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Review

Parasites, Bacteria and Viruses of the Edible Dormouse *Glis glis* (Rodentia: Gliridae) in the Western Palaearctic

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Abstract: An overview of the parasites, bacteria and viruses of *Glis glis* (Rodentia, Gliridae) inhabiting the Western Palearctic is given. A total of 85 articles published from 1895 to 2021 were reviewed and analysed in our study. According to the literature's data, 104 species associated with *G. glis* are recorded: 4 viruses, 8 Protozoa, 6 Cestoda, 6 Trematoda, 4 Nematoda, 1 Heteroptera, 2 Anoplura, 39 Siphonaptera and 34 Acari. The most studied group is ectoparasites. To a lesser extent, parasitic worms in G. glis were studied. There is very little data about the dormouse protozoans and viruses. The most studied parasites, viruses and protozoans of *G. glis* are in Germany, where 21 species were noted. The largest number of parasites was found in the dormouse in Russia (22), but of two groups only: helminths and ectoparasites. Only 20 out of 104 parasite species recorded in *G. glis* are host-specific. Most parasites (60 species) found in *G. glis* have a Palaearctic and cosmopolitan distribution. Three viruses, six species of protozoa and three helminths have veterinary and medical significance as potential pathogens of dangerous zoonoses. Also, many species of fleas, mites and ticks found on *G. glis* are vectors of a number of dangerous vector-borne diseases in humans and domestic and wild animals.

Keywords: ectoparasites; *Glis glis*; helminths; overview; protozoans; viruses; Western Palaearctic

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1. Introduction

Rodents (Rodentia), due to their number and species diversity, are important elements of natural ecosystems. Some species of rodents are widely distributed [1–7]. The European edible dormouse, *Glis glis* (Linnaeus, 1766) is one such species and is widespread across western Eurasia. This rodent species is found in most European countries and regions of western Asia: through northern Turkey to the Caucasus, northern Iran and Turkmenistan [8–11]. *Glis glis* is the largest member of the family Gliridae, arboreal rodent with a nocturnal lifestyle. This rodent has the longest period of hibernation among the mammals of Europe, up to 9 months [12].

It is known that small wild rodents play an important role in the life cycles of the helminths of carnivorous mammals and birds of prey in higher trophic levels. Small rodents are involved in maintaining natural foci of zoonoses—diseases dangerous to humans and animals [4,13–21]. In this regard, the study of the parasite fauna of *G. glis* is of great scientific (biodiversity monitoring) and practical importance (study of the dormouse's role in the spread and preservation of zoonoses).

The literature on parasites, viruses and protozoans of *G. glis* currently contains about 180 references, covering an approximately 200-year period. The first attempts to bring together data about the viruses, parasites and protozoans of *G. glis* were undertaken in the reviews by Rossolimo [22] and Kryštufek [23,24], which contained data on 64 species of ecto- and endoparasites found in the dormouse. Unfortunately, these reviews did not

include most papers not indexed in electronic databases, so they are still inaccessible to most researchers.

Therefore, the purpose of our study is to review the parasites, pathogens and symbionts associated with *G. glis* across the rodent range and to systematize all data about them taking into account recent conceptions.

Our overview is based on analysis of literature data on parasites, bacteria and viruses of the edible dormouse inhabiting the Western Palaearctic. We searched and selected relevant papers using the online international databases Scopus, Web of Science Core Collection and Google Scholar and the Russian scientific electronic library eLIBRARY.ru. Our searches covered the scientific literature published up to February 2022 with no time or language limits. To find studies on *G. glis,* the following search strings were used: Topic: [("Parasites" or "Helminths" or "Trematodes" or "Cestodes" or "Nematodes" or "Acanthocephalans" or "Ectoparasites" or "Siphonaptera" or "Fleas" or "Acari" or "Mites" or "Ticks" or "Viruses" or "Protozoa" or "Bacteria") and ("Dormouse" or "Edible dormouse" or "*Glis glis*" or "*Glis*" or "*Myoxus glis*" or "Gliridae")]. Both English and Russian characters were used to enter search strings in eLIBRARY.ru (a Russian database).

A number of articles for our review were taken from former USSR parasitological literature in Russian, which were not indexed in electronic databases. Literature sources were collected in public libraries: the National Library of Russia (St. Petersburg), M. Gorky Scientific Library of St Petersburg University and Samara Regional Universal Scientific Library. Analysis of literary sources was carried out on journal articles, conference papers, books and book chapters in the period from 1895 to 2021. Complementary data were obtained from reviews on the rodent parasites from the former USSR [13,25–33] and adjacent countries, such as Moldova [34], Bulgaria [35] and Belarus [36]. Data about the medical and veterinary significance of the viruses, protozoans and parasites found in *G. glis* are given according to the papers and reviews on this theme [13,17,37–56].

Recent parasite taxonomy is given according to the Fauna Europaea Database (https://fauna-eu.org/, (accessed on 18 February 2022)) [57], Global Cestode Database (http://tapewormdb.uconn.edu (accessed on 12 February 2022)) [58] and articles of Makarikov with co-authors [59–61].

2. Parasites, Bacteria and Viruses of *Glis glis* in the Western Palaearctic

At the present stage of research, 104 species (with subspecies) of viruses, protozoans, ectoparasites and helminths were recorded in *G. glis*: 4 viruses, 8 Protozoa, 6 Cestoda, 6 Trematoda, 4 Nematoda, 1 Heteroptera, 2 Anoplura, 39 Siphonaptera and 34 Acari.

2.1. Viruses of Glis glis

The study of viruses in *G. glis* has a short history spanning only the last decades. Four viruses of three families were found in the edible dormouse (Table 1).

Encephalocarditis virus (EMCV) is found in many species of wild and domestic animals in various regions of the world [49]. The host-specific *Polyomavirus* found in *G. glis* belongs to a group of DNA viruses that infect mammals, birds and fish [67,68]. *Hantaan orthohantavirus* (formerly known as *Hantaan virus*) is a negative-sense RNA virus species. The edible dormouse is a reservoir host for the *Hantaan orthohantavirus* (HTNV). *Dobrava-Belgrade virus* (also known as *Dobrava virus*), found in the edible dormouse, is common in the former Yugoslavia, Germany, Estonia, Slovakia, European Russia and other Eastern European countries [69]. All viruses have a European range (Table 1).

2.2. Protozoa of Glis glis

Eight protozoan species from the five families are known in the edible dormouse (Table 2).

Among the protozoa found in *G. glis*, *Borellia* spp. (family Spirochaetaceae) are most represented (four species). They belong to the *Borrelia burgdorferi* (Johnson et al., 1984) sensu lato species complex. The natural reservoir hosts of *Borrelia* are wild animals (rodents, birds

and deer). *Borrelia afzelii* and *B. bavariensis* are associated with rodents [45,72,78]. *Borrelia garinii* is better adapted to birds [79].

Table 1. Viruses of *Glis glis* in Western Palaearctic.

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Picornoviridae *Encephalocarditis virus* (EMCV)	E	small rodents	cause myocarditis, diabetes mellitus, reproductive disorders and nervous system damage	Italy	[62,63]
family Polyomaviridae *Polyomavirus*	E	*Glis glis*	—	Germany	[64]
Family Bunyaviridae *Hantaan orthohantavirus* (HTNV)	E	small rodents	main causative agent of Korean hemorrhagic fever in humans	Slovenia	[65]
Dobrava-Belgrade orthohantavirus (DOBV)	E	*Apodemus* mice	cause hemorrhagic fever with renal syndrome	Serbia	[66]

Note: E—Europe.

Table 2. Protozoa of *Glis glis* in Western Palaearctic.

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Borreliaceae *Borrelia afzelii* Canica et al. 1994	E	rodents,	causative agent of Lime disease (LD)	Croatia	[70]
		dormice		Germany	[71–74]
Borrelia garinii Baranton et al., 1992	E	birds	causative agent of LD	Germany	[72]
Borrelia bavariensis Margos et al., 2009	E	rodents, dormice	causative agent of LD	Germany	[72]
Borrelia miyamotoi Fukunaga et al., 1995	E	dormice	—	Germany	[72]
Family Rickettsiaceae *Rickettsia typhi* (Wolbach and Todd, 1920)	C	rodents	causative agent of murine typhus, an endemic human typhus	Slovenia	[75]
Family Yersiniaceae *Yersinia pestis* (Lehmann and Neumann, 1896)	C	wild and domestic animals (mainly rodents)	plague pathogen	Europe	[54]
Family Eimeriidae *Eimeria gliris* Musaev and Veysov, 1961	E	*Glis glis*	—	Azerbaijan	[76]
Family Francisellaceae *Francisella tularensis* (McCoy and Chapin 1912)	H	rodents, humans	pathogen of gram-negative coccobacillus, causative agent of tularemia	Switzerland	[77]

Note: E—Europe, C—Cosmopolitan, H—Holarctic.

The obligate intracellular bacteria *Rickettsia typhi* (Wolbach and Todd, 1920) is best known as the causative agent of an endemic human typhus that occurs worldwide [39]. This protozoan species can be transmitted to a mammalian host by the bite of an infected flea or louse [80].

In nature, carriers of the bacteria *Yersinia pestis* (Lehmann and Neumann, 1896) are about 300 species of wild and domestic animals, especially rodents (rats, marmots, ground squirrels, voles and gerbils). Despite the fact that the infection caused by *Y. pestis* is very

fatal for humans, for the edible dormouse, this bacteria species can qualify as a commensal or opportunistic microorganism [54].

The apicomplexan parasite *Eimeria gliris* Musaev and Veysov, 1961 and the aerobic bacterium *Francisella tularensis* (McCoy and Chapin, 1912) were also recorded in *G. glis* (Table 2). The intracellular parasitic protozoa *E. gliris* belongs to a group of host-specific parasites of *G. glis*. In addition, it is possible to find *Anaplasma* spp. rickettsia in *G. glis*, previously noted in other species of European glirids [22].

Two species of protozoa are cosmopolitans. One species has a Holarctic distribution. The distribution of five protozoan species is limited to Europe (Table 2).

2.3. Helminths of Glis glis

In total, 16 species of parasitic worms were recorded in *G. glis*: 6 Cestoda, 6 Trematoda and 4 Nematoda (Table 3). Most of the helminth species parasitise the edible dormouse at the mature stage (14 species). Only two species of helminths were noted at the larval stage: the trematode *Alaria alata* (Goeze, 1782) and the cestode *Mesocestoides lineatus* (Goeze, 1782), for which the dormice serve as paratenic hosts. The finding of a small number of larval stages of parasitic worms indicates an insignificant role of *G. glis* in the life cycles of helminths of vertebrates of high trophic levels.

Table 3. Helminths of *Glis glis* in Western Palaearctic.

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Dicrocoeliidae *Dicrocoelium dendriticum* (Rudolphi, 1819)	C	mammals (mainly ungulates)	causative agent of dicroceliosis of livestock	Belarus	[81]
Lyperosomum armenicum (Stcherbakova, 1942)	E	*Glis glis*	—	Armenia Belarus	[82] [36,81,83]
Family Brachylaimidae *Brachylaima recurva* (Dujardin, 1845)	P	small rodents	—	Russia	[84]
Family Plagiorchiidae *Plagiorchis elegans* (Rudolphi, 1802)	H	birds, small mammals, reptiles	—	Belarus	[36,81]
Family Lecithodendriidae *Lecithodendrium semen* (Kirschenblatt, 1941)	E	*Glis glis*	—	Belarus	[36,81,85]
Family Diplostomidae *Alaria alata* (Goeze, 1782), msc.	C	amphibians, reptiles, small mammals	causative agent of alariasis of farmed fur animals	Belarus	[86]
Family Hymenolepididae *Armadolepis myoxi* (sensu stricto) (Rudolphi, 1819) (syn.: *Hymenolepis sulcata* (von Linstow, 1879))	E	*Glis glis*	—	Switzerland Slovakia Croatia Hungary Spain Germany	[87] reported as *H. sulcata* [88–92] reported as *H. sulcata* [93] reported as *H. sulcata*, [94] [95] reported as *H. sulcata* [96,97] reported as *H. sulcata* [98,99] reported as *H. sulcata*

Table 3. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Armadolepis longisoma Makarikov, Stakheev and Tkach, 2018	E	*Glis glis*	—	Russia	[100] reported as *Armadolepis* sp. 1, [60,101]
Armadolepis genovi Makarikov and Georgiev, 2020	E	*Glis glis*	—	Bulgaria	[35] reported as *H. myoxi*, [61]
Armadolepis sp.	E	*Glis glis*	—	Russia	[84] reported as *H. myoxi*
Hymenolepididae sp.	E	—	—	Moldova Belarus Azerbaijan Ukraine Slovakia	[34,102] reported as *Hymenolepis horrida* (Linstow, 1901) [36] reported as *H. horrida* and *Rodentolepis straminea* (Goeze, 1782) [103] reported as *Hymenolepis diminuta* (Rudolphi, 1819) [104] reported as *R. straminea* [91] reported as *Rodentolepis* sp.
Family Mesocestoididae *Mesocestoides lineatus* (Goeze, 1782), tetrathyridia	P	reptiles, small mammals	cause mesocestidosis in humans, carnivores	Italy	[105]
Family Capillariidae *Pterothominx sadovskoi* (Morozov, 1956) (syn.: *Thominx sadovskoi* Morozov, 1956; *Armocapillaria sadovskoi* (Morozov, 1956))	P	small rodents	—	Belarus	[36,81,83]
Family Heligmonellidae *Paraheligmonina gracilis* (Leuckart, 1842) (syn.: *Heligmosomum gracile* (Leuckart, 1842); *Longistriata schulzi* Schachnasarova, 1949; *Longistriata elpatievskii* Schachnasarova, 1949)	WP	*Glis glis*	—	Russia Belarus Germany Bulgaria Ukraine Azerbaijan Armenia Croatia Spain Italy, France Slovakia	[84,100,101] [36,81,83,86] [106,107] [35] [104,108,109] [103,110] [111,112] [93,94] [96] [107] [88,89]
Family Rictulariidae *Rictularia cristata* (Frölich, 1802)	E	small rodents	—	Central Europe	[113–115]
Rictularia amurensis Schulz, 1927	P	small rodents	—	Belarus	[36,81]

Note: E—Europe, C—Cosmopolitan, H—Holarctic, P—Palaearctic, WP—Western Palaearctic.

Seven species (the trematodes *Lyperosomum armenicum* (Stcherbakova, 1942), *Lecithodendrium semen* (Kirschenblatt, 1941), the cestodes *Armadolepis myoxi* (Rudolphi, 1819), *Armadolepis longisoma* (Makarikov, Stakheev and Tkach, 2018), *Armadolepis genovi* Makarikov

and Georgiev, 2020, *Armadolepis* sp. and the nematode *Paraheligmonina gracilis* (Leuckart, 1842)) are host-specific parasites of the edible dormouse.

Trematode species are most represented in the helminth fauna of *G. glis*. The edible dormouse has six species of trematodes from five families: Dicrocoeliidae (2), Brachylaimidae (1), Plagiorchiidae (1), Lecithodendriidae (1) and Diplostomidae (1) (Table 3). Six species of cestodes of two families, Hymenolepididae (5) and Mesocestoididae (1) are recorded in *G. glis*. Only four species of nematodes from three families are noted in the dormouse: Capillariidae (1), Heligmonellidae (1) and Rictulariidae (1) (Table 3).

The most common species of helminths are the nematode *P. gracilis* and the cestode *A. myoxi*, which are noted in dormice in 12 and 6 countries, respectively (Table 3). The nematode *Rictularia cristata* is registered in *G. glis* in the countries of Central Europe. The trematode *L. armenicum* is recorded in two countries. Other species of helminths are found only in one country each (Table 3).

The following are some remarks on the taxonomy of helminths found in *G. glis*. Genov [35] considers that all noted and described *Lecithodendrium* spp. from glirids (including *L. semen*) are synonyms of *Lecithodendrium linstowi* (Dollfus, 1931), which has a wide morphological variability. In addition to *L. semen*, *Lecithodendrium dryomi* (Matsaberidze and Khotenovskiy, 1966) in Georgia, *Lecithodendrium granulosum* (Looss, 1907) in Ukraine and *L. linstowi* in Bulgaria were found in *Dryomys nitedula* (Pallas, 1778) [35,116–118].

A recent revision of hymenolepidids by Makarikov with co-authors [59–61] revealed that *G. glis* was reliably parasitized by three species of *Armadolepis*: *Armadolepis myoxi* (Rudolphi, 1819), *Armadolepis longisoma* (Makarikov, Stakheev and Tkach, 2018) and *Armadolepis genovi* (Makarikov and Georgiev, 2020). *Armadolepis* sp., found by Sosnina [84] in the Caucasus Nature Reserve (Russia) (reported as *Hymenolepis myoxi* (Rudolphi, 1819)), probably also belongs to species *A. longisoma*, described by Makarikov with co-authors [60] in the edible dormouse from the Republic of Adygeya (Caucasus). *Armadolepis myoxi* (Rudolphi, 1819) is one of the most common parasites of *G. glis*, recorded over most of the rodent's range. Two other species of the genus *Armadolepis* (*A. longisoma* and *A. genovi*) have local distributions—the Caucasus (Russia) and Bulgaria, respectively.

Other species of hymenolepidids, such as *Arostrilepis horrida* (Linstow, 1901) (reported as *Hymenolepis horrida* (Linstow, 1901) [34,36,102], *Hymenolepis diminuta* (Rudolphi, 1819) [103], *Rodentolepis straminea* (Goeze, 1782) [36,104] and *Rodentolepis* sp. [91], were previously recorded in *G. glis*. However, according to Makarikov [59], there was a misidentification of cestodes/misidentification of other *Armadolepis* species, or these were potentially undescribed species. For example, Makarikov [59] established that the specimen recorded by Merkusheva and Bobkova [119] in *Dryomis nitedula* in Belarus, originally identified as *R. straminea*, belongs to the genus *Armadolepis*.

The nematode *P. sadovskoi* is a parasite of many rodent species, recorded mainly in the territory of the former USSR [31,35]. Moravec [120] suggested that *P. sadovskoi* is synonymous with *Aonchotheca annulosa* (Dujardin, 1845), a parasite that is also commonly reported in small rodents in Europe.

Anderson [121] considers *Rictularia amurensis* as a synonym of *Rictularia cristata*. Molecular genetic studies are necessary to confirm the validity of these two species.

Noteworthy is the low helminth diversity in *G. glis* compared to other rodent species. The arboreal lifestyle and the predominantly herbivorous diet of these dormice with a small proportion of animal food cause their relatively low helminth infection. Low contact with the soil reduces the likelihood of contact of the edible dormouse with the invasive helminth eggs and larvae. The short annual period of the rodent's activity probably also affects infection with helminths. A long period of hibernation excludes the possibility of infection of dormice with helminths.

The helminth infection values of different *G. glis* populations vary widely. Because of this, Sosnina [84] noted a common high infection of the edible dormouse with helminths in the Caucasus Nature Reserve—92.5%. The nematode *P. gracilis* (prevalence of infection (*p*) = 86.2%; mean abundance (MA) = 31.6) and cestode Hymenolepididae sp., reported as

H. myoxis (p = 50.0%; MA = 6.8) are most often observed in the dormouse. The trematode *B. recurva* was recorded in only one dormouse in the amount of two specimens [84]. a host-specific parasite, the nematode *P. gracilis*, was most often found in the edible dormouse, noted in 80% of dormice in Armenia [111]. Only one parasite species, the nematode *P. gracilis* (reported as *Longistriata schulzi*), was found in *G. glis* from the Belovezhskaya Pushcha (Belarus); the infection rates were 53.9% and 14.8 [83]. Only two species of parasites were found in *G. glis* in Croatia: *Armadolepis myoxi* and *Paraheligmonina gracilis* [93,94]. Konjevic [93] reported a common helminth infestation of *G. glis*—63.7%. The common infection rate of the dormouse with helminths in Busch [94] was 87.2%.

At the same time, there are many studies that have not revealed infection of edible dormouse with helminths. Helminths were not found in the studied dormice in the studies of Bychovskaya-Pavlovskaya [122], Melnichenko and Panasenko [123] in Ukraine, Ershova [124] in the Caucasus Nature Reserve and Shaldybin [125] in the Mordovia Nature Reserve (Russia). In our studies of the parasite fauna in rodents from the Samarskaya Luka (Russia), we also did not find helminths in *G. glis* [126,127].

The distribution of about half of the helminth species (7) found in the dormouse is limited to Europe. Five species of helminths have a Palearctic distribution. Only one species is distributed in the Holarctic. Two species are cosmopolitan (Table 3).

2.4. Ectoparasites of Glis glis

In total, 76 species of ectoparasites were found on *G. glis*, belonging to Anoplura (2 species), Heteroptera (1), Siphonaptera (39) and Acari (34) (Table 4). Only eight species of ectoparasites are host-specific parasites of the edible dormouse: the lice *Schizophthirus gliris* (Blagoveshtchensky, 1965) and *Schizophthirus pleurophaeus* (Burmeister, 1839); the fleas *Myoxopsylla jordani* (Ioff and Argyropoulo, 1934) and *Myoxopsylla laverani* (Rothschild, 1911); and the mites *Hirstionyssus gliricolus* (Masan and Ambros, 2010), *Hirstionyssus paulisimilis* (Masan and Fenda, 2010), *Gliricoptes glirinus* (Canestrini, 1895) and *Radfordia gliricola* (Vesmanis and Lukoschus, 1978). Three species of ectopatasites are common parasites of arboreal rodents (squirrels and dormice): the fleas *Ceratophyllus sciurorum* (Schrank, 1803) and *Leptopsylla sciurobia* (Wagner, 1934) and the mite *Hirstionyssus sciurinus* (Hirst, 1921). The other 65 species of ectoparasites are accidental and facultative dormouse parasites, which parasitise many species of mammals and birds.

Table 4. Ectoparasites of *Glis glis* in the Western Palaearctic.

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Hoplopleuridae *Schizophthirus gliris* Blagoveshtchensky, 1965	E	*Glis glis*	—	Poland, Bulgaria, North Makedonia	[128,129]
Schizophthirus pleurophaeus (Burmeister 1839)	WP	dormice	—	West Europe, Belarus Hungary	[128,129] [130]
Family Cimicidae *Oeciacus hirundinis* (Lamarck, 1816)	P	birds (mainly swallows)	—	Slovenia Slovakia	[131] [132]
Family Pulicidae *Pulex irritans* Linnaeus, 1758	C	mammals (including humans), birds	vector of plague bacteria *Yersinia pestis*; intermediate host of the cucumber tapeworm *Dipylidium caninum* (Linnaeus, 1758), which cause helminthiasis in dogs and cats	Slovenia	[133,134]

Table 4. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Ceratophyllidae *Amalareus penicilliger* (Grube, 1851)	P	forest rodents	—	Ukraine	[135]
Leptopsylla taschenbergi (Wagner, 1898)	P	forest rodents, insectivores	—	Armenia Russia	[136] [137]
Leptopsylla segnis (Schönherr, 1811)	C	house mice, rats	vector of plague and tularemia	Croatia	[133,134]
Leptopsylla sciurobia (Wagner, 1934)	P	squirrels, dormice, *Apodemus* mice	—	Serbia	[133,134]
Peromyscopsylla bidentata (Kolenati, 1863)	P	forest rodents	—	Ukraine	[135,138]
Ceratophyllus sciurorum (Schrank, 1803)	P	squirrels, dormice	vector of tularemia	Russia Italy Germany Lithuania Serbia, Croatia, Montenegro, Slovenia, North Macedonia Bosnia and Herzegovina Ukraine Armenia Belarus Moldova Hungary Poland Bulgaria	[13,15,51,84,137,139–142] [105,143,144] [106,145,146] [147] [75,133,134] [75,133,134,148] [135,149] [136,150] [127,151] [34,102] [152] [153] [154]
Ceratophyllus sciurorum sciurorum (Schrank, 1803)	P	squirrels, dormice	—	Slovenia Germany	[75] [155]
Ceratophyllus rusticus Wagner, 1903	E	birds	—	Slovenia	[133,134]
Ceratophyllus carniolicus Brelih and Trilar, 2001	E	*Glis glis*	—	Slovenia	[156]
Ceratophyllus hirundinis (Curtis, 1826)	P	birds	—	Slovenia	[133,134]
Ceratophyllus gallinae (Schrank, 1803)	C	birds	—	Slovenia Germany Lithuania	[134] [155] [147]
Ceratophyllus borealis Rothschild, 1907	P, G	birds	—	Russia	[84]
Ceratophyllus (Monopsyllus) sp.	E	—	—	Slovenia	[134]
Dasypsyllus gallinulae gallinulae (Dale, 1878)	C	birds	—	Slovenia	[134]
Megabothris turbidus (Rothschild, 1909)	P	forest rodents	vector of viral hemorrhagic fever and tularemia	Ukraine Germany Russia Lithuania	[135,138,149] [155] [13,140] [147]
Megabothris walkeri (Rothschild, 1902)	P	forest rodents	vector of tularemia	Russia	[13,140]
Myoxopsylla jordani Ioff and Argyropoulo, 1934	E, I	dormice	—	Armenia Russia Georgia	[150] [51,84,141,142] [157]
Myoxopsylla laverani (Rothschild, 1911)	WP	dormice	—	Germany France	[145,146,155] [158]
Nosopsyllus consimilis (Wagner, 1898)	P	forest rodents	vector of plague and tularemia	Armenia Russia	[136] [13,140]

Table 4. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Nosopsyllus fasciatus (Bosc d'Antic, 1800)	C	house mice, rats	vector of the rat tapeworm *H. diminuta*	Serbia	[148]
Orchopeas howardi (Baker, 1895) (syn.: *Orchopeas wickhami* (Baker, 1895))	N	*Sciurus carolinensis* Gmelin, 1788	—	UK	[159]
Family Ctenophthalmidae *Ctenophthalmus wagneri* Tiflov, 1927	P	voles	vector of tularemia	Russia	[13,140]
Ctenophthalmus monticola (Kohaut, 1904)	E	insectivores	—	Serbia	[133,134]
Ctenophthalmus agyrtes (Heller, 1896)	E	*Apodemus* mice	vector of tularemia	Ukraine Germany	[135,138] [155]
Ctenophthalmus agyrtes ohridanus Wagner, 1939	E	small mammals	—	Croatia	[133,134]
Ctenophthalmus agyrtes wagnerianus Peus, 1950	E	small mammals	—	Slovenia	[133,134]
Ctenophthalmus proximus (Wagner, 1903)	E	small mammals	—	Russia	[137]
Ctenophthalmus assimilis (Taschenberg, 1880)	P	voles	—	Ukraine	[135]
Ctenophthalmus congener Rothschild, 1907	WP	small mammals	—	Slovenia	[133,134]
Ctenophthalmus nifetodes Wagner, 1933	E	*Dinaromys bogdanovi* (V. and E. Martino, 1922)	—	Bosnia & Herzegovina, Montenegro	[133,134,160]
Ctenophthalmus nifetodes brelihi Rosicky and Carnelutti, 1959	E	*Dinaromys bogdanovi*	—	Slovenia	[133,134,160,161]
Ctenophthalmus nifetodes tvrtkovici Brelih, 1986	E	*Dinaromys bogdanovi*	—	Croatia	[133,134,160]
Palaeopsylla soricis (Dale, 1878)	P	insectivores	vector and reservoir of tularemia	Germany Russia	[155] [13,140]
Doratopsylla dasycnema dasycnema (Rothschild, 1897)	P	insectivores	—	former Yugoslavia Germany	[162] [155]
Family Hystrichopsyllidae *Hystrichopsylla talpae* (Curtis 1826)	P	*Talpa europaea*	vector and reservoir of tick-borne encephalitis	Lithuania Russia	[147] [13,140]
Hystrichopsylla orientalis Smit, 1956	E	small rodents, insectivores	—	Lithuania	[163]
Hystrichopsylla orientalis orientalis Smit, 1956	E	small rodents, insectivores	—	Bosnia & Herzegovina	[133,134]
Family Ischnopsyllidae *Ischnopsyllus intermedius* (Rothschild, 1898)	E	bats	—	Germany	[155]
Family Laelapidae *Androlaelaps casalis* (Berlese, 1887) (syn.: *Haemolaelaps casalis* (Berlese, 1887)	C	birds	cause human dermatitis	Moldova Ukraine Belarus	[34,102] [138] [151]

Table 4. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Laelaps agilis C.L. Koch, 1836	P	forest mice, insectivores, carnivores	vector of plague, tularemia, hemorrhagic fever with renal syndrome (HFRS), tick-borne encephalitis, leptospirosis, brucellosis	Slovakia	[164]
Eulaelaps stabularis (C.L. Koch, 1836)	C	small mammals, birds	vector of tularemia, Q fever, tick-borne encephalitis, brucellosis, leptospirosis	Slovakia	[164]
Myonyssus gigas (Oudemans, 1912)	P	rodents, insectivores, carnivores	—	Slovakia	[164]
Haemogamasus horridus Michael, 1892	WP	rodents, insectivores, carnivores	—	Slovakia	[164]
Haemogamasus nidi Michael, 1892	H	rodents, insectivores, carnivores	vector of tularemia	Slovakia	[164]
Haemogamasus pontiger (Berlese, 1904)	C	rodents, insectivores, carnivores	—	Slovakia	[164]
Family Hirstionyssidae *Hirstionyssus sciurinus* (Hirst, 1921)	P	*Sciurus vulgaris*, *Glis glis*	vector of tularemia, tick-borne encephalitis, brucellosis, leptospirosis	Russia Slovakia	[13,140] [164]
Hirstionyssus gliricolus Masan and Ambros, 2010	E	*Glis glis*	—	Slovakia	[164]
Hirstionyssus paulisimilis Masan and Fenda, 2010	E	*Glis glis*	—	Slovakia	[164]
Hirstionyssus sunci Wang, 1962	P	small rodents, insectivores	cause human dermatitis	Slovakia	[164]
Family Glycyphagidae *Labidophorus talpae* Kramer, 1877	E	moles	—	Europe	[27]
Family Ixodidae *Ixodes (Ixodes) ricinus* (Linnaeus, 1758)	P	mammals, birds	vector of louping-ill virus of sheep, Lyme disease, ehrlichiosis (tick-borne fever) of cattle; transmits *Babesia* spp., which causes Redwater fever in cattle and sheep	Russia Moldova Ukraine Germany Belarus	[84] [34] [138,149] [71,73,165,166] [151]
Ixodes (Ixodes) acuminatus Neumann, 1901 (syn. *I. redikorzevi* Olenev, 1927)	P	rodents, insectivores, carnivores	vector of LD, tularemia, Q fever	Europe	[29]
Ixodes (Ixodes) laguri Olenev, 1929 (syn.: *I. laguri colchicus* Pomerantzev, 1948)	P	small rodents, hedgehogs, small carnivores	vector of plague and tularemia	Russia	[25,28,84]
Ixodes (Exopalpiger) trianguliceps Birula, 1895	P	rodents, insectivores, carnivores	vector of LD	Ukraine Germany	[138,149] [166]

Table 4. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Family Amblyommidae *Dermacentor marginatus* (Sulzer, 1776)	P	mammals, insectivores, small carnivores	vector of tick-borne Russian spring–summer encephalitis (TBRSSE), North Asian tick typhus	Croatia	[167]
Family Bdellidae *Bdella muscorum* Ewing, 1909	H	small mammals	—	Bulgaria	[168]
Cyta latirostris (Hermann, 1804)	C	small mammals	—	Bulgaria	[168]
Cyta coerulipes (Duges, 1834)	C	small mammals	—	Bulgaria	[168]
Family Myocoptidae *Glricoptes glirinus* (Canestrini, 1895) (syn.: *Myocoptes glirinus* Can. 1895)	WP	*Glis glis*	—	Germany Italy France Belgium Armenia Russia UK	[146,169] [170,171] [170,171] [172] [171,173] [174] [169]
Family Myobiidae *Radfordia (Graphiurobia) gliricola* Vesmanis and Lukoschus, 1978	WP	*Glis glis*	—	Germany Russia	[175] [176]
Family Trombiculidae *Ascoschoengastia latyshevi* (Schluger, 1955)	P	rodents, insectivores, birds	—	Europe	[33]
Leptotrombidium europaeum (Daniel and Brelih, 1959) (syn.: *Leptotrombidium intermedia europaea* Daniel and Brelih, 1959	P	rodents, insectivores	vector of rickettsiosis tsutsugamushi	former Czechoslovakia, former Yugoslavia, Bulgaria, Albania, Spain	[177]
Leptotrombidium sylvaticum Hushcha and Schluger, 1967	P	rodents, insectivores	vector of rickettsiosis tsutsugamushi	Ukraine	[149,178]
Miyatrombicula muris (Oudemans, 1910)	E	rodents, insectivores	—	Central and South Europe, Russia	[33]
Neotrombicula vernalis (Willmann, 1942)	WP	rodents, insectivores	vector of rickettsiosis tsutsugamushi	Austria	[177]
Neotrombicula austriaca Kepka, 1964	E	rodents, insectivores	vector of rickettsiosis tsutsugamushi	Bulgaria, Moldova	[33]
Neotrombicula inopinata (Oudemans, 1909) (syn.: *N. germanica* Willmann, 1952; *N. autumnalis germanica* (Willmann, 1952)	WP	rodents, insectivores, birds	vector of rickettsiosis tsutsugamushi, cause human trombiculiasis	Germany Ukraine	[33,146] [33,178]
Neotrombicula japonica (Tanaka, Kaiwa, Teramura & Kagaya, 1930) (syn.: *Trombicula dubinini* Schluger, 1955)	P	rodents, insectivores	vector of rickettsiosis tsutsugamushi	Ukraine	[33,149]
Neotrombicula nagayoi Sasa, Hayashi, Sato, Miura and Asahima, 1950	P	rodents	vector of rickettsiosis tsutsugamushi	Moldova	[34,179]
Neotrombicula vulgaris (Schluger, 1955)	E	rodents	vector of rickettsiosis tsutsugamushi	Ukraine	[149]

Table 4. *Cont.*

Species	Distribution	Host Range	Medical & Veterinary Significance	Country	References
Hirsutiella zachvatkini (Schluger, 1948) (syn.: *Trombicula zachvatkini* Schluger, 1948; *Neotrombicula zachvatkini*)	P	rodents	vector of diseases causes by *Rickettsia* spp.	Moldova Ukraine Russia	[34,102] [33,149,178] [13,140]
Schoutedenichia sp.	P	—	—	Moldova	[34]

Note: E—Europe, C—Cosmopolitan, H—Holarctic, P—Palaearctic, WP—Western Palaearctic, G—Greenland, I—Iran, N—Nearctic.

Many species of fleas, mites and ticks can parasitise hosts that are not specific to them [180,181]. Species of small mammals inhabiting the biocenosis largely determine the structure of flea and acari fauna. The habitation of animals of various systematic taxa in the same biocenosis leads to the fact that they have common ectoparasite species. The broad exchange of parasitic arthropods is a consequence of the contact of small mammals with each other and with birds and their nests. Sometimes, the main hosts of fleas, mites and ticks are not their specific hosts but animals that dominate in a biocenosis [180]. Most of the ectoparasites found in *G. glis* pass to the dormice from small mammals (Rodentia and Eulipotyphla).

Sucking lice (Anoplura) in *G. glis* are represented by two species from the family Hoplopleuridae (Table 4). Findings of *S. gliris* are limited to Eastern Europe. *Schizophthirus pleurophaeus*, parasitising all dormice of the family Gliridae, has been reported mainly in Western Europe [128,129]. The identification these louse species on *G. glis* is considered probable in Hungary [130].

Only one member of the order Hemiptera, *Oeciacus hirundinis* (Lamarck, 1816) from the family Cimicidae, was found in dormouse nests [131,132]. The swallow bug, *O. hirundinis*, is widespread in Europe [133]. *Oeciacus hirundinis* passes to *G. glis* when the rodent visits bird nests for rest or for feeding.

According to recent data, 33 species and 6 subspecies of fleas (Siphonaptera) from five families were recorded on *G. glis* (Table 4). The flea family Ceratophyllidae has the largest representation in the parasite fauna of *G. glis*—21 species. The family Ctenophthalmidae is represented by 13 species in the parasite fauna of *G. glis*. From the family Hystrichopsyllidae, three species were found on *G. glis*. The families Pulicidae and Ischnopsyllidae are represented by one species each (Table 4).

The specific flea of squirrels and dormice *C. sciurorum*, found on *G. glis* in 17 countries, is the most common parasite of the edible dormouse (Table 4). *Doratopsylla dasycnema* has been reported in the dormouse in seven countries. *Megabothris turbidus* has been registered on *G. glis* in four countries. *Ceratophyllus gallinae* and *M. jordani* are found on *G. glis* in three countries. Seven flea species were each recorded in two countries. The remaining 27 flea species were each registered in only one country (Table 4).

Currently, there are 34 species of mites and ticks from nine families associated with *G. glis* (Table 4). The most represented family, Trombiculidae, includes 12 species. Seven species of the gamasid mites from the family Laelapidae were recorded on *G. glis* (Table 4). The ixodid ticks of the family Ixodidae are represented by four species. Additionally, four species from the family Hirstionyssidae are noted on the dormouse. Three species of the snout mites of the family Bdellidae were found in the nests of dormice [168]. The families Myobiidae, Myocoptidae Glycyphagidae and Amblyommidae are represented by one species each (Table 4).

Findings of the rodent parasite *Neotrombicula nagayoi* Sasa, Hayashi, Sato, Miura and Asahima, 1950 on *G. glis* in Moldova [102,179] are doubtful and need revision, since this species is similar to closely related *N. inopinata* and *Neotrombicula obscura* Schluger and Davidov, 1967 [33].

Among the mites and ticks of *G. glis*, the most common parasite is the host-specific *G. glirinus*, which is noted in seven countries (Table 4). *Ixodes ricinus* and *L. europaeum* are each found in five European countries. *Androlaelaps casalis* is recorded on *G. glis* in three countries. The other 27 species of mites and ticks are found on the dormouse in one to two countries. The sites of the findings are not indicated for *L. talpae, I. acuminatus* and *A. latyshevi* (Table 4).

More than half of the ectoparasite species found on *G. glis* (41 species) have a Palaearctic distribution. The distribution of 21 species of dormouse ectoparasites is limited to Europe. Ten species are cosmopolitans. Only three species are distributed in the Holarctic. Additionally, one flea species has a Nearctic distribution (Table 4).

2.5. Distribution of the Research Effort on Parasites, Bacteria and Viruses of Glis glis among European Countries

Data on parasites, bacteria and viruses of various *G. glis* populations are mostly fragmentary and are associated with the study of only separate taxonomic groups. The ectoparasites of the edible dormouse were studied quite fully and in detail. From about 180 references, the data on ectoparasites (fleas, mites and ticks) contain about 70 papers and monographs (Table 4). This cannot be said for other taxonomic groups of helminths, viruses and protozoans. The parasitic worms of *G. glis* have been studied to a lesser extent. Slightly more than 40 articles and monographs on helminths of *G. glis* are known (Table 3). There are very few data about dormouse protozoa and viruses. The study of viruses in *G. glis* has a short history—the last 30 years (Tables 1 and 2).

To date, there are data of varying degrees of completeness on the parasites of *G. glis* inhabiting 27 European countries (Figure 1).

Of course, the figure does not reflect the entire diversity and distribution of viruses, bacteria or parasites of *G. glis* but only shows the results of research efforts in these countries aimed at studying one or a few systematic groups. The most fully studied viruses, protozoa, ectoparasites and helminths of *G. glis* are in Germany, where 21 species have been identified for the dormouse (Figure 1). Three taxonomic groups were studied in Slovenia (16 species), Croatia (10) and Italy (5). In most of the countries (23 out of 27 studied), the studies cover only one or two taxonomic groups of pathogens or symbionts (Figure 1). Ectoparasites and helminths were found in *G. glis* in 10 countries. In Russia, the greatest number of parasite species (22) related to these groups was identified. Endo- and ectoparasite fauna in *G. glis* were less diverse in Ukraine (16 species), Slovakia (15) and Belarus (13). In Serbia, ectoparasites (6) and viruses (1) of *G. glis* are known. Helminths and protozoa parasitising *G. glis* are studied in Switzerland (3 species) and Azerbaijan (3). There is only data about ectoparasites of the edible dormouse in other 10 countries (Figure 1).

So far, viruses have been detected in *G. glis* only in four European countries (Table 1, Figure 1). The most protozoan species were found in the edible dormouse in Germany (4 species). Only one bacteria species was found in each of the remaining five countries (Table 2, Figure 1).

The parasitic worms of the edible dormouse were studied in 15 countries (Table 3, Figure 1). The greatest number of helminths was noted in *G. glis* from Belarus, where nine species of parasites were found. Four species of helminths were registered in *G. glis* in Russia. Three species of helminths have been found in dormice from Slovakia. Two species of helminths are noted in *G. glis* in 10 countries (Table 3, Figure 1). Only one species of helminths is found in *G. glis* from Hungary and Moldova. Nematodes and cestodes are noted in almost all countries where helminths were studied, with the exception of Switzerland, Hungary and Moldova (for nematodes) and France and Armenia (for cestodes). Trematodes are found in *G. glis* only in three countries: Belarus, Armenia and Russia.

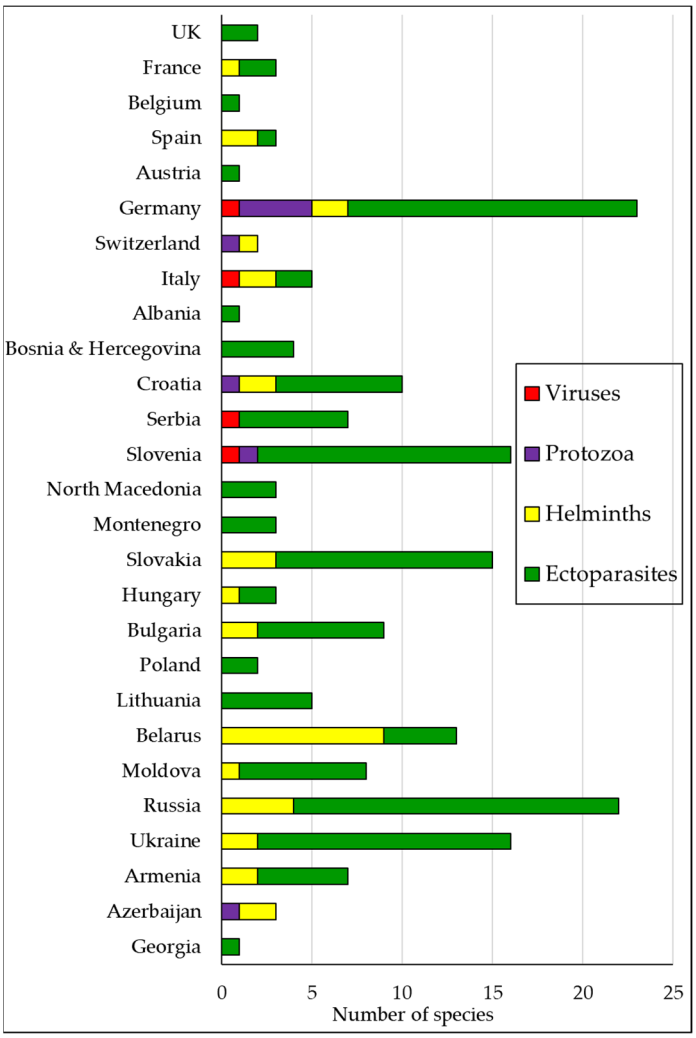

Figure 1. Number of species of parasites, bacteria and viruses found in *Glis glis* reflect different research efforts in various European countries.

Dormouse ectoparasites are observed in most countries (25) (Figure 1). Sucking lice are found on the edible dormouse in five countries. True bugs on *G. glis* were only reported in Slovenia (Table 4). Fleas were found on *G. glis* in 20 countries. Dormouse flea fauna is most represented in Slovenia (13 species), Russia (11) and Germany (9). The flea fauna is relatively less diverse in Ukraine (6), Serbia, Croatia and Lithuania (5 species each). Four species of fleas are found in the dormice from Armenia and Bosnia and Herzegovina. In Montenegro and North Macedonia, three and two species of fleas are found on the dormouse, respectively. In each of the other nine countries, *G. glis* has one flea species (Table 4).

Mites and ticks on *G. glis* are found in 17 European countries. The greatest diversity of acarine fauna is noted in Slovakia (11 species). In Ukraine and Russia, eight and four species of ticks are registered, respectively. Six species of ticks were found on the dormouse in each Germany and Moldova. Five species of Acari are found on *G. glis* in Bulgaria. Two species are noted on the dormouse in Belarus and Croatia. Only one species of tick or mite are each recorded on *G. glis* in nine countries (Table 4).

3. Conclusions

At the present period of study of *G. glis*, 104 species of parasites, bacteria and viruses are associated with the dormouse: 4 viruses, 8 Protozoa, 6 Cestoda, 6 Trematoda, 4 Nematoda, 1 Heteroptera, 2 Anoplura, 39 Siphonaptera and 34 Acari. The most studied group is

ectoparasites. To a lesser extent, parasitic worms in *G. glis* were studied. There are very few data regarding dormouse protozoans and viruses.

In the dormouse range, the most studied parasites, viruses and protozoans of *G. glis* are in Germany, where 21 species from all taxonomic groups were noted. The largest number of parasite species was found in the edible dormouse of the Russian fauna (22), but they belonged to only two groups: helminths and ectoparasites.

Among 104 species of viruses, bacteria and parasites found in *G. glis*, three viruses, six species of protozoa and three helminths have veterinary and medical significance as potential pathogens of dangerous zoonoses. Additionally, many species of fleas, mites and ticks found on *G. glis* are vectors and reservoirs of a number of dangerous vector-borne diseases in humans, domestic and wild animals.

Perspectives for further parasitological research: the study of unexplored taxonomic groups of viruses, protozoa and parasites associated with the dormouse as well as expanding the geography of research at the expense of unexplored regions. This is necessary to elucidate the role of the species as an alternative host of parasites, a supporting natural foci of zoocenoses and a possible method of infection of tree-dwelling herbivorous species as well as the organization of its biocoenotic relationships.

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