycle, which can be completed easily in a closed system[11]. The danger of new forms of monogenoiosis appearing with the introduction of new members into fish culture which threatens not only freshwater but marine fishes as well[23]. If we stick to one host one parasite rule, a very big gap exists in the state of our knowledge as far as biodiversity of freshwater monogeneans are concerned and only few work have been done in India[24].

However, the data clearly shows that only one fourth freshwater fish fauna has so far been screened. If we look at individual river system of India, a very big scope of investigation exists in West coast followed by Brahmaputra and Indus river system which warrants serious attention of helminths taxonomists to concentrate upon. Only little bit work has been done on the parasites of Brahmaputra river system by workers in India[25,26]. Previous studies indicate that no information was provided on the total diversity of monogeneans at the species level in Indian region. For this, the best way is to use molecular data which can constitute the only practical means of obtaining species–level resolution in a survey of monogeneans. Additional molecular sampling might uncover the diversity of these species rich group of parasites but this trend has not much popular in case of monogeneans. In India, only a few species of freshwater monogeneans has been sequenced through studies of some workers[27–30]. But with this data, it is difficult to establish the phylogeny and discuss the validity of freshwater monogenean having very minute differences in their body parts. Therefore, molecular analysis of the fauna is strongly urged to be investigated. This study also suggests that molecular data will reveal unexpectedly high diversity with varying ecological and phylogenetic affinity. These findings represent a known diversity of these widely occurring fish pathogens. Monogeneans diversity from India is still in infancy and the total possible number of these parasites showed that Indian region indicates only low percentage of these parasites that are presently known. Besides this, the available information also indicates that an integrated approach is necessary which should start with morphological characterization followed by molecular characterization of monogenean parasites in all river system of India.

In conclusion, this study suggests that subsequent comparison of monogenean fauna present in different river systems of India can be made. This information might prove to be a meaningful observation that can be used in designing the control measures of these serious pathogens of fishes. It is clear that much remains to be learned about this group within India and the biodiversity tools including molecular studies provides a practical means of moving forward.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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Comments

Background

Monogeneans are common and specific parasites of fishes. Most of them cause infection in the gills. A great number of monogenean species has been described from India, and the occurrence of several unknown species can be expected. Due to their pathogenic effect on cultured and wild fishes, studies on their occurrence, development, pathomechanism, etc. is reasonable.

Research frontiers

Authors collected data on monogeneans of freshwater fishes from the five major river systems of India. In tables they included both fishes infected with monogeneans and those having no data on monogenean infection. They also presented data on species studied by molecular methods.

Related reports

Monogenean fauna of fishes in the Palaearctic Fauna region is well studied and several species of monogeneans have been described from different fishes. Fish fauna of the Indian Fauna Region is rich in species, but only about one forth of them has been studied for monogenean infection. Authors of this manuscript study their biodiversity in the five river systems.

Innovations and breakthroughs

Authors present a catalogue of described monogeneans by the major river systems of India and analyze the stage of research accordingly.

Applications

The work which the authors have done has a character of a synopsis and it is a useful analysis of the present situation. It could be utilized by all researchers who intend to study monogeneans of Indian fishes or compare them with...
monogeneans of other regions.

Peer review

Authors studied monogenean infections of freshwater fishes in the five major water basins of India and collected data from the available specific literature and illustrated them in separate tables. These data are useful for other researchers who want to work on monogeneans in India and elsewhere.

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