NEW HOST RECORD OF SOME GASTROINTESTINAL PARASITES OF IRRAWADDY SQUIRREL (CALLOSCIURUS PYGERYTHRUS) FROM CHITTAGONG, BANGLADESH

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Abstract: Gastrointestinal (GI) tract of 60 Irrawaddy squirrels (Callosciurus pygerythrus) were collected between September 2013 and August 2014 from four different spots of Chittagong University campus and its adjacent areas to study the ento-helminth fauna. Eight different parasite species were identified - one belonging to Cestoda and represented by Hymenolepis diminuta, and the remaining seven were to Nematoda viz., Strongyloides callosciurus, Trichuris ovis, Monodontus sp., Cyclodontostomum purvisi, Moguranema nipponicum, Ascarops talpa and Syphacia obvelata. The nematodes were found as dominant species most preferably inhabiting the small intestine. The present host is the new host record for all of these parasites and S. callosciurus, T. ovis, Monodontus sp., M. nipponicum and A. talpa are the new records for Bangladesh too. All these parasites have very wide host specificity, though most of them are restricted to various rodent hosts but H. diminuta and S. callosciurus were found to have more wider specificity, including other vertebrates too. All identified parasites might have been acquired from the environment where the host inhabits, since host specificity perspective no parasites were found to be specific to the present host. H. diminuta and Syphacia obvelata might have zoonotic role to other wild animals and human and vice versa.

Key words: Irrawaddy squirrel, Rodents, Helminths, Zoonosis, Host specificity

INTRODUCTION

Squirrels, members of the family Sciuridae, are small or medium size rodents and indigenous to the Americas, Eurasia, and Africa, and have been introduced to Australia (Seebeck 2013). In Bangladesh nine species of squirrels have been recorded by Ahmed et al. (2009) though Antara et al. (2015) reported 8 species. The Irrawaddy squirrel (Callosciurus pygerythrus Geoffroy Saint Hilaire, 1931), the host animal of the present study, is a medium sized, elongated and dark brown squirrel widely distributed in northeastern South Asia, southern China and western Southeast Asia at elevations of 500 to 1,560 metres. In Bangladesh, this squirrel is common almost all over the country but very widely distributed in riverine and mixed forest and near village (Menon 2003; IUCN Bangladesh

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2015). Though globally it is considered vulnerable (VU) but in Bangladesh not yet considered threatened (IUCN Bangladesh 2015). However, the naturalization of squirrel present various issues, such as damages to agriculture and forestry and competition with other sciurids (Thorington et al. 1966). Not only that, from a number of works done around the globe it has been anticipated that both the native and introduced squirrel species might have negative role in various diseases and population decline to other wild animals (Shinozaki et al. 2004 a, b, Rushton et al. 2006, Sato et al. 2007, Sainsbury et al. 2008), perhaps because of various disease mediated competition (Khodakevich et al. 1986, Anonymous 2003, Dozieres et al. 2010, Bertolino and Lurz 2013). As for instance, the Pallas’s squirrel (Callosciurus erythraeus), also known as Asian red bellied squirrel, introduced into so many countries such as Japan, Argentina and three European countries (Belgium, France and the Netherlands) because of its aesthetic value and also under international pet trade (Palmer et al. 2007, Bertolino 2009), was found to be a potential carrier of the pathogens of some infectious diseases that can affect humans as well as domestic and native wild mammals (Bertolino and Lurz 2013). Therefore, like other squirrel species of the world, the Irrawaddy squirrel may also be a potential carrier of pathogens of some infectious diseases that can affect humans as well as domestic and native wild animals as they live at the vicinity to human and other animals’ habitation. Parasitological investigations on this species is very rare in literature, so this animal was selected as an interesting host not only to fill the gap of knowledge but also to evaluate its role as a host of specific or acquired parasites from the community where it really belongs to.

**MATERIAL AND METHODS**

Chittagong University campus and its adjacent areas were selected as study area and the study was done between September, 2013 and August, 2014. After a pre-surveillance on the host abundance, the study area was segregated into four spots - Spot 1: Forest behind the Marine Science and Fisheries Institute; Spot 2: Botanical garden; Spot 3: Adjacent areas of Shahid Abdur Rab Hall; and Spot 4: Adjacent areas of Chittagong University campus. However, the guiding factors behind this spot selection or habitat segregation were the availability of food and fruit trees and closeness with the human habitation.

Samples were collected regularly every month by live trapping and/or shooting. Monthly at least one sample was collected from each spot and a total of 60 (39 males and 21 females) host specimens were collected during the study period. Live-trapped squirrels were euthanized following animal handling procedures approved by international guidelines (AVMA 2007). For helminths
prospection, complete gut wall and lumen from oesophagus to rectum were dissected and carefully analyzed using stereo-microscope. To restrict morphological deterioration the parasites were fixed in hot AFA (Alcohol-formol-acetic) for cestodes and GA (Glycerine-alcohol) for nematodes and later half of these parasites were preserved in 70% alcohol and the rest in lactophenol for clearing and microscopic observations. Microdissections were performed wherever needed for detailed taxonomic studies. Microphotographs were taken by digital cameras (Sony, DSC-T90; Samsung ES99 and Optika Digital Microscopy, Optika 4083.B5) and drawings were prepared with the support of a camera lucida (Weswox, HLm-6 Black). The scheme of classification and taxonomic features were mainly followed after Yamaguti (1985c, 1961, 1959), with additional consultations from Anderson et al. (2009), Wardle and McLeod (1952), Chandler (1949), and various other online resources.

RESULTS AND DISCUSSION

Of the 60 (39 males and 21 females) host samples, 49 (33 males and 16 females) samples were found to be infected with 8 different helminth parasites - 1 cestode and the remaining 7 were nematodes (Table 1). No trematode and acanthocephalan parasites were encountered. The nematodes were found to be the prevalent parasite species and the family Trichostrongylidae and Oxyuridae appeared to be the dominant parasite group. The small intestine was the most favourable niche for the parasites which was validated by the recovery of 6 parasite species i.e. *H. diminuta*, *S. callosciurus*, *Monodontus* sp., *C. purvisi*, *Moguranema nipponicum* and *A. talpa* though *M. nipponicum* also recovered from the stomach but were more abundant in the

| Scientific name of the parasite | Order          | Family            | Site of infection    |
|--------------------------------|----------------|-------------------|----------------------|
| **Cestoda**                    |                |                   |                      |
| *Hymenolepis diminuta*         | Cyclophyllidea | Hymenolepididae   | Small Intestine      |
| **Nematoda**                   |                |                   |                      |
| *Strongyloides callosciurus*    | Rhabdiasidea  | Strongylida       | Small intestine      |
| *Trichuris ovis*               | Trichuridea    | Trichuridae       | Large intestine      |
| *Monodontus* sp.               | Strongylida    | Ancylostomatidae  | Small Intestine      |
| *Cyclodontostomum purvisi*     | Strongylida    | Ancylostomatidae  | Small Intestine      |
| *Moguranema nipponicum*        | Strongylida    | Trichostrongylida | Stomach and small Intestine |
| *Ascarops talpa*               | Spirurida      | Spirurida         | Small Intestine      |
| *Syphacia obvelata*            | Oxyurida       | Oxyurida          | Large intestine      |
small intestine. Based on available literatures consulted in the present study, 5 out of 8 identified species, namely - *S. callosciurus*, *T. ovis*; *Monodontus* sp., *M. nipponicum* and *A. talpa* are considered as new records for Bangladesh and obviously the host animal is the new host record for all these parasites.

**Cestoda:** *Hymenolepis diminuta* Rudolphi 1819. (Cyclophyllidea: Hymenolepididae: Hymenolepidinae). The genus *Hymenolepis* is thought to be included in a complex of cryptic species because some species of this genus possess unarmed rostellum while others have no rostellum (Haukisalmi et al. 2010). However, after numerous revisions, *Hymenolepis* currently includes hymenolepidid cestodes with an unarmed scolex which parasitize rodents (12-13 species), bats (about 4 species) and hedgehogs (López-Neyra 1942a,b, Gulyaev and Melnikova 2005). Therefore, the unarmed scolex (Fig. 1) and much broader proglottids of the present cestode confirmed its identity as *Hymenolepis* (Chandler 1955, Wardle and McLeeod 1952) and absence of filaments in the onchosphere (Fig. 2) distinguished this species from other species of this genus. It is now established that the life cycle of *H. diminuta* involves rodents as the definitive host and beetles or other arthropods as the intermediate hosts (Andreassen et al. 1999, Makki et al. 2011). Not only that, for this parasite, a diverse assemblage of rodent definitive hosts (i.e. Sciuridae, Gliridae, Dipodidae, Cricetidae, Muridae and Gerbillinae) has been reported by many parasitologist all over the world and some of these rodents are - *Bandicota indica*, *B. savilei*; *Berylmys berdmorei*, *Berylmys bowersi*, *Leopoldamys edwardsi*, *Maxomys surifer*; *Mus cookie*; *Niviventer fulvescens*; *Rattus exulans*; *R. losea* and *R. tanezumi* (Ryzhikov et al. 1978). In Bangladesh, this species first reported from *Rattus rattus*, *Bandicota benghalensis*, *Scalopus scapanus*, and human (Huq 1969, Areekul and Radomyos 1970, Sinniah 1979, Chenchittikul et al. 1983). However, the present host is the new record for this cestode.

**Nematoda:** *Strongyloides callosciurus* Sato, H. 2007. (Rhabdiasidea: Strongyloidiidae) *Strongyloides* has only parthenogenetic females in the parasitic phase and Sato et al. (2007) mentioned that they should be characterized mainly by the morphology of parasitic females (Figs 6 and 7) and exhibit both homogonic and heterogonic development in their life cycle (Schad 1989, Viney 1994, Dorris et al. 2002). Approximately 50 species are recognized to parasitize different amphibians, reptiles, birds and mammals (Speare 1989). Little (1966a) and Speare (1989) found three characteristics in parasitic female useful for the identification of species – (a) the form of the stroma, (b) the form of the ovaries; and (c) the stage passed in the feces (Fig. 6). However, from all species of this genus only two *viz.*, *S. robustus* and *S. callosciurus* showed morphological resemblance with the present samples but *S. callosciurus* had the highest
similarity with the present specimen both morphometrically and host preference (Table 2). This is the first record of this parasite from Bangladesh and the host as new host record too.

**Table 2. Comparison between two closely related species of *Strongyloides* with the present species (Measurements in mm unless mentioned otherwise).**

| Characters                  | *S. robustus* (Sato *et al.* 2007) | *S. callosciurus* (Sato *et al.* 2007) | Present species (Based on 5 female samples) |
|-----------------------------|-----------------------------------|--------------------------------------|-------------------------------------------|
| Body length                 | 5.5 - 6.5 (6)                     | 6.25                                 | 5.54 - 10.2                               |
| Body width at the distal end of oesophagus | 0.052 - 0.058 (0.056)            | 0.048                               | 0.037 - 0.039                             |
| Length of oesophagus        | 1.14 - 1.4 (1.29)                 | 0.939                               | 0.923 - 0.98                              |
| Vulva from anterior end     | 3.3 - 3.9 (3.6)                   | 4.05                                | 3.82 - 4.13                               |
| Length of tail              | 0.090 - 0.116 (0.1)               | 0.070                               | 0.0781 - 0.0786                           |
| Greater diameter of egg     | 0.045 - 0.072 (0.058)             | 0.054 - 0.066 (0.056)               | 0.040 - 0.0462                            |
| Lesser diameter of egg      | 0.033 - 0.042 (0.036)             | 0.027 - 0.038 (0.032)               | 0.025 - 0.027                             |
| Host                        | *Sciurus* spp.                    | *Patamiasciurus* spp.               | *Asian squirrel*                          |
|                             | *Glaucomys* spp.                  | *Spermophilus* spp. and *Tamias* spp.| *Irrawaddy squirrel*                      |

*Trichuris ovis* Abild 1795. (Trichuridea: Trichuridae: Trichurinae). The presence or absence of the spicular tube, the length of the spicule and cloacal tube, the shape of the proximal and distal cloacal tube along with the classical morphometric characteristics have been used as features with high discriminatory value for species differentiation (Schwartz 1926), while the body length, vagina length and egg size could also be used as variables to discriminate and classify entire female and the analysis might yield a 100% accurate classification (Gomes *et al.* 1992, Spakulova 1994, Suriano and Navone 1994, Rossin and Malizia 2005, Robles *et al.* 2006). Yamaguti (1985c) enlisted 71 species from the genus *Trichuris*. Based on the egg shape and size \[0.087 \times 0.046 \text{ mm} (0.04-0.075 \text{ mm})\] (Figs 3-5) and the length of the oesophagus \[28.120 \text{ mm} (24.5-32 \text{ mm})\], the present species was identified as *T. ovis*. Like other nematode parasites of this present study, it is also the new record for Bangladesh and the present host is new host record for this parasite.

*Monodontus* sp. Mollin 1861. (Strongylidea: Ancyclostomatidae: Bunostominae) *Monodontella* (Yorke and Maplonestone 1926) has been regarded a synonym of *Monodontus* by different authors (Lichtenfels 1980, Kalia and Gupta 1983). A pair of ventral cutting plate (Fig. 8), infundibular buccal capsule (Fig.
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8), subventral lancets (Fig. 8), large common trunk (Fig. 9), bifurcated dorsal ray (Fig. 9) and symmetrical spicule with opposed uteri are the characters to place the present sample under the genus *Monodontus*. Up to now, eight species of the genus *Monodontus* has been described (Kalia and Gupta 1983) though Yamaguti (1985c) enlisted 10 species under this genus. However, surprisingly, the species of this genus can be placed into two distinct groups, *M. giraffae* and the remaining species of this genus. No clear evidence has been proposed by any taxonomist behind this grouping. But from the comparative study between *M. giraffae* and other species show a clear distinction in between them (Table 3). From the comparison it was seen that the present *Monodontus* samples showed numerous resemblances with *M. lousianensis*, but lack of sufficient sample no conclusion could be made. However, no parasitological works from Bangladesh reported the presence of this parasite from any host. So, this genus might be the new record for Bangladesh from this host.

*Cyclodontostomum purvisi* Adams 1933. (Strongylida: Ancylostomatidae: Ancylostomatinae) From morphology and geographical point of view, *C. purvisi* appears to be most nearly related to *Agriostomum*, which occurs in ruminants in Southeast Asia and South Africa. The presence of anteriorly tilled cephalic end (Fig. 10), cephalic collar (Fig. 10), 8 pairs of strongly curved teeth (Fig. 10), esophageal funnel (Fig. 10) and larger dorsal lobe (Fig. 11) directed the present species under the genus. Yamaguti (1985c) reported only one species i.e. *C. purvisi* under this genus and the present species showed considerable resemblance with the description found in other literature except the host type (Table 4). However, previously this parasite was recorded from a number of rat host, including the genera *Rattus, Bandicota, Berylmys, Leopoldamys, Maxomys, Niveventer*, and *Sundamys* (Hasegawa and Safruddin 1994). In Bangladesh, Huq (1969) reported *C. purvisi* from *Rattus rattus*, *Bandicota bengalensis* and *Scalopus scapanus* from Mymensingh district. So, the present host is the new host record for this parasite from Bangladesh.

*Moguranema nipponicum* Yamaguti 1941. (Strongylida: Trichostrongylidae: Graphidiinae) Durette-Desset (1977) placed this genus in Molineinae, in Molineidae, but later she (1983) removed this species to Haemonchinae, in Trichostrongylidae. This trichostrongylid nematode species has resemblance with a few other genera under this family, namely *Pararhabdonema, Nochtia, Histiostrongylus, Allintoshius, Viannaia, Trichotravassosia*. However, the presence of corona radiata (Fig. 16) in the present species, perhaps, separated the identified genus from rest of the other genera since no literatures were found reporting the presence of corona radiata in the later genera, though Yamaguti (1941) did not confirm the presence of this structure in the type species but
New host record of some gastrointestinal parasites

Figs 1-17. Microphotographs representing taxonomic features of the identified parasite species of *Callosciurus pygerythrus*. 1. *H. diminuta* scolex; 2. *H. diminuta* oncosphere; 3. *Trichuris ovis* egg; 4. *T. ovis* female anal opening; 5. *T. ovis* vulval opening; 6. *Strongylodes callosciurus* vulval and embryonated egg; 7. *S. callosciurus* anterior region; 8. *Monodontus* sp. anterior end; 9. *Monodontus* sp. bursa; 10. *Cyclodontostomum purvisi* anterior region; 11. *C. purvisi* posterior region; 12. *Syphacia obvelata* anterior region; 13. *S. obvelata* posterior region; 14. *A. talpa* male posterior region; 15. *A. talpa* spicule; 16. *Moguranema nipponicum* anterior region; 17. *M. nipponicum* bursa. Abbreviations: AO: Anal opening; AR: Area rugosa; BC: Buccal capsule; CA: Cervical alae; CC: Cephalic collar; CI: Cuticular inflation; CP: Cervical papillae; CR: Corona radiata; CT: Curved teeth; DBF: Dorsal bifurcation; DL: Dorsal lobe; DR: Dorsal ray; DT: Dorsal teeth; E: Egg; ED: Externolateral; EE: Embryonated egg; EOF: Esophageal funnel; GC: Gubernaculum; GEO: Glandular esophagus; IS: Intestine; LCT: Large common trunk; LL: Lateral lobe; MEO: Muscular esophagus; OE: Oesophagus; PP: Pedunculated papillae; RC: Rectum; RP: Rostellar pouch; S: Sucker; SP: Spicule; VCP: Ventral cutting plate; VL: Ventral lobe; VV: Vulva.
Table 3. Comparison between present species with two groups of species under the genus *Monodontus* (measurements in mm unless mentioned otherwise)

| Characters                          | *M. giraffae* | *M. louisianensis* | Present species |
|------------------------------------|---------------|--------------------|-----------------|
|                                    | (Ming *et al.* 2010) | (Chitwood and Jordan 1965) |                  |
|                                    | Male (10 samples) | Female (10 samples) | Male | Female | Male (4 sample) | Female (5 sample) |
| Total body length                  | 13.70 - 15.50 | 17.79 - 19.97     | 8 - 9.7 | 12.5 - 16 | 7.8 - 9.7 | 9.78 - 11.47 |
| Maximum body width                 | 0.380 - 0.440 | 0.5 - 0.77        | -     | 0.31 - 0.38 | 0.31 - 0.33 | 0.3 - 0.36 |
| Length of buccal capsule           | 0.200         | 0.2               | 0.09  | 0.15 - 0.16 | 0.13 - 0.15 | 0.18 - 0.223 |
| Width of buccal capsule            | 0.080         | 0.07              | 0.083 | 0.133 - 0.11 | 0.10 - 0.12 | 0.1 - 0.11 |
| Length of oesophagus               | 1.15 - 1.45   | 1.4 - 1.65        | 0.94  | 1.3       | 0.88 - 0.90 | 0.80 - 0.84 |
| Maximum width of oesophagus        | 0.16 - 0.24   | 0.21 - 0.30       | 0.15  | 0.18      | 0.165 - 0.173 | 0.160 - 0.20 |
| Minimum width of oesophagus        | -             | -                 | 0.10  | 0.07      | 0.085 - 0.093 | 0.70 - 0.80 |
| Nerve ring from anterior end       | 0.50 - 0.67   | 0.55 - 0.65       | 0.39  | 0.45      | 0.340 - 0.390 | 0.475 - 0.515 |
| Excretory pore from anterior end    | 0.65 - 0.75   | 0.75 - 0.82       | 0.40  | 0.50      | 0.380 - 0.400 | 0.640 - 0.650 |
| Vulva from posterior end           | -             | 9.22 - 11.39      | -     | 5.6       | -            | 3.41 |
| Greater diameter of egg            | -             | 0.049 - 0.069     | -     | 0.05 - 0.063 | -            | 50 - 59 |
| Lesser diameter of egg             | -             | 0.028 - 0.044     | -     | 0.035 - 0.04 | -            | 0.030 - 0.038 |
Table 4. Comparative measurements of *Cyclodontostomum purvisi* from different hosts and Localities (measurements in mm unless mentioned otherwise) (only the male)

| Characters                  | *Maxomys whiteheadi*, East Kalimantan, Indonesia (Hasegawa and Syafruddin 1994) | *Eropeplus canus, Paruromys dominator*, South Sulawesi, Indonesia (Hasegawa and Syafruddin 1994) | *Callosciurus pygerythrus*, Chittagong, Bangladesh (Male, 1 sample) |
|-----------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Length                      | 6.9 - 9.7                                                                        | 4.4 - 8.8                                                                                      | 4.44                                                               |
| Width                       | 0.260 - 0.332                                                                   | 0.292 - 0.384                                                                                  | 0.21                                                              |
| Cephalic collar diameter    | 0.116 - 0.154                                                                   | 0.115 - 0.148                                                                                  | 0.11                                                              |
| Oesophagus length           | 0.506 - 0.608                                                                   | 0.475 - 0.584                                                                                  | 0.460                                                             |
| Width of oesophagus         | 0.156 - 0.189                                                                   | 0.16 - 0.2                                                                                     | 0.137                                                             |
| Nerve ring                  | 0.261 - 0.339                                                                   | 0.259 - 0.312                                                                                  | 0.24                                                              |
| Excretory pore              | 0.388 - 0.49                                                                    | 0.304 - 0.42                                                                                   | 0.51                                                              |
| Length of spicule           | 0.537 - 0.711                                                                   | 0.528 - 0.712                                                                                  | 0.66                                                              |
| Length of gubernaculum      | 0.051                                                                           | 0.051                                                                                          | 0.051                                                             |
Yokohota et al. (1988) disclosed this structure in their redescription. The present species has transverse striations, though Yamaguti (1941) did not mention this structure, which is very prominent in its cephalic cuticular inflation (Fig. 16) but not so in rest of the body and there is no transverse striation in the bursa like that of the Pararhabdonema, Nochtia and Allinotoshius. Longitudinal ridge or striation, running from the end of cuticular inflation to throughout the body, was not a character of Moguranema while it was a common character to the other mentioned genera. Symmetrical bursa with poorly differentiating dorsal lobe (Fig. 17) and thick arcuate externodorsal (Fig. 17) finalized the position of the present species under this genus. Till now, only one species has been reported under this genus i.e. Moguranema nipponicum and the description of the present species showed most similarity with the description of Moguranema nipponicum given by Yamaguti (1941) and Yokohota et al. (1988). Previously, this species has been recorded only from a number of shrew mole and Japanese mole viz., Dymecodon pilirostris, Urotichus talpoides, Talpa mizura, Mogera wogura, M. koeae and M. tokudae (Yokohota et al. 1988). However, Meyers and Kuntz (1964) reported this species from Formosan mole (Talpa micrura isularis), Taiwan. This is the first record of this species from squirrel and also from Bangladesh.

Table 5. Comparative measurements of the three species of the genus Ascarops and the present species (measurements in mm unless mentioned otherwise) (Only the male)

| Characters                          | A. kutassi Huber et al. 1983 | A. tuvensis Huber et al. 1983 | A. talpa Huber et al. 1983 | Present species [3 samples] |
|-------------------------------------|------------------------------|-------------------------------|----------------------------|-----------------------------|
| Ratio between left and right spicules | 1 : 4                        | 1 : 3.8                       | 1 : 5.5                    | 1 : 5.31                    |
| Length of area rugosa               | 1.25                         | Not mentioned but very minute | 0.17                      | 0.181                       |

Ascarops talpa Huber et al. 1983. (Spirurida: Spiruridae) Asymmetrical spicules (Fig. 15), area rugosa (Fig. 14), lateral flanges, cervical papillae, 4 pairs of preanal pedunculated papillae (Fig. 14) are the main distinguishing characters of the genus Ascarops. According to Yamaguti (1985c), this genus has 5 species whereas Huber et al. (1983) reported 7 species under this genus. The key characteristics to differentiate the species of this genus are – the ration of left to right spicules and the length of the area rugosa (Yamaguti 1985c). Based on the differentiating characters, the present Ascarops species showed maximum similarity with A. talpa though two other species viz., A. kutassi and A. tubensis also showed similarity in many morphometric characters other than the mentioned two characters (Table 5). Van Beneden (1973) for the first time
recorded the genus Ascarops from an insectivore. Goldberg et al. (1997) reported a number of vertebrates paratenic hosts of this parasite, particularly those that habitually feed upon insects: rodents, shrews, armadillos, birds and lizards. However, this is the first record of the occurrence of this parasite from the present host and also from Bangladesh.

**Syphacia obvelata** Rudolphi 1802. (Oxyurida: Oxyuridae: Syphaciinae) The presence of cervical alae (Fig. 1), prebulbar swelling (Fig. 12) and a distinct posterior bulb containing a valvular apparatus (Fig. 12), a large pendunculate postanal papillae, single spicule (Fig. 13) and anteriorly positioned conspicuous vulva (Fig. 12) placed the present sample into this genus Syphacia. The present specimen, however, fully agree with the diagnosis of the genus Syphacia mentioned in Yamaguti (1959). Yamaguti enlisted 23 species under this genus of which S. muris and S. obvelata were from rats, which have almost similar morphological details though the present specimen showed maximum resemblance with S. obvelata described by Riley (1920). However, the main differences between S. muris and S. obvelata was the head, shape and size of spicule and gubernaculum, pronounced post-cloacal papillae, length of tail and number of the location of the mamelons (Table 6) (Farrar et al. 1994, Parel et al. 2008). In Bangladesh Khanum and Arefin (2003) reported S. obvelata from laboratory mice, Mus musculus. Bhowmick (2010) and Huq et al. (1985) reported the presence of this parasite in a review report and also commented on its economic importance as causative agent for about 150 to 200 diseases to laboratory animals and humans (zoonosis).

**Table 6. Comparison between Syphacia muris, S. obvelata and the present species (measurements in mm unless mentioned otherwise)**

| Characters              | S. muris Pinto et al. 2001 | S. obvelata Riley 1920 | Male (Based on 5 samples) | Female (Based on 5 samples) |
|-------------------------|-----------------------------|------------------------|---------------------------|-----------------------------|
| Body length             | 2.5 - 2.8                   | 3.5-5.7                | 1.45 - 2.29               | 3.65 - 4.10                 |
| Body width              | 0.17 - 0.2                  | 0.3                    | 0.15 - 0.21               | 0.14 - 0.3                  |
| Length of oesophagus    | 0.15                        | 0.3                    | 0.24 - 0.342              | 0.33 - 0.38                 |
| Diameter of bulb        | 0.050 - 0.080               | 0.1                    | 0.060 - 0.070             | 0.090 - 0.1                 |
| Vulva from anterior end | 0.72 - 0.75                 | 0.5                    | -                         | 0.65 - 0.77                 |
| Egg                     | Greater diameter            | 0.060 - 0.072          | 0.125                     | 0.11 - 0.13                 |
|                         | Lesser diameter             | 0.028 - 0.032          | 0.040                     | 0.030 - 0.040               |
| Spicule                 | 0.048                       | 0.08                   | 0.045 - 0.070             | -                           |
| Gubernaculum            | 0.028                       | 0.035                  | 0.045 - 0.055             | -                           |
Table 7. Host specificity spectrum and life cycle pattern of the identified parasites of *Callosciurus pygerythrus*

| Name of the parasites | Previously recorded hosts | Previous records in Bangladesh | Host specificity | Life cycle | Remarks |
|-----------------------|---------------------------|-------------------------------|------------------|------------|---------|
| *H. diminuta*         | Rodents of the family Sciuridae, Gliridae, Dipodidae, Cricetidae, Muridae and Gerbillinae | Rats and human (Areekul and Radomyos 1970, Sinnah 1979) | Broad host specificity but restricted only to rodents | Two hosts - Man/rat as definitive and beetle as intermediate (CDC 2009) | Host record of this parasite in Bangladesh |
| *Strongyloides callosciurus* | Reptiles, birds, amphibians, mammals. Pallas squirrel in Japan (Speare 1989) | - | Much broader host specificity | Complex free-living and parasitic with autoinfection and multiplication (Olsen et al. 2009) | Both the host and the parasite are the new record for Bangladesh |
| *Trichuris ovis*      | Cattle, pig, goat, sheep and camel (Brayton 1911) | - | Much broader host specificity but only in herbivores | Direct (Brayton 1911) | Both the host and the parasite are the new record for Bangladesh |
| *Monodontus* sp.      | Herbivores like giraffe, camel, deer, rodents and suids (Chitwood and Jordan 1965, Ming et al. 2010) | - | In herbivore host but specificity not narrow | Not sure but may be direct life cycle (Ming et al. 2010) | Both the host and the parasite are the new record for Bangladesh |
| *Cyclodontos-tomum purvisi* | Rats and moles (Hasegawa and Syafruddin 1994) | Rats and moles (Huq 1969) | Broad host specificity but restricted only to rodents | Direct but there may have possibility of having insect involvement (Varughese 1973) | Host record of this parasite in Bangladesh |
| *Moguraneuma nipponicum* | Recorded from shrew mole and Japanese mole, Formosan mole (Yokohata et al. 1988) | - | Broad host specificity but restricted only to rodents | No document | Both the host and the parasite are the new record for Bangladesh |
| *Ascarops talpa*      | Insectivores (rodents, shrews, armadillos, birds and lizards) (Goldberg et al. 1997) | - | Much broader host specificity | Two hosts – Man/rat as definitive and beetle as intermediate host** | Both the host and the parasite are the new record for Bangladesh |
| *Syphacea obvelata*   | Both laboratory and natural rats and mice and also in human (Smale 2001) | laboratory mice and human (Khanum and Arefin 2003, Huq et al. 1985) | Much broader host specificity | Direct life cycle either by re-infection or by contaminated water and food (Prince 1950) | Host record of this parasite in Bangladesh |

** In case of *Ascarops strongylina* it was found that the life cycle is indirect and dung beetle engulf the larval or adult stage during meal and when pig ingest it with water or feed then the parasite transfer into their definitive host (http://parasites.ftz.czu.cz/parasites/parasite.php?idParasite=52). As the present host is also an insectivore (Datta and Nandini 2015), so same method might also be applicable for the present host.
CONCLUSION

All the identified parasites showed broad host specificity, however, more specifically, *Strongyloides callosciurus* and *Ascarops talpa* had much broader host specificity including all vertebrate hosts, while the others were restricted only in various rodent families (Table 7). Therefore, the present parasites might be acquired from either intermediate hosts or from other hosts for which the rodents may have been accused most. The intestine, especially the small intestine, was the most favorable niche for the identified parasites. The dominancy of nematode parasites, perhaps, due to the involvement of arthropod insects into host diet (Thorington et al. 2006, Datta and Nandini 2015, IUCN Bangladesh 2015) which might have served as intermediate host and the affiliation of beetle in the life cycle of *Cyclodontostomum purvisi* and *Ascarops talpa* has already been proved (Table 7). The absence of trematodes may be attributed to the fact that for completion of life cycle of these parasites, implication of aquatic molluscan intermediate host is advocated, though the present host has terrestrial habitation. However, such confinement could not be proposed for acanthocephalan as previously many acanthocephalans have reported from terrestrial rodents. *H. diminuta* and *S. obvelata* may have zoonotic role to human and other vertebrates or vice versa, as their role as zoonotic agent has already been established by others.

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LITERATURE CITED

AHMED, A. T. A., KABIR, S. M. H., AHMED, M., AHMED, Z. U., BEGUM, Z. N. T., HASSAN, M. A., and KHONDKER, M. (eds.). 2009. *Encyclopedia of Flora and Fauna of Bangladesh*, Vol. 27. Mammals. Asiatic Society of Bangladesh, Dhaka. 264.

ANDERSON, R. C., CHABAUD, A. G. and WILLMOTT, S. 2009. *Keys to the nematode parasites of vertebrates*. Archival volume. CAB International, Wallingford, Oxfordshire, UK.

ANDREASSEN, J., BENNET-JENKINS, E. and BRYANT, C. 1999. Immunology and biochemistry of *Hymenolepis diminuta*. *Adv. Parasit.* 42: 223-275.

ANONYMOUS. 2003. Multistate outbreak of monkeypox - Illions, Indiana, and Wisconsin, 2003. *Morbidity and Mortality Weekly Report* 52: 537-540.

ANTARA, S. A., ASMA S. and SADNIMAN R. 2015. Habit and habitat of squirrels in Bangladesh. *IJRRLS* 2(1): 41-44.
AREEKUL, S. and P. RADOMYOS. 1970. Preliminary report of *Railletina* sp. infection in man and rats in Thailand. *Southeast Asian J. Trop. Pub. Health* 1: 559.

AVMA. 2007. American Veterinary Medical Association. Guidelines on Euthanasia. Available from http://www.avma.org/issue/animal/welfare/euthanasia.pdf.

BERTOLINO, S. 2009. Animal trade and non-indigenous species introduction: the world-wide spread of squirrel. *Drivers. Distrib.* 15: 701-708.

BERTOLINO, S. and LURZ, P. W. W. 2013. *Callosciurus* squirrels: worldwide introductions, ecological impacts and recommendations to prevent the establishment of new invasive populations. *Mammals Rev.* 43: 22-33.

BHOWMICK, R. C. 2010. Gastrointestinal Helminths of *Bandicota bengalensis* (Gray and Hardwicke, 1833), *Mus musculus* (Linnaeus 1758) and *Suncus murinus* (Linnaeus, 1768) (Insectivora) of some localities of Chittagong. MS thesis. Department of Zoology, University of Chittagong.

CHANDLER, A. C. 1949. *Introduction to Parasitology*. New York: Wiley.

CHANDLER, A. C. 1955. *Introduction to Parasitology, with Special Reference to the Parasites of man*. New York: Wiley.

CHENCHITTIKUL, M., DAENGPIUM, S., HASEGAWA, M., ITOH, T. and PHANTHUMACHINDA, B. 1983. A study of commensal rodents and shrews with reference to the parasite of medical importance in Chanthaburi Province, Thailand. *Southeast Asian J. Trop. Med. Pub. Health*, 14: 255-259.

CHITWOOD, M.B. and JORDAN, H.E. 1965. *Monodontus louisianensis* sp. n. (Nematoda: Ancylostomatidae) a hookworm from the white-tailed deer, *Odocoileus virginianus* (Zimmermann), and a key to the species of *Monodontus*. *J. Parasitol.* 51, 942-944.

DATTA, A. and NANDINI, R. 2015. Sciruids. In: Johnsingh A. J. T., and Manjrekar, N. (Eds.) *Mammals of South Asia: Volume 2*. University Press, Hyderabad. 551-553.

DORRIS, M., VINEY, M.E. and BLAXTER, M.L. 2002. Molecular phylogenetic analysis of the genus *Strongyloides* and related nematodes. *Inter. J.Parasitol.* 32: 1507-1517.

DOZIERES, A., PISANU, B., GERRIET, O, LAPEYRE, C., STUYCK, J. and CHAPUIS J. L. 2010. Macro-parasites of Pallas’s squirrels (*Callosciurus erythraeus*) introduced into Europe. *Vet. Parasitol.* 172: 172-176.

DURETTE-DESSER, M.C. 1983. CIH keys to the nematode parasites of vertebrates. No. 10 Keys to genera of the superfamily Trichostrongyloidea. *London: Commonwealth Agricultural Bureaux*. 1-86.

DURETTE-DESSET, M.C. 1977. Position systematique du genre *Moguranema* Yamaguti, 1941. *Ann. Parasit. Hum. comp.* 52: 583-586.

FARRAR, P.L., WANGER, J.E. and KAGIYAMA, N. 1994. *Syphacia* spp. In Waggie, K., Kagiyama, N., Allen, A., Nomura, T. (Eds.), *Manual of Microbiologic Monitoring of Laboratory Animals*. 2nd ed. Natl I Health, USA 219-24.

GOLDBERG, S.R., BURSEY, C.R. and CHEAM, H. 1997. Helminths of 12 species of Anolis Lizards (Polychrotidae) from the Lesser Antilles, West Indies. *J. Helminthol. Soc. Wash.* 64(2): 248-257.

GOMES, D.C., LANFREDI, R.M., PINTO, R.M. and DE SOUZA, W. 1992. Description of *Trichuris* n. sp. (Nematoda Trichuridae) from a Brazilian rodent by light and scanning electron microscope. *Mem. Inst. Oswaldo. Cruz.* 87: 1-10.

GULYAEV, V.D. and MELNKOVA Y.A. 2005. [New genus of Cestoda from moles *Talpolepis* gen. n. and the redescription of *T. peigingensis* problems of cestodology III. A.F. Alimov (ed.) Izdatel’stvo Rossiiskoi Akademii Nauk. St. Petersburg, Russia, 130-139 (In Russian).
New host record of some gastrointestinal parasites

HASEGAWA, H. and SYAFFRUDDIN. 1994. Cyclodontostomum purvisi (Syn. Ancistronema coronatum) (Nematoda: Strongyloidea: Chabertiidae) from Rats of Kalismantan and Sulawesi, Indonesia. J. Parasitol. 80(4): 657-660.

HAUKISALMI, V., LOTTA, M.H., PILAR, F., CARLOS, F., LAAKKONEN, J., JUKKA, N., LETHONEN, J.T. and HEIKKI, H. 2010. Systematic relationship of hymenolepidid cestodes of rodents and shrews inferred from sequences of 28S ribosomal RNA. Zoologica Scripta. 39(6): 631-641.

HUBER, P.M., G.D. SCHMIDT and R. E. KUNTZ. 1983. Ascarops talpa sp. n. (Nematoda: Spirocercidae) from the Formosan Mole, Talpa micrura insularis, in Taiwan. J. Parasitol. 69(4): 761-763.

HUQ, M. M., KARIM, M. J. and SHEIKH, H. 1985. Helminth parasites of rats, house mice and moles in Bangladesh. Pak. Vet. J. 5(3): 143-144.

HUQ, M. M. 1969. A survey of the helminth parasites of roof rats Rattus rattus, digger rats Bandicota bengalensis and mole Scalopus scalopus in Mymensingh district, East Pakistan. Pakistan J. Vet. Sci. 5: 143-144.

IUCN BANGLADESH. 2015. Red List of Bangladesh Volume 2: Mammals. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. xvi+232.

KALIA, D.C. and GUPTA, N.K. 1983. Monodontus bainae n. sp. (Nematoda: Bunostominae) a hook worm from a porcupine, Hystrix indica Kerr, along with a pictorial key to the species of the genus. Zeitshrift fur Angewandte Zoologie 70: 441-338.

KHODAKEVICH, I., JEZEK, Z. and KINZANZKA, K. 1986. Isolation of monkeypox virus from wild squirrel infected in nature. The Lancet. 11: 98-99.

LICHTENFELS, J.R. 1980. Keys to genera of the subfamilies Ancylostomatoidea and Diaphanocephaloidea, In: (Eds. R.C. Anderson, A. G. Chabaud and S. Willmott) CIH Keys to the Nematode Parasites of Vertebrates, No. 8, Commonwealth Agricultural Bureaux, Farnham Royal, U. K., 1-19.

LITTLE, M.D. 1966a. Comparative morphology of six species of Strongyloides (Nematoda) and redefinition of the genus. J. Parasitol. 52(1): 69-84.

LÓPEZ-NEYRA, C.R. 1942a. División del genero Hymenolepis Weinland (S. L.) en otros mas naturals. Cientificas, Instituto “Jose de Acosta”, Section de Helmininthologia, Granada, 205.

LÓPEZ-NEYRA, C.R. 1942b. Division del genero Hymenolepis Weinland (S. L.) en otros mas naturals. Revista Iberica de Parasitologia 2: 46-85.

MAKKI, M.S., SHAHBAZI, F., TEIMOORI, S., ROKNI, M.B., ABAEI, M.R., MOBEDI, I., HASSANPOUR, GH. and MOWLAVI, GH. 2011. Establishment of Hymenolepis diminuta Life cycle to provide parasite mass production. Iraniana J. Parasitol. 6(2): 60-63.

MENON, V. 2003. A Field Guide to Indian Mammals. Dorling Kindersley (India) Pvt. Limited, Delhi.

MEYERS, B.J. and KUNTZ, R.E. 1964. Nematode parasites from mammals taken on Taiwan (Formosa) and its offshore islands. Can. J. Zool. 42: 863-868.

MING, Z., ZHANG, LI. and ZHANG, L. 2010. Redescription of Monodontus giraffae York et Maplestone 1926 (Nematoda: Ancylostomatidae) from a giraffe, Giraffa camelopardalis, from Zoo in China, with a discussion on the taxonomic status of Monodontella. Acta Parasitol. 55(1): 66-70.

OLSEN, A., VAN LIESHOUT, L., MARTI, H., POLDERMAN, T., POLMAN, K., STEINMANN, P., STOTHARD, R., THYBO, S., VERWEIJ, J. J. and MAGNUSSEN, P. 2009. “Strongyloidiasis” – the most neglected of the neglected tropical diseases? Trans. Royal Socie. Trop. Med. Hyg. 103(10): 967-72.
Hussain et al.

PALMER, G.H., KOPROWSKI, J. and PERNAS, T. 2007. Tree squirrels as invasive species: conservation and management implications. In: Wilmer G.W., Pitt W.C., Fagerstone K.A., (Eds). Managing Vertebrate Invasive Species: Proceeding of an International Symposium. USDA/APHIS/WS, National Wildlife Research Centre, Fort Collins, CO. 273-282.

PAREL, J. D. C., GALULA, J. U. and OOI, H. K. 2008. Characterization of rDNA sequences from Syphacia obvelata, Syphacia muris, and Aspicularis tetraperta and development of a PCR-based method for identification. Vet. Parasitol. 153: 379-83.

PINTO, R. M., GONCALVES, L., NORONHA, D. and GOMES, C. D. 2001. Worm burdens in outbred and inbred laboratory rats with morphometric data on Syphacia muris (Yamaguti, 1935) Yamaguti, 1941 (Nematoda, Oxyuroidea). Mem. Inst. Oswaldo. Cruz. Rio de Janerio. 96(1): 133-136.

PRINCE, M.J.R. 1950. Studies on the life cycle of Syphacia obvelata, a common Nematode parasite of Rats. Science 111(2873): 66-67.

RILEY, W.A. 1920. A mouse oxyurid, Syphacia obvelata, as a parasite of man. J. Parasitol. 6(2): 89-93.

ROBLES, M.R., NAVONE, G.T. and NATARNICOLA. 2006. A new species of Trichurus (Nematoda: Trichuridae) from Phyllotomini rodents in Argentina. J. Parasitol. 92(1): 22-204.

ROSSIN, M.A. and MALIZIA, A.I. 2005. Redescription of Trichurus panecana (Nematoda: Trichuridae) from the South American subterranean rodent Ctenomys talarum, Thomas. Thomuch , 1898 (Rodentia: Octodontidae) J. Parasitol. 91: 127-130.

RUSHTON, S.P., LURZ, P.W.W., GURNELL, J., NETTLETON, P., BRUEMMER, C., SHIRLEY, M.D.F. and SAINSBURY, A. W. 2006. Disease threats posed by alien species: the role of a poxvirus in the decline of the native red squirrel in Britain. Epidemiol. Infect. 134: 521-533.

RYZHIKOV, K.M., GVOZDEV, E.V., TOKOBAEV, M.M., SHALDYBIN, L.S., MATZABERIDZE, G.V., MERKUSHEVA I. V., NADTOCHII, E. V., KHOLOVA, I.G. and SHARPILO, L.D. (Eds.). 1978. [Keys to the helminthes of the rodent fauna of the USSR. Cestodes and trematodes]. Izdavatel'stvo Nauka, Moskva, 232. (In Russian).

SAINSBURY, A.W., DEAVILLE, R., LAWSON, B., COOLEY, W.A., FARELLY, S.S.J. and STACK, M.J. 2008. Poxvial disease in red squirrels Sciurus vulgaris in the UK: spatial and temporal trends of an emergent threat. Ecohealth 5: 305-316.

SATO, H., TORII, H., UNE, Y. and OOI, H.K. 2007. A new rhabditid nematode species in Asian sciurids, distinct from Strongyloides robustus in north American sciurids. J. Parasit. 93: 1476-1486.

SCHAD, G.A. 1989. Morphology and life history of Strongyloides stercoralis. In strongyloidiasis: A major roundworm infection of man, D.I. Grove (ed.) Taylor and Francis, London, U. K. 85-104.

SCHWARTZ, B. 1926. Specific identity of whipworms from swine. J. Agri. Res. 33(4): 311-316.

SEEBECK, J.H. 2013. “Sciuridae”. Fauna of Australia. https://www.environment.gov.au/system/files/pages/a117ced5-9a94-4586-adfb-1f333618e1c3/files/46-ind.pdf.

SHINOZAKI, Y., SHIBASHI, T., YOSHIZAWA, K., MURATA, K., KIMURA, J., MARUYAMA, S., HAYAMA, Y., YOSHIDA, H. and NOGAMI, S. 2004a. Ectoparasites of the Pallas squirrel Callosciurus erythraeus, introduced to Japan. Med. Vet. Entomol. 18: 61-63.

SHINOZAKI, Y., YOSHIZAWA, K., MURATA, K., SHIBASHI, T., KIMURA, J., MARUYAMA, S., HAYAMA, Y., YOSHIDA, H. and NOGAMI, S. 2004b. The first record of sucking louse, Neoacarosapina callosciuri, infesting Pallas Squirrels in Japan. J. Vet. Med Sci. 66: 333-335.

SINNIAH, B. 1979 Parasites of some rodents in Malaysia. Southeastern Asian. J. Trop. Med. Pub. Health 10:115-121.
New host record of some gastrointestinal parasites

SMALES, L.R. 2001. Syphacia longaeuccauda n. sp. (Nematoda: Oxyuridae) Syphacineae from Melomys spp. (Muridae: Hydromyinae) from Papua New Guinea and Irian Jaya, Indonesia. Parasite 8: 39–43.

SPAKULOVA, M. 1994. Discriminant analysis as a method for the numerical evaluation of taxonomic characters in male trichurid nematodes. Syst. Parasitol. 29: 113-119.

SPEARE, R. 1989. Identification of species of Strongyloides. In Strongyloidiasis. A major roundworm infection of man. D. I. Grove (ed.). Tailor and Francis. London, UK. 1: 11-83.

SURIANO, D. M. and NAVONE, G.T. 1994. Three new species of the genus Trichuris Roederer, 1761 Roederer, 1761 (Nematoda: Trichuridae) from cricetidce and octodontidce rodents in Argentina. Res. Rev. Parasitol. 54: 39-46.

THORINGTON JR., R.W. and HOFFMANN, R.S. 1966. Family Sciuridae. In Mammal Species of the World. A taxonomic and Geographic Reference. Third edition (Wilson DE, Reeder DM, eds), pp. 754-8181. Johns Hopkins University Press, Baltimore.

THORINGTON R.W., THORINGTON JR., R.W. and FERRELL, K.E. 2006. Squirrels: The Animal Answer Guide. JHU press. 183.

VAN BENEDEN, P.J. 1973. Les parasites des chauvesouris de Belgique. Mem. Acad. Roy. Soc. Sci. Belg. 40: 3-42.

VARUGHESE, G. 1973. Studies on the life cycle and developmental morphology of Cyclohydnostomum purvisi (Adam, 1933) a hookworm parasite of Malayan giant rats. Southeast Asian J. Trop. Med. Pub. Health. 4(1): 78-95.

VINEY, M.E. 1994. A genetic analysis of reproduction in Strongyloides ratti. Parasitol. 109: 511-515.

WARDLE, R.A. and MCLEOD, J.A. 1952. The Zoology of Tapeworm. University of Minnesota Press: 780 pp.

YAMAGUTI, S. 1985c. Systema Helminthum. Vol. III. The nematodes of vertebrates. Part I and II. International Books and Periodical Supply Service, Indian reprint, New Delhi.

YAMAGUTI, S. 1961. Systema Helminthum. The Nematode of Vertebrates. Vol. III., part I and II, Interscience Publishers, New York, London. 1261

YAMAGUTI, S. 1959. Systema helminthum. Vol II. The cestodes of vertebrates. Interscience Publishers, New York, 415-420.

YAMAGUTI, S. 1941. Studies on the helminth fauna of Japan. Part 35. Mammalian nematodes II., Jpn. J. Zool. 9: 409-438.

YOKOHOTA, Y., ABE, H. and KAMIYA, M. 1988. Redescription and multivariate morphometrics of Moguranema nipponicum Yamaguti, 1941. Jpn. J. Vet. Res. 36: 223-233.

YORKE, W. and MAPLESTONE, P. A. 1926. The nematode parasites of Vertebrates. pp. 536.

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