

Host specificity of the badger's flea (*Paraceras melis*) and first detection on a bat host

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Abstract Defining the whole spectrum of potential hosts of a parasite has large epidemiological and evolutionary implications in biology. Specialized parasites might be able to occasionally exploit a range of different host species, increasing the individual survival and the chances of successful dispersal. For long time *Paraceras melis* has been considered a specific flea of European badger *Meles meles*. Anyway, it has occasionally been reported on different hosts. In this work, we summarize the host spectrum of *P. melis* from literature and we report its first detection on a bat host. Ten species were identified as occasional hosts, man included, and the plasticity of this flea in host exploitation is noteworthy because of possible increase of pathogens transmission to humans and domestic species.

Keywords Den sharing · Host spectrum · Lesser horseshoe bat · Transmission of pathogens

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Introduction

Host specificity, i.e., the tendency of a parasite to occur on one or a few host species, is a key aspect of the ecology and distribution of parasites as it strongly influences their probability of global (Holt et al. 2003) and local (Krasnov et al. 2004) extinction as well as their distribution and range size (Krasnov et al. 2005). From an epidemiological perspective, the degree of host specificity of a given parasite is an important predictor of the potential impact upon other taxa, including domestic species and humans, representing the likelihood of a successful host switch (Mouillot et al. 2006). Plasticity in the exploitation of different host species is known to be triggered by repeated and frequent exposure to multiple species (Krasnov et al. 2007), e.g., copresence of potential hosts at the same site/roost/den or interspecific behavioral interactions. Fleas (Siphonaptera) are parasites generally specialized on mammals that alternate between periods of direct occurrence upon the host's body and in the substrate of their host's nest or den. The degree of host specificity of fleas is highly variable among species, ranging to highly host-specific to opportunistic (Marshall 1981).

The badger flea *Paraceras melis* has been described as the main host-specific flea of the European badgers *Meles meles* (Hancox, 1980; Cox et al. 1999), widely distributed from Spain to Central-Southern Asia throughout the whole of Europe (Beaucornu and Launay 1990; Abramov and Medvedev 2003). *P. melis* is also the primary vector of *Trypanosoma pestanai* in European badgers (Lizundia et al. 2011).

Defining the whole spectrum of potential hosts has large epidemiological and evolutionary implications on parasite biology, thus an assessment of the range of hosts is a primary task in the study of parasites. *P. melis* is deemed as specialized on *M. meles*, but it has also been relatively often detected on the red fox *Vulpes vulpes* (O'Mahony

1940; Ross and Fairley 1969; Mei 1996) and, more occasionally, on other mammals (cf. Beaucornu and Launay 1990).

In this work, we review the actual knowledge of hosts recorded for the badger flea *P. melis* in literature and we report the first detection of the species on a bat host.

Materials and methods

We assessed studies on online databases, i.e., ISI Web of Science, Scopus, Zoological Records, Google Scholar, to review the actual knowledge of hosts recorded for the badger flea. Search terms included all the possible combinations of these words: badger flea*, *Paraceras melis*, host*. Additional studies were identified through the reference lists of all the collected studies and by consulting the main monographs on fleas of the Mediterranean basin (Russell 1913; Beaucornu and Launay 1990).

The first detection of *P. melis* on a bat host took place in a cave named “Buca del Gallo” in Southern Tuscany (Central Italy: 43,089,411°N, 10,971,580°E). The cave reaches a negative slope of 7 m and a spatial development of 25 m. Insect taxa detected belonged to the orders of Trichoptera (*Stenophylax* sp.), Orthoptera (*Dolichopoda schiavazzii*, *Gryllomorpha dalmatina*), Diptera (*Limonia* sp.), and Coleoptera (*Laemostenus latialis*, *Asida* sp.). Among mammals, a mixed-species winter-colony of horseshoe bats (*Rhinolophus ferrumequinum*, *Rhinolophus hipposideros*, and *Rhinolophus euryale*) numbering around 10–15 individuals, are regularly

present. A skull of an adult (cf. Neal and Cheeseman 1996) Eurasian badger *M. meles* was also detected inside the cave in August 2013 by one of the authors (E.M.).

During a speleological excursion (20 March 2013), an adult female of *R. hipposideros* was present in the cave; the bat was captured with a hand-held net for close inspection and parasite sampling. Required permits for capturing and handling bats were obtained from the Ministry of Environment, Rome, Italy (permit number: 0011284 - 08/02/2013-PNM II). Collected parasites were stored in absolute ethanol and sent to the Maremma Natural History Museum for conservation. Fleas were then photographed and measured through a Leica M205 C stereomicroscope.

Results

Occasional hosts of *P. melis*

We collected a total of 104 cases in 63 published works dealing with *P. melis* (Table 1). In 65.38 % cases, the flea was reported in its specific host, the European badger, and in 21.15 % cases in *Vulpes vulpes*. Other hosts are represented by very few (*Dama dama* 2.88 %; *Mustela putorius*, *Canis familiaris* 1.92 %) or single isolated cases (0.96 %) from mammals (*Talpa europaea*, *Homo sapiens*, *Martes foina*, *Felis catus*) and only one bird (*Corvus cornix*).

A work on *P. melis sinensis* was excluded because this subspecies has been recently splitted and considered as a proper species (cf. Abramov and Medvedev 2003).

Table 1 Occasional hosts of the badger's flea, location of records, and main references

Host	Number of studies	Country	Main references
Red fox— <i>Vulpes vulpes</i>	22	Northern Ireland East England, Great Britain Ireland Italy Hungary France	Ross and Fairley (1969) Thompson (1969) Sleeman (1983) Mei (1996) Srèter et al. (2003) Beaucornu and Launay (1990)
European polecat— <i>Mustela putorius</i>	2	Wales, Great Britain France	Walton and Page (1970) Beaucornu and Launay (1990)
Stone marten— <i>Martes foina</i>	1	France	Beaucornu and Launay (1990)
European mole— <i>Talpa europaea</i>	1	North West England, Great Britain	Britten (1948)
Fallow deer— <i>Dama dama</i>	3	Ireland	Sleeman (1983)
Hooded crow— <i>Corvus cornix</i>	1	France	Beaucornu and Launay (1990)
Domestic dog— <i>Canis familiaris</i>	2	Ireland Germany	Sleeman (1983) Visser et al. (2001)
Domestic cat— <i>Felis catus</i>	1	England, Great Britain	Coward (1991)
Man— <i>Homo sapiens</i>	1	France	Beaucornu and Launay (1990)
Lesser horseshoe bat— <i>Rhinolophus hipposideros</i>	1	Central Italy	Present work

Fig. 1 The adult female of lesser horseshoe bat *Rhinolophus hipposideros* upon which *Paraceras melis* was found; **a** frontal view of the bat, **b** the same individual roosting on the cave ceiling



Record of *P. melis* on a bat host

Two fleas were collected on the female bat (Fig. 1), both from the fur on the ventral side of the body.

With a size of 3.6 mm and reddish body coloration, both fleas were identified as *P. melis* (Fig. 2), and the specific determination was also confirmed by other two experts (i.e., D.W. Macdonald and C. Newman). Both fleas were identified as females, according to the structure of the last abdominal segment (cf. Russell 1913; Beaucornu and Launay 1990).

Discussion

Our finding represents the first report of *P. melis* on a bat host and one of the very few cases of hosts different from the Eurasian badger for this flea species. The review of available literature confirms that this is a host-specific flea, although it may be occasionally detected on other mammals, man included, and at least on one bird species. *P. melis* thus should probably be considered as a “flexible” specialist, as it proved able to exploit a rather wide range of different hosts, albeit probably only occasionally. Studies on different species indicate that parasite fitness and ability to feed upon occasional hosts can be comparable to that on the preferred ones (Krasnov et al. 2007), even independently by hosts’ phylogenetic relationships, but this is not valid for all species. Thus, further studies focused on feeding efficiency on occasional

hosts of *P. melis* should verify parasite fitness, as well as the ability of this species to complete its biological cycle on hosts different from *M. meles*. Burrows used by badgers and underground habitats (i.e., caves) are probably good sites of *P. melis* for encountering new potential hosts. The second most commonly reported host for *P. melis* is indeed the red fox, which is also the species that frequently shares burrows with the European badger (Neal 1986). Red foxes are known to share burrows with Eurasian badgers as well as other mammals (e.g., stone martens, crested porcupines Mori et al. 2014). The life cycle of fleas includes periods during which the parasite is in the substrate of the host’s den/nest, thus burrow sharing may easily facilitate host switch in *P. melis*. The same pathway may also apply to bats, particularly in the case of cave-dwelling bats (Dietz et al. 2009). Moreover, many bats enter into torpor during winter (Dietz et al. 2009) as an energy-saving strategy, which on the other hand makes them an easy target to fleas (Korine et al. 2012). Other potential hosts may be reached by *P. melis* during predation (e.g., moles) or casual interspecific interactions between badgers and other mammals (Mori et al. 2014).

Reaching and feeding on unusual hosts is a strategy that increases parasite fitness and survival (Krasnov et al. 2004), e.g., over the local extinction of the main host. Moreover, moving onto a bat host largely increases the potential spread and colonization range of the parasite: compared to the main host of *P. melis*, bats are more mobile and able to cover larger distances (up to 153 km in the case of *R. hipposideros* Schober and Grimmberger 1997; up to 8.3 km of dispersal distance for

Fig. 2 Badger fleas *Paraceras melis* collected from an adult lesser horseshoe bat *Rhinolophus hipposideros*



M. meles Cheeseman et al. 1988), thus representing a far more efficient mechanism for parasite dispersion. Additionally, bats usually form colonies where individuals are in close physical contact (Dietz et al. 2009), sometimes also with heterospecifics, increasing the chances of host switch and thus the range of potential hosts.

Many bat species use buildings and other human-made structures as roosts (including *R. hipposideros* Dietz et al., 2009), thus the probability of *P. melis* to encounter other potential hosts such as domestic mammals and humans further increases by exploiting a bat host, with relevant consequences in the transmission of pathogens in which this flea is a vector (Lizundia et al. 2011).

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