

# Ectoparasites and Pathogens of Kuhl’s Pipistrelle *Pipistrellus kuhlii* (Kuhl, 1817) (Chiroptera: Vespertilionidae): Our Own and Published Data Review

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**Abstract**—Here we report the results of our own survey and literary published data on the ectoparasite fauna and pathogens of the alien bat species, the Kuhl’s pipistrelle *Pipistrellus kuhlii* (Kuhl, 1817) (Chiroptera: Vespertilionidae). This bat is a host of 36 species of parasitic mites, ticks and insects (including accidental findings) and 13 species of pathogens (protozoa, bacteria, viruses). The flea *Ischnopsyllus variabilis* is re-recorded on this host for the first time. We have found that outside of the host ancestral range, the core of the bat parasite fauna is significantly different due to the loss of host species-specific ectoparasites. Particularly, in Russia, only 6 species of parasitic arthropods have been recorded for Kuhl’s pipistrelle and all of them are host genus-specific. At the same time, the features of ecology and occasional finds of extrinsic parasites allow to suggest that *P. kuhlii* has wide contacts with animals which are the reservoirs of zoonotic infections, that in combination with the fact of isolation of several pathogens from this species (including two coronaviruses) points to a possible medical importance of Kuhl’s pipistrelle.

**Keywords:** Kuhl’s pipistrelle, *Pipistrellus kuhlii*, bat ectoparasites, *Steatonyssus periblepharus*, *Ischnopsyllus variabilis*, *Carios vespertilionis*

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## INTRODUCTION

The Kuhl’s pipistrelle or Mediterranean *Pipistrellus kuhlii* (Kuhl 1817), originating from the south (Strelkov and Il’in, 1990; Vernier and Bogdanowicz, 1999), originally preferred open plain arid and semi-arid landscapes of the Mediterranean, North Africa, Near East, and Kashmir (Strelkov et al., 1985). Progressive spread of this species was reported over the last several decades in Europe (Il’in, 2000; Strelkov, 2004; Bogdanowicz, 2004; Sachanowicz et al., 2006). This contributed to the expansion of the total area of the range by a factor of five (Ancillotto et al., 2016). A pronounced tendency toward synanthropy, high adaptability to various climatic conditions, and general global warming induced its rapid dispersal in the northerly and easterly directions. From the direction of the south of Central and Eastern European, the spe-

cies expansion northward was first reported as early as the 1980s, when *P. kuhlii* was recorded from the north of the Alps in Switzerland, southern Germany, Austria, and Hungary (Haffner et al., 1991; Feher, 1995; Bauer, 1996; Meschede et al., 1998; Fiedler et al., 1999; Spitzenberger and Bauer, 2001). Currently, the species has reached the latitude of 50° and was reported from Slovakia (Ceľuch and Ševčík, 2006; Danko, 2007), the Czech Republic (Reiter et al., 2007), and Poland (Sachnowicz et al., 2006). Additionally, the active dispersal was recorded in Ukraine (Kedrov and Shurshak, 1999; Godlevsky et al., 2000; Poluda and Zagorodnyuk, 2001; Gavrish’ and Kotserzhinskaya, 2002; Zagorodnyuk and Reznik, 2007; Gashchak et al., 2009; Godlevs’ka, 2015), Belarus (Demyanchik, 2013; Shpak and Larchenko, 2016), and Central Asia (Strelkov, 2004).

Prior to the mid-20th century, finds of *P. kuhlii* were known to be rare from the regions neighboring Russia, specifically, a few settlements in Transcaucasia and Central Asia and in Crimea (Kuzyakin, 1950; Strelkov, 1963). In the east of European Russia, the starting point of this species expansion was southeastern Transcaucasia, where a rapid buildup of its population level was observed in the 1940s–1950s (Vereshchagin, 1959). The first finds were made in Rostov-on-Don in 1975 (Yarmysh and Kazakov, 1977), in Grozny and Abrau-Dyurso in Krasnodar territory in 1977 (Yarmysh et al., 1980), and North Ossetia in 1978 (Komarov and Kuchiev, 1982). In the Volga region, *P. kuhlii* was first discovered in 1980 in the vicinity of Lake Baskunchak in Astrakhan region (48° N) (Lindeman and Subbotin, 1983), where the typical plain species was able to arrive exclusively from the south, while migrating along the western coast of the Caspian Sea (Strelkov et al., 1985). Taking into account, however, its subsequent spread northward, it is not implausible that the species could have found its way to the region much earlier. By 1985, its finds had already been reported from the north of Volgograd region, where it reached 50° N (Strelkov et al., 1985). *P. kuhlii* was detected in Saratov region at 51° latitude in 1988 (Strelkov and Il'in, 1990) and reported from 52° N as early as 1995 (Zav'yalov and Shlyakhtin, 1999). In 1997, the animals were already found by us in Samara, whereas soon after, its habitat was identified in the cities of Novokuibyshevsk and Tolyatti (Smirnov and Vekhnik, 2011). The species was found at Samara Bend and in Penza and Ul'yanovsk regions in the early 2000s (Il'in et al., 2006; Zolina et al., 2007; Smirnov et al., 2007; Shepelev et al., 2008; Smirnov and Vekhnik, 2011), as well as in the Republic of Mordovia (Artaev and Smirnov, 2016). About the same time, it was detected in Voronezh (Smirnov and Vekhnik, 2011), Tambov (Lada, 2010), Bryansk (Sitnikova et al., 2009), and Moscow (Kruskop and Kozhurina, personal communication) regions. Prior to 1990 in the Transvolga, finds of *P. kuhlii* were limited to occasional spots located easterly up to the Bolshoy Uzen River within the Volga-Ural interfluvium (Strelkov and Il'in, 1990). Further eastward, the species was found at the end of the 20th century strictly in the proximity to the Ural River Delta (Shaimardanov, 2001). Attempts made in the 1990s and in the early 2000s with intent to find it in the floodplain of the lower and middle reaches of the Ural River yielded no result; but in 2008, *P. kuhlii* was detected at a number of points in Orenburg and Chelyabinsk regions nevertheless (Davygora et al., 2009). The northernmost find was made in Udmurtiya (Izhevsk) in winter 1991, but the animal was probably transported there accidentally by vehicle from the south (Kapitonov and Grigor'ev, 1995).

Despite the spotlight recently put on the Kuhl's pipistrelle (Smirnov and Vekhnik, 2011; Godlevskaya, 2015; Shpak and Larchenko, 2016; Ancillotto et al., 2016; Sachnowicz et al., 2017), the parasitic fauna and

pathogens associated with the species are considered in scattered fragmentary communications from various (primarily, African, Asian, and South European) parts of the range. As for Russia, five or six species of ectoparasites were described earlier. No information, in actual fact, is available from Western Europe. From the epidemiological perspective, bats are, however, known to be a huge reservoir of zoonotic infections. The literature mentions at least 250 virus agents alone, including infectious agents of dangerous diseases, such as rabies, Ebola fever, SARS, MERS, and COVID-2019 isolated from microbats or otherwise detected in their body (Schountz, 2013; Moratelli and Calisher, 2015), while, in addition, many of their ectoparasites are involved in circulation of agents of different nature (Orlova and Kononova, 2018). As already been mentioned, the Kuhl's pipistrelle demonstrates active expansion across the territory of Russia and, therefore, may possibly transport the temporal ectoparasites over a considerable distance, thus causing a number of diseases to spread further.

## MATERIALS AND METHODS

Bats were captured using the trapping nets during the period of 2006–2019; the age and sex were determined in each individual and the reproductive state (pregnancy and lactation) was determined in females (Racey, 2009). Thirty-nine individuals of the studied species were captured in Astrakhan region by D.G. Smirnov, V.P. Vekhnik, and A.M. Luk'yanenko in the following localities: village of Ivanchug (46°04' N, 47°59' E; May 22, 2018, four specimens); Astrakhan Nature Reserve, Damchikskii site (45°47' N, 47°53' E; May 23, 2018, 17 specimens); Astrakhan Nature Reserve, Obzhorovskii cordon (guard station) (46°18' N, 48°59' E; August 27 and 28, 2019; 18 specimens). In Dagestan, pipistrelles were captured by Smirnov and Vekhnik in the village of Kochubei (44°24' N, 46°32' E; April 24, 2019; five individuals examined), in the outskirts of Khasavyurt on the Aktash River (43°17' N, 46°38' E; May 20, 2019; three specimens), and in the Agra-khanskii Sanctuary of the Dagestan State Natural Reserve (43°48' N, 47°31' E; May 23, 2019; three specimens). One animal of this species was captured by Smirnov in the village of Novospasskoe, Ul'yanovsk region (53°08' N, 43°45' E; August 17, 2006). In Rostov region, one individual was trapped by Zabashta in the outskirts of Rostov-on-Don (47°29' N, 39°56' E; July 20, 2019). Thus, a total of 52 individuals of *P. kuhlii* were examined in eight localities of the Russian south; after the examination and collection of ectoparasites, all bats were released in the wild.

Ectoparasites were sampled using tweezers and needle and fixed in 70% ethanol. Permanent preparations were made using Faure-Berlese mounting medium according to standard technique (Whitaker, 1988); parasites were identified by M.V. Orlova using standard keys and other taxonomic publications (Hopkins

**Table 1.** Distribution of the Kuhl's pipistrelle across the localities (*n* is the number of examined hosts; first line is the absolute number; second line is MI; and third line is *P*, %)

Locality	Astrakhan region			Dagestan			Rostov region	Ul'yanovsk region	Total
	Astrakhan Nature Reserve		Ivanchug village	Kochubei village	Khasavyurt outskirts	Agrakhanskii Sanctuary			
	Obzhorovskii cordon	Damchikskii site							
Species of parasite	<i>n</i> = 18	<i>n</i> = 17	<i>n</i> = 4	<i>n</i> = 5	<i>n</i> = 3	<i>n</i> = 3	<i>n</i> = 1	<i>n</i> = 1	<i>n</i> = 52
<i>Steatonyssus periblepharus</i>	10			18	7	10			52
	1	–	–	3.6	3.5	3.3	7	–	2.5
	56			100	67	100			40
<i>Carios vespertilionis</i>	4								4
	2	–	–	–	–	–	–	–	2
	11								4
<i>Ischnopsyllus octactenus</i>	5	3	5	2		1			16
	1	1	1.3	2	–	1	–	–	1.14
	28	18	100	20		33			27
<i>Ischnopsyllus variabilis</i>	–	–	–	–	–	–	–	1	1
									2
Total	19	3	5	20	7	11			73
	2.1	1	1.3	4	3.5	3.7	7	1	2.6
	50	18	100	100	67	100			54

and Rothschild, 1956; Filippova, 1966; Orlova et al., 2016). The core of the parasitic fauna was assessed on the basis of the parameters proposed by Balashov (2009). Host infestation parameters are presented using the standard parasitology indices, such as MI (mean intensity), which is the mean number of parasites per infested host, and *P* (prevalence), which is percentage of infested individuals.

## RESULTS

There were 73 specimens of four ectoparasite species (in Acari and insects) collected from the examined individuals of *P. kuhlii* (Table 1).

### Acari: Gamasina: Macronyssidae

*Steatonyssus periblepharus* Kolenati, 1858: 4 ♀♀, 6 N1 (Astrakhansk Nature Reserve, Obzhorovskii cordon, August 27 and 28, 2019); 13 ♀♀, 5 N1 (Dagestan, Kochubei village, April 24, 2019); 3 ♀♀, 4 N1 (Dagestan, Khasavyurt outskirts, May 20, 2019); 9 ♀♀ (including one with intrauterine egg); N1 (Dagestan, Agrakhanskii Sanctuary, May 23, 2019); ♂, 6 N1 (Rostov region, Platov Airport, July 20, 2019).

### Acari: Parasitiformes: Argasidae

*Carios vespertilionis* Latreille, 1796: 4 L (Astrakhan Nature Reserve, Obzhorovskii cordon, August 27 and 28, 2019).

### Insecta: Siphonaptera: Ischnopsyllidae

*Ischnopsyllus octactenus* (Kolenati, 1856): 5 ♀♀ (Astrakhan region, Ivanchug, May 22, 2018); 2 ♀♀, ♂ (Astrakhan Nature Reserve, Damchikskii site, May 23, 2018); 4 ♀♀, ♂ (Astrakhan Nature Reserve, Obzhorovskii cordon, August 27 and 28, 2019); ♀ and ♂ (Dagestan, Kochubei village, April 24, 2019); ♀ (Dagestan, Agrakhanskii Sanctuary, May 23, 2019).

*Ischnopsyllus variabilis* (Wagner, 1898): ♀ (Ul'yanovsk region, Novospasskoe village, August 17, 2006).

## DISCUSSION

Our samples feature the dominant number of *S. periblepharus* (52 out of 73 specimens (in other words, nearly three-fourth of the collected parasites) found in five out of eight inspected localities. The intensity of their infestation of bats is relatively low (MI not exceeding 3.6); the proportion of infested

**Table 2.** Arthropods collected from the Kuhl's pipistrelle and their medical importance

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
Acari: Prostigmata: Myobiidae				
<i>Pteracarus pipistrellus pipistrellus</i> (Radford, 1938)	–	Armenia (Dusbabek and Arutunian, 1976)	Pipistrelles <i>Pipistrellus</i> spp.	–
<i>Acanthophthirus kolenatii</i> Dusbabek, Arutunian, 1976	–	Armenia (Dusbabek and Arutunian, 1976)	Type host is <i>P. kuhlii</i>	–
<i>Calcaromyobia</i> sp.	–	Azerbaijan (Dubovchenko, 1968)	–	–
Myobiidae gen. sp.	–	Azerbaijan (Dubovchenko, 1968)	–	–
Acari: Prostigmata: Trombiculidae				
<i>Oudemansidium komareki</i> (Daniel et Dusbabek, 1959)	–	Spain (Minorka Island) (Stekolnikov and Quetglas, 2019)	Multiple horseshoe and simple nosed microbats; finds from rodents are known	–
Acari: Gamasina: Ameroseiidae				
<i>Kleemannia</i> sp.	–	Azerbaijan (Dubovchenko, 1968)	Mites of this genus do not parasitize	–
Acari: Gamasina: Laelaptidae				
<i>Laelaps algericus</i> Hirst, 1925	–	Azerbaijan (Dubovchenko, 1968)	Rodents (Rodentia), more commonly house mouse <i>Mus musculus</i> Linnaeus, 1758	Carrier of plague <i>Yersinia pestis</i> (Lehmann and Neumann 1896) van Loghem 1944 and lymphocytic choriomeningitis virus LCMV (Arenaviridae) (Zemskaya, 1973)
Acari: Gamasina: Dermanyssidae				
<i>Dermanyssus gallinae</i> Redi, 1674	–	Azerbaijan (Dubovchenko, 1968)	Domestic and wild birds (Aves)	Cause dermatosis; carry paramyxoviridae, horse encephalomyelitis virus, birds' causative agents <i>Pasteurella multocida</i> (Lehmann and Neumann 1899) Rosenbusch and Merchant 1939, <i>Salmonella gallinarum</i> (Flochlay et al., 2017)
Acari: Gamasina: Spinturnicidae				
<i>Meristaspis lateralis</i> Kolenati, 1857	–	Iran (Benda et al., 2012)	Megabats from the family Pteropodidae (Chiroptera: Pteropodidae)	–

Table 2. (Contd.)

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
<i>Spinturnix acuminatus</i> (Koch, 1836)	–	Palestine (Anciaux de Faveaux, 1976)	Noctule bats <i>Nyctalus</i> spp.	–
<i>Spinturnix acuminata</i> group	–	Libya (Benda et al., 2014)	–	–
<i>Spinturnix bakeri</i> Rudnick, 1960	–	Azerbaijan (Dubovchenko, 1968)	–	–
<i>Spinturnix myoti</i> (Kolenati, 1856)	–	Azerbaijan (Gadzhiev and Dubovchenko, 1967)	Mouse-eared bat <i>Myotis</i> spp.	Carry bacteria <i>Bartonella</i> sp. (Hornok et al., 2012)
<i>Spinturnix kolenatii</i> Oudemans, 1910	–	Azerbaijan (Gadzhiev and Dubovchenko, 1967)	<i>Eptesicus</i> spp.	–
<i>Spinturnix psi</i> (Kolenati, 1856)	–	Armenia (Arutyunyan and Ogadzhanian, 1974)	Long-winged bats (Miniopteridae)	Carry bacteria <i>Anaplasma phagocytophilum</i> (Foggie 1949) Dumler et al., 2001 (Reeves et al., 2006)
Acari: Gamasina: Macronyssidae				
<i>Macronyssus cyclaspis</i> (Oudemans, 1906)	The former Soviet Union, no indication of specific state (Stanyukovich, 1997)		Pipistrelle <i>Pipistrellus</i> spp.	–
<i>Macronyssus flavus</i> (Kolenati, 1856)	–	Azerbaijan (Dubovchenko, 1968)	Noctule bats <i>Nyctalus</i> spp.	–
<i>Macronyssus kolenatii</i> (Oudemans, 1902)	Rostov region (Zabashita et al., 2019)	Egypt (Radovsky, 1967)	Pipistrelles <i>Pipistrellus</i> spp.	–
	The former Soviet Union, no indication of specific state (Stanyukovich, 1997)			
<i>Steatonyssus periblepharus</i> Kolenati, 1858	Rostov region (Zabashita et al., 2019; present article), Astrakhan region (Zabashita et al., 2019; present article), Dagestan (present article)	Azerbaijan (Dubovchenko, 1968); Armenia (Ogadzhanian and Arutyunyan, 1974); Israel (Korine et al., 2017); Jordan (Benda et al., 2010); Palestine (Anciaux de Faveaux, 1976); Iran (Benda et al., 2012); Lybia (Benda et al., 2014)	Pipistrelles <i>Pipistrellus</i> spp.	Carry bacteria <i>Borellia afzelii</i> Canica et al., 1994 (Zabashita et al., 2019)
	–	Iran (Sharifi et al., 2008)		
<i>Steatonyssus</i> sp.	–		–	–

Table 2. (Contd.)

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
<i>Parasteatonyssus ca. nycitroni</i>	–	Israel (Korine et al., 2017)	Free-tailed bats <i>Tadarida</i> spp. (Chiroptera: Molossidae)	–
Acari: Parasitiformes: Argasidae				
<i>Carios vespertilonis</i> Latreille, 1796	Astrakhan region (Zabashita et al., 2019; present article)	Spain (Imaz et al., 1999) Iran (Sharifi et al., 2008) Israel (Korine et al., 2017) Jordan (Benda et al., 2010) Algeria (Bendjeddou et al., 2017) Lybia (Benda et al., 2014)	Pipistrelles <i>Pipistrellus</i> spp.	Carry bacteria <i>Rickettsia</i> sp. AvBat, <i>Ehrlichia</i> sp. AvBat, <i>Borrelia</i> sp. CPB1 (Socolovschi et al., 2012), <i>Babesia vesperuginis</i> Dionisi, 1899 (Apicomplexa: Piroplasmida) (Gardner and Molyneux, 1988; Hornok et al., 2016, 2017); Issyk-Kul Virus ISKV, Keterah orthonairovirus KTRV (Bunyvirales: Nairoviridae) (Lyov et al., 1973; International Catalogue of Arboviruses..., 1985; Al'khovskii et al., 2013), virus from the fam. Bunyviridae (similar to Issyk-Kul virus) (Oba et al., 2016), tick-borne encephalitis virus (Flaviviridae) (I.V. Kuz'min and V.V. Yakimenko, personal communication)
Acari: Parasitiformes: Ixodidae				
<i>Hyalomma dromedarii</i> Koch 1844	–	Algeria (Bendjeddou et al., 2017)	Camels (Artiodactyla: Camelidae)	Carrier of protozoa <i>Theileria camelensis</i> (Apicomplexa: Piroplasmida) (Hoogstraal, 1954, Abd El-Baky, 2001; Hamed et al., 2011)
Insecta: Diptera: Nycteribiidae				
<i>Nycteribia schmidlii</i> Schiner, 1853	–	Turkey (Aktaş and Hasbenli 1994)	Long-winged bats <i>Miniopterus</i> spp.	Carrier of virus from the family Rhabdoviridae (Aznar-Lopez et al., 2013)
<i>Nycteribia vexata</i> Westwood, 1835	–	Turkey (Aktaş and Hasbenli, 1994)	Mouse-eared bats	–

Table 2. (Contd.)

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
<i>Penicillidia conspicua</i> Speiser, 1901	—	Turkey (Aktaş and Hasbenli 1994)	Long-winged bats <i>Miniopterus</i> spp.	Carrier of virus from family Rhabdoviridae (Aznar-Lopez et al., 2013)
<i>Phthiridium biarticulatum</i> (Hermann, 1804)	—	Algeria (Bendjeddou et al., 2014)	Horseshoe microbats (Chiroptera: Rhinolophi- dae), predominantly greater horseshoe bat <i>Rhinolophus</i> <i>ferrumequinum</i> (Schreber, 1774)	—
<i>Basilia daganiae</i> Theodor and Moscona, 1954	—	Egypt (Theodor, 1956); Palestine (Theodor, 1967); Jordan (Benda et al., 2010) Cyprus (Bequaert, 1953; Theodor, 1967; Kock, 1974)	<i>P. kuhlii</i>	—
Insecta: Siphonaptera: Ischnopsyllidae				
<i>Ischnopsyllus octactenus</i> (Kolenati, 1856)	Rostov region, Astrakhan region (Zabashita et al., 2019; present article); Dagestan (present article)	Algeria (Bendjeddou et al., 2013, 2017); Tunisia (Beaucournu and Kock, 1996); Morocco (Quetglas et al., 2014); Iran (Maleki-Ravasan et al., 2017) Turkey (Aktaş 1987, 1990); Azerbaijan (Dubovchenko, 1968, 1969); Spain (Balearic Islands) (Quetglas et al., 2014)	Pipistrelles <i>Pipistrellus</i> spp.	Carry bacteria <i>Bartonella</i> sp. (Hornok et al., 2012)
<i>I. variabilis</i> (Wagner, 1898)*	Ul'yanovsk region (present article)	—	Pipistrelles <i>Pipistrellus</i> spp.	—
<i>I. intermedius</i> (Rothschild, 1898)	—	Azerbaijan (Dubovchenko, 1965, 1969)	Different species of simple nosed bats family: pond bat <i>M. dasycneme</i> (Boie, 1825), common pipistrelle <i>P. pipist-</i> <i>rellus</i> sensu stricto, serotine bat <i>Eptesicus serotinus</i> Schreber, 1774	—

Table 2. (Contd.)

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
<i>I. dolosus</i> Dampf, 1912	—	Azerbaijan (Dubovchenko, 1968, 1969)	Some mouse-eared bat species	—
<i>I. consimilis</i> (Wahlgren, 1904)	—	Turkey (Smit, 1954), Palestine (Theodor and Moscona, 1954; Hopkins and Rothschild, 1956); Egypt (Lewis 1962; Hoogstraal and Traub, 1963; Haas and Tomich, 1973) Israel (Hopkins and Rothschild, 1956) Lebanon (Lewis, 1962) Lybia (Hürka, 1982)	Pipistrelles <i>Pipistrellus</i> spp.	—
<i>Nycteridopsylla eusarca</i> Dampf, 1908	—	Czechoslovakia (Rosický, 1957)	Common noctule <i>N. noctula</i> (Schreber, 1774)	Carrier of bacteria <i>Rickettsia helvetica</i> Beati et al., 1993 (Hornok et al., 2012)
<i>N. pentactena</i> (Kolenati, 1856)	—	Azerbaijan (Ioff et al., 1965; Dubovchenko, 1968, 1969) Algeria (Bendjeddou et al., 2017)	Long-eared bat <i>Plecotus</i> spp. and <i>Barbastella</i> spp.	—
<i>N. levantina</i> Jordan, 1942	—	Cyprus (Jordan, 1942)	Species is known on the basis of a single find	—
Insecta: Siphonaptera: Pulicidae				
<i>Xenopsylla cheopis</i> (Rothschild, 1903)	—	Palestine (Theodor and Moscona, 1954)	Rodents, predominantly rats, ( <i>Rattus</i> spp., <i>Nesokia</i> spp.) and gerbils (Gerbillinae)	Carry bacteria <i>Yersinia pestis</i> , causative agent of endemic typhus <i>Rickettsia typhi</i> (Wolbach and Todd 1920) Philip 1943 (Shrewsbury, 2005; Christou et al., 2010)
<i>Leptopsylla sengis</i> (Schoenherr, 1911)	—	Palestine (Theodor and Moscona, 1954)	Rats <i>Rattus</i> spp.	Carry bacteria <i>Rickettsia typhi</i> (Christou et al., 2010)



Table 2. (Contd.)

Ectoparasite	Finds in Russia	Finds outside of Russia	Principal hosts	Medical importance
Insecta: Hemiptera: Cimicidae				
<i>Cimex pipistrelli</i> (Jennyns, 1839)/ <i>Cimex</i> ex gr. <i>pipistrelli</i>	Rostov region (Zabashta et al., 2019)	Algeria (Bendjeddou et al., 2013, 2017)	Pipistrelles <i>Pipistrellus</i> spp.	Carrier of causative agents of tularemia <i>Francisella tularensis</i> (McCoy and Chapin 1912) Dorofe'ev 1947 (Zabashta et al., 2019)
<i>Cimex lectularius</i> Linnaeus, 1758	—	Lybia (Hufnagl, 1972); Iraq (Abul-Hab and Shihab, 1990)	Homeothermic animals, including humans	Carry bacteria <i>Francisella tularensis</i> ; causative agents of brucellosis <i>Brucella</i> sp., hepatitis B virus, tuberculosis <i>Mycobacterium tuberculosis</i> (Zopf 1883) Lehmann and Neumann 1896, salmonellosis <i>Salmonella typhi</i> , and anthrax <i>Bacillus anthracis</i> Cohn 1872 (Shestopalov et al., 2012)
<i>Cacodmus vicinus</i> Horváth, 1934	—	Turkey (Aktaş and Kiyak 1990); Cyprus (Quetglas et al., 2012); Syria (Quetglas et al., 2012); Lebanon (Usinger, 1966); Israel (Quetglas et al., 2012); Jordan (Usinger, 1966); Benda et al., 2010; Quetglas et al., 2012); Algeria (Bendjeddou et al., 2017) Egypt (Usinger, 1966; Quetglas et al., 2012); Lybia (Hürka, 1982) Tunisia (Usinger, 1966); Chad (Péricart, 1996)	<i>P. kuhlii</i>	—

\* Host-parasite association recorded for the first time. The table did not include finds of *Steatonyssus musculi* (Schränk, 1803) and *Steatonyssus murinus* Lucas, 1840 in Azerbaijan (Dubovchenko, 1968), inasmuch as currently these taxa are not considered valid.

**Table 3.** Pathogens isolated from the Kuhl's pipistrelle

Pathogen	Territory	Source	Diseases caused
Apicomplexa: Eimeriidae			
<i>Eimeria pipistrellus</i>	Saudi Arabia	Alyousif et al., 1999	Coccidiosis (eimeriosis)
<i>Eimeria chiropteri</i>		Alyousif, 1999a	
<i>Eimeria kuhliensis</i>		Alyousif, 1999b	
Bacteria: Spirochaetaceae			
<i>Borrelia</i> sp.	Rostov region, Russia	Zabashta et al., 2019	Lyme disease
<i>Borrelia afzelii</i>			
<i>Borrelia burgdorferi</i> s. l. genospecies <i>Borrelia afzelii</i>			
Anaplasmataceae			
<i>Ehrlichia</i> sp.	Rostov region, Russia	Zabashta et al., 2019	Ehrlichiosis
Francisellaceae			
<i>Francisella tularensis</i>	Rostov region, Russia	Zabashta et al., 2019	Tularemia
Virus			
Vaprio virus (VAPV) (Rhabdoviridae)	Italy	Lelli et al., 2018	–
Toscana virus (TOSV) (Bunyaviridae)		Verani et al., 1988	–
Alphacoronavirus (Coronaviridae)	Italy, Spain	Lelli et al., 2013 Falcón et al., 2011	–
Betacoronavirus (Coronaviridae)	Italy	Lelli et al., 2013	–
Orthoreovirus (Reoviridae)	Germany, Italy	Kohl et al., 2012 Lelli et al., 2012	–

individuals ranges from 56 to 100%. The next abundant species in our material flea *I. octactenus* is characterized by smaller infestation parameters (MI from 1 to 2, P from 18 to 100%). The remaining two species (tick *C. vespertilionis* and flea *I. variabilis*) are represented by isolated individuals.

Thus, according to our own and published data, 37 arthropods identified to species were recorded from the Kuhl's pipistrelle (mites, ticks, and insects), among which 36 are parasites (Table 2). In addition, 13 pathogenic microorganisms were isolated from this species over the past 20 years: three protozoan species (coccidia) of genus *Eimeria*, three groups of *Borrelia* (*Borrelia burgdorferi* s. l., *Borrelia afzelii*, and *Borrelia* sp.), *Ehrlichia* sp., *Francisella tularensis*, and five viruses belonging to four families (Rhabdoviridae, Bunyaviridae, Coronaviridae, and Reoviridae) (Table 3).

In faunistic terms, arthropods are represented by Acari, including 16 species from eight families of three orders, and insects, including 18 species from four families of three orders.

Apparently, only some of the arthropod finds are due to parasitism. Thus, nonparasitic *Kleemannia* sp. appears to be an accidental find, because these mites are associated with bees. A number of finds are artifacts (mites *Laelaps algericus*, *Dermanyssus gallinae*,

*Spinturnix psi*, *Meristaspis lateralis*, *Parasteatonyssus ca. nyctinomi*, and *Hyalomma dromedarii*; bat flies *Nycteribia schmidlii*, *Phthiridium biarticulatum*, *Penicillidia conspicua*; fleas *Xenopsylla cheopis* and *Leptopsylla sengis*). At the same time, these finds, in particular, characterize active contacts of the Kuhl's pipistrelle with other bat species, as well as vertebrates from other classes (birds) and orders (primarily, domestic animals, such as rats and mice). In this case, the Kuhl's pipistrelle acts as a primary host (or one of these hosts) only for 11 species of ectoparasites (five Acari and six insect species), the most abundant and common among which (Acari *St. periblepharus* and *C. vespertilionis*, fleas *I. octactenus* and *I. consimilis*, bat flies *B. daganiae*, and bugs *Cacodmus vicinus*) appear to form a core of ectoparasitic *P. kuhlii* fauna.

Data on parasites of this species in Russia is on a smaller scale. As few as six arthropod species (three Acari and three insect species) and three taxa of pathogens were similarly recorded by us earlier, which can be attributed to insufficient knowledge about this host. Interestingly, all ectoparasitic species recorded in Russia are common to *Pipistrellus* spp. without being exclusively specific to *P. kuhlii*. As range of the bats expands northward, the core of their ectoparasitic fauna can be assumed to undergo a series of changes in

that, in particular, highly host-specific species are lost. The latter include ectoparasitic insects typical to the Kuhl's pipistrelle, such as bat fly *Basilina daganiae*, flea *Ichnopsyllus consimilis*, and bug *C. vicinus*, the finds of which outside of the Mediterranean are unknown. All of the three listed species are transient ectoparasites sensitive, among other factors, to environmental parameters. Therefore, lack of the ecologically adequate conditions in their shelters and, primarily, not sufficiently high temperature can explain allocation (confinedness) of these insects to the ancestral range of *P. kuhlii*. In actual fact, outside of the Mediterranean, the core of ectoparasitic fauna of this host is represented only by pipistrelle genus-specific parasites (Acari *St. periblepharus* and *C. vespertilionis* and flea *I. octactenus*). Our finding from the Kuhl's pipistrelle of flea *I. variabilis* common to temperate belt of Europe, stretching from the Atlantic region to Urals, and not seen within the ancestral range of this host suggests that *P. kuhlii* can enter a spectrum of hosts of extrinsic parasites from allied bat species.

Of particular concern are the multiple finds (including accidental encounters) from the Kuhl's pipistrelle of bat flies, which are vectors of various diseases, such as *C. vespertilionis*, *L. algericus*, *D. gallinae*, *X. cheopis*, and *Lept. sengis*, as well as data with respect to the its isolated pathogens. Presumably, *P. kuhlii* is involved in transmission of a number of bacteria harmful to humans, e.g., *Borrelia*, *Ehrlichia*, and tularemia agent, and coronaviruses, for which a possibility of transmission to humans was confirmed by the 2020 pandemic (Table 3). Along with this, it has acquired a status of abundant species in some areas, after having become established in, e.g., many cities of European Russia. Additionally, as a bat, the Kuhl's pipistrelle is characterized by all traits common to this group, such as a capacity to cover long distances (can potentially spread pathogens over considerable area) and active use of anthropogenic structures for day roosts and hibernation roosts; in other words, it has contacts with humans and synanthropic species, including the ones involved in circulation of the natural focus infections, such as rats and house mice, and has the possibility to exchange pathogens. Altogether this determines urgency for the further in-depth inquiry into the ecology and medical importance of the Kuhl's pipistrelle and associated parasites in Russia.

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#### COMPLIANCE WITH ETHICAL STANDARDS

*Conflict of interest.* The authors declare that they have no conflict of interest.

*Statement on the welfare of animals.* All experimental protocols were implemented in compliance with the guiding principles of the European Union for the care and use of animals (86/609/CEE) and in compliance with rules approved by the instruction of the Presidium of the USSR Academy of Sciences dated April 2, 1980, no. 12000-496, and the order of the Ministry of Higher Educational Institutions of the Soviet Union dated September 13, 1984, no. 22. Every effort was made to use the minimum number of animals necessary to obtain reliable scientific data.

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