

Synopsis of the hard ticks (Acari: Ixodidae) of Romania with update on host associations and geographical distribution

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Abstract The current paper is a synoptic review of the distribution and host associations of the 25 species of hard tick fauna (family Ixodidae) in Romania. In addition to a full literature survey, original data is presented, based on eight years of occasional or targeted sample collection. The literature data on geographical distribution was transposed digitally to the decimal degree coordinate system. For each species, an updated distribution map is given together with all historical data and new host associations. Overall, our paper records 58 new tick-host associations for Romania: 20 for *Ixodes ricinus*, 1 for *I. apronophorus*, 6 for *I. arboricola*, 2 for *I. hexagonus*, 9 for *I. redikorzevi*, 1 for *I. trianguliceps*, 2 for *I. vespertilionis*, 2 for *Haemaphysalis punctata*, 1 for *H. sulcata*, 2 for *H. concinna*, 1 for

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D. marginatus, 4 for *Rhipicephalus sanguineus* sensu lato, 1 for *R. bursa* and 6 for *Hyalomma marginatum*.

Keywords Ixodidae · Romania · Tick fauna · Geographical distribution

Introduction

Ticks are medically important arthropods mainly because of their vectorial capacity. Hard-ticks are notorious as vectors of human and animal disease agents (protozoa, bacteria, viruses). They transmit a greater variety of infectious organisms than any other group of blood-sucking arthropods (Nicholson et al. 2009). Clarifying the host preferences and distribution of ticks is essential for understanding the complex ecological and epidemiological features of associated diseases. Few studies are available in Romania on the distribution and host preferences of hard ticks. Most of them are focused on domestic mammals with little data on wildlife hosts.

The only exhaustive review on hard-tick diversity in Romania was published more than 45 years ago (Feider 1965). According to Feider's review and subsequent new species records (Mironescu 1966; Georgescu 1968) there are 25 valid species (considering the taxonomic update by Guglielmone et al. 2010) of ticks for the fauna of Romania: *Ixodes ricinus*, *I. redikorzevi*, *I. laguri*, *I. arboricola*, *I. apronophorus*, *I. hexagonus*, *I. crenulatus*, *I. rugicollis*, *I. vespertilionis*, *I. simplex*, *I. trianguliceps*, *Haemaphysalis inermis*, *H. punctata*, *H. sulcata*, *H. parva*, *H. concinna*, *Dermacentor marginatus*, *D. reticulatus*, *Rhipicephalus annulatus*, *R. sanguineus* sensu lato (s.l.), *R. bursa*, *R. rossicus*, *Hyalomma aegyptium*, *H. marginatum*, and *H. scupense*. In addition, most of the data related to host associations and territorial distribution is rather old and available only in Romanian, thus not easily available to researchers for comparative studies. Moreover, similar synoptic papers were recently published for Portugal (Santos-Silva et al. 2011), Sulawesi (Durden et al. 2008), China (Chen et al. 2010) and Chile (González-Acuña and Guglielmone 2005).

Thus, the aim of the present study was to update the known information with new records on the host spectrum and to show the current geographical distribution data for all hard-tick species of Romania.

Materials and methods

Original data

Between February 2004 and October 2011, 4,745 ticks were collected from 597 individuals belonging to 58 host species (Mammalia, Aves, Reptilia) (Table 1) in various localities from Romania. Additionally, between March 2010 and September 2011, 14,041 ticks were captured by flagging from forest habitats in Romania (method adapted from Estrada-Peña 2001). All ticks were collected within the frame of a research project focused on tick-borne pathogens (manuscripts regarding prevalence and intensity on hosts and tick community structure on vegetation are in preparation). All ticks were deposited at the Department of Parasitology and Parasitic Diseases from the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. For all occurrences, GPS derived coordinates were recorded (latitude, longitude). All collection sites (n = 342) were located in the geographic limits of Romania and are shown on the maps from the results section.

Table 1 Host species with ticks included in the present study and the diversity of their tick communities

No	Host	Host individuals with ticks	Tick species recorded (stages)
Reptilia			
1.	<i>Emys orbicularis</i>	1	<i>I. ricinus</i> (N)
2.	<i>Lacerta agilis</i>	37	<i>I. ricinus</i> (F, N, L)
3.	<i>Lacerta viridis</i>	6	<i>I. ricinus</i> (F, N, L) <i>H. concinna</i> (N) <i>H. marginatum</i> (N)
4.	<i>Podarcis tauricus</i>	5	<i>H. concinna</i> (N) <i>H. marginatum</i> (L)
5.	<i>Testudo graeca</i>	44	<i>H. aegyptium</i> (M, F, N, L)
6.	<i>Zootoca vivipara</i>	1	<i>I. ricinus</i> (F, N, L)
Aves			
7.	<i>Acrocephalus arundinaceus</i>	1	<i>R. sanguineus</i> s.l. (F)
8.	<i>Carduelis carduelis</i>	1	<i>I. redikorzevi</i> (F)
9.	<i>Crex crex</i>	7	<i>I. ricinus</i> (N)
10.	<i>Cyanistes caeruleus</i>	2	<i>I. redikorzevi</i> (N) <i>I. arboricola</i> (L)
11.	<i>Erithacus rubecula</i>	8	<i>I. ricinus</i> (N, L) <i>I. arboricola</i> (N, L)
12.	<i>Fringilla coelebs</i>	3	<i>I. ricinus</i> (N, L) <i>I. redikorzevi</i> (N, L)
13.	<i>Garrulus glandarius</i>	1	<i>I. ricinus</i> (N)
14.	<i>Muscicapa striata</i>	2	<i>I. arboricola</i> (N) <i>H. marginatum</i> (N)
15.	<i>Parus major</i>	9	<i>I. ricinus</i> (N, L) <i>I. arboricola</i> (N, L) <i>I. redikorzevi</i> (N, L)
16.	<i>Phoenicurus ochruros</i>	1	<i>I. ricinus</i> (N)
17.	<i>Phoenicurus phoenicurus</i>	2	<i>I. arboricola</i> (N, L) <i>I. redikorzevi</i> (L)
18.	<i>Pica pica</i>	3	<i>I. ricinus</i> (F, N, L) <i>I. redikorzevi</i> (N, L)
19.	<i>Sturnus vulgaris</i>	3	<i>I. ricinus</i> (N, L)
20.	<i>Turdus merula</i>	25	<i>I. ricinus</i> (F, N, L) <i>I. arboricola</i> (N) <i>I. redikorzevi</i> (F)
21.	<i>Turdus philomelos</i>	2	<i>I. ricinus</i> (N, L)
22.	<i>Turdus pilaris</i>	1	<i>I. ricinus</i> (N, L)
Mammalia			
23.	<i>Apodemus agrarius</i>	17	<i>I. ricinus</i> (N, L)
24.	<i>Apodemus flavicollis</i>	23	<i>I. ricinus</i> (N, L) <i>I. apronophorus</i> (L) <i>R. sanguineus</i> s.l. (N, L)
25.	<i>Apodemus microps</i>	5	<i>I. ricinus</i> (N)

Table 1 continued

No	Host	Host individuals with ticks	Tick species recorded (stages)
			<i>I. redikorzevi</i> (M, F)
26.	<i>Apodemus sylvaticus</i>	4	<i>I. ricinus</i> (N, L)
27.	<i>Apodemus uralensis</i>	3	<i>I. ricinus</i> (L)
28.	<i>Arvicola terrestris</i>	2	<i>I. ricinus</i> (N, L)
29.	<i>Canis aureus</i>	4	<i>I. ricinus</i> (M, F) <i>H. punctata</i> (N) <i>R. sanguineus</i> s.l. (M)
30.	<i>Canis familiaris</i>	87	<i>I. ricinus</i> (M, F, N) <i>D. marginatus</i> (M, F) <i>R. sanguineus</i> s.l. (M, F, N)
31.	<i>Canis lupus</i>	2	<i>I. ricinus</i> (M, F)
32.	<i>Capra hircus</i>	15	<i>I. ricinus</i> (M, F) <i>D. marginatus</i> (M, F) <i>H. marginatum</i> (F)
33.	<i>Capreolus capreolus</i>	9	<i>I. ricinus</i> (M, F, N, L) <i>D. marginatus</i> (M, F)
34.	<i>Clethrionomys glareolus</i>	16	<i>I. ricinus</i> (L)
35.	<i>Crocidura leucodon</i>	1	<i>I. ricinus</i> (L)
36.	<i>Crocidura suaveolens</i>	6	<i>I. ricinus</i> (N, L)
37.	<i>Equus caballus</i>	4	<i>I. ricinus</i> (F) <i>D. marginatus</i> (M, F)
38.	<i>Erinaceus roumanicus</i>	31	<i>I. ricinus</i> (M, F, N, L) <i>H. punctata</i> (M, N) <i>D. marginatus</i> (N) <i>R. sanguineus</i> s.l. (N) <i>R. rossicus</i> (M, F, N, L) <i>Hyalomma marginatum</i> (N)
39.	<i>Felis catus</i>	29	<i>I. ricinus</i> (M, F, N)
40.	<i>Felis silvestris</i>	2	<i>I. ricinus</i> (F) <i>I. hexagonus</i> (F, N)
41.	<i>Homo sapiens</i>	57	<i>I. ricinus</i> (M, F, N, L) <i>D. marginatus</i> (M, F) <i>R. bursa</i> (N) <i>H. marginatum</i> (M)
42.	<i>Micromys minutus</i>	2	<i>I. ricinus</i> (F) <i>I. redikorzevi</i> (M)
43.	<i>Microtus arvalis</i>	14	<i>I. ricinus</i> (M, F, N, L) <i>D. marginatus</i> (M)
44.	<i>Microtus subterraneus</i>	2	<i>I. ricinus</i> (L) <i>I. trianguliceps</i> (F)
45.	<i>Mus spicilegus</i>	1	<i>R. sanguineus</i> s.l. (N)
46.	<i>Muscardinus avellanarius</i>	2	<i>I. ricinus</i> (N, L)
47.	<i>Mustela putorius</i>	1	<i>I. ricinus</i> (M, N)

Table 1 continued

No	Host	Host individuals with ticks	Tick species recorded (stages)
48.	<i>Myotis alcaethoe</i>	1	<i>I. vespertilionis</i> (N)
49.	<i>Neomys fodiens</i>	1	<i>I. ricinus</i> (L)
50.	<i>Ovis aries</i>	16	<i>I. ricinus</i> (F) <i>D. marginatus</i> (M, F) <i>H. marginatum</i> (M, F)
51.	<i>Rhinolophus euryale</i>	1	<i>I. vespertilionis</i> (N)
52.	<i>Rhinolophus ferrumequinum</i>	2	<i>I. vespertilionis</i> (N, L)
53.	<i>Sciurus vulgaris</i>	1	<i>I. ricinus</i> (N)
54.	<i>Sorex araneus</i>	8	<i>I. ricinus</i> (N, L)
55.	<i>Sorex minutus</i>	3	<i>I. ricinus</i> (N)
56.	<i>Spermophilus citellus</i>	2	<i>I. laguri</i> (F) <i>H. sulcata</i> (L)
57.	<i>Sus scrofa</i>	3	<i>I. ricinus</i> (M, F) <i>D. marginatus</i> (M, F)
58.	<i>Vulpes vulpes</i>	55	<i>I. ricinus</i> (M, F, N, L) <i>I. crenulatus</i> (F, N, L) <i>I. hexagonus</i> (F, N, L) <i>D. marginatus</i> (M, F)
	Total	597	

Abbreviations used for stages of ticks: *M* males, *F* females, *N* nymphs, *L* larvae

Tick identification and taxonomy used

Ticks were separated by developmental stage and gender (adults) and identified to the species level by using morphological keys (Pomerantzev 1950; Feider 1965; Nosek and Sixl 1972; Filippova 1977; Walker et al. 2000; Estrada-Peña et al. 2004) and descriptions (Filippova and Panova 2000; Apanaskevich and Horak 2008). All species names and accepted synonyms are updated in agreement with recent amendments in tick nomenclature (Horak et al. 2002; Barker and Murrell 2004; Guglielmone et al. 2009, 2010).

Processing of literature data regarding geographical distribution

All literature data on geographical distribution was introduced to a tabular database system (i.e. Microsoft Excel[®]), recording the tick species and geographical distribution (transposed to decimal degree coordinate system using Google Earth). All georeferenced data (from literature and original contributions) are included in a supplementary electronic material. Digital maps were created using ArcGis/ArcMap 9.2 (ESRI, 1999–2006).

Results

Nineteen species of ticks were collected from the 58 host species examined (Table 1). By flagging, we collected 11 species of ticks (Mihalca et al. in press). Overall, the total number of identified tick species was 21.

The tick-host associations reported by the current study together with literature data are shown in Table 2. Overall our paper records 58 new tick-host associations for Romania: 20 for *I. ricinus*, 1 for *I. apronophorus*, 6 for *I. arboricola*, 2 for *I. hexagonus*, 9 for *I. redikorzevi*, 1 for *I. trianguliceps*, 2 for *I. vespertilionis*, 2 for *Haemaphysalis punctata*, 1 for *H. sulcata*, 2 for *H. concinna*, 1 for *D. marginatus*, 4 for *Rhipicephalus sanguineus* s.l., 1 for *R. bursa* and 6 for *Hyalomma marginatum*.

Table 2 Host associations of hard ticks (Ixodidae) in Romania (underlined hosts are new records for Romania)

Species	Hosts
<i>I. ricinus</i>	Reptilia: <i>Lacerta agilis</i> ^{1,7,8,11,a} , <i>L. viridis</i> ^{1,a} , <i>Podarcis tauricus</i> ¹ , <i>Z. vivipara</i> ^{1,a} , <i>Emys orbicularis</i> ^a . Aves: <i>Phasianus colchicus</i> ¹ , <i>Perdix perdix</i> ¹ , <i>Meleagris gallopavo</i> ⁵ , <i>Falco tinnunculus</i> ¹ , <i>Crex crex</i> ^{11,a} , <i>Bombycilla garrulus</i> ¹ , <i>Pica pica</i> ^a , <i>Erithacus rubecula</i> ^a , <i>Luscinia megarhynchos</i> ¹ , <i>Phoenicurus ochruros</i> ^a , <i>Turdus merula</i> ^{1,11,a} , <i>T. pilaris</i> ^a , <i>T. iliacus</i> ¹ , <i>T. philomelos</i> ^{11,a} , <i>Sturnus vulgaris</i> ^{11,a} , <i>Fringilla coelebs</i> ^a , <i>Coccothraustes coccothraustes</i> ¹ , <i>Garrulus glandarius</i> ^a , <i>Parus major</i> ^{11,a} , <i>Emberiza citrinella</i> ¹ . Mammalia: <i>Homo sapiens</i> ^{1,4,5,10,a} , <i>Vulpes vulpes</i> ^{1,11,a} , <i>Canis aureus</i> ^{11,a} , <i>C. familiaris</i> ^{1,5,11,a} , <i>C. lupus</i> ^{11,a} , <i>Felis catus</i> ^{1,5,11,a} , <i>F. silvestris</i> ^a , <i>Mustela nivalis</i> ¹ , <i>M. putorius</i> ^a , <i>Sciurus vulgaris</i> ^{1,a} , <i>Spermophilus citellus</i> ¹ , <i>Muscardinus avellanarius</i> ^{1,a} , <i>Eliomys quercinus</i> ¹ , <i>Dryomys nitedula</i> ¹ , <i>Apodemus agrarius</i> ^{1,a} , <i>A. microps</i> ^a , <i>A. sylvaticus</i> ^{1,a} , <i>A. flavicollis</i> ^{1,a} , <i>A. uralensis</i> ^a , <i>Arvicola terrestris</i> ^{11,a} , <i>Clethrionomys glareolus</i> ^a , <i>Microtus arvalis</i> ¹ , <i>M. subterraneus</i> ^a , <i>Micromys minutus</i> ^a , <i>Oryctolagus cuniculus</i> ¹ , <i>Erinaceus roumanicus</i> ^{1,11,a} , <i>Sorex araneus</i> ^a , <i>S. minutus</i> ^a , <i>Crocidura leucodon</i> ^a , <i>C. suaveolens</i> ^a , <i>Neomys fodiens</i> ^a , <i>Bos taurus</i> ^{1,4,5} , <i>Capra hircus</i> ^{1,5,11,a} , <i>Ovis aries</i> ^{1,4,5,a} , <i>Capreolus capreolus</i> ^{11,a} , <i>Sus scrofa</i> ^{1,11,a} , <i>Equus caballus</i> ^{4,5,11,a} , <i>E. asinus</i> ⁵
<i>I. apronophorus</i>	Mammalia: <i>Micromys minutus</i> ¹ , <i>Apodemus agrarius</i> ¹ , <i>A. flavicollis</i> ^a
<i>I. arboricola</i>	Aves: <i>Erithacus rubecula</i> ^a , <i>Phoenicurus phoenicurus</i> ^a , <i>Turdus merula</i> ^a , <i>Sturnus vulgaris</i> ² , <i>Parus major</i> ^a , <i>Cyanistes caeruleus</i> ^a , <i>Muscicapa striata</i> ^a
<i>I. crenulatus</i>	Mammalia: <i>Vulpes vulpes</i> ^{1,a} , <i>Meles meles</i> ¹ , <i>Erinaceus roumanicus</i> ¹
<i>I. hexagonus</i>	Mammalia: <i>Vulpes vulpes</i> ^a , <i>Felis silvestris</i> ^a , <i>Mustela putorius</i> ¹
<i>I. laguri</i>	Mammalia: <i>Spermophilus citellus</i> ^{1,a} , <i>Mesocricetus newtoni</i> ¹ , <i>Spalax</i> sp. ¹
<i>I. redikorzevi</i>	Aves: <i>Pica pica</i> ^a , <i>Phoenicurus phoenicurus</i> ^a , <i>Turdus merula</i> ^a , <i>T. pilaris</i> ¹ , <i>Parus major</i> ^a , <i>Cyanistes caeruleus</i> ^a , <i>Carduelis carduelis</i> ^a , <i>Fringilla coelebs</i> ^a , <i>Passer domesticus</i> ¹ . Mammalia: <i>Mustela putorius</i> ¹ , <i>Spermophilus citellus</i> ¹ , <i>Cricetus cricetus</i> ¹ , <i>Microtus arvalis</i> ¹ , <i>M. agrestis</i> ¹ , <i>Apodemus agrarius</i> ¹ , <i>A. sylvaticus</i> ¹ , <i>A. microps</i> ^a , <i>A. flavicollis</i> ¹ , <i>Micromys minutus</i> ^a , <i>Spalax</i> sp. ¹ , <i>Erinaceus roumanicus</i> ¹
<i>I. rugicollis</i>	Mammalia: <i>Mustela putorius</i> ¹
<i>I. simplex</i>	Mammalia: <i>Rhinolophus ferrumequinum</i> ¹ , <i>Miniopterus schreibersii</i> ^{1,3}
<i>I. trianguliceps</i>	Mammalia: <i>Microtus arvalis</i> ¹ , <i>M. subterraneus</i> ^a , <i>Sorex araneus</i> ¹ , <i>S. alpinus</i> ¹ , <i>Talpa europaea</i> ¹
<i>I. vespertilionis</i>	Mammalia: <i>Rhinolophus ferrumequinum</i> ^{1,3,a} , <i>R. hipposideros</i> ³ , <i>R. euryale</i> ^a , <i>R. blasii</i> ³ , <i>Miniopterus schreibersii</i> ^{1,3} , <i>Myotis myotis</i> ³ , <i>M. alcaethoe</i> ^a
<i>H. inermis</i>	Mammalia: <i>Bos taurus</i> ¹ , <i>Ovis aries</i> ¹
<i>H. punctata</i>	Aves: <i>Meleagris gallopavo</i> ⁵ . Mammalia: <i>Homo sapiens</i> ^{4,10} , <i>Canis familiaris</i> ^{1,5} , <i>C. aureus</i> ^a , <i>Felis catus</i> ⁵ , <i>Microtus arvalis</i> ¹ , <i>Erinaceus roumanicus</i> ^a , <i>Bos taurus</i> ^{1,4,5} , <i>Ovis aries</i> ^{1,5} , <i>Capra hircus</i> ^{1,5} , <i>Equus caballus</i> ^{1,4,5} , <i>E. asinus</i> ⁵
<i>H. sulcata</i>	Reptilia: <i>Lacerta viridis</i> ¹ , <i>Podarcis muralis</i> ¹ . Mammalia: <i>Spermophilus citellus</i> ^a , <i>Bos taurus</i> ¹ , <i>Ovis aries</i> ^{1,5} , <i>Capra hircus</i> ¹ , <i>Equus caballus</i> ¹
<i>H. parva</i>	Reptilia: <i>Podarcis tauricus</i> ¹ . Aves: <i>Gallinago gallinago</i> ¹ . Mammalia: <i>Lepus europaeus</i> ¹ , <i>Bos taurus</i> ¹ , <i>Ovis aries</i> ¹ , <i>Capra hircus</i> ¹ , <i>Equus caballus</i> ¹

Table 2 continued

Species	Hosts
<i>H. concinna</i>	Reptilia: <i>Lacerta viridis</i> ^a , <i>Podarcis tauricus</i> ^a . Mammalia: <i>Homo sapiens</i> ^{4,10} , <i>Canis familiaris</i> ⁵ , <i>Mustela putorius</i> ¹ , <i>Apodemus sylvaticus</i> ¹ , <i>Lepus europaeus</i> ¹ , <i>Ovis aries</i> ^{1,5} , <i>Capreolus capreolus</i> ^{1,5} , <i>Equus caballus</i> ¹
<i>D. marginatus</i>	Aves: <i>Emberiza citrinella</i> ¹ . Mammalia: <i>Homo sapiens</i> ^{4,10,a} , <i>Canis familiaris</i> ^{11,a} , <i>Mus musculus</i> ¹ , <i>Microtus arvalis</i> ^a , <i>Erinaceus roumanicus</i> ^a , <i>Bos taurus</i> ^{1,4,5} , <i>Ovis aries</i> ^{1,4,11,a} , <i>Capreolus capreolus</i> ^{11,a} , <i>Capra hircus</i> ^{1,3,a} , <i>Sus scrofa</i> ^{1,11,a} , <i>Equus caballus</i> ^{1,4,5,11,a}
<i>D. reticulatus</i>	Mammalia: <i>Canis lupus</i> ¹ , <i>Bos taurus</i> ¹ , <i>Ovis aries</i> ¹ , <i>Capra hircus</i> ¹
<i>R. annulatus</i>	Mammalia: <i>Bos taurus</i> ^{1,4} , <i>Ovis aries</i> ¹ , <i>Equus caballus</i> ¹
<i>R. bursa</i>	Mammalia: <i>Homo sapiens</i> ^a , <i>Mustela putorius</i> ¹ , <i>Erinaceus roumanicus</i> ¹ , <i>Bos taurus</i> ^{1,a} , <i>Ovis aries</i> ^{1,a} , <i>Capra hircus</i> ¹ , <i>Equus caballus</i> ^{1,a}
<i>R. sanguineus</i> s.l.	Aves: <i>Acrocephalus arundinaceus</i> ^a . Mammalia: <i>Canis familiaris</i> ^{1,5,a} , <i>C. aureus</i> ^{11,a} , <i>Ondatra zibethicus</i> ¹ , <i>Microtus</i> sp. ¹ , <i>Apodemus flavicollis</i> ^a , <i>Mus spicilegus</i> ^a , <i>Erinaceus roumanicus</i> ^a , <i>Bos taurus</i> ^{1,5} , <i>Ovis aries</i> ^{1,3} , <i>Equus caballus</i> ⁴
<i>R. rossicus</i>	Mammalia: <i>Spermophilus citellus</i> ¹ , <i>Erinaceus roumanicus</i> ^{1,a}
<i>H. aegyptium</i>	Reptilia: <i>Testudo graeca</i> ^{1,6,9,a} . Mammalia: <i>Erinaceus roumanicus</i> ¹
<i>H. marginatum</i>	Reptilia: <i>Lacerta viridis</i> ^a , <i>Podarcis tauricus</i> ^a , <i>Vipera ammodytes</i> ¹ . Aves: <i>Gallus gallus</i> ¹ , <i>Athene noctua</i> ¹ , <i>Muscicapa striata</i> ^a , <i>Emberiza citrinella</i> ¹ . Mammalia: <i>Homo sapiens</i> ^a , <i>Canis familiaris</i> ^a , <i>Mesocricetus newtoni</i> ¹ , <i>Apodemus sylvaticus</i> ¹ , <i>Lepus europaeus</i> ¹ , <i>Erinaceus roumanicus</i> ^a , <i>Bos taurus</i> ^{1,4} , <i>Ovis aries</i> ^{1,4,11,a} , <i>Capra hircus</i> ^{1,11,a} , <i>Sus scrofa</i> ¹ , <i>Equus caballus</i> ^{1,4,a}
<i>H. scupense</i>	Mammalia: <i>Bos taurus</i> ^{1,5} , <i>Capreolus capreolus</i> ¹

(1) Feider (1965) (all references cited by Feider are included here)

(2) Mironescu (1966)

(3) Georgescu (1968)

(4) Teodorescu and Popa (2002)

(5) Chițimia (2006)

(6) Široký et al. (2006)

(7) Mihalca (2007)

(8) Majláthová et al. (2008)

(9) Široký et al. (2009)

(10) Briciu et al. (2011)

(11) Dumitrache et al. (2012)

^a Current study. Underlined binomials are new host records for Romania

Discussion

According to the literature review (Feider 1965; Teodorescu and Popa 2002; Ioniță 2003; Chițimia 2006; Briciu et al. 2011; Dumitrache et al. 2012) and our own observations, *I. ricinus* is the most widespread hard-tick species in Romania, both regarding its distribution range and host spectrum. Throughout its global distribution range, more than 300 host species have been recorded for *I. ricinus* (Anderson 1991). In Romania the reported hosts include 5 reptile species (1 new), 20 birds (7 new) and 38 mammals (12 new). Hence, our synopsis contributes with 20 new hosts for Romania. In Central Europe, Nosek and Sixl (1972) reported *I. ricinus* in 5 reptile species, 86 bird species and 53 mammal species.

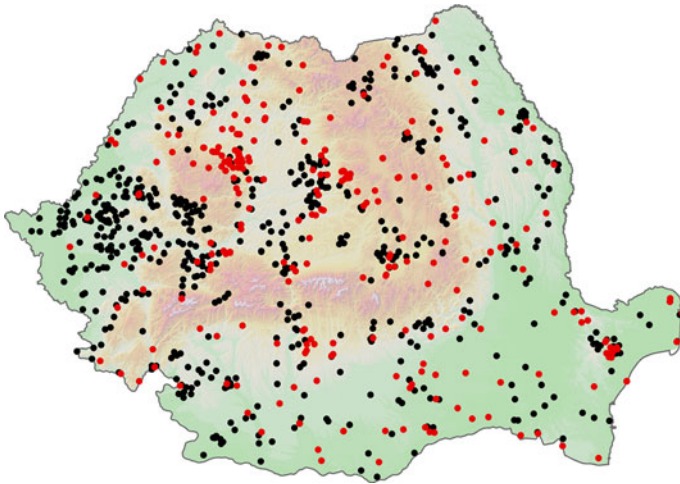


Fig. 1 Distribution of *I. ricinus* in Romania. *Black dots* show literature data (Feider 1965; Georgescu 1968; Teodorescu and Popa 2002; Ioniță 2003; Chițimia 2006; Majláthová et al. 2008; Coipan and Vladimirescu 2010; Ioniță 2010; Coipan and Vladimirescu 2011). *Red dots* show our original contribution. (Color figure online)

Among the new host records for *I. ricinus* in Romania given in this paper, the most interesting is the European pond turtle, *Emys orbicularis* which according to our knowledge is the first worldwide report. Although our data bring new locations to the geographical distribution of *I. ricinus* in Romania (Fig. 1), their significance is limited, as this ticks species is ubiquitous, but restricted to forest habitats or ecotone areas close to forested habitats (Mihalca et al. in press).

Ixodes apronophorus is a rodent specialist, with preferred hosts belonging to the Cricetidae family (Gilot et al. 1976). However, in Romania this tick species is reported only on rodents from family Muridae (table 2). In Central Europe, *I. apronophorus* was found on 6 species of rodents (Nosek and Sixl 1972). Despite of extensive studies on small mammals, it has been reported only sporadically in Romania (Fig. 2). However, its distribution range is probably larger than the actual records show.

The main hosts for *I. arboricola* are birds, which harbor all the developmental stages (Spitalská et al. 2011). Nevertheless, there are some reports from mammals in Great Britain (Martyń 1988) or China (Yu and Ye 1997). Prior to the current study, *I. arboricola* has been reported in Romania only from one location by Mironescu (1966). Our report lists six new host species for Romania and adds three new distinct geographical locations to its distribution range (Fig. 3).

Main hosts of all stages of *Ixodes crenulatus* are carnivores (mustelids and canids) and rodents (marmots) (Filippova 1977). In Romania the species has been found on three host species by Feider (1965), including carnivores and hedgehogs, *Erinaceus roumanicus*. Our results did not reveal new host records, but confirmed the fox, *Vulpes vulpes* as the main host in Romania. However, one uncommon finding in this study was the collection of this species from vegetation, by flagging. Prior to our study, *I. crenulatus* was known only from Eastern and Southeastern Romania (Feider 1965). We found it also in Central and Northwestern Romania as well in Danube Delta, showing this tick species is more widespread than previously thought (Fig. 4).

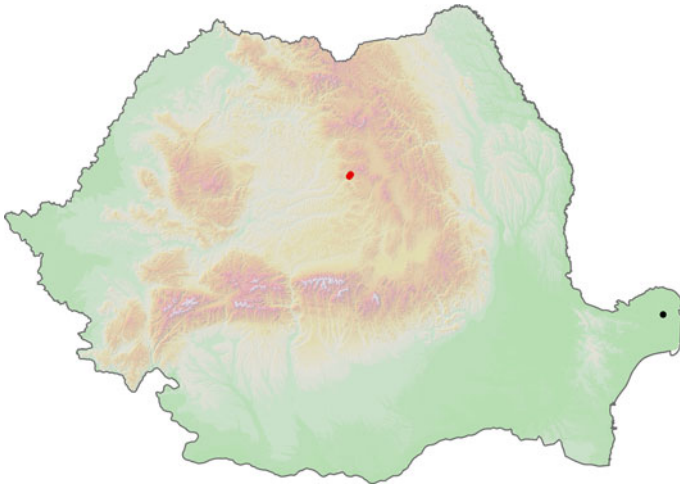


Fig. 2 Distribution of *I. apronophorus* in Romania. Black dot shows literature data (Feider 1965). Red dot shows our original contribution. (Color figure online)

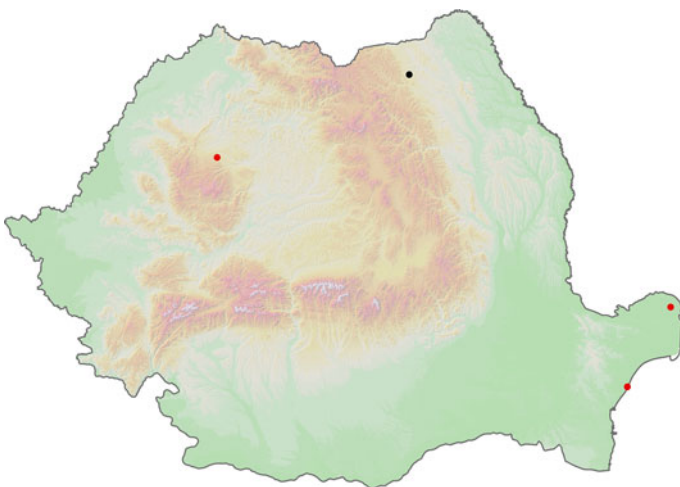


Fig. 3 Distribution of *I. arboricola* in Romania. Black dot shows literature data (Mironescu 1966). Red dots show our original contribution. (Color figure online)

Although there are numerous hosts reported for *Ixodes hexagonus* in Europe, the primary species used for feeding are carnivores and hedgehogs (Liebisch and Walter 1986; Lorusso et al. 2011). Prior to the current synopsis, *I. hexagonus* has been rarely reported in Romania (Feider 1965). Our new data list two new carnivore hosts and new geographical records in Eastern and Central Romania (Fig. 5).

Ixodes laguri is a burrow tick feeding almost exclusively on ground squirrels (*Spermophilus* spp.). In Romania the species was also found on other rodents (*Spalax* sp., *Mesocricetus newtonii*) but only in few locations (Feider 1965). Its distribution range in

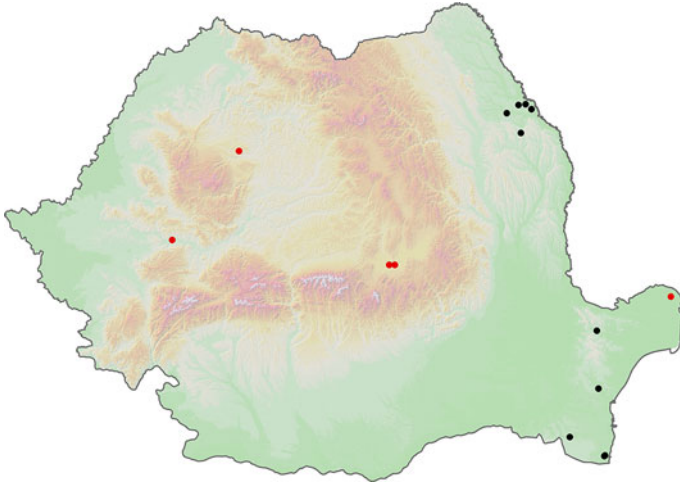


Fig. 4 Distribution of *I. crenulatus* in Romania. *Black dots* show literature data (Feider 1965; Georgescu 1968). *Red dots* show our original contribution. (Color figure online)

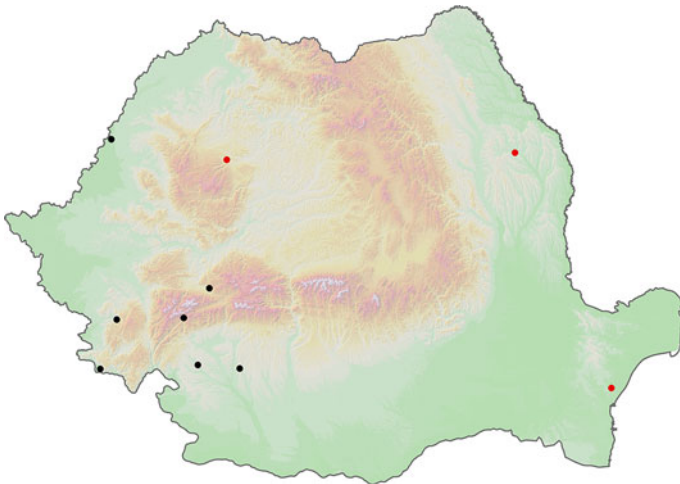


Fig. 5 Distribution of *I. hexagonus* in Romania. *Black dots* show literature data (Feider 1965; Georgescu 1968). *Red dots* show our original contribution. (Color figure online)

Romania (Fig. 6) probably overlaps with the distribution of the European souslik, *Spermophilus citellus*, one of its principal hosts. Interestingly, we have also collected it from vegetation by flagging in Southern Romania.

Ixodes redikorzevi, erroneously listed to be synonym with *I. acuminatus* by Kolonin (2009), is still considered valid by Guglielmone et al. (2010) based on the works of Filippova (1977). Although principal hosts are mammals (Emchuk 1967), our findings confirm that birds also play an important role in the life cycle of this tick. The role of birds as hosts for *I. redikorzevi* has been previously reported mainly for larvae by Emchuk (1967)

and Filippova (1977). In Romania, *I. redikorzevi* has been found on various mammals and birds (Feider 1965) but we report it in 7 new avian and 2 new mammalian hosts, all in the Danube Delta (Fig. 7).

Ixodes rugicollis is a rare tick species with mustelids being the primary hosts (Siuda et al. 2010). In Romania there is a single report on European polecat (Feider 1965), in the western part of the country (Fig. 8). Our studies did not reveal the presence of this species, probably because of the low number of the typical hosts sampled.

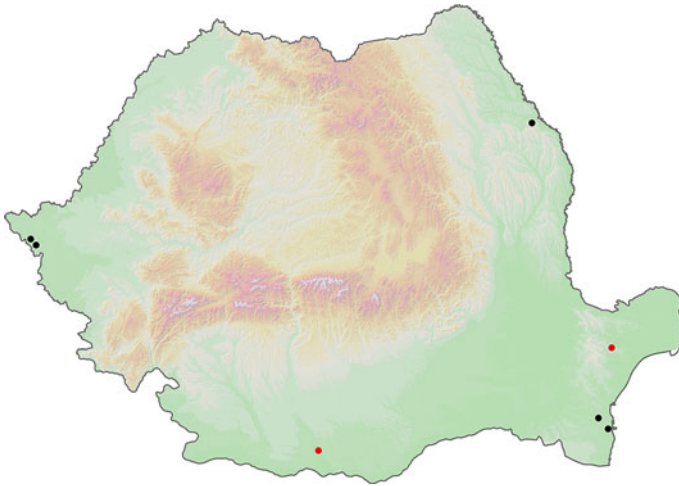


Fig. 6 Distribution of *I. laguri* in Romania. Black dots show literature data (Feider 1965). Red dots show our original contribution. (Color figure online)

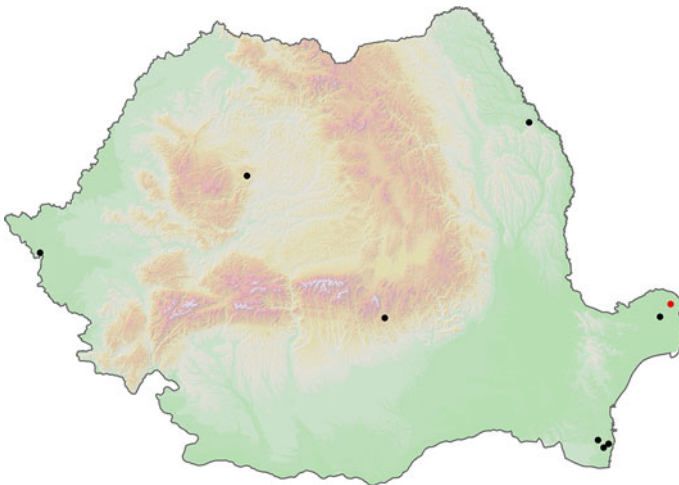


Fig. 7 Distribution of *I. redikorzevi* in Romania. Black dots show literature data (Feider 1965). Red dots show our original contribution. (Color figure online)

Ixodes simplex has been reported in Romania by Feider (1965). The principal host is the long-winged bat, *Miniopterus schreibersi* (Kolonin 2009), but other host species were also recorded in Europe, Africa (Arthur 1956) and China (Bush and Robbins 2012). Nevertheless, compared to *I. vespertilionis*, the other bat specialist tick reported in Romania, it seems that *I. simplex* has a narrower host spectrum (Table 2) and distribution (Fig. 9). Our studies did not reveal the presence of this species, but no bats from the principal host were examined.

Adults of *I. trianguliceps* feed almost exclusively on small mammals (Filippova 1977). The species has been reported in Romania sporadically by Feider (1965) on shrews, moles and rodents. We also report a new rodent host in Romania (Table 2, Fig. 10).

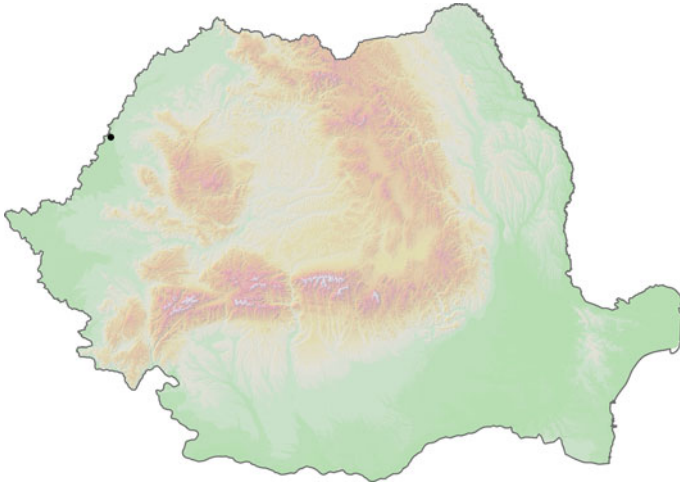


Fig. 8 Distribution of *I. rugicollis* in Romania. Black dot shows literature data (Feider 1965)

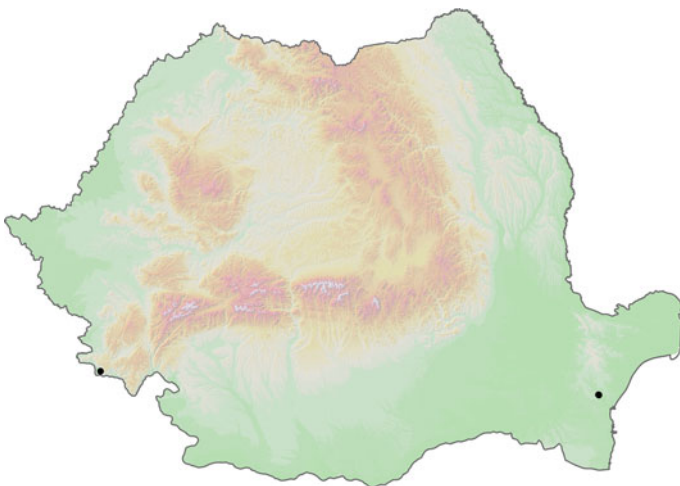


Fig. 9 Distribution of *I. simplex* in Romania. Black dots show literature data (Feider 1965; Georgescu 1968)

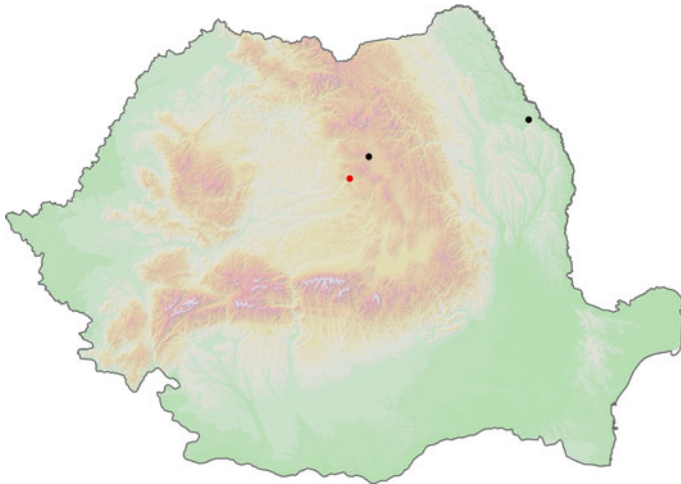


Fig. 10 Distribution of *I. trianguliceps* in Romania. Black dot show literature data (Feider 1965). Red dot shows our original contribution. (Color figure online)

Ixodes vespertilionis is the most widespread bat tick from Europe, being associated with several chiropteran species, mostly of the genus *Rhinolophus* (Arthur 1956). In Romania it has been reported on various bat species in numerous caves from Southwestern and Western part of the country (Georgescu 1968). We report it on two new chiropteran hosts in Romania, in the Southeastern Romania (Fig. 11).

Adults of *H. inermis* are ungulate specialists, but immature forms are found commonly on small mammals (Perez-Eid et al. 1993). In Romania, the species has been collected only on domestic ruminants (Feider 1965) in the outer Carpathian arch (Fig. 12). No new records are being reported by the present paper.

The main hosts for *H. punctata* are wild and domestic ruminants, but carnivores, hedgehogs, rodents and birds were also reported (Nosek 1971a). Most common hosts in Romania are domestic mammals (Feider 1965). We report it for the first time in hedgehogs and golden jackals. It is the most widespread species of its genus in Romania (Fig. 13).

Like the previous species, adults of *H. sulcata* use mainly livestock for feeding, but pre-imaginal stages parasitize small vertebrates like reptiles, birds and mammals (Filippova 1977). In Romania, the species was reported previously on lizards and domestic animals (Feider 1965). Our new host record is *Spermophilus citellus*. The species is confined to Southern Romania (Fig. 14).

In its adult stage, *H. parva* is parasitic on various mammals while immature stages feed on microvertebrates (Filippova 1977). In Romania, *H. parva* is distributed mostly in the Eastern (Moldavia) and Southeastern (Dobrogea) parts (Fig. 15).

Immature stages of *Haemaphysalis concinna* prefer insectivores, rodents, hares and birds while adults primarily feed on ungulates (Nosek 1971b). Its distribution in Romania is mainly in Western, Southwestern and Southeastern regions of the country (Fig. 16). Prior to the current report, it has been recorded only in mammals (Feider 1965), but we recorded it for the first time in Romania on lizards. To our knowledge, *Podarcis tauricus* is a first ever host record for this species.

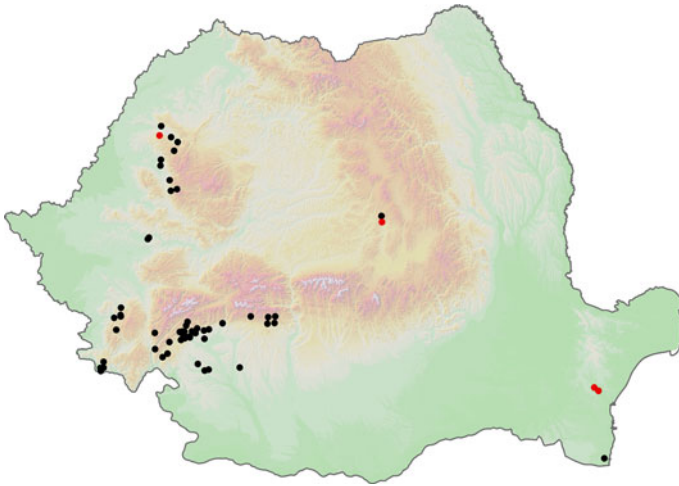


Fig. 11 Distribution of *I. vespertilionis* in Romania. *Black dots* show literature data (Feider 1965; Georgescu 1968). *Red dots* show our original contribution. (Color figure online)

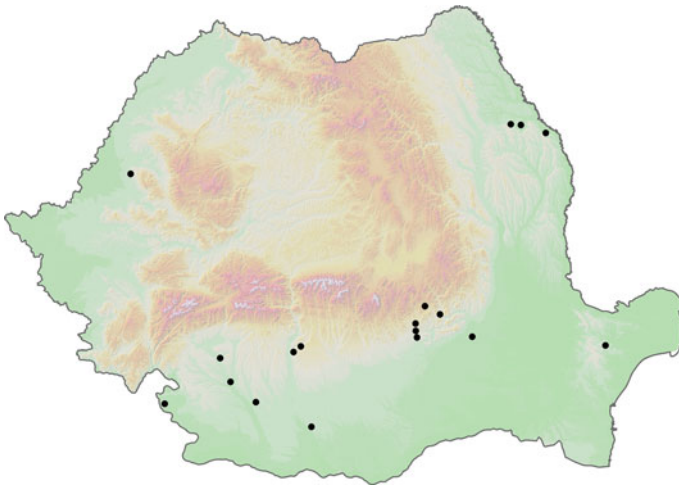


Fig. 12 Distribution of *H. inermis* in Romania. *Black dots* show literature data (Feider 1965)

Although *Dermacentor marginatus* is almost as widespread (Fig. 17) as *I. ricinus*, its host spectrum is significantly narrower (Nosek and Sixl 1972). In Romania, it is the second most common questing tick (Mihalca et al. in press). Two new hosts for Romania are reported for the first time in this study.

The distribution range of *D. reticulatus* has been reported to expand recently to higher latitudes and altitudes throughout central Europe, namely in Germany, Poland, Hungary and Slovakia (Široký et al. 2011). Nevertheless, our studies failed to confirm this range

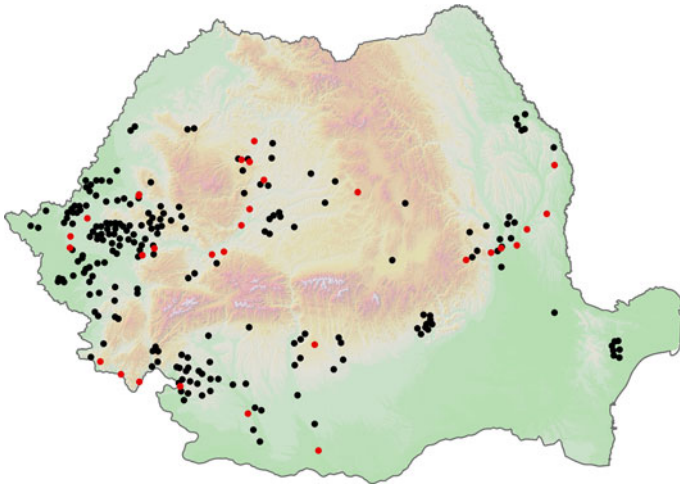


Fig. 13 Distribution of *H. punctata* in Romania. *Black dots* show literature data (Feider 1965; Teodorescu and Popa 2002; Chițimia 2006). *Red dots* show our original contribution. (Color figure online)

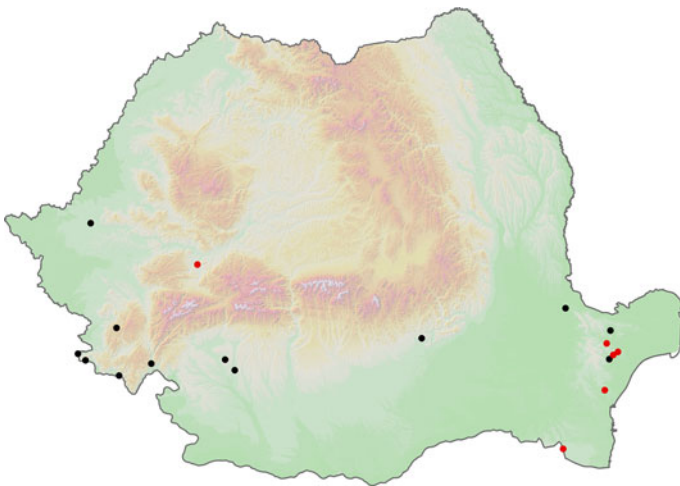


Fig. 14 Distribution of *H. sulcata* in Romania. *Black dots* show literature data (Feider 1965; Chițimia 2006). *Red dots* show our original contribution. (Color figure online)

extension for *D. reticulatus* in Romania (Fig. 18). Most common hosts reported are domestic mammals (Feider 1965).

Rhipicephalus annulatus was the type species of the former genus *Boophilus*, now a subgenus of *Rhipicephalus*. It is one of the most widespread hard tick in the world. It has a typical one-host life cycle, the main hosts being livestock and occasionally wild ungulates (Kolonin 2009). In Romania the species occurs in the plains from the southern part of the country (Fig. 19). No new locality or host records are provided by our study.

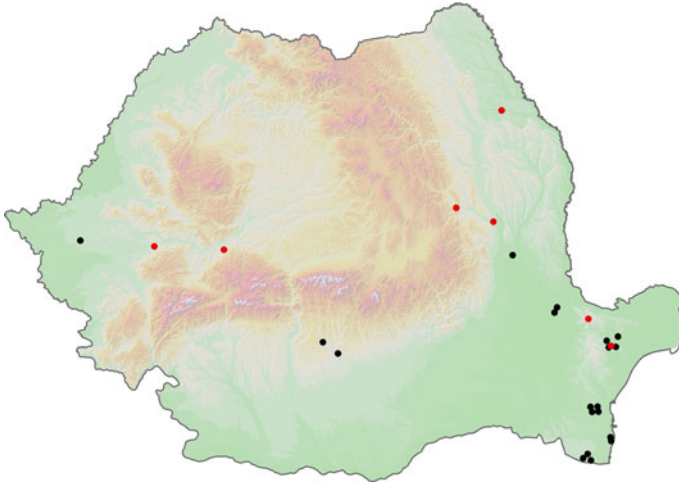


Fig. 15 Distribution of *H. parva* in Romania. *Black dots* show literature data (Feider 1965; Chițimia 2006). *Red dots* show our original contribution. (Color figure online)

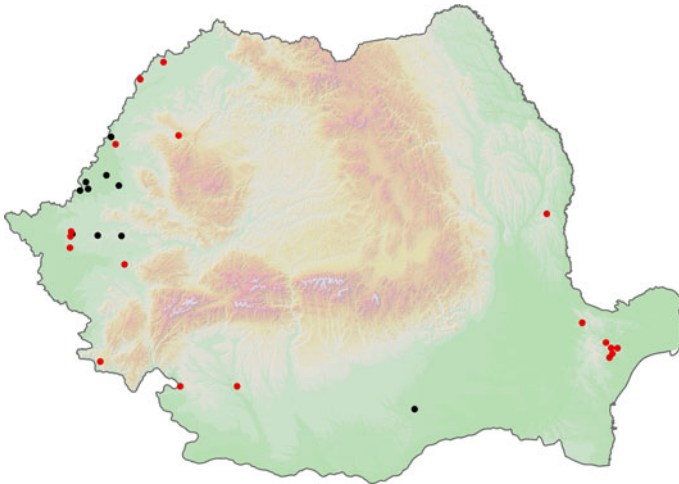


Fig. 16 Distribution of *H. concinna* in Romania. *Black dots* show literature data (Feider 1965; Chițimia 2006). *Red dots* show our original contribution. (Color figure online)

Adults of *R. bursa* prefer ruminants for feeding but also other domestic animals (equids, dogs), wildlife or human hosts were recorded. Its distribution is around the Mediterranean basin (Walker et al. 2000). In Romania we found this species on sheep, cattle and horses. Feider (1965) also reported *R. bursa* on wild mammals (hedgehogs, polecats). We report for the first time in Romania its occurrence on humans. Its distribution in Romania is restricted to the Southern lowland region but there are sporadic reports also from Central

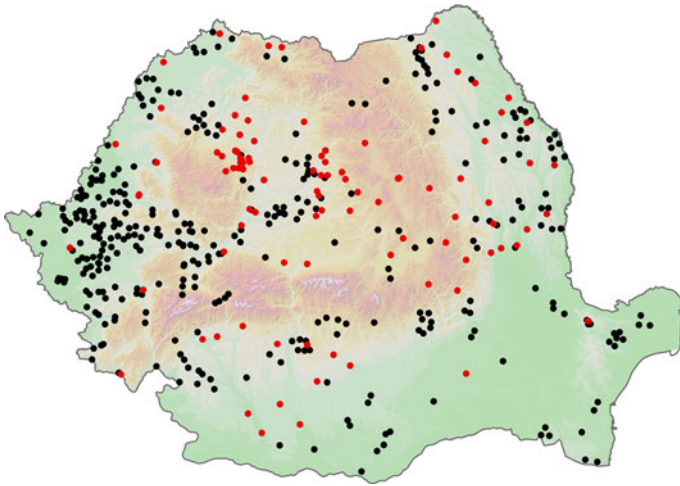


Fig. 17 Distribution of *D. marginatus* in Romania. *Black dots* show literature data (Feider 1965; Teodorescu and Popa 2002; Ioniță 2003; Chițimia 2006; Ioniță 2010). *Red dots* show our original contribution. (Color figure online)

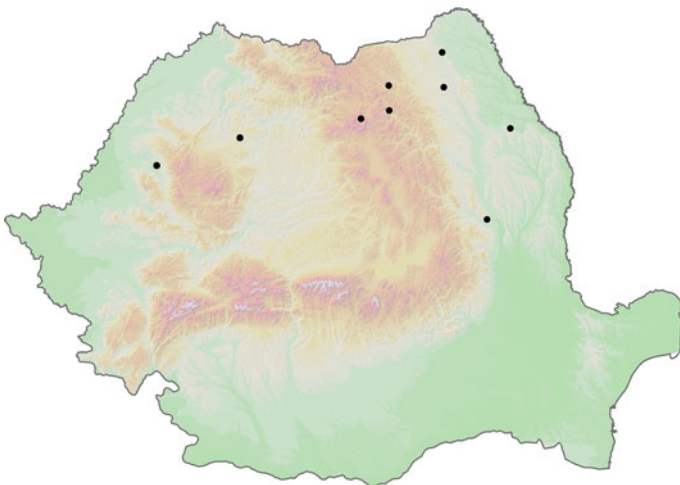


Fig. 18 Distribution of *D. reticulatus* in Romania. *Black dots* show literature data (Feider 1965)

and Northwestern parts, suggesting a possible colonization with transport of livestock (Fig. 20).

Rhipicephalus sanguineus s.l. is a tick with worldwide distribution that feeds primarily on dogs and occasionally on other hosts, including humans (Dantas-Torres 2008). In Romania, *R. sanguineus* s.l. was found on dogs, cattle, sheep, but also on wildlife mainly in Southern lowlands (Feider 1965; Chițimia 2006). Herein, we report as new host for Romania one bird and three mammalian species. We have also reported new geographic

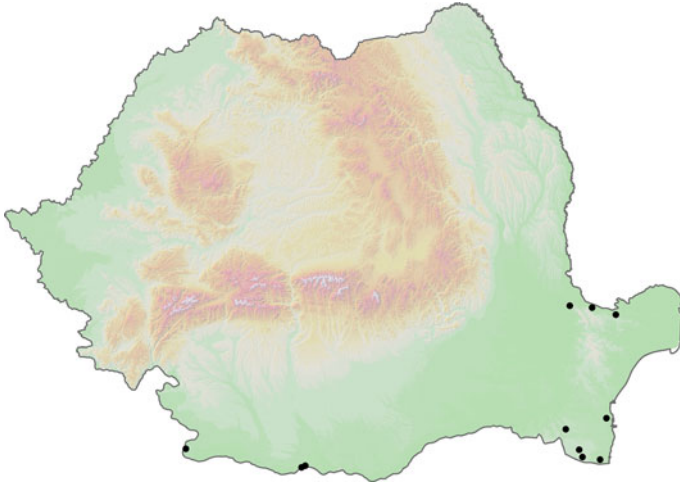


Fig. 19 Distribution of *R. annulatus* in Romania. *Black dots* show literature data (Feider 1965)

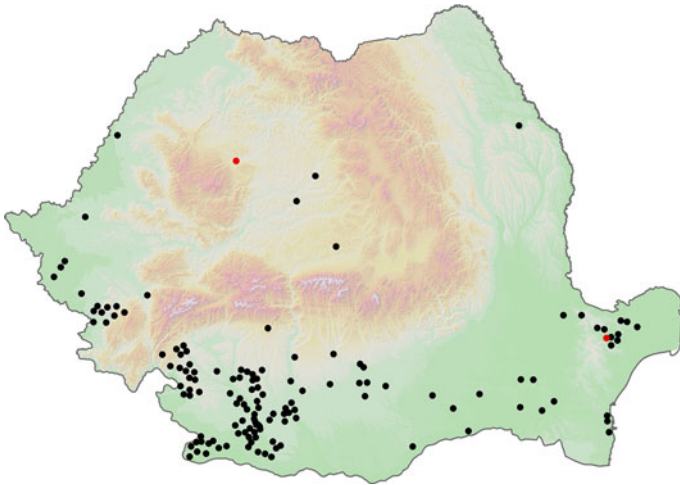


Fig. 20 Distribution of *R. bursa* in Romania. *Black dots* show literature data (Feider 1965; Ioniță 2003; Ioniță 2010). *Red dots* show our original contribution. (Color figure online)

areas for this tick in the Northeastern part of the country, in the Transylvanian basin (Fig. 21).

Rhipicephalus rossicus feeds on domestic animals, hedgehogs and occasionally on humans. It has a scattered distribution in Europe and Asia (Walker et al. 2000). In Romania, historical data (Feider 1965) showed its presence on small mammals; our findings report this species only in Southeastern Romania (Fig. 22) on hedgehogs.

Hyalomma aegyptium is strictly associated with land tortoises of genus *Testudo* (Široký et al. 2006, 2009). Its distribution in Romania is restricted to Dobrogea (Fig. 23), because

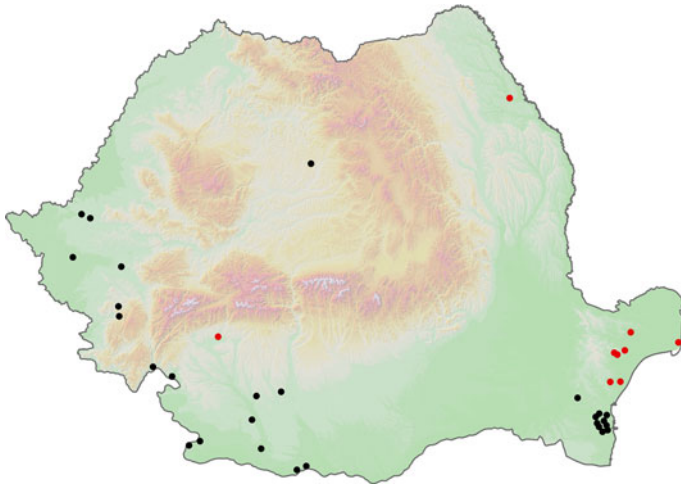


Fig. 21 Distribution of *R. sanguineus* s.l. in Romania. *Black dots* show literature data (Feider 1965; Chițimia 2006). *Red dots* show our original contribution. (Color figure online)

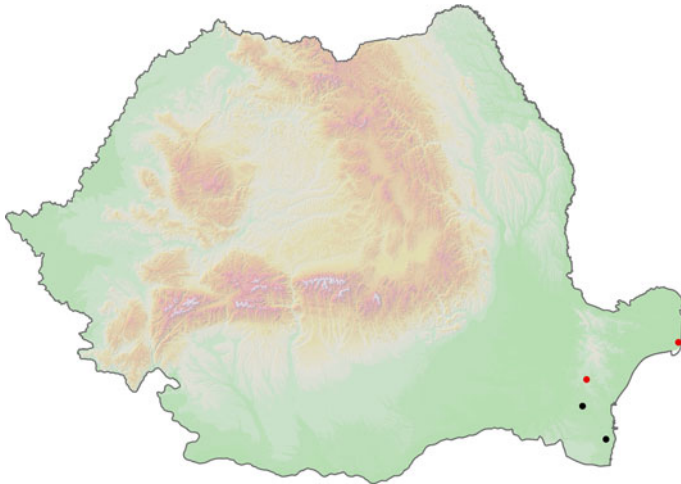


Fig. 22 Distribution of *R. rossicus* in Romania. *Black dots* show literature data (Feider 1965). *Red dots* show our original contribution. (Color figure online)

of its co-distribution pattern with its host. Accidental reports of Feider (1965) include hedgehogs.

The principal hosts of the adults of *H. marginatum* are various wild and domestic ungulates. It is a very widespread and prevalent tick of livestock in Southern Europe, Northern Africa and Central and Western Asia (Apanaskevich and Horak 2008). Its distribution in Romania is limited to Southern, Southeastern and Southwestern regions

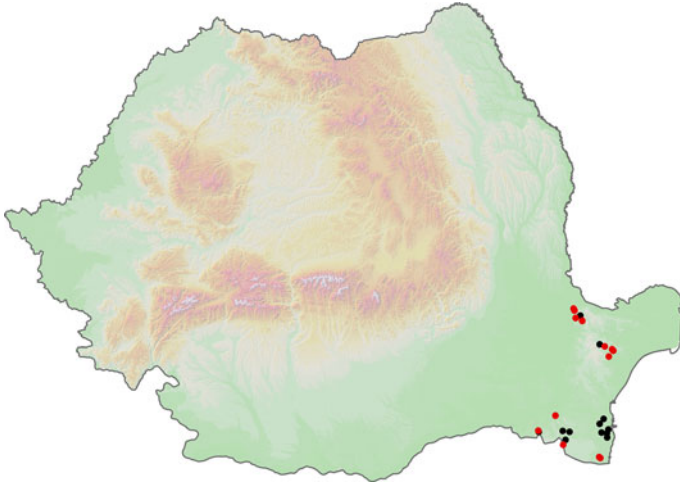


Fig. 23 Distribution of *H. aegyptium* in Romania. *Black dots* show literature data (Feider 1965; Široký et al. 2006). *Red dots* show our original contribution. (Color figure online)

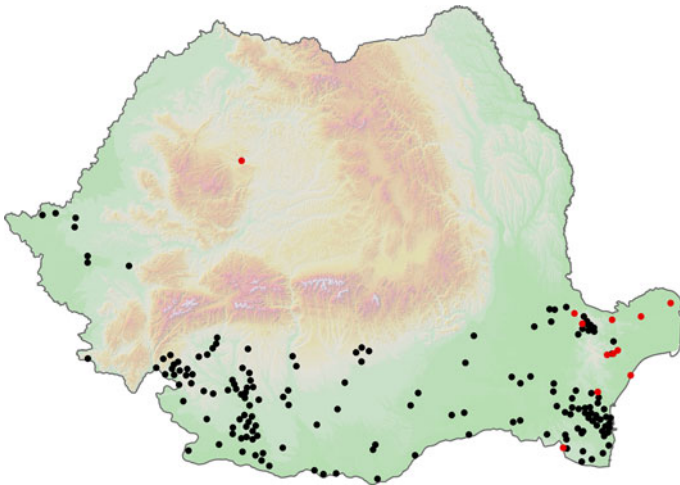


Fig. 24 Distribution of *H. marginatum* in Romania. *Black dots* show literature data (Feider 1965; Teodorescu and Popa 2002; Ioniță 2003; Ioniță 2010). *Red dots* show our original contribution. (Color figure online)

(Fig. 24). Interestingly, we found a single individual on a hedgehog captured in an urban area from Northwestern Romania. Moreover, we list 6 new hosts for Romania (including its occurrence on humans).

Hyalomma scupense has one of the largest distribution ranges amongst the *Hyalomma* ticks, extending from Western Europe and North Africa to Eastern China. Both the adults and the immature stages use large and medium-sized ungulates as hosts (Apanaskevich

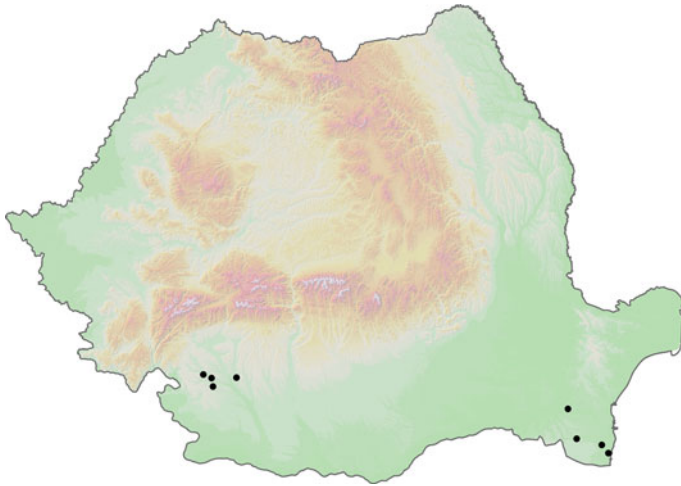


Fig. 25 Distribution of *H. scupense* in Romania. Black dots show literature data (Feider 1965; Chițimia 2006)

et al. 2010). In Romania, its range is restricted to the southern part of the country (Feider 1965) (Fig. 25).

Except the 25 species of hard ticks reported in Romania so far, at least three other are possibly present. The distribution of *Ixodes lividus*, a specific parasite of Sand martin, *Riparia riparia* overlaps with the one of its host (Filippova 1977; Peterson et al. 1993). *R. riparia* is a relatively common bird in Romania (Sándor pers. obs.), so the absence of this tick is probably because the lack of studies on the ectoparasites of this species. The same reason (lack of extensive studies on ticks of birds in Romania) is probably the reason why *Ixodes frontalis*, another common tick found on Passeriformes in the Western Palearctic (Filippova 1977) was not reported yet in this country. The absence of *Rhipicephalus turanicus* from Romanian reports is probably caused by misidentification with *R. sanguineus* s.l.

Habitat variety and available host diversity (Doniță et al. 2005), account for relatively high tick species diversity in Romania, as compared to neighboring countries (Koloinin 2009). Distribution maps and host spectrum show that the most widespread ticks in Romania are *I. ricinus*, *D. marginatus* and *H. punctata*. However, in southern Romania, thermophilic Palearctic species like *R. bursa* and *H. marginatum* are also common. Ticks specifically associated with their hosts (i.e. *H. aegyptium*; *I. laguri*) are co-distributed with them. One of the most interesting findings which highlight the importance of permanent monitoring of tick communities is the presence of *H. marginatum* and *R. bursa* in the Transylvanian basin. Previously these ticks were found in Romania only in the south, in regions with lower altitude and warmer climate. This increase in range (while crossing a large forested mountain buffer) is either a sign of frequent translocation of their hosts or a colonization process of new areas due to climate change.

We consider that our paper, together with its supplementary electronic material provides to researchers in tick-borne pathogen epidemiology and ecology a valuable tool for modeling and prediction.

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