First record of Laboulbeniales (Fungi: Ascomycota) infection on bat flies (Diptera: Nycteribiidae) from the Caucasus region

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Abstract – The ectoparasitic fungus, Arthrorhynchus nycteribiae (Peyritsch) Thaxter (Fungi: Laboulbeniales) is recorded for the first time in Georgia. It was found on the obligate, hematophagous bat fly, Penicillidia conspicua Speiser, 1901 (Diptera: Nycteribiidae), parasitizing the cave-dwelling bat species, Miniopterus schreibersii (Kuhl, 1817) (Chiroptera: Miniopteridae). This record represents the first observation of Laboulbeniales infection on bat flies from the Caucasus region. With one figure.

Key words – Arthrorhynchus nycteribiae, Miniopterus, Penicillidia

INTRODUCTION

Bats host a wide variety of highly specific ectoparasites, such as fleas, mites and bat flies (Marshall 1982). Bat flies (Diptera: Nycteribiidae and Streblidae) are obligate, hematophagous ectoparasites of bats. They belong to the superfamily Hippoboscoidea, along withouse flies, Hippoboscidae and tsetse flies, Glossinidae (Dittmar et al. 2006, Petersen et al. 2007). The family Nycteribiidae currently contains ~280 described species, showing higher diversity in Eastern Hemisphere, whereas family Streblidae have ~230 species, distributed mainly in the Western Hemisphere (Dick & Patterson 2006).
In Europe, 16 species of nycteribiids and one species of streblids have been recorded (Szentiványi et al. 2016). The family Nycteribiidae represents four genera in Europe: Basilia Miranda-Ribeiro, 1903 (6 species), Nycteribia Latreille, 1796 (5 species), Penicillidia Kolenati, 1863 (3 species) and Phthiridium Hermann, 1804 (2 species). The family Streblidae represents one species, Brachytarsina flavipennis Macquart, 1851 (Szentiványi et al. 2016). Nycteribiids are wingless, and most species are eyeless due to their parasitic life-style. Bat flies show highly specialized reproductive strategy: one single larva develops within the female and as soon as it reaches the third larval stage it is deposited by the female on a substrate (e.g. cave wall). The deposited larva immediately pupates. After emergence the fly actively searches for its bat hosts. Female flies only leave their hosts during pupal deposition (Marshall 1982, Dick & Patterson 2006). This type of reproductive strategy known as obligate pseudo-placental unilarviparity (Meier et al. 1999), which is a common characteristic within the superfamily Hippoboscoidea.

Bat flies show different degree of specificity, being monoxenous (one host species), oligoxenous (multiple host species within one genus) or polyxenous (several host species in different genera or families). High degree of specificity is common in bat flies (Dick & Patterson 2006). Bat flies are known as vectors and potential vectors of several pathogens, such as Polychromophilus spp. and Bartonella spp. (Gardner & Molyneux 1988, Sándor et al. 2018).

Bat flies are also known to host different parasitic organisms, such as ectoparasitic fungi (Blackwell 1980, Marshall 1982, Haelewaters et al. 2017, Szentiványi et al. 2018). Laboulbeniales (Fungi: Ascomycota) are widely distributed and species rich microparasites of arthropods. Unlike other multicellular fungi, Laboulbeniales form thallus (plural: thalli) instead of hyphae or mycelia. These fungus species occur on a wide variety of host groups, such as Coleoptera, Diptera and Hymenoptera (Weir & Hammond 1997, Csata et al. 2013, Haelewaters et al. 2015, 2018b, Pfliegler et al. 2016). The most common species on nycteribiid bat flies are Arthrorhynchus eucampsiopodea Thaxter and Arthrorhynchus nycteribiae (Peyritsch) Thaxter (Haelewaters et al. 2018a).

In Europe, Arthrorhynchus species mostly occur on Nycteribia schmidi Schiner, 1853, Penicillidia conspicua Speiser, 1901 and Penicillidia dufouri (Westwood, 1835) (Haelewaters et al. 2017, Szentiványi et al. 2018). A comprehensive study showed that the main bat host of fungi infected flies is the cave-dwelling common bent-wing bat, Miniopterus schreibersii (Kuhl, 1817) (Haelewaters et al. 2017). Haelewaters et al. (2017) also presented a comprehensive literature search on fungi occurrence which showed that Arthrorhynchus spp. are not documented in Georgia, neither in neighbouring countries.
MATERIALS AND METHODS

Samples were collected from *Miniopterus schreibersii* during August 2014 in the Batumi Botanical garden, Batumi, Georgia (N41.694504°, E41.707491°) (Fig. 1). Bats were caught using mist nest near the concrete tunnel (20 m long), which they used as a day roost. All bat individuals were released after collection of parasites and taking parameters such as sex, age, body mass and forearm length. All manipulation with animals were done according to the ethic guidelines of the American Society of the Mammalogists (Sikes & Gannon 2011), and approved by permit no. 4752, 26 August 2014 issued by the Ministry of Environment and Natural Resources Protection of Georgia.

Parasites were collected by forceps from the bat host, and placed in 70% ethanol. Bat flies were identified based on Theodor’s (1967) key. Fungal thalli were counted, and species identification was based on Thaxter (1908) and Haelewaters *et al.* (2017). Voucher specimens of both bat flies and fungi are deposited at Museum of Zoology Lausanne, Switzerland.

![Fig. 1. Location of bat fly sampling is indicated on the map (black asterisk)](image-url)
RESULTS

Bat flies were sampled from a single *Miniopterus schreibersii* (occasional sampling) in Georgia (Table 1). All sampled flies (n = 8) have been identified as *Penicillidia conspicua*. Two individuals (one female and one male) were found infected by *Arthrorhynchus nycteribiae* (prevalence = 25%). The female *Penicillidia conspicua* had 32 thalli, while the male individual was infected by 86 thalli. Both flies had infection by immature and fruiting fungal bodies. The position of the infection appeared on the ventral and dorsal parts of the abdomen as well as on the genitalia in both individuals. *Arthrorhynchus nycteribiae* infected *Penicillidia conspicua* were previously collected from various bat species, includ-

<table>
<thead>
<tr>
<th>Country</th>
<th>Bat host</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Not known</td>
<td>BLACKWELL (1980)</td>
</tr>
<tr>
<td>Bulgaria and/or Slovakia</td>
<td><em>Miniopterus schreibersii</em></td>
<td>SAMŠIŇÁKOVÁ (1960)</td>
</tr>
<tr>
<td>“Central Europe”</td>
<td><em>Rhinolophus euryale</em></td>
<td>KOLENATI (1857)</td>
</tr>
<tr>
<td>Croatia</td>
<td><em>Miniopterus schreibersii</em></td>
<td>KOLENATI (1857), Szentiványi et al. (2018)</td>
</tr>
<tr>
<td>“Czecho-Slovakia”</td>
<td><em>Miniopterus schreibersii</em></td>
<td>BALAZUC (1971)</td>
</tr>
<tr>
<td>Georgia</td>
<td><em>Miniopterus schreibersii</em></td>
<td>This study</td>
</tr>
<tr>
<td>Portugal</td>
<td><em>Miniopterus schreibersii</em></td>
<td>JENSEN et al. (2018), Szentiványi et al. (2018)</td>
</tr>
<tr>
<td>Romania</td>
<td><em>Miniopterus schreibersii/ Myotis daubentonii / Rhinolophus ferrumequinum</em></td>
<td>BLACKWELL (1980), HAELEWATERS et al. (2017)</td>
</tr>
<tr>
<td>Serbia</td>
<td><em>Rhinolophus euryale</em></td>
<td>BECHET &amp; BECHET (1970)</td>
</tr>
<tr>
<td>Slovakia</td>
<td><em>Miniopterus schreibersii</em></td>
<td>Szentiványi et al. (2018)</td>
</tr>
<tr>
<td>Spain</td>
<td><em>Miniopterus schreibersii</em></td>
<td>BALCELLS (1954), Szentiványi et al. (2018)</td>
</tr>
<tr>
<td>Switzerland</td>
<td><em>Miniopterus schreibersii/not known</em></td>
<td>BERNASCONI (1961), BALAZUC (1971)</td>
</tr>
</tbody>
</table>

*Table 1. Distribution and bat host records of Arthrorhynchus nycteribiae infecting Penicillidia conspicua*
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ing Miniopterus schreiberi, Myotis capaccinii Bonaparte, 1837, Myotis daubentonii (Kuhl, 1837), Myotis myotis (Borkhausen, 1797), Rhinolophus euryale (Blasius, 1853) and Rhinolophus ferrumequinum (Lacépède, 1799) (Table 1).

DISCUSSION

Here we report the first occurrence of Laboulbeniales infection on bat flies from Georgia. The bat host, Miniopterus schreiberi is a widely distributed species in Southern Europe, North Africa and the Middle East to the Caucasus (Appleton et al. 2004). Two bat fly species, Nycteribia schmidii and Penicillidia conspicua often parasitize Miniopterus schreiberi and both considered as highly specific on this bat host. Szentiványi et al. (2018) showed the presence of Arthrorhynchus nycteribiae on Penicillidia conspicua in Croatia, Hungary, Portugal, Slovakia and Spain, which suggests that Arthrorhynchus infection might be present within the whole distribution of its fly and bat host. The average prevalence of fungal infection on Penicillidia conspicua was 22.9% (n = 144) (Szentiványi et al. 2018). Similarly, Haelewaters et al. (2017) observed a 25% (n = 152) prevalence of Penicillidia conspicua in Central Europe (Hungary and Romania).

Arthrorhynchus nycteribiae infection also occurs on Penicillidia dufourii, but it is considered as an “accidental transfer” from Penicillidia conspicua, which seems to be the main host of this fungus species (Haelewaters et al. 2017). Haelewaters et al. (2017) found a 2% (n = 102) prevalence, while Szentiványi et al. (2018) observed a 7.7% (n = 52) prevalence of Penicillidia dufourii infected by Arthrorhynchus nycteribiae. In this study, we cannot conclude the infection patterns of the bat fly population due to the low sample number (due to occasional sampling). Additional parasite sampling of potential hosts in poorly researched countries will contribute to our understanding of the distribution patterns of Laboulbeniales species.

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