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Original paper

Ectoparasites collected from dead bats (Chiroptera: Vespertilionidae) in east-central Poland

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ABSTRACT. During routine inspections of 4 bat shelters in central-eastern Poland, 36 dead bats belonging to 6 species were found: *Myotis daubentonii*, *M. nattereri*, *M. myotis*, *Nyctalus noctula*, *Plecotus auritus* and *Eptescius serotinus*. In the laboratory, 298 arthropods from 15 taxa (57 insects and 241 mites) were collected from these bats, and their relationships with their hosts were analysed. The first probable record of *I. ricinus* feeding on *P. auritus* is published.

Keywords: Chiroptera, bat ectoparasite, Poland

Introduction

Owing to their complex lifestyle and to the highly distinctive habits of their hosts, bat parasites, e.g. gamasid mites (Mesostigmata), ticks (Argasidae), fleas (Ischnopsyllidae) and bat flies (Nycteribiidae), have become the subject of multidisciplinary scientific research. Nevertheless, intensive taxonomic, ecological and phylogenetic studies need to be continued [1–7]. A separate problem is the role of bat ectoparasites in the transmission of pathogens [4,8–10]. For example, bat ticks are responsible for the transmission of viruses, bacteria, protozoa and filariae [11–13]. Thus, the presence of parasitic arthropods on bats can affect not only their health but may also cause diseases to spread among humans and livestock [14–18]. An inherent difficulty with studying bat parasites is that the methods of catching bats and collecting parasites from them are complicated [2,19,20]. The stress experienced by live bats when they are being examined for parasites must be minimized, so that there is always a chance of some arthropods being missed. Hence, knowledge of bat ectoparasites remains insufficient [21–23]. Dead bats, on the other hand, can be meticulously searched at leisure, and even the tiniest parasites can be collected. However, little research based on parasites gleaned from dead bats has been done. However, separate studies are still needed to assess the extent to which the results of studies on ectoparasites collected from living bats are comparable to the results of studies on ectoparasites from dead bats.

The present research should also help to elucidate the changes occurring among the ectoparasite assemblage after their host's death.

Materials and Methods

During routine inspections of bat refuges or overwintering sites, dead bats (only individuals not showing any signs of decomposition or mechanical injury) were collected in the following localities:

Ryki (church attic), 51°62N, 21°92E, on 11.06.2016;

Lublin (old tenement basements), 51°24N, 22°56E, on 15.05.2013 and 24.04.2014;

Puławy (artificial caves), 51°41N, 21°96E, on 22.04.1953;

Bielany (church attic), 52°33N, 22°24E, on 02.09.1954.

The hosts were preserved separately in jars containing 95% ethanol and deposited in the collection of the Zoological Museum of the Maria Curie-Skłodowska University, Lublin (Poland). In 2023, the bats were removed from their jars for morphological identification (species, sex and age) and measurement (front, back, tail, wings, ears, uropatagium) according to the methods outlined by Ditz et al. [24]. All the measurements are given in millimetres (mm). A total of 36 bat specimens belonging to 6 species were examined: *Myotis daubentonii* (1♀, 1♂), *M. nattereri* (2♀, 2♂), *M. myotis* (4♀, 1♂), *Nyctalus noctula* (9♀, 12♂), *Plecotus auritus* (1♀, 1♂) and *Eptescius serotinus* (2♂) (Table 1).

Next, each bat was examined visually for ectoparasites under a binocular microscope (Olympus SZ 11) at an appropriate magnification in accordance with the method of Kadulski and Izdebska [25]. All the ectoparasites from one host were removed and placed into a single tube containing 70% ethanol. Afterwards, the bats were replaced in their jars containing 95% ethanol. For identification purposes, each arthropod found (except the flea larvae) was cleared in 5% KOH (adult fleas and *Spinturnix* for 24 h, Macronyssidae and other Acari for 10 h), after which it was rinsed in distilled water and mounted on a permanent microscope slide in Faure–Berlese fluid (50 g gum arabic and 45 g chloral hydrate dissolved in 80 g distilled water and 60 cm^3 glycerol) [26].

The ectoparasites were identified to species level using the following keys: Rudnick [1], Filippova [27], Stanyukovich [28], Radovsky [29] and Orlova et al. [10,30,31]. Ticks were identified on the basis of the characters given by Estrada-Peña et al. [32]. All the slides are deposited in the collection of the Department of Zoology and Nature Protection, Maria Curie-Skłodowska University, Lublin (Poland).

Results

A total of 298 parasitic arthropods: 57 insects (various stages) from 2 species and 241 adult mites from 13 taxa, were collected and identified (abbreviations: ex – single specimen; exx – more than specimens).

Class Arachnida
Order Ixodida
Family Ixodidae

Ixodes ricinus (Linnaeus, 1758) (Fig. 1A): 1 larva, 15.05.2013, Lublin, on *P. auritus*

Order Mesostigmata
Family Spinturnicidae

Spinturnix myoti (Kolenati, 1856) (Fig. 1B): 1 ex., 22.04.1953, Puławy, on *M. myotis*; 4 exx., 02.09.1954, Bielany, on *M. myotis*; 2 exx., 22.04.1953, Puławy, on *N. noctula*

Spinturnix plecotina (Koch, 1839) (Fig. 1C): 13 exx., 11.06.2016, Ryki, on *N. noctula*

Spinturnix psi (Kolenati, 1856) (Fig. 1D): 3 exx., 02.09.1954, Bielany, on *M. myotis*

Family Macronyssidae

Macronyssus flavus (Kolenati, 1857) (Fig. 1E): 29 exx., 22.04.1953, Puławy, on *N. noctula*; 2 exx., 02.09.1954, Bielany, on *M. myotis*; 53 exx., 11.06.2016, Ryki, on *N. noctula*; 7 exx., 24.04.2014, Lublin, on *N. noctula*

Macronyssus kolenatii (Oudemans, 1902) (Fig. 1F): 60 exx., 22.04.1953, Puławy, on *N. noctula*; 1 ex., 22.04.1953, Puławy, on *E. serotinus*; 13 exx., 11.06.2016, Ryki, on *N. noctula*

Steatonyssus noctulus Rybin, 1992 (Fig. 2A): 9 exx., 11.06.2016, Ryki, on *N. noctula*; 8 exx., 15.02.2018, Lublin, on *N. noctula*

Steatonyssus periblepharus Kolenati, 1858 (Fig. 2B): 1 ex., 22.04.1953, Puławy, on *E. serotinus*; 12 exx., 22.04.1953, Puławy, on *N. noctula*; 1 ex., 22.04.1953, Puławy, on *M. nattereri*; 11 exx., 11.06.2016, Ryki, on *N. noctula*; 2 exx., 24.04.2014, Lublin, on *N. noctula*

Ornithonyssus pipistrelle (Oudemans, 1904) (Fig. 2C): 2 ex., 22.04.1953, Puławy, on *E. serotinus*; 1 ex., 11.06.2016, Ryki, on *N. noctula*; 1 ex., 24.04.2014, Lublin, on *N. noctula*

Order Sarcoptiformes
Family Oppiidae

Oppiella nova (Oudemans, 1904) (Fig. 2D): 1 ex., 15.05.2013, Lublin, on *P. auritus*

Family Sarcoptidae

Sarcoptes sp. (Fig. 2E): 1 ex., 15.05.2013, Lublin, on *P. auritus*

Order Trombidiformes
Family Trombiculidae

Leptotrombidium russicum (Oudemans, 1903) (Fig. 2F): 1 ex., 02.09.1954, Bielany, on *M. myotis*; 1 ex., 11.06.2016, Ryki, on *N. noctula*

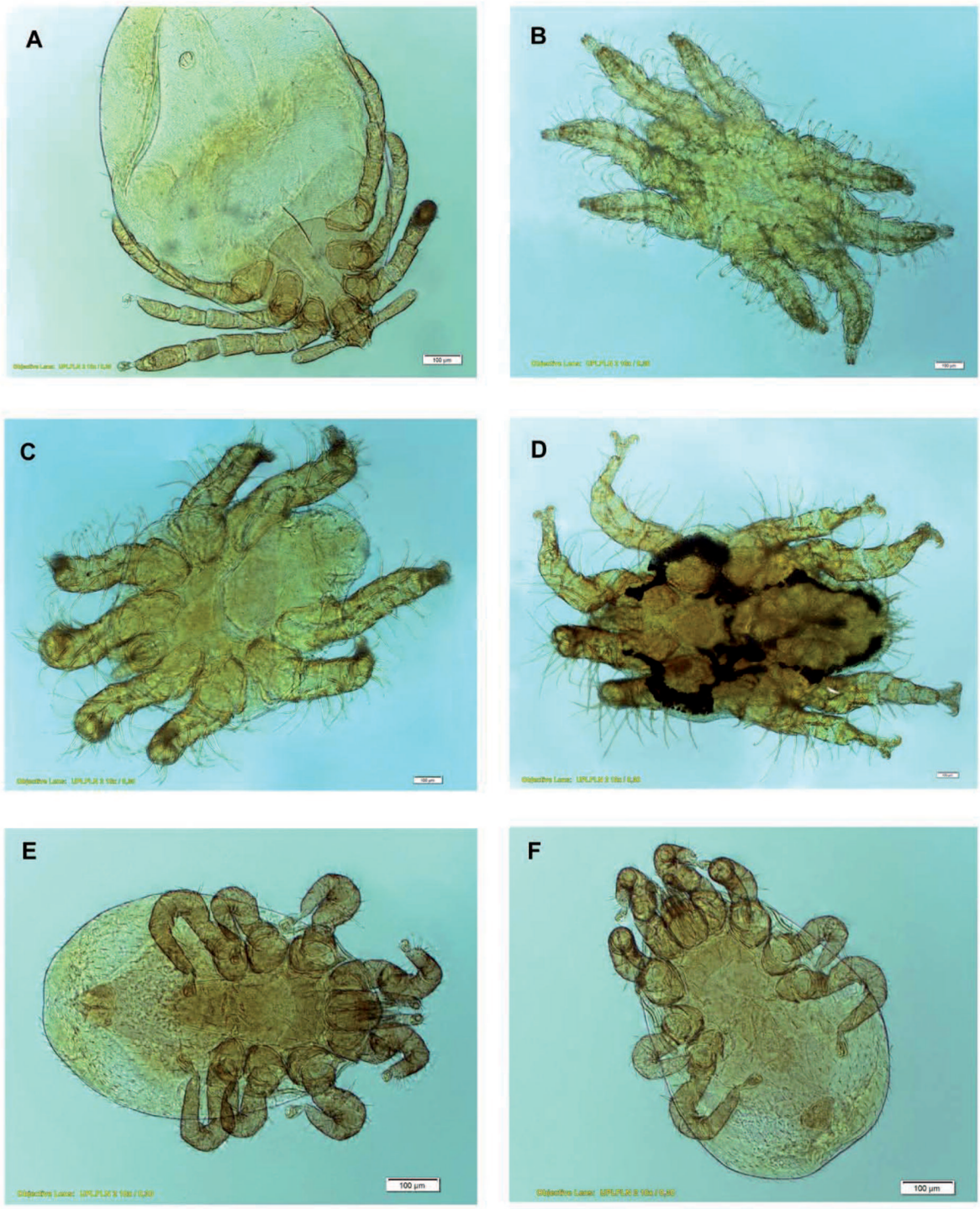

Figure 1. *Ixodes ricinus* (A); *Spinturnix myoti* (B); *S. plecotina* (C); *S. psi* (D); *Macronyssus flavus* (E); *M. kolenatii* (F) (photo R. Gosik).

Insecta
Order Siphonaptera
Family Ischnopsyllidae

Ischnopsyllus elongates (Curtis, 1832) (Fig. 2G): 1 ex., 22.04.1954, Puławy, on *N. noctula*; 1 ex., 11.06.2016, Ryki, on *N. noctula.*

Nyctoridopsylla pentactena (Kolenati, 1856) (Fig. 2H): 3exx., 11.06.2016, Ryki, on *N. noctula.*

Immature stages

Based on the existing literature, it was not possible to identify the developmental stages of fleas, both in terms of the larval stage and species affiliation. The preimaginal stages of *I. elongates* and *N. pentactena* remain undescribed.

Egg: 3 exx, 11.06.2016, Ryki, on *N. noctula*; 6 exx., 11.06.2016, Ryki, on *P. auritus*; 1 ex.,

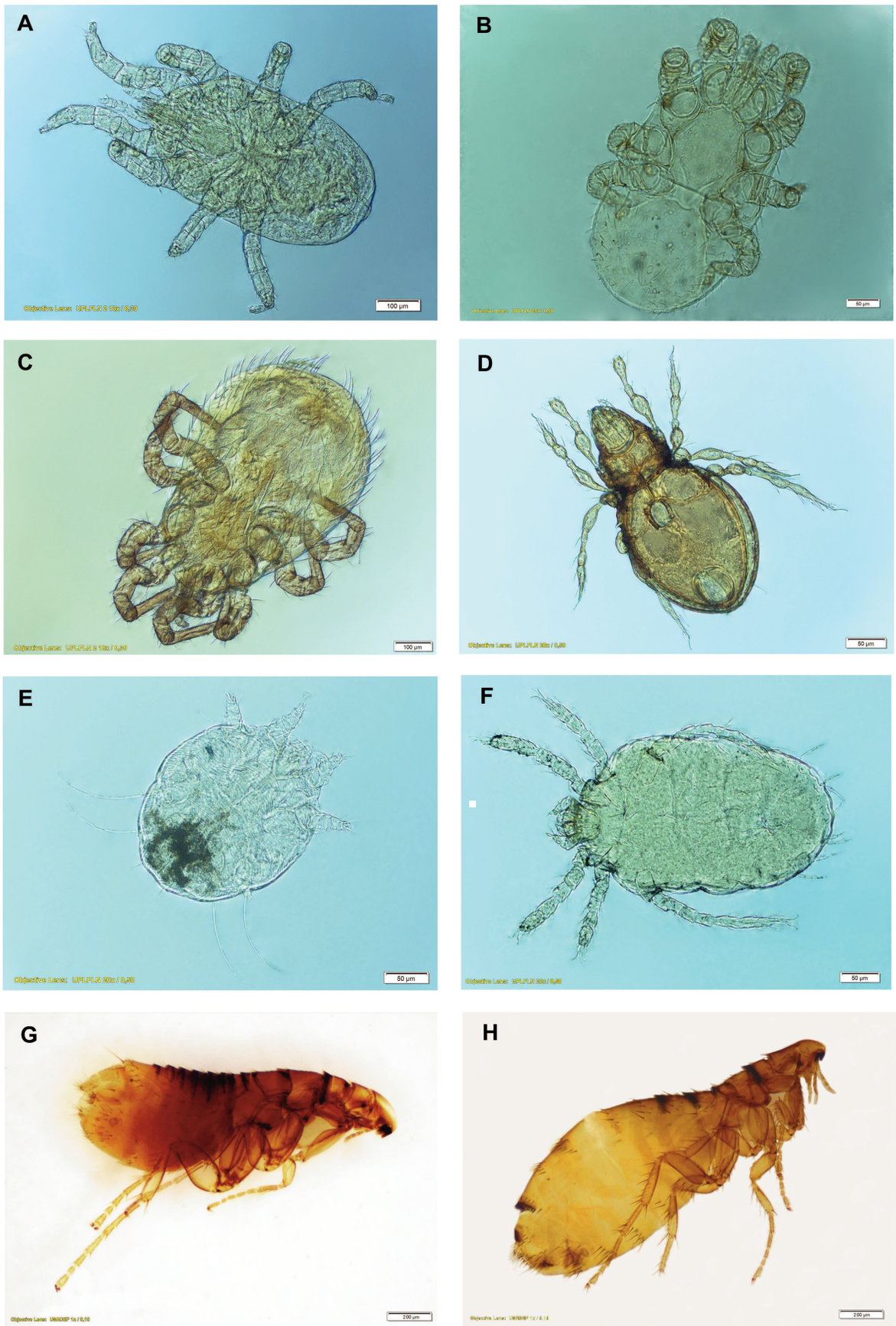

Figure 2. *Steatonyssus periblepharus* (A); *S. noctulus* (B); *Ornithonyssus pipistrelle* (C); *Oppiella nova* (D); *Sarcoptes* sp. (E); *Leptotrombidium russicum* (F); *Ischnopsyllus elongates* (G); *Nyctoridopsylla pentactena* (H) (photo R. Gosik).

Table 1. List of bats and their ectoparasites collected during study.

Species	Sex	Ra (mm)	Age	Tooth wear	Gender identification	Date of collection	Place of collection	*I. ricinus*	*S. myoti*	*S. plecotinus*	*S. psi*	*M. flavus*	*M. kolenati*	*S. noctulus*	*S. periblepharus*	*O. pipistrelli*	*Oppiella nova*	*Sarcoptes sp.*	*L. russicum*	*I. elongatus*	*N. pentactena*	Siphonaptera (egg)	Siphonaptera (larvae)	Siphonaptera (pupa)	∑
N. noctula	male	52.8	adult	20%	testis invisible; epididymis invisible	6/11/16	Ryki																2		2
N. noctula	male	52.6	adult	10%	testis invisible; epididymis invisible	6/11/16	Ryki					6		1			4		11				4		11
N. noctula	female	53.5	adult	5%	nipples flat (2.5 mm)	6/11/16	Ryki			4		2											2		8
N. noctula	female	54.0	adult	5%	nipples flat (2.0 mm)	6/11/16	Ryki			2													1		3
N. noctula	female	53.7	adult	0% (with a red vein)	nipples flat (3.0 mm)	6/11/16	Ryki								2							3	5	1	11
N. noctula	male	53.1	adult	10%	testis invisible; epididymis invisible	6/11/16	Ryki								1								4	1	6
N. noctula	female	53.9	adult	10%	nipples convex (3.0 mm)	6/11/16	Ryki			4		15	1	2		1			1				7		31
N. noctula	female	51.6	adult	15%	nipples flat (2.0 mm)	6/11/16	Ryki					14	1	2									3		20
N. noctula	male	53.1	adult	10%	testis invisible; epididymis black colored	6/11/16	Ryki								1								4		5
N. noctula	male	53.6	adult	5%	testis invisible; epididymis invisible	6/11/16	Ryki																1		1
N. noctula	male	53.5	adult	10%	testis invisible; epididymis invisible	6/11/16	Ryki					7	1	1	1								2		12
N. noctula	male	55.0	adult	15%	testis invisible; epididymis black colored	6/11/16	Ryki					5	5	1	3					1			1		16
N. noctula	male	53.3	adult	20%	testis invisible; epididymis black colored	6/11/16	Ryki			1		1	1								1		2		6
N. noctula	male	55.5	adult	10%	testis invisible; epididymis black colored	6/11/16	Ryki						1								1				2
N. noctula	male	54.5	sad(+/- 20 day)	0%	testis invisible; epididymis invisible	6/11/16	Ryki			2		3	3	2	3						1				14

Table 1. List of bats and their ectoparasites collected during study.

Species	Sex	Ra (mm)	Age	Tooth wear	Gender identification	Date of collection	Place of collection	*I. ricinus*	*S. myoti*	*S. plecotinus*	*S. psi*	*M. flavus*	*M. kolenati*	*S. noctulus*	*S. periblepharus*	*O. pipistrelli*	*Oppiella nova*	*Sarcoptes sp.*	*L. russicum*	*I. elongatus*	*N. pentactena*	Siphonaptera (egg)	Siphonaptera (larvae)	Siphonaptera (pupa)	∑
N. noctula	male	54.1	adult	5%	testis raised; epididymis black colored	4/24/14	Lublin																		0
N. noctula	female	54.3	adult	5%	nipples convex (3.0 mm)	4/24/14	Lublin					7		8	2	1									18
N. noctula	female	52.6	adult	15%	nipples flat (2.5 mm)	4/22/53	Puławy		2			8	16		9							1			36
N. noctula	female	55.2	adult	10%	nipples convex (3.0 mm)	4/22/53	Puławy					8	23												31
N. noctula	male	52.2	adult	5%	testis invisible; epididymis invisible	4/22/53	Puławy					2	1			1									5
N. noctula	female	51.3	adult	5%	nipples flat (3.0 mm).	4/22/53	Puławy					11	20		3								2		36
M. daubentonii	female	36.8	adult	5%	nipples convex (1.0 mm)	6/11/16	Ryki																		0
M. daubentonii	male	38.4	adult	5%	testis invisible; epididymis invisible	6/11/16	Ryki																		0
M. myotis	female	48.2	sad(+/- 21 day)	0%	nipples flat (2.0 mm)	9/2/54	Bielany		1		2	1													4
M. myotis	female	35.1	sad(+/- 14 day)	0%	nipples convex (2.0 mm)	9/2/54	Bielany		1			1													2
M. myotis	male	24.0	sad(+/- 9 day)	0%	testis invisible; epididymis invisible	9/2/54	Bielany		2		1														3
M. myotis	female	66.4	adult	0%	nipples convex (4.0 mm)	9/2/54	Bielany												1						1
M. myotis	female	62.0	adult	35%	nipples convex (4.0 mm)	4/22/53	Puławy	1																	1
M. nattereri	male	38.1	adult	5%	testis invisible; epididymis invisible	4/22/53	Puławy								1										1

Table 1. List of bats and their ectoparasites collected during study.

Species	Sex	Ra (mm)	Age	Tooth wear	Gender identification	Date of collection	Place of collection	*I. ricinus*	*S. myoti*	*S. plecotinus*	*S. psi*	*M. flavus*	*M. kolenati*	*S. noctulus*	*S. periblepharus*	*O. pipistrelli*	*Oppiella nova*	*Sarcoptes sp.*	*L. russicum*	*I. elongatus*	*N. pentactena*	Siphonaptera (egg)	Siphonaptera (larvae)	Siphonaptera (pupa)	∑
M. nattereri	male	40.2	adult	5%	testis invisible; epididymis invisible	4/24/14	Lublin																		0
M. nattereri	female	40.6	adult	0%	nipples convex (1.0 mm)	4/24/14	Lublin																		0
M. nattereri	female	40.1	adult	0%	nipples convex (1.5 mm)	4/24/14	Lublin																		0
P. auritus	female	39.7	adult	0%	nipples convex (1.5 mm)	5/15/13	Lublin	1									1	1							3
P. auritus	male	38.8	adult	0%	testis lowered down; epididymis invisible	6/11/16	Ryki															6			6
E. serotinus	male	51.7	adult	5%	testis invisible; epididymis invisible	4/24/14	Lublin																		0
E. serotinus	male	51.8	adult	5%	testis invisible; epididymis invisible	4/22/53	Puławy				1		1		1	1									3
								1	7	13	3	91	74	17	27	4	1	1	2	2	3	10	40	2	298

22.04.1953, Puławy, on *N. noctula.*

Larvae, various instars: 38 exx, 11.06.2016, Ryki, on *N. noctula*; 2 exx., 22.04.1954, Puławy, on *N. noctula*

Pupa: 2 exx, 11.06.2016, Ryki, on *N. noctula*

Discussion

Of the 36 bats examined, only 7 specimens – *Myotis daubentonii* (2 exx. from Ryki), *M. nattereri* (3 exx. from Lublin), *E. serotinus* (1 ex. from Lublin) and *N. noctula* (1 ex. from Lublin) – were free of parasites. The remainder harboured from 1 to 35 individuals of various arthropods (1–7 species).

This research has shown that, both quantitatively and qualitatively, the mite species collected from dead bats e.g. [33] were very similar to those collected from live ones e.g. [7,30,31]. *S. myoti* was collected mainly on *M. myotis* and *N. noctula*; *S. plecotina* on *N. noctula*; *S. psi* on *M. myotis*; *M. flavus* on *N. noctula* and *M. myotis*; *M. kolenatii* on *N. noctula* (but its presence on *E. serotinus* has not been reported yet); *S. periblepharus* on *E. serotinus*, *N. noctula* and *M. nattereri*; *S. noctulus* on *N. noctula*; *O. pipistrelle* on *E. serotinus* and *N. noctula*. These data confirm the results of previous studies on ectoparasites of bats, especially those living in Central Europe [10,21,23,28,34]. As in Scheffler [7], *M. flavus* should be considered the most common parasite of *N. noctula*.

The same applies to fleas: *I. elongates* and *N. pentactena* have already been recorded on *N. noctula* [7,35]. For lack of identification keys, however, it is impossible to determine what species the flea larvae collected from the bats belong to, especially as more than one species of flea may be present on one bat at the same time [2].

A separate problem is that of fleas feeding on bats. Whereas adult fleas have been quite well studied in terms of their occurrence on bats, the feeding of flea larvae and their development are only fragmentarily known [2]. Typically, flea eggs are laid in bat excrement, where they hatch, develop and pupate [2]. Bartnicka et al. [23] claim that flea larvae, being saprophages, develop in bat roosts, but they do not occur on live bats at all. A great number of flea larvae (in different developmental stadia) and eggs were found on the bats we examined. Most likely, they got onto the bats after these fell to the floor of the site where they had been sheltering. However, no other insects were found inhabiting the dead animals. This means that flea larvae would be the first insects to inhabit dead bats. Therefore, it cannot be ruled out that flea larvae can develop in bat fur. Hůrka [2] found flea eggs and a single larva of *I. intermedius* in the fur of *M. myotis*. This author states that the critical moment in the development of fleas is the search for the first host, for which a freshly metamorphosed flea has no more than 3–4 days [2]. In the case of buildings with high ceilings (e.g. church attics), this may form an almost insurmountable barrier. Therefore, it would be reasonable for the larvae to remain in contact with the future host as long as possible.

Although *I. ricinus* is probably the most common tick in Central Europe, having a huge range of potential hosts including bats [36], and is characterized by enormous ecological plasticity, its occurrence on bats is surprisingly rare [37,38]. In Slovakia, it has been sporadically recorded on *Rhinolophus euryale* [38], and in Poland on *Myotis myotis*, *M. bechsteinii*, *M. dasycneme* and *M. mystacinus* [39,40]. Hence, the record published here is probably the first one of *I. ricinus* on *P. auritus*.

Only one specimen of *Sarcoptes* sp. was found in the material examined. Moreover, no changes caused by these parasites were found on the bats' skin. It can be assumed that, at least in the study area, *Sacroptes* are an incidental element among bat ectoparasites. Similarly, there were very few individuals of *Leptotrombidium russicum* and *Oppiella nova*. *L. russicum* can occur frequently on *B. barbastellus* and *E. serotinus* [41] but has not been recorded from *N. noctula* and *M. myotis*. Probably because of its positive phototropism, *L. russicum* avoids bats that are strictly nocturnal and chooses shelters to which light has no access [42]. *O. nova*, on the other hand, is considered to be one of the most cosmopolitan mites, leading a mainly saprophagous existence. Occasionally, it is also found on small invertebrates (nematodes and arthropods) [43] and some vertebrates (birds and small mammals), on which it probably feeds on exfoliated epidermis and feathers [44–46]. It was also found in large numbers in bat excrement at the bottom of caves [47]. Hence, the incidental presence of this mite on a dead bat is not surprising.

The positive relationship reported by Bartnicka et al. [23] between the number of bats in one particular shelter and the number of parasites, was confirmed. Hence, bats living in high densities had the most mites (Ryki). Up to a hundred roosting bats were regularly encountered in the Ryki shelter,

whereas there were never more than a dozen or so in the other shelters (Lublin, Bielany, Puławy).

As a rule, female bats usually have more parasites than males, and this was also confirmed [5,23,48,49]. Females of *N. noctula* had from 8 to 35 specimens (median 20 specimens; 1 to 7 species) of parasites, while males had from 1 to 16 specimens (median 5 specimens; 1 to 6 species). However, no correlation could be established between the size of a bat (ramnus length) and the number of parasites it carried.

No bat flies (Nycteribiidae), one of the main groups of bat ectoparasites, were recorded in the material examined [7,50]. But since some bat fly species are widely distributed in Poland and their numbers are often three times as high as the number of fleas [39,50], their presence is to be expected. Most likely, however, their relatively large body size and high mobility make them the only parasites that could leave dead hosts and move on to live bats. Hence, dead bats cannot be regarded as a reliable source for research into bat flies. Unlike keds, the chances of mites escaping from the fur of a dead host and reaching another host are slim.

Despite the fact that collecting parasites from dead bats is regarded as ethically acceptable [33], this research method has some limitations, one of which is its probable inapplicability to studies of bat flies. In addition, the overrepresentation of flea larvae on dead bats requires separate explanation.

Acknowledgements

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