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COMMUNITY STRUCTURE AND SYSTEMATIC STUDY OF HELMINTH PARASITES OF FRESHWATER SNAILS OF THE CHITTAGONG UNIVERSITY CAMPUS

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Abstract: In all, 13 parasite taxa - eight cercariae, three nematodes, one rhabdocoel and one aspidogastrean - were recorded from 205 out of the 642 snails autopsied. Of the carcariae, xiphidiocercous was the most diversified (five taxa), followed by the echinostome (two) and the furcocercous (one). Infection by the nematodes, though rather poor in diversity, was much higher (23.99%) than that (12.15%) by the developmental stages of Trematoda. The rhabdocoel and the aspidogastrean were minor infestors having 1.56% and 2.80% prevalence, respectively. *Bellamya bengalensis* was the most abundant host, had the highest parasite diversity (12 taxa) and also the highest prevalence of infection (51.59%). Though the second highest abundant host, *Paludomus blanfordiana* had the least parasite diversity (only an oxyurid nematode) and a very low prevalence (2.04%) as well. *Brotia costula*, the big strong snail harboured two taxa (a carcaria and a nematode), and also had a low prevalence (8.65%). The amphibious *Pila globosa*, though least abundant among the four hosts, had moderately high parasite diversity (four carcariae and two nematodes) and prevalence (40.26%).

Key words: Community structure, taxonomic accounts, helminths, freshwater snails, Bangladesh

INTRODUCTION

Freshwater snails are generally infected by trematodes, occasionally by nematodes, and rarely by turbellarians. Of them, the digeneans are of great medical and veterinary importance. They have an indirect complicated life cycle involving vertebrate definitive host and molluscan intermediate host.

In case of trematode parasites, molluscs are the almost obligatory first intermediate hosts (Esch *et al.* 2001, Littlewood and Bray 2001). About 100 species of snails are reported to act as intermediate hosts for the trematode parasites (Subba Rao and Mitra 1989). They serve not only as a source of food and a place of reproduction for those parasites, but also as a means of transport for getting to their next hosts (Lockyer *et al.* 2004). Many researchers have no doubt that these parasites were originally linked with molluscs, and only as a consequence of evolutionary development did they include in their life cycle a further group of hosts (Pojmanska and Grabda-Kazubska 1985, Cribb *et al.* 2001).

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Snail-trematode assemblages have recently attracted considerable interest from evolutionary ecologists studying the evolution of sexual reproduction (Lively 1996), host-parasite co-evolution (Lively 1996, Dybdahl and Lively 1998), the effect of parasitism on life-history evolution of host (Jokela and Lively 1995) and the evolution of host resistance (Webster and Woolhouse 1998).

Documentation of the larval trematode fauna is important not only for its own sake, but also to provide a more realistic understanding of the ecological settings in which schistosomiasis, fascioliasis and other snail borne diseases occur (Locker *et al.* 1981). It is important to note in this context that trematodes infecting humans, specially liver fluke and intestinal flukes, are highly prevalent in southeast Asian countries (Wongratanacheewin *et al.* 2001, Chai *et al.* 2005).

Works on snail parasites are virtually at the initial stage in Bangladesh. The only major attempt is that of Rahman and Jahan (1999, 2001, 2002, 2004, 2006) who worked on the taxonomic and epidemiological aspects of the developmental stages of Trematoda (DST) of nine freshwater snail species of Rajshahi. Of late, Islam *et al.* (2012) worked on the ecology and distribution of six (four common to those of Rahman and Jahan) snail vectors, and the epidemiological aspects of their five types of cercaria. Earlier works (Qadir 1982, Begum 1993, Rahman *et al.* 1997, Mondal *et al.* 2003) mainly dealt with the parasites of some ruminants, and primary factors related to the prevalence of their DST.

However, considerable works in this line have been done in major tropical countries of southeast Asia - India (Mukherjee 1966, 1986, 1992, Das Gupta 1989, Mohandas 1974, Das Mahapatra *et al.* 1982, Subba Rao and Mitra 1989, Choubisa 2008, Gautam and Kakulte 2014, Tigga *et al.* 2014), Pakistan (Ahmed and Khan 1967, Khan and Haseeb 1979, 1981, Haseeb and Khan 1982, 1983, Niaz *et al.* 2013), Sri Lanka (Jayawardena *et al.* 2010) and Thailand (Krailas *et al.* 2003, Dechruksa *et al.* 2007, Ukong *et al.* 2007, Chontananarth and Wongsawad 2013).

Based on monthly samplings, almost invariably, of the hosts over a period of one year (January, 2009 to January, 2010), the present work deals with the systematic accounts, community structure and epidemiological aspects of the parasites (DST, nematodes, aspidogastrean and rhabdocoel) of four snail species (*Bellamya bengalensis, Paludomus blanfordiana*, *Brotia costula* and *Pila globosa*) of two ponds and one stream of the Chittagong University Campus, Bangladesh.

The primary objective of the work was to investigate the DST infections in four common freshwater snails of Bangladesh. Nematodes, aspidogastrean and rhabdocoel were later on included in the work, as they were available in autopsy, the former very frequently and the latter two occasionally.

MATERIAL AND METHODS

Study area: The Chittagong University Campus is a hilly land which has been considerably modified for establishing the university. The sampled waterbodies were different in size, area, depth, water colour, extent of use by men, bathing and washing of cattle, etc. These were: (i) a narrow stream with a wide pool zone, locally known as "Chhara", (ii) a individually owned small pond (designated as IOP) used exclusively by a family for domestic purposes, and (iii) a shallow ditch like pond located beside the Chittagong University Railway line (designated as RLP).

Snail hosts:

Bellamya bengalensis Lamarck 1822 (**Fig. 1**)

B. bengalensis, a common freshwater snail, is known to prefer stagnant water with soft bottom and aquatic vegetations and is found in all the districts of Bangladesh. It occurs in permanent ponds and canals as well as temporary waterbodies like paddy fields. The species was very common in all the three present waterbodies throughout the year. It is also available in Malaysia, Myanmar, India, Pakistan, Sri Lanka, Australia, Europe and North America. It is already known as a common intermediate host of various digenetic trematodes (Rahman and Jahan 2001, 2006).

Paludomus blanfordiana Nevill 1877 (**Fig. 1**)

This scavenger snail prefers hard and rocky bottoms. It occurs in streams, rivers, irrigation canals and also ponds. It was presently abundant only in the stream, where the snails were found to attach to the rocky substrata of the bottom and sides. It occurs in almost all the hilly districts of Bangladesh. The species was virtually absent in the IOP and the RLP. *P. blanfordiana* is a common snail species of the Indo-Pacific region, including India, Sri Lanka, Myanmar, Bhutan and the Philippines.

Brotia costula Refinesque 1833 (**Fig. 1**)

This big herbivorous snail remains attached to the submerged plants or on the muddy, sandy bottoms of lotic waters like rivers, canals, streams, and also in stagnant waters. The species was collected from all the three present waterbodies. It is common all over Bangladesh. It is also found in India, Myanmar, the Malay Archipelago and Indonesia.

Pila globosa Swainson 1882 (**Fig. 1**)

This herbivorous large snail is abundant in ponds, tanks and submerged rice fields, but may also be found in freshwater streams, river, and even in brackish water of low salinity in the rainy season. But as the ponds or rice fields dry up, the animal burrows into the moist soil underneath for aestivation. It shows an increasing trend towards terrestrial habitat for breeding activities. It was the least available host among the four species examined, and was very rare in the winter. *P. globosa* is common almost all over Bangladesh. It is also very common

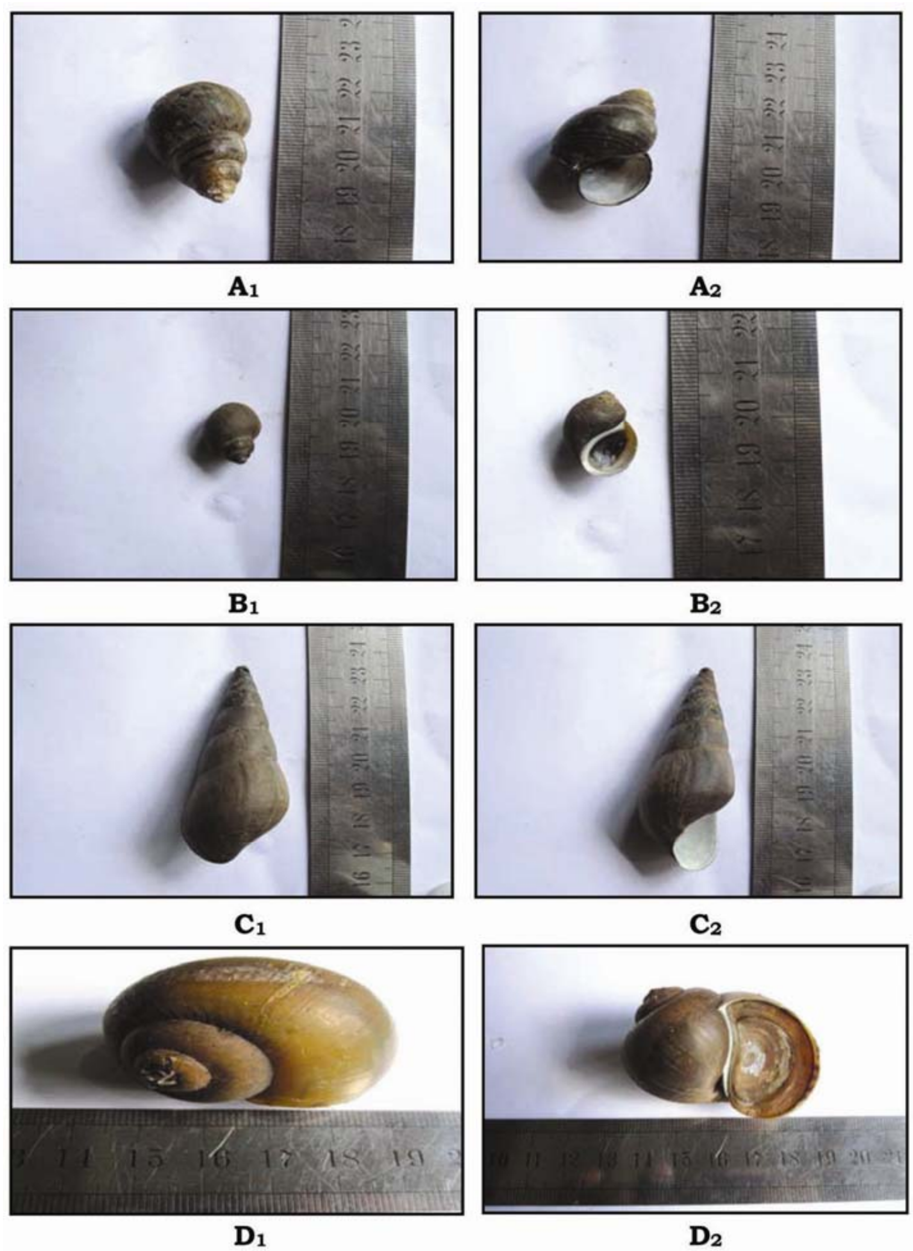

Fig. 1. A_1: *Bellamya bengalensis* (dorsal); A_2: *B. bengalensis* (ventral); B_1: *Paludomus blanfordiana* (dorsal); B_2: *P. blanfordiana* (ventral); C_1: *Brotia costula* (dorsal); C_2: *B. costula* (ventral); D_1: *Pila globosa* (dorsal); D_2: *P. globosa* (ventral).

in the Indo-Pacific, from India, Pakistan, Sri Lanka, Thailand, Myanmar, Malaysia, Vietnam and Indonesia, to the Philippines and the Ethiopian regions. It is already known to be a common intermediate host of many digenetic trematode parasites of vertebrates (Rahman and Jahan 2001, 2006).

Sampling: Each waterbody was, as a rule, sampled once in the first week of a month. However, for unavoidable reasons few samplings had to be missed, which should not affect the objectives as it is mainly a qualitative work. It may, however, be mentioned here that the above general sampling plan was also deviated in special cases, for example a waterbody was sampled again in the end part of a month, when considerable developmental stages were present in its sample. Hosts were collected following ample dragging by a dredge net in the marginal and litoral zones of the IOP and the RLP. For the stream, only hand picking from the rocky substrata was followed.

Study of parasites: All collected snails were examined live. The shell was broken with tweezers; the mantle, the digestive gland, and the viscera in general, were sliced under a binocular dissecting microscope into small fragments for examination.

Each collected parasite was fixed on a slide in slightly warm Glycerine Alcohol, the medium in which it was also mounted. The slide was sealed by quality grade nail polish. The parasites were studied under a high power Trinocular Research Microscope (Micros, MC100, made in Austria), and measurements were taken in millimetres. Microphotographs were taken by a high power camera (Canon Power Shot A 640), though only Camera Lucida drawings have been given here for better presentation of the structures, specially the finer ones.

RESULTS AND DISCUSSION

Taxonomic accounts of the snail parasites: Eight morphotypes of cercaria, one aspidogastrea, one rhabdocoel and three nematode taxa were recorded from 642 specimens of four species of freshwater gastropods, *viz., Bellamya bengalensis* (n = 314), *Paludomus blanfordiana* (n = 147), *Brotia costula* (n = 104) and *Pila globosa* (n = 77), of three different waterbodies of the Chittagong University campus. As crushing method for collection of parasites was followed, the parasite taxa could at best be said to have been present in the visceral mass and the mantle of the snails.

The cercariae have been identified as only xiphidiocercous, echinostome and furcocercous morphotypes, following Dawes (1968) and Frandsen and Christensen (1984), as cercarial taxonomy cannot yet be systematically pursued even to generic level. In many works (Ismail *et al.* 1988, Krailas *et al.* 2003, Rahman and Jahan 2006, Moema *et al.* 2008, Martorelli *et al.* 2013, etc.), cercaria-identification was not more definite than that of the level in which the present work has been done. However, binomial nomenclature of cercariae has been given by a number of workers (Ditrich *et al.* 1997, Jezewaski 2004, Faltynkova *et al.* 2007b, Ukong *et al.* 2007, Choubisa 2008, Gautam and Kakulte 2014, etc.), without following definite systematic keys and diagnoses.

Keys for the present cercariae:

1. Collar spines present — *Echinostome cercaria* (2)
   Collar spines absent — (3)
2. Cuticle frilly, oral sucker round — *Echinostome cercaria* E_1
   Cuticle not frilly, oral sucker not round, rather slightly extended backwardly — *Echinostome cercaria* E_2
3. Tail unforked, with oral stylet — *Xiphidiocercous cercaria* (4)
   Tail forked, without oral stylet — *Furcocercous cercaria*
4. Cercarial disc uniformly oval — *Xiphidiocercous cercaria* A (5)
   Cercarial disc elongated — (6)
5. Tail narrow, long and without lateral wrinkling — *Xiphidiocercous cercaria* A_1
   Tail stumpy, short and with lateral wrinkling — *Xiphidiocercous cercaria* A_2
6. Cercarial disc without prominent expansion just in front of the ventral sucker — *Xiphidiocercous cercaria* B (7)
   Cercarial disc with prominent expansion just in front of the ventral sucker — *Xiphidiocercous cercaria* C
7. Oral sucker smaller than ventral sucker — *Xiphidiocercous cercaria* B_1
   Oral sucker larger than ventral sucker — *Xiphidiocercous cercaria* B_2

Xiphidiocercous cercariae: Five morphotypes, designated here as XA_1, XA_2, XB_1, XB_2 and XC, were collected. In none of them, structures like the pharyngeal bulb, intestinal caeca, cystogenous glands and the excretory vesicle were at all developed.

***Xiphidiocercous cercaria* A_1 (XA_1) (Fig. 2, Table 1)**

Cercarial disc small. Oral sucker slightly larger than the ventral sucker, the latter situated at about the middle of the disc. Oral stylet has a pointed anterior end and two prominent lateral protrusions. Tail without fin fold, and shorter than the disc. Short setae are arranged in bundles all over the disc.

***Xiphidiocercous cercaria* A_2 (XA_2) (Fig. 2, Table 1)**

Except for the structure of stylet and arrangement of disc setae, all other characters are similar to those of XA_1. The stylet is pointed but without any lateral protrusions. *Short setae are sparsely distributed all over the disc.*

***Xiphidiocercous cercaria* B_1 (XB_1) (Fig. 2, Table 1)**

Cercarial disc large. Ventral sucker at about the middle of the disc. Stylet long, narrow, pointed and without lateral protrusions. Tail without fin fold and shorter than the disc; base of the tail inserted into a caudal pocket and bears numerous setae like structures.

***Xiphidiocercous cercaria* B_2 (XB_2) (Fig. 2, Table 1)**

The stylet is short but three times broader than that of the XB_1, except which other characters are similar to those of XB_1.

***Xiphidiocercous cercaria* C (XC) (Fig. 2, Table 1)**

Cercarial disc large, elongated, with the maximum breadth (about half of the length of the cercarial disc) just anterior to the ventral sucker. Both suckers are prominent; the oral smaller than the ventral one, which is located at about the middle of the disc. Stylet pointed. Tail without fin fold and shorter than the disc; base of the tail inserted into a caudal pocket and bears numerous setae like structures.

Rahman and Jahan (2001, 2006), in a work on nine freshwater snail species of Rajshahi, northern Bangladesh, reported only one xiphidiocercous cercaria from *Bellamya bengalensis* and *Gyraulus convexiusculus*, which is different from any of the five present ones. Recently, Islam *et al.* (2012) recorded another different xiphidiocercous morphotype from *Vivipara* spp. (wrongly identified; in fact *Bellamya* spp.) of Mymenshingh, central Bangladesh. It thus appears that xiphidiocercous cercariae are moderately, at least, rich in our common freshwater snails. Jayawardena *et al.* (2010) reported one type of xiphidio-cercous cercaria from *Thiara tuberculata* (a common freshwater snail of Bangladesh also) of Sri Lanka, whose description was too inadequate to make any comparison with the present types. Zhytova (2010) gave detailed description of one species of xiphidiocercous cercaria (*Plagiorchis mutationis*) from *Lymnaea stagnata* of Ukraine. *Lymnaea* is also a common genus of our freshwater. Size of stylet and suckers, and some other morphological measurements of *P. mutationis* were somewhat similar to those of the present xiphidiocercous A_1, from which the Ukraine species differed in having seven pairs of fine hairs on each side of the body.

Echinostome cercariae: During the present study two morphotypes (E_1 and E_2) of echinostome cercaria were recorded.

***Echinostome cercaria* E_1 (E_1) (Fig. 2, Table 1)**

Cercarial disc ovate. Collar bears 34 - 37 spines; majority with 36 spines. Ventral sucker much larger than the oral sucker, situated at the last one third of the disc. Tail blunt, stouter, rather wrinkled, muscular and slightly longer than the disc. Pharynx preceded by a short pre-pharynx; oesophagus long, bifurcates immediately in front of the ventral sucker. Intestinal caeca end up at the base of the tail. Cystogenous glands distinct. Long setae are arranged all over the disc.

***Echinostome cercaria* E_2 (E_2) (Fig. 2, Table 1)**

Cercarial disc ovate. Collar invariably with 36 spines. Ventral sucker considerably larger than the oral sucker, situated at the last one third of the disc, comparatively more posteriorly than that of E_1. Tail distinctly longer than the disc. Other internal characters and the arrangement of setae of this echinostome are similar to those of E_1.

Rahman and Jahan (2001, 2006) reported only one type of echinostome cercaria from *P. globosa*, but their account was not sufficient to decide about similarity or dissimilarity with the present specimens. On the other hand, Islam *et al.* (2012) mentioned only about the occurrence of echinostome cercaria in *Lymnaea auricularia* and *Indoplanorbis exustus*, common freshwater snails of Bangladesh. Martorelli *et al.* (2013) reported four types of echinostome cercaria (designated as E1, E2, E3 and E4) of the superfamily Echinostomatoidea from different species of freshwater *Biomphalaria* of Argentina. Except for that E2, which had somewhat similar number of collar spines (37) like those of the present ones (34-37, and 36), the remaining three types had different numbers of collar spines (27-28, 58, 19). But the lateral fin fold of their E2 is absent in the present both echinostome types.

Furcocercous cercaria: Only one type of furcocercous cercaria (apharyngeal brevifurcate monostome) was presently collected.

***Furcocercous cercaria* F_1 (F_1) (Fig. 2, Table 1)**

Body long and cylindrical, divided into body proper, tail stem and two furci. Body proper as long as the tail stem. Oral sucker terminal, triangular, feebly developed with almost indistinguishable musculature. It rather appears to be a small protrusible central portion of the anterior most margin, bearing small setae or bristle like structures. Ventral sucker and pharynx not developed, rather absent. Each furcus is thin, slender, shorter than the tail stem, and with a distinct constriction near the end, for which the terminal portion like of a small curved 'glandular claw'.

Rahman and Jahan (2001, 2006) recorded one type of furcocercous (distome) from *Lymnaea acuminata* and *Indoplanorbis exustus* of Rajshahi, whereas Islam *et al.* (2012) reported only the occurrence, without any morphological description, of furcocercous cercaria in *Vivipara* spp. and *I. exustus* of Mymenshingh. Faltynkova *et al.* (2007a) reported eight morphotypes (seven distome and one monostome) from four snail species of central Finland.

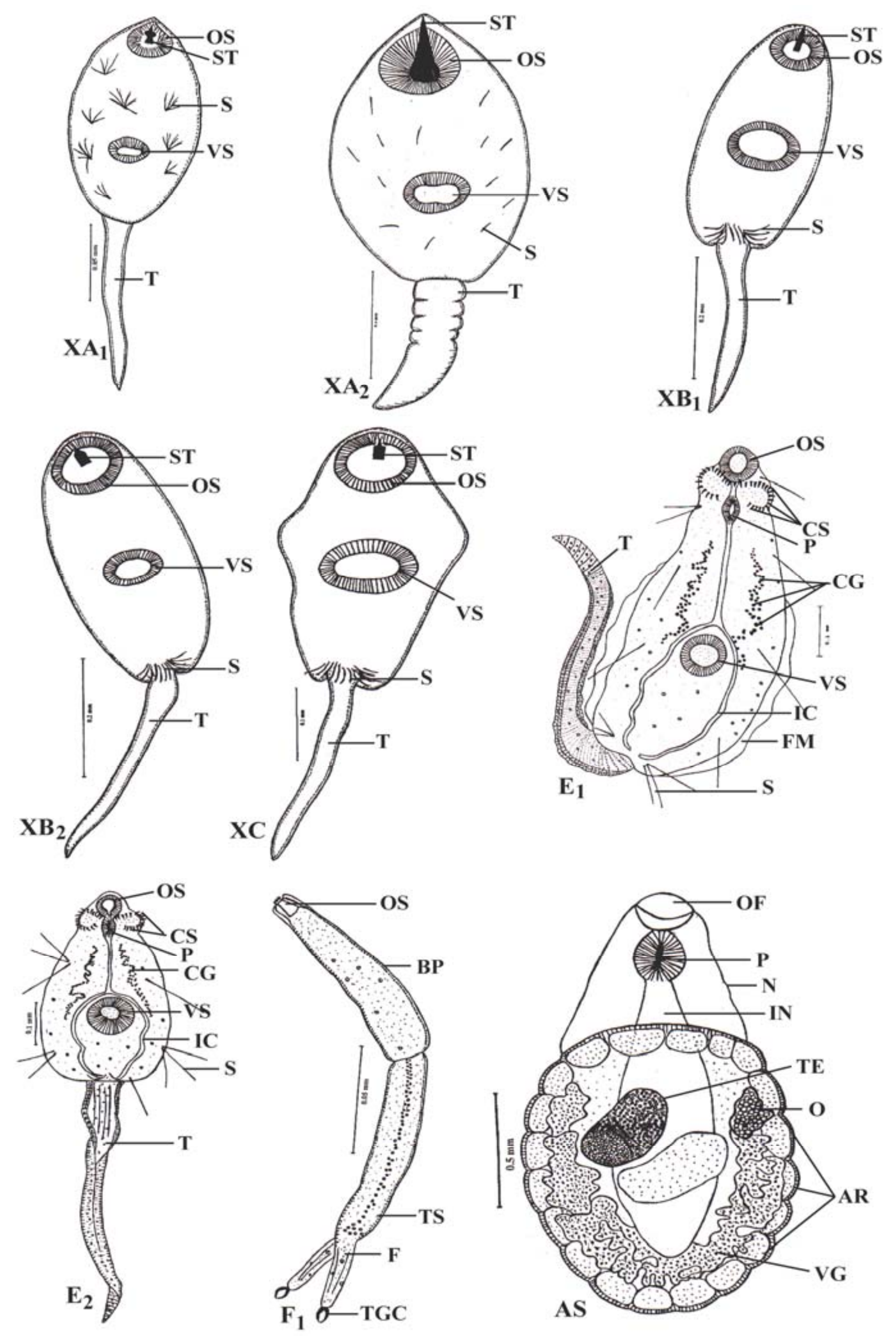

Fig. 2. XA1: *Xiphidiocercous cercaria* A1; XA2: *Xiphidiocercous cercaria* A2; XB1: *Xiphidiocercous cercaria* B1; XB2: *Xiphidiocercous cercaria* B2; XC: *Xiphidiocercous cercaria* C; E1: *Echinostome cercaria* E1; E2: *Echinostome cercaria* E2; F1: *Furcocercous cercaria* F1; AS: Aspidogastrea (*Cotylaspis insignis*). AR: Areoli; BP: Body proper; CG: Cystogenous glands; CS: Collar spines; F: Furcus; FM: Frilly membrane; IC: Intestinal caeca; IN: Intestine; N: Neck; O: Ovary; OF: Oral funnel; OS: Oral sucker; P: Pharynx; S: Setae; ST: Stylet; T: Tail; TE: Testis; TGC: Terminal glandular claw; TS: Tail stem; VG: Vitelline gland; VS: Ventral sucker.

Table 1. Morphometric parameters and morphological characters of the parasites (all measurements in mm)

Developmental stages of Trematoda (DST)

Cercaria	Hosts	Total length	Cercarial disc	Oral sucker (O.S.)	Ventral sucker (V.S.)	V.S. from anterior end	Stylet	Tail
XA_1	*B. bengalensis* *P. globosa*	0.256	0.147×0.095	0.028×0.024	0.021×0.019	0.08	0.016×0.003	0.109×0.017
XA_2	*B. bengalensis*	0.186	0.114×0.074	0.026×0.023	0.018×0.015	0.077	0.021×0.003	0.072×0.026
XB_1	*B. bengalensis* *P. globosa*	0.70	0.418×0.166	0.076×0.074	0.085×0.072	0.212	0.034×0.003	0.282×0.036
XB_2	*B. bengalensis* *P. globosa*	0.67	0.404×0.164	0.081×0.076	0.066×0.057	0.208	0.026×0.009	0.268×0.036
XC	*B. costula*	0.72	0.421×0.220	0.086×0.073	0.092×0.065	0.229	0.024×0.006	0.299×0.041
E_1	*B. bengalensis* *P. globosa*	1.265	0.623×0.348	0.066×0.064	0.113×0.107	0.394	Absent	0.642×0.094
E_2	*B. bengalensis*	1.224	0.519×0.312	0.06×0.072	0.108×0.096	0.330	Absent	0.705×0.096
F_1	*B. bengalensis*	0.28	0.115×0.037	Indistinct (not measured)	Absent	V.S. absent	Absent	0.174×0.019

Nematoda

Nematode	Hosts	Body size	Length of oesophagus	Vulval opening from anterior end	Tail length	Cuticle	Labial papillae	Stylet	Oeso-phageal bulb	Tail spike
Oionchus sp.	*B. bengalensis*	Female:1.835×0.056	0.385	0.727	0.187	Wrinkled	Present	Present	Absent	Absent
	P. globosa	Male: 1.912×0.03	0.402	Absent	0.03	Smooth	Present	Present	Absent	Absent
Mononchus sp.	*B. bengalensis*	Female:1.198×0.059 Male: Not collected	0.266	0.525	0.167	Smooth	Present	Absent	Absent	Present
Oxyurid	*B. bengalensis* *P. blanfordiana* *B. costula* *P. globosa*	Female:0.655×0.034 Male: Not collected	0.149	0.275	0.189	Smooth	Absent	Absent	Present	Present

Aspidogastrea

Aspido-gastrea	Host	Total length	Disc length	Disc breadth	Neck breadth	Oral funnel	Pharynx	Intestine	Testis	Ovary
C. insignis	*B. bengalensis*	1.38	0.938	0.830	0.494	0.154×0.115	0.110×0.106	0.967	0.276×0.175	Too indistinguishable for measurement

Their monostome was different from the present one in having dorsal crista and fin fold in tail. Jayawardena *et al.* (2010) recorded distome furcocercous cercaria from *Thiara tuberculata* and *T. scabra* (both common in freshwaters of Bangladesh) of Sri Lanka. Yousif *et al.* (2010) reported two distome furcocerous cercariae from *Melanoides tuberculata* (*T. tuberculata*) of Egypt. Martorelli *et al.* (2013) reported eight distome furcocercous cercariae from different species of Biomphalarian snails of Argentina. It thus appears that distome furcocercous are more common than the monostomes in gastropods.

Cotylaspis insignis Leidy1857 (Aspidogastrea : Aspidogasteridae) **(Fig. 2, Table 1)**

Body elongated, divided into a narrow anterior part and a broad posterior disc. Mouth sub-terminal, usually a funnel like opening regarded also as a rudimentary oral sucker. A short pre-pharynx and a large round pharynx occupy the slender 'neck' region. The large sac-like intestine extends almost to the posterior extremity. The adhesive disc is oval, covers 68% of the body length and bears three rows of alveoli (20 + 9). Testis single, median and post-equatorial. Cirrus pouch contains well differentiated prostate complex. Ovary sub-median, pre-testicular; no Laurer's canal and no receptaculum seminis. Vitellaria consist of large follicles, extending to hind body, lateral and posterior to other reproductive organs. The hermaphroditic form was an adult, but without completely developed secondary reproductive structures.

Rahman and Jahan (2001, 2006) and Islam *et al.* (2012) did not record any aspidogastrean in their works on freshwater snails. Hence, the present finding of *C. insignis* (from *B. bengalensis* only) is a new record of aspidogastrean from freshwater snails of Bangladesh. The genus *Cotylaspis* was established by Leidy in 1857 with the type species *C. insignis* from two species of *Anodonta* of North America. *C. insignis* has also been reported by Fulhage (1954), Yamaguti (1963), Hendrix and Short (1965) and Stromberg (1970) from clams and turtles.

Unidentified Rhabdocoel

Body cylindrical, 0.034 long and 0.078 broad, ciliated all throughout. Cilia rather thick and prominent anteriorly. Mouth ventral and sub-terminal. Digestive tract is a long tube (0.338 long and 0.015 broad), extending from the anterior to the posterior end; no diverticula. Rhabdoids short, blunt; some protruded outside. The flatworm was an immature form and collected from *B. bengalensis* only.

Keys for the present nematodes:

1.	Oral stylet present	*Oionchus* sp.
	Oral stylet absent	(2)
2.	Oesophagus with a bulb	*Oxyurid*
	Oesophagus without bulb	*Mononchus* sp.

***Oionchus* sp. (N_1)** (Mononchida: Mononchulidae) **(Fig. 3, Table 1)**

Female: Body long, tubular, cuticle wrinkled. Labial papillae four, clearly distinguishable. Oral stylet (St1) moderately long, retractable through the mouth opening. A slightly bigger additional stylet (St 2) present in the anterior oesophageal region, 0.095 from the anterior end. Oesophagus long and divisible into a winding anterior glandular part and a straight posterior muscular part. Intestine not well formed – filled with granules resembling mesenchyme. Reproductive organs also not clearly distinguishable. Vulval opening slightly behind the anterior one third of the body. Tail much longer (more than six times) than that of the male.

Male: Body slightly longer than that of the female; cuticle smooth. Labial papillae four, rudimentary, almost indistinguishable. Oral stylet longer than that of the female. The St 2 is obscure in the male. Oesophagus slightly longer than that of the female. Spicules two, equal, short, somewhat thick. Tail short and blunt.

***Mononchus* sp. (N_2)** (Mononchida: Mononchidae) **(Fig. 3, Table 1)**

Female: Only female specimens were available. Body small; cuticle smooth. Four labial papillae. Cephalic setae distinct. Buccal capsule large, well sclerotized and toothed. Oesophagus tubular, long and muscular. Reproductive organs not developed. Tail long, the tip somewhat oar or paddle like and bears a small spike terminally.

***Oxyurid* (N_3)** (Ascaridida: Oxyuroidea) **(Fig. 3, Table 1)**

Female: Only matured female specimens were available. Body small; cuticle smooth. Oesophagus oxyuroid type, long, tubular with slight windings in some specimens; bulb small but prominent. Tail long, pointed and bears a spike terminally. Reproductive organs quite developed in spite of the smaller size of the worms.

Farahnak *et al.* (2006) recorded *Oionchus* (both larva and adult) from *B. bengalensis* of Iran. In the works of Rahman and Jahan (2001, 2006) and Islam *et al.* (2012), no nematode was recorded. Hence, the present finding is a new record of nematodes from snail hosts of Bangladesh, and the present three species, might be in a transition pathway from aquatic free living mode to commensalic or parasitic life.

Parasitism by nematodes, although not as common as trematodes, also occurs in aquatic gastropods. Three different types of associations between nematodes and their gastropod hosts are known (Grewal *et al.* 2003) - as paratenic hosts that serve to transfer a larval stage of a parasite from one host to another but in which little or no development takes place (Moravec 1996,

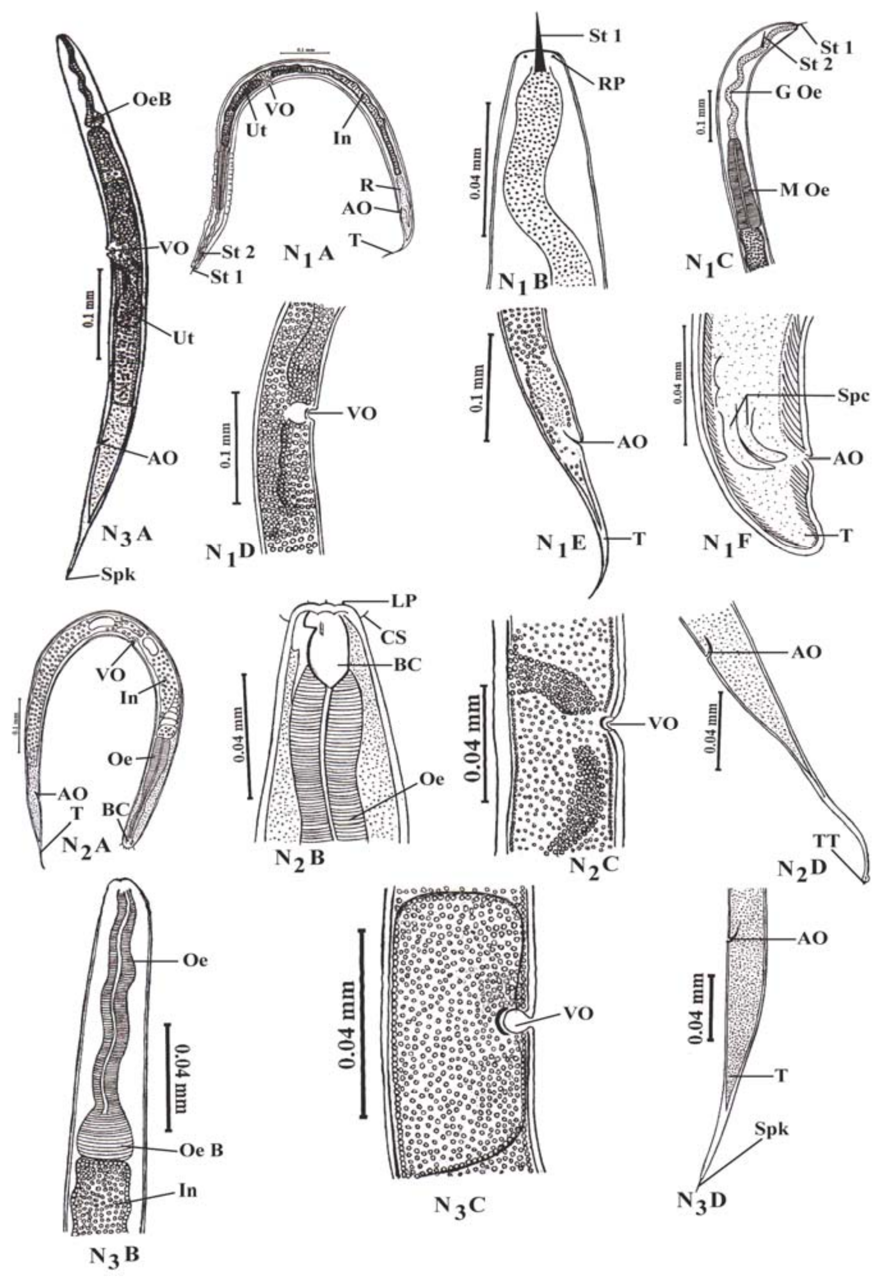

Fig. 3. N_1: *Oionchus* sp. (N_1A-N_1F); N_2: *Mononchus* sp. (N_2A-N_2D); N_3: Oxyurid (N_3A-N_3D); N_1A: Female whole view; N_1B: Anterior portion of male; N_1C: Anterior portion of female; N_1D: Vulval region; N_1E: Posterior portion of female; N_1F: Posterior portion of male; N_2A: Female whole view; N_2B: Anterior portion; N_2C: Vulval region; N_2D: Posterior portion; N_3A: Female whole view; N_3B: Anterior portion; N_3C: Vulval region; N_3D: Posterior portion; AO: Anal opening; BC: Buccal Capsule; CS: Cephalic seta; G Oe: Glandular part of the oesophagus; In: Intestine; M Oe: Muscular part of the Oesophagus; LP: Labial papilla; Oe: Oesophagus; Oe B: Oesophageal bulb; R: Rectum; RP: Rudimentary papilla; Spc: Spicule; Spk : Spike; St 1: Stylet 1; St 2: Stylet 2; T: Tail; TT: Tail tip; Ut: Uterus; VO: Vulval opening.

Komalamisra *et al.* 2009), as intermediate hosts for which vertebrates serve as final hosts (Anderson 2000, McCoy and Nudds 2000), and as definitive hosts in which the entire nematode life cycle is completed (Odaibo *et al.* 2000, Tan and Grewal 2001).

Community structure and prevalence of the parasites:

In *Bellamya bengalensis*

Of the four snail species harbouring 13 parasite taxa (eight DST, one aspidogastrean, one rhabdocoel and three nematodes), *B. bengalensis,* the most common one, was found to be infested by 12 taxa. Among them, the DST were most diversified (seven taxa) representing xiphidiocercous, echinostome and furcocercous cercariae, of which the former type had the richest diversity (four taxa) and the highest prevalence.

Earlier, Rahman and Jahan (2001, 2006) reported amphistome, distome and xiphidiocercous cercariae, the first being the dominant one, from *B. bengalensis* specimens of Rajshahi, whereas Islam *et al.* (2012) recorded only furcocercous and xiphidiocercous cercariae from the same snail of Mymensingh. So it is evident that at least five groups of cercaria do infest *B. bengalensis* of Bangladesh. Interestingly, Mukherjee (1992) and Gupta *et al.* (2011) each found only one type of cercaria (echinostome and furcocercous cercaria, respectively) in *B. bengalensis* of India.

Of the 314 *B. bengalensis* specimens autopsied, 162 (51.59%) were infected in all by four groups of parasites (DST, aspidogastrean, rhabdocoel and nematodes, with prevalences of 37.65, 11.11, 6.17 and 77.16%, respectively). Single infection was the most dominant (72.84%), followed by double (22.84%), triple (3.70%) and quadruple (0.62%) infections. Among the former cases, nematodes were the most dominant (73.73%), followed by DST (18.64%), rhabdocoel (5.08%) and aspidogastrean (2.54%). Of the double infection cases, the nematode + DST combination was the most dominant one (70.27%), followed by DST + aspidigastrean (16.22%), rhabdocoel + nematode (8.11%) and aspidogastrean + nematode (5.41%) combinations. Triple infection was found in only six individuals and in only one combination (DST + aspidogastrean + nematode). Quadruple infection (DST + aspidogastrean + rhabdocoel + nematode) occurred in only one host.

Vast majority (80.33%) of the DST-infections, with or without other parasites, were of the single type. Many workers (Ghobadi and Farahnak 2004, Faltynkova *et al.* 2007b, Dechruksa *et al.* 2007, Ukong *et al.* 2007, Sharif *et al.* 2010, Jayawardena *et al.* 2010, Bdir and Adwan 2012, etc.) also reported vast dominance of single infection by DST in various snail species including *B. bengalensis*. Presently, only six snails had double infection by DST types – four by X + E and two by X + F. No two morphotypes of any of the cercarial groups (e.g., like XA_1 + XC, or E_1 + E_2) were present in multiple infection, indicating the avoidance of interspecific competition among the closely related members. That inference is also apparent, from an opposite angle, in the observed combination like XA_1+E_1 and XA_1+F_1, which possibly resulted through niche segregation of different kinds of organisms.

Though the incidence of double infection in snails was considered as an accidental case by some earlier workers (Cort 1915, Faust 1917, Sewell 1922, Brown 1926), many recent works (Faltynkova 2005, Choubisa 2008, Moraes *et al*. 2009) reveal that double infection by DST is not uncommon in snails. Rahman and Jahan (2001, 2006) observed frequent incidence of double infection by DST in *Thiara tuberculata, B. bengalensis* and *Indoplanorbis exustus*, common freshwater snail species of Bangladesh. They also reported a triple infection by DST from *Lymnaea acuminata*.

The prevalence rate of double infection is generally low, which can be related to the antagonism between two species (Lim and Heyneman 1972, Sousa 1992, Lafferty *et al.* 1994). The competition among larvae from different trematode species inside mollusc can reduce both parasite number and snail population (Basch *et al.* 1969 and Lim and Heyneman 1972). Kuris (1990) stated that interspecific competition among intramolluscan stages strongly influenced double infection in the snail *Cerithidea californica*, whereas Fernandez and Esch (1991) related the snail numbers of *Helisoma anceps* carrying double infections to low host invagility and to several temporal and spatial factors. Habitat structure, definite host behaviour, biology of the infectious stages and snail population dynamics are among other factors that have been associated with multiple infections in freshwater snails (Fernandez and Esch 1991).

Among the nematodes, single infection was the most common one (60.0%) followed by double (25.6%) and triple (14.4%). Contrary to common knowledge, nematodes were found to have much higher prevalence (77.16%), though with much lesser diversity, than that of DST (37.65%) (including multiple infection cases).

In works on various snail species by Mukherjee (1966, 1992), Suuba Rao (1989), Rahman and Jahan (2001, 2006), Vasandakumar and Janardanan (2006), Gupta *et al*. (2011) and Islam *et al*. (2012), no nematode infection was reported. It is not clear whether they did not find any one or just omitted the nematode case as not within the purview of the objective (the DST) of the works. The latter appears to be more likely in view of the significantly higher prevalence of nematodes in the present snail hosts. However, Farahnak *et al*. (2006) reported a nematode, *Oionchus* sp., from *B. bengalensis* of Iran, and Mohammad (2015) in his work on parasites of seven snail species, reported oxyurid larval occurrence in *B. bengalensis* of central Iraq.

Presently, one aspidogastrean and one rhabdocoel (both minor infestors) were found in *B. bengalensis*, with prevalence of 5.73% and 3.18%, respectively. However, Rahman and Jahan (2001, 2006) and Ialam *et al.* (2012) did not report anything about these helminths from snails of Bangladesh.

In *Paludomus blanfordiana*

P. blanfordiana, the second most abundant (147 out of the 642 autopsied) species included in the present work, had a very poor parasitic infestation (2.04%). It was infested by only one parasite taxon, the oxyurid nematodes.

No parasitological work has earlier been done on this snail host species in Bangladesh, and apparently in India as well. This species was not present in a good number of such Indian works (Subba Rao 1989, Mukherjee 1992, Gupta *et al.* 2011, Tigga *et al.* 2014). However, DST was recorded from different *Paludomus* species of India, Sri Lanka and Thailand. Vasandakumar and Janardanan (2006) recorded two new 'species' of xiphidiocercous cercaria from *P. tanschauricus* of Malabar, Kerala. Jayawardena *et al.* (2010) reported five cercarial types (oculopleurophocercous, distome, gymnocephalous, gymnophallus and microcercous) from a different *Paludomus* (*P. sphearica*) of Sri Lanka. Krailas *et al.* (2003), likewise, recorded four cercarial types (xiphidiocercous, amphistome, furcocercous cercariae types I and II) from *P. petrosus* from Thailand. In view of these findings, considerable number of autopsies (147) undertaken in the present work, the total absence of DST in the present *P. blanfordiana* specimens appear to be interesting indicating the necessity of further investigation.

In *Brotia costula*

B. costula was the third abundant (104 out of 642) snail species of the present work. This big and strong snail with a very hard shell was found to harbour only two parasite taxa - a xiphidiocercous cercaria and a nematode. The prevalence of infection was low (8.65%) and all infection were single. However, a reproductively matured amphistome trematode was latter on collected from this host in a separate undergoing work.

Except for Islam *et al.* (2012), no other parasitological work has been done on this snail species of Bangladesh. However, Islam's work was on a snail named only as *Brotia* species, from which, that too, no parasite was recorded. Dechruksa *et al.* (2007) in a work on six species of *Brotia* of Thailand, not including *B. costula*, found only one species to be infested by only one DST taxon. Similarly, Chontananarth and Wongsawad (2013) reported only pleurolophocercous cercaria from *B. costula* of Thailand.

In *Pila globosa*

This snail with efficient adaptation to also terrestrial life was found to be the second susceptible species to parasitic infection (40.26%). Both DST (41.94%) and nematode (67.74%) had considerably higher prevalences (including mixed infections) in this amphibious species. DST included four cercarial types, viz., XA_1, XB_1, XB_2 and E_1, no two of them formed any multiple infection. However, DST and nematodes formed multiple infection in three hosts. Of the two cercarial groups obtained in this snail, xiphidiocercous cercaria had notably higher diversity and prevalence than those of the echinostome.

As in *B. bengalensis*, the prevalence of nematode infection was higher, than that of the DST, in this snail species. The two nematode taxa, *Oionchus* sp. and *Mononchus* sp., had almost similar prevalence. They were present in both single and double infections.

Rahman and Jahan (2001, 2006) reported three cercarial taxa from *P. globosa*, of which the echinostome type has also been recorded in the present work. It is thus evident from the present work and those of Rahman and Jahan (2001, 2006) that in Bangladesh *P. globosa* is an intermediate host of at least six species of Trematoda.

Among the Indian works, findings of Mukherjee (1966) and Subba Rao (1989) were rather contradictory. Mukherjee stated that *P. globosa* was not susceptible as a harbouring host of DST, whereas Subba Rao reported five 'species' of cercaria from this species. Like the observation of Mukherjee, Devkota *et al.* (2011) and Islam *et al.* (2012) did not find any DST infection in this host species from central Nepal and Bangladesh, respectively.

CONCLUSION

Contrary to the common knowledge, nematode infection was much more prevalent than that of the DST. Though poor in diversity, they infested all the four host species. In spite of its wide habitat diversity and moderate, at least, abundance, *Paludomus blanfordiana* was infested by only one parasite, an oxyurid nematode, whereas, the co-occurring *Bellamya bengalensis* harboured 12 parasite taxa. Identification of the cercariae, the most diversified infectors of snails, is yet, even globally true, to be systematically done to the species level. Each of the above aspects is an interesting problem for future research.

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