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Stjepan Krčmar * and Roman Ozimec

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Article

Review of Hard Ticks (Acari: Ixodida: Ixodidae) in Underground Habitats in Croatia

Stjepan Krčmar [1,*] and Roman Ozimec [2]

[1] Department of Biology, Josip Juraj Strossmayer University of Osijek, Cara Hadrijana 8/A, 31000 Osijek, Croatia

[2] ADIPA Society for Research & Conservation of Croatian Natural Diversity, Orehovečki ogranak 37, 10040 Zagreb, Croatia

* Correspondence: stjepan@biologija.unios.hr; Tel: +385-31-399-922

Abstract

Between 1993 and 2024, 274 hard ticks (Ixodidae) were collected from 138 underground localities in Croatia. This study represents the most extensive survey of hard tick fauna in Croatian underground habitats to date. The collected hard ticks were classified into three genera and seven species. *Ixodes* was the most abundant genus, with five species, while *Haemaphysalis*, and *Hyalomma* were each represented by one species. The highest number of hard tick species was collected in underground habitats in Dalmatia, followed by north-western Croatia and Slavonia. *Ixodes vespertilionis* Koch, 1844 was the most abundant species in the collected sample, comprising 81.02%, and was recorded in all studied regions. Only *I. vespertilionis* was recorded throughout the year, while *I. hexagonus* was found in nine months, *I. frontalis* in four months, and the other species in shorter periods. The largest number of *I. vespertilionis* specimens was collected during the spring months (33.17%), while the fewest were collected in winter (16.58%). The discovery of *Ixodes lividus* Koch, 1844 in north-western Croatia represents a new country record, increasing the number of hard tick species currently known in Croatia to 28.

Keywords: hard ticks; Ixodidae; underground habitats; Croatia; taxonomy; biogeography

1. Introduction

Hard ticks (Ixodidae) are obligatory hematophagous ectoparasites of many vertebrate species from the classes Mammalia, Aves, Reptilia and Amphibia [1], and can transmit various bacteria, viruses, parasitic protozoa and helminths to a wide range of domestic and wild animals from these classes, including humans [2–4]. Their habit of blood-feeding and exploiting different hosts in the larval, nymphal, and adult stages increases the vector potential of ticks, making them the second most effective vectors of disease agents in animals and humans [5]. Hard ticks are widely distributed across all terrestrial biomes of the Earth [6]. Accordingly, ticks have been intensively studied worldwide in various natural ecosystems [7], as well as in numerous anthropogenic habitats such as urban green spaces and various agroecosystems [8–11]. Among the great diversity of existing biotopes, underground habitats (caves, semi-caves, pits) are notable for their specific microclimate, lighting, and the unique nature of their connections with other terrestrial ecosystems [12].

Despite the fact that underground habitats in Central Europe contain important vector groups of arthropods, such as hard ticks, taxonomically targeted and geographically widespread studies in these habitats are rare [13]. In Croatia, studies on the diversity of hard tick fauna and their vector potential in various natural ecosystems or anthropogenic habitats began in the first half of the last century and have continued to the present. This is confirmed by recent findings of several species from the genus *Ixodes* newly recorded in the Croatian fauna [14,15]. In Croatia, hard ticks have mainly been collected by the flag-dragging method over vegetation in various ecosystems, and manually from live or dead animals. However, data on the fauna of hard ticks from underground habitats are

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very scarce. The historical synthesis of mites in cave habitats began with the work of the second author in the last decade of the 20th century, resulting in several papers [16–19] presented here, supplemented but limited to hard ticks only. The first cavernicolous hard tick mentioned in Croatia was *Ixodes vespertilionis* (as *Eschatocephalus gracilipes*), found in the cave Trojama u Srijanima in Dalmatia by Umberto Girometta (1883-1939), gymnasium professor and speleologist from Split [20]. Faculty professor and entomologist August Langhoffer (1861-1940) from Zagreb repeated Girometta's finding and also reported the same taxon from a cave on Vis island (Spilja od Vore), the Varaždin region (Repnjak), and Medvednica Mt. (Žurenščak) [21]. The most important contribution to the Dinarides was the material collected by the renowned Moravian biospeleologist Karel Absolon (1877-1960) before the Second World War. This material was investigated by the German acarologist Carl Willmann (1881-1968), initially in short papers [22,23], and finally as the monograph Die Acari der Höhlen der Balkanhalbinsel [24]. In this monograph, four taxa have been reported for Croatia, partly determined by German acarologist Paul Leopold Ernst Schulze (1887-1949): *Ixodes vespertilionis* from seven caves, *Ixodes ricinus* from one cave on Mljet Island, *Ixodes hexagonus* from Vrlovka Cave near Kamanje, and *Hyalomma marginatum* from one cave in Istria [24]. This contribution represents the most extensive data on the hard tick fauna collected in underground habitats in Croatia since the Second World War. The aim of this study was to improve knowledge of the diversity of hard tick fauna in underground habitats in Croatia, and, for the first time, to analyze the abundance, distribution, and seasonal dynamics of the recorded species.

2. Materials and Methods

2.1. Study Area

2.1.1. Croatian Dinaric Karst, Caves, and Cave Habitats

Croatia is a south European, Mediterranean, Pannonian, Dinaric, and Balkan country, member of EU, in which karst covers approximately 26,000 km² of southern Croatia, including the islands. Croatia includes four large macro-tectonic entities: the Adriatic, Dinaric, Supradinaric, and Pannonian (Figure 1). The Dinarides represent about 46% of Croatia, but even 40% of the total Dinarides surface area (65,000 km²) (Figure 2). Research on the Dinaric karst began over 200 years ago, resulting in *locus typicus* for many karst phenomena, developed both on the surface and underground. Therefore, geologists refer to the Dinarides as the world's classical karst, with local, also Croatian karst terms such as *ponor, dolina, polje*, and *jama* now common in international geological vocabulary. Today, geopolitically, the Dinarides extend from north-eastern Italy and south-western Slovenia across Croatia, Bosnia and Herzegovina, through Montenegro, into north-western Albania, over a distance of approximately 700 km [19].

There are over 10,000 caves recorded in the Dinaric part of Croatia, and it is estimated that at least as many more exist. In other, non-Dinaric Croatian regions, there are only small areas of isolated karst or non-karstic caves. The majority, over 99% of Croatian caves, developed in limestone, dolomite bedrock, or a combination of both, mostly through the combined erosion and corrosion of water percolating through tectonically predominant limestone bedrock. In the Dinaric range, there are vertical caves (jama, potholes) up to 1.5 km deep (Lukina jama-Trojama, -1,431 m) and caves over 67 km long (Jamski sustav Crnopac cave system, 67,387 m). Thirty-one caves are protected by nature conservation legislation: 29 classified as geomorphological monuments of nature and two as paleontological sites [19]. More than 300 caves are protected as NATURA 2000 sites, and many more as part of larger protected polygonal Natura sites. The basic underground habitats according to the Croatian National Habitat Classification (NKS 5.0.), harmonized with the European Habitats Directive, are presented in Table 1 [19]. The most important habitat where hard ticks can be expected is at the first level, Karstic caves and pits; secondly, Terrestrial karstic cave habitats; and finally, Caves with subtroglophilic vertebrates. It should be noted that this classification should be improved, because, for example, in the same habitat, subtroglophilic vertebrates, troglophilic invertebrates, and

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troglobiotic invertebrates can be found, so terrestrial habitats should be more closely connected with ecological habitat features.

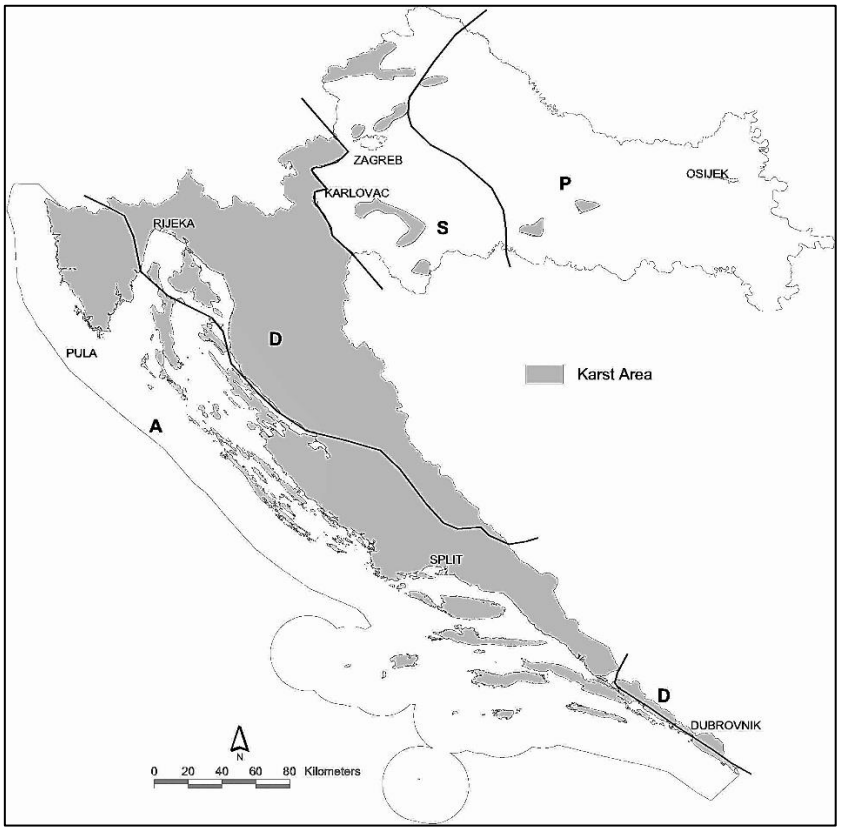

Figure 1. Simplified tectonic map of the Croatian Dinarides: A: Adriaticum, Adriatic carbonate platform; D: Dinaricum, carbonate platform; S: Supradinaricum, eudynamic area; P: Pannonian basin geological structures [19].

Figure 2. Dinaric karst area with the Adriatic Carbonate Platform (AdCP), based on outcrops and offshore data, with schematic geological column of the Dinaric Karst [25].

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Table 1. Croatian National Habitat Classification of underground habitats [19].

Type of underground habitat		
1. Karstic caves and pits	1.1. Terrestrial karstic cave habitats	Half-caves and cave entrances
		Dry fossil cave
		Caves with subtroglophilic vertebrates
		Caves with troglobiotic invertebrates
		Caves with troglophilic invertebrates
		Atroglozoocenotic caves
	1.2. Amphibian karstic cave habitats	Amphibian karst cave habitats (hygropetric, marifugial layers)
	1.3. Water (freshwater) karstic cave habitats	Underground flowing water
		Underground standing water
	1.4. Anchialine karstic caves	Anchialine karstic caves
	1.5. Sulphury karstic caves	Hydrothermal sulphury karstic caves
2. Non-karstic caves and pits	2.1 Non-karstic caves and pits	Caves and pits in flysch
		Caves and pits in marls
3. Interstitial underground habitats	3.1. Interstitial terrestrial habitats	Interstitial terrestrial habitats (MSS, cracks in rocks)
	3.2. Interstitial aquatic habitats	Interstitial aquatic habitats (phreatic, hyporheic, hypotelminorheic)
4. Anthropogenic underground habitats	4.1. Anthropogenic terrestrial underground habitats	Mines and underground passages
	4.2. Anthropogenic aquatic underground habitats	Groundwater anthropogenic accumulation
		Underground anthropogenic streams

2.1.2. Cave Biodiversity

Biospeleological research in Croatia began in the first half of the 19th century, at the inception of biospeleology, and has continued to the present day with an increasing number of interested scientists involved. Practically all taxonomic kingdoms can be found in cave habitats, but, photosynthetic flora only on illuminated entrance parts, and as in surface habitats, fauna predominates. The Croatian Dinaric range includes three biogeographical regions: the North Dinaric biogeographic region, with endemic taxa distributed between the northern end of the Dinaric range and the tectonic fracture of the Una-Zrmanja rivers; the Central Dinaric biogeographic region (Dalmatian), with endemic taxa distributed from the Una-Zrmanja fracture to the Neretva river fracture; and the South Dinaric biogeographic region, with endemic taxa distributed from the Neretva river fracture to the end of the Dinarides, on the border with the Taurid mountain range [19]. The total number of cave taxa, stygobionts and troglobionts, recorded for Croatia and estimated up to 2022, is about 650 species. In addition to cave-adapted taxa, there are many troglophilic and stygophilic taxa, including edaphic, guanophilic, and parasitic taxa, among which hard ticks (Ixodidae) are included.

2.2. Samplings and Identification

2.2.1. Fieldwork Methodology

All hard ticks were collected as part of systematic biospeleological research in caves at 138 locations, conducted or organized primarily by the second author or donated by colleagues (Table A1, Figure 3).

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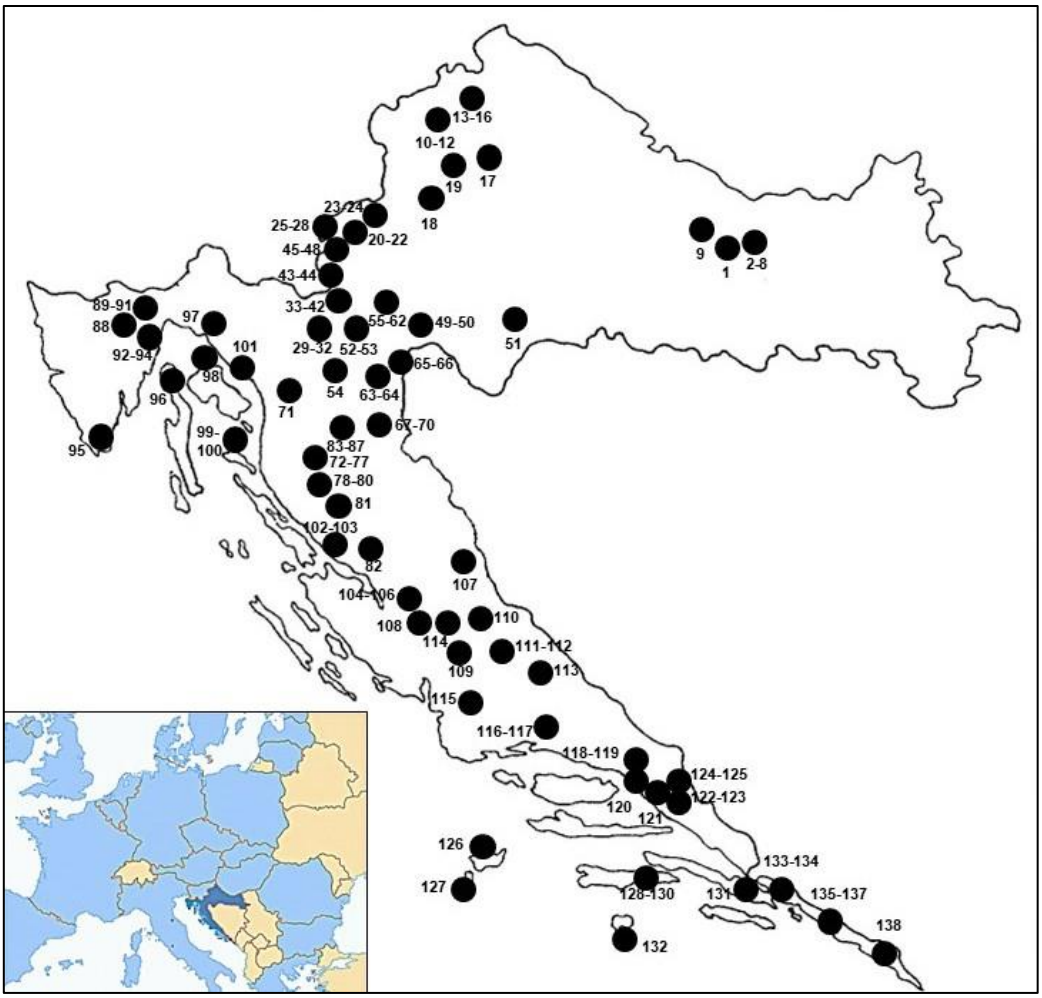

Figure 3. Distribution map of whole 138 sampled underground locations in Croatia, listed in Supplementary Materials (Table S1).

The research included identification of cave habitats, microclimatic measurements (air temperature, sediment and water where present; relative air humidity; CO_2 content), assessment of cave biodiversity, and collection of specimens from certain taxonomic groups or soil/water samples. Sampling for hard ticks was usually performed after visual observation, using tweezers to collect specimens from cave walls, stone crevices, or sinter. Typically, only the presence of bats or other mammals or vertebrates was noted, along with the number of specimens observed. It should be noted that in many cases no vertebrates were observed, so the finding of ticks indicates the periodic presence of bats or other mammals, also recognized by observed excrements. In this way, besides bats, the presence of the European edible dormouse (*Glis glis*) and martens (*Martes* sp.) was mostly documented. As part of the fieldwork methodology, many tick specimens were photographed in situ. All collected specimens were preserved in 8 ml plastic vials containing 70% ethanol. After collection, vials were labelled with a hard paper label containing the minimum necessary handwritten data: cave name, basic location, date of sampling, and collector names. Labels written with a permanent marker were placed inside closed vials containing ethanol and deposited in the Roman Ozimec Collection (ROC) for further processing. In cabinet, further material isolation is performed, collected specimens was removed into 2 ml plastic vials containing 96% ethanol, contain laser printing permanent labels, with all data as previous vials, but with final corrections and taxonomical data (Ixodida) same as number of specimens added.

2.2.2. Tick Identification

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Identification of species and sexes was performed using a Carl Zeiss Jena stereomicroscope (x40 magnification) according to available identification keys [26–28] and illustrations for tick identification [29,30]. For collected hard ticks, the following data are provided for each record: species name, locality, main localities (village, city, mountain, or protected area), name of municipality or city, or name of island, date of collection, name of collector, number and sex of specimens, and depository (Table S2). Species marked with an asterisk (*) were recorded for the first time in Croatia. All hard ticks collected in underground habitats in Croatia are deposited in the tick collections of the Roman Ozimec Collection (ROC), part of the Natural Science Department of the City Museum of Varaždin (GMV).

3. Results

A total of 274 specimens of hard ticks (Ixodidae) were collected in 138 underground habitats, located in 13 Croatian regions (Tables 2 and 3, Table A2). Collected hard ticks were classified into seven species and three genera (Table 2).

Table 2. Species list, abundance and developmental stages of hard ticks (Ixodidae).

Species/Stage	Females	Males	Nymphs	∑
Ixodes vespertilionis Koch, 1844	30	175	17	222
Ixodes hexagonus Leach, 1815	14	16	-	30
Ixodes frontalis (Panzer, 1798)	-	9	-	9
Ixodes ricinus (Linnaeus, 1758)	1	6	-	7
**Ixodes lividus* Koch, 1844	2	1	-	3
Haemaphysalis erinacei Pavesi, 1884	1	1	-	2
Hyalomma marginatum Koch, 1844	-	1	-	1
∑	**48**	**209**	**17**	**274**

Legend: * new country record.

Table 3. Species diversity and abundance of hard ticks (Ixodidae) by region in Croatia.

Region /Species	1.	2.	3.	4.	5.	6.	7.	∑
	Ixodes vespertilionis	*Ixodes hexagonus*	*Ixodes frontalis*	*Ixodes ricinus*	**Ixodes lividus*	*Haemaphysalis erinacei*	*Hyalomma marginatum*	
Slavonia	5	2	6	-	-	-	-	13
NW Croatia	16	11	-	7	3	-	-	37
Medvednica Mt.	9	-	-	-	-	-	-	9
Žumberak Mt.	11	1	-	-	-	-	-	12
Banovina	6	-	-	-	-	-	-	6
Pokuplje	41	11	-	-	-	-	-	52
Kordun	24	2	-	-	-	-	-	26
Lika	27	-	-	-	-	-	-	27
Istria	24	-	1	-	-	-	-	25
Kvarner Bay	8	-	-	-	-	-	-	8
Velebit Mt.	5	1	-	-	-	-	-	6
Pounje	1	-	-	-	-	-	-	1
Dalmatia	45	2	2	-	-	2	1	52
∑	**222**	**30**	**9**	**7**	**3**	**2**	**1**	**274**

Legend: * new country record.

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The most abundant genus was *Ixodes* Latreille, 1795 with five species, while the other two genera: *Haemaphysalis* Koch, 1844 and *Hyalomma* Koch, 1844 were each represented by one species (Table 2). *Ixodes vespertilionis* Koch, 1844 was the most abundant species in the collected sample, comprising 81.02%, followed by *Ixodes hexagonus* Leach, 1815 with 10.94%, *Ixodes frontalis* (Panzer, 1798) with 3.28%, *Ixodes ricinus* (Linnaeus, 1758) with 2.55%, *Ixodes lividus* Koch, 1844 with 1.09%, *Haemaphysalis erinacei* Pavesi, 1884 with 0.72% and *Hyalomma marginatum* Koch, 1844 representing 0.36% of the collected hard tick samples (Table 2). The majority, 93.79%, of collected ticks was in the adult stage, while the nymphal stage accounted for 6.20% (Table 2). Males accounted for 76.27%, females for 17.51%, and nymphs for 6.20% (Table 2). Nymphs have recorded only in the species *I. vespertilionis* (Table 2). The largest number of hard ticks (52) were recorded in Pokuplje and Dalmatia (Table 3). However, the largest number of species (5) was recorded in Dalmatia (Table 3). Four species of hard ticks have recorded in NW Croatia (Croatian Zagorje and Varaždin area), three in Slavonia, while two or one species have recorded in other regions (Table 3). Only, *I. vespertilionis* was recorded in all 13 studied regions in Croatia (Table 3). *Ixodes hexagonus* was recorded in seven Croatian regions, followed by *I. frontalis* in three, while the other four species were recorded in one region each (Table 3). The finding of *I. lividus* in Ravna Gora Mountain in the NW Croatia region represents a new country record (Tables 2 and 3). The number of hard tick species currently known in Croatia has increased to 28. Only one species, *I. vespertilionis* has been recorded during all 12 months of the year (Figure 4).

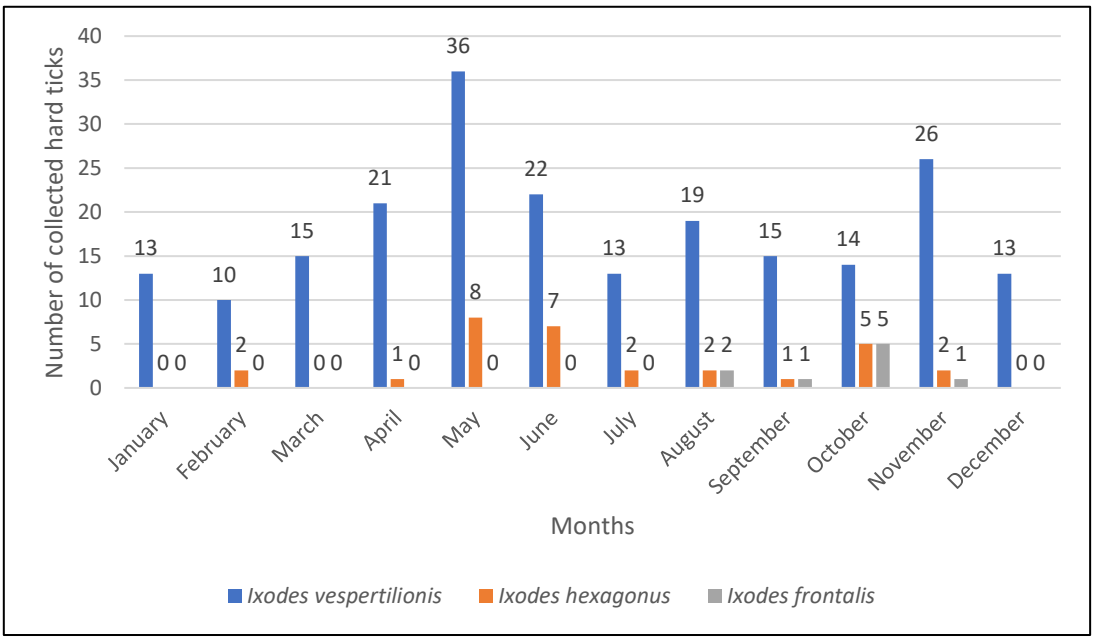

Figure 4. Seasonal dynamics of the three most abundant hard ticks in the studied area.

Ixodes hexagonus was recorded in nine months, *I. frontalis* in four months (Figure 4), while other species were collected over a shorter period of one or two months. The highest activity of *I. vespertilionis* was recorded in May and November, with 28.57% of specimens collected in these two months (Figure 4). However, the largest number of *I. vespertilionis* specimens was collected during the spring months (33.17%), while the smallest was collected in winter (16.58%) (Figure 4). During the summer and autumn months, almost equal numbers of specimens of *I. vespertilionis* were collected (24.88% and 25.34%, respectively) (Figure 4). The highest activity of *I. hexagonus* was recorded in May and June, with considerably lower numbers in other months, except October (Figure 4). *Ixodes hexagonus* and *I. frontalis*, the second and third most abundant species, differed significantly in their seasonality (Figure 4). The highest abundance of *I. hexagonus* was recorded in summer (36.66%), while the highest abundance of *I. frontalis* was recorded in autumn (77.77%) (Figure 4). Seasonality for the other four species was not analyzed due to the significantly smaller number of specimens collected.

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Of all seven recorded species, only *H. erinacei* has been recorded in Dalmatia (Mediterranean region of Croatia). In contrast, *I. lividus* has only been recorded in the NW Croatia (Continental region of Croatia) (Table 3). *Ixodes frontalis* has been recorded in two biogeographical regions of Croatia (Continental and Mediterranean). *Ixodes hexagonus* and *I. vespertilionis* have been recorded in all three biogeographic regions in Croatia (Continental, Alpine, and Mediterranean) (Table 3). while the other species have been recorded in one biogeographical region (Table 3).

4. Discussion

4.1. Comparison with Other Underground Habitats in Europe

Comparing the hard tick species recorded in this study with those from other studies across Europe, it appears that the most diverse hard tick fauna has been found in Croatian underground habitats. Six species of hard ticks have been recorded in cave habitats in the Central German uplands and Luxemburg [13], of which two species *I. hexagonus*, and *I. ricinus* have also been recorded in this study. Furthermore, five species of hard ticks have been recorded in cave habitats in Turkey [1] of which *I. vespertilionis* and *Hae. erinacei* have also been recorded in this study. Four species of hard ticks have been recorded in caves in the Crimea and Caucasus in Russia [12]. Of the four tick species recorded in Russia, three *I. vespertilionis*, *I. hexagonus* and *H. marginatum* have also been recorded in this study. Three nidicolous species of hard ticks have been recorded in Central Europe, specifically associated with bats [31]. Of these three species, only *I. vespertilionis* was recorded in this study, as the other two tick species have not yet been recorded in Croatia.

4.2. Ixodes Vespertilionis

Of all seven recorded species of hard ticks, only *I. vespertilionis* was found in all studied regions in Croatia. All specimens (222) was collected by speleologists from the walls and crevices of underground habitats (Figure 5, Figure 6). In this study, not a single specimen was collected from bats. Similarly, in studies conducted in Slovenia, Hungary and Turkey, *I. vespertilionis* was the most prevalent species and was found mainly on cave walls and in crevices [1,32,33]. In Slovenia, most *I. vespertilionis* ticks were collected from January to April [32]. This partially coincides with our data, as in Croatia the largest number of *I. vespertilionis* ticks were collected during the spring months. A similar seasonal pattern was observed in Hungary, with maximum abundance of *I. vespertilionis* in the spring months [33]. In previous studies *I. vespertilionis* was sporadically collected in Croatia, with data available from only a few localities: Trojama u Srijanima [20], Spilja od Vore - Vis island, Varaždin region (Repnjak) and Medvednica Mt. (Žurenščak) [21], Močiljska špilja (Dubrovnik), Petrićevi špilja Čampari (Cres Island), Rabakova peć, Ročko polje (Roč) and Krbavsko polje [32,34]. This research confirmed these earlier findings in three cave habitats (Petrićevi špilja, Čampari, Cres Island; Rabakova peć, Ročko polje Roč; Spilja (rudnik) od Vore, Vis Island). It is known that *I. vespertilionis* and *I. hexagonus* often share the same type of underground habitat, but their hosts differ significantly [32]. Only in four caves out of 141 investigated underground localities in this study were both tick species *I. vespertilionis* and *I. hexagonus*, collected together. This was recorded in NW Croatia (Varaždin area) in cave Zdenac pri Ciglaru, Klenovnik, Ravna Gora Mt., in Pokuplje in caves Pivnica jama, Sela Žakanjska; Hrenov Grič, Kamanje, and in Kordun in cave Dragina peć na Dobri Gabrk, Podumol. In the western Palearctic, free living stages of *I. vespertilionis* predominate in caves, and males were recorded frequently than females [6]. A similar pattern was observed in our study, where males of *I. vespertilionis* represented 78.82%. Distribution of *I. vespertilionis* in the western Palearctic overlaps with the geographic ranges of five bat species as primary hosts: greater mouse-eared bat (*Myotis myotis*), Maghrebian mouse-eared bat (*M. punicus*), Mediterranean horsehoe bat (*Rhinolophus euryale*), greater horsehoe bat (*R. ferrumequinum*) and lesser horsehoe bat (*R. hipposideros*) [6]. Four of these five primary host species have been recorded in the Croatian fauna [35]. This fact clearly explains why this endophilic cave-dwelling tick species has been recorded in all studied regions. Of

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all seven tick species recorded in this study, only *I. vespertiolionis* was recorded throughout the year. The same has been observed for this tick species in Hungary [33].

Figure 5. *Ixodes vespertilionis* female photographed *in situ* in Biserujka cave on Krk Island on 26.05.2009, photo by R. Ozimec.

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Figure 6. *Ixodes vespertilionis* male photographed *in situ* in Pišurka cave on Korčula Island on 4.12.2018, photo by R. Ozimec.

4.3. Ixodes Hexagonus

Ixodes hexagonus was the second most abundant species, accounting for 10.75%, and was recorded in seven of the 13 studied Croatian regions. This hard tick species has previously been recorded in an underground habitat in Croatia, having been collected in the first half of the 20th century in the Vrlovka cave, Kamanje in Pokuplje [24]. This finding was also confirmed in the present study. *Ixodes hexagonus* mainly inhabits lowlands, but also occurs in the mountainous areas, at elevations up to 1000 meters above sea level [36]. In mountainous areas, this tick is ecologically strictly tied to cave habitats, which are common in such regions [36]. This is confirmed by findings of *I. hexagonus* in caves on Papuk Mountain (953 m a.s.l.) in Slavonia, as well as in the mountains of north-western Croatia: Varaždin area and Croatian Zagorje (Ivanščica 1059 m a.s.l., Ravna Gora 686 m a.s.l., and Strahinjčica 846 m a.s.l.) and on Velebit where the altitude ranges from 1214 to 1757 m a.s.l. In the study area, *I. hexagonus* was recorded in nine months, while *I. vespertilionis* was recorded throughout the year. This observation can be explained as a direct consequence of the tick's lifestyle, since both species are endophilic one is nest-dwelling, the other cave dwelling [28]. In underground habitats with stable microclimatic conditions, free forms of both species find favorable conditions that do not depend directly on atmospheric circumstances and therefore prefer such habitats [32,36,37]. Furthermore, the hedgehog *Erinaceus roumanicus*, one of the main hosts of *I. hexagonus* often hibernates in semi-caves or at cave entrances [36]. These habitats are also visited by other hosts of *I. hexagonus* from the families Mustelidae and Canidae [36]. However, in some cases, *I. hexagonus* has been recorded on certain bat species such as *M. myotis* and *R. ferrumequinum* [6].

4.4. Ixodes Frontalis

Ixodes frontalis, at 3.22% was the third most abundant tick, and was recorded in cave habitats of Papuk Mt. (Slavonia), Učka Mt. (Istria) and Biokovo Mt. (Dalmatia). This tick is a typical bird parasite (ornithophilic tick), and in a study by D. Tovornik it was found in the Dubrovnik area on two bird species: Bohemian waxwing (*Bombycilla garrulus*) and black redstart (*Phoenicurus ochruros*) [38]. In all life stages, it infests various bird species, both cavity-nesting and open nesting [28]. There is evidence that it parasitizes a much larger number of bird species from the orders: Passeriformes, Charadriiformes, Accipitriformes, Galliformes, Falconiformes, Coraciiformes, Gruiformes, Columbiformes and Strigiformes [38–40]. The first unexpected finding of this tick in relation to its host was recorded near Zagreb on a stone marten (*Martes foina*) [36,38]. It has also been recently recorded at several localities in the continental part of Croatia [11,41].

4.5. Ixodes Ricinus

Ixodes ricinus, the most abundant and widespread tick in Europe [42,43], was represented by only 2.50%. in underground habitats in Croatia. This tick transmits a large number of pathogens of medical and veterinary importance, shows a low degree of host specificity, and has been recorded in more than 300 species of terrestrial vertebrates [43,44]. *Ixodes ricinus* mainly inhabits open mountainous areas, deciduous and mixed forests, as these forests are inhabited by deer (roe deer *Capreolus capreolus*; red deer *Cervus elaphus*) and wild boar (*Sus scrofa*). These large animals are considered the most important hosts for maintaining high populations of *I. ricinus* ticks in these habitats [43,45]. Despite ungulates being the main hosts, *I. ricinus* often parasitizes birds [46]. During the 1980s, eight tick species were recorded on 114 infested birds classified in 11 orders and 62 species in the former Yugoslavia, and in this sample of hard ticks *I. ricinus* was the most abundant at 87.5% [46]. Many more tick species have been recorded on birds across Europe, as many as 38 tick species, among which *I. ricinus* is the most common in Central and Northern Europe [40]. In Croatia, *I. ricinus* has been recorded on six bird species: tree pipit (*Anthus trivialis*), common buzzard (*Buteo buteo*),

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cetti's warbler (*Cettia cetti*), common nightingale (*Luscinia megarhynchos*), common pheasant (*Phasianus colchicus*), eurasian magpie (*Pica, pica*) and rock partrige (*Alectoris graeca*) [15,46]. Birds, especially migratory species, play an important role in the spread of *I. ricinus* ticks and tick-borne pathogens of veterinary and public health significance [43,47]. Almost every European bird species has been recognized as a potential carrier of *I. ricinus*, as birds infested with ticks may carry these ectoparasites over long distances during seasonal migration [46,48]. Despite the large number of birds infested with *I. ricinus*, this tick has also been recorded on 18 species of bats that inhabit cave habitats [6]. In this study, *I. ricinus* was recorded only in caves in north-western Croatia: Varaždin area and Croatian Zagorje (Ravna Gora Mt. and Strahinjčica Mt.), which clearly shows that underground habitats are unsuitable for this exophilic tick species. Despite this, the first record of this species in underground habitats in Croatia was from a cave on the island of Mljet [24].

4.6. Ixodes Lividus

The record of *I. lividus* in a cave on Ravna Gora Mt. in north-west Croatia represents the first records of this species in the Croatian fauna. This ornithophilic tick species was recorded at only one locality. Previously, it was usually associated with birds living in holes in trees, while now it is a specific parasite of the sand martin (*Riparia riparia*), [30], but can also be found in its burrows [40]. Some previous literature indicates that it also parasitizes other bird species such as the common starling (*Sturnus vulgaris*), common blackbird (*Turdus merula*) [39], great tit (*Parus major*), tree sparrow (*Paser montanus*), blue tit (*Cynistes caeruleus*) [49] and barn swallow (*Hirundo rustica*) [40]. However, sporadic findings of this tick have also been recorded on bats in the UK, Germany and the Netherlands [6]. It should be emphasized that the distribution area of this tick includes Europe and Asia and it is found wherever sand martins nest [49].

4.7. Hyalomma Marginatum

One adult specimen of *Hyalomma marginatum* was collected in cave habitats of Mount Biokovo in Dalmatia. However, the first record of this species in underground habitats was in Istria [24]. This tick species is widespread along the entire Croatian Adriatic coast from Pula to Dubrovnik [34,50]. In previous studies, larvae and nymphs were collected from hedgehogs [36], while adults were mainly collected from horses (*Equus caballus*), cows (*Bos taurus*) and sheep (*Ovis aries*) [34,50]. It is not surprising that the adults stage of this tick is often collected from horses or cows, as horses are one of the preferred hosts of this tick in the adult stage [51]. Some studies indicate a preference of this tick for high temperatures, but low precipitation and low relative humidity [51]. The conditions in the underground habitats are exactly the opposite in terms of temperature and humidity, which may explain the small number of *H. marginatum* specimens collected in the caves.

4.8. Haemaphysalis Erinacei

The finding of the *Hae. erinacei* in a cave in the Dubrovnik area represents the second record of this hard tick in Croatia after 1964. The first record of this hard tick in Croatia was also in the Dubrovnik area, and it was found on a bird, the Alpine swift (*Apus melba*) [46]. In addition to Croatia, *Hae. erinacei* has also been recorded in cave habitats in Turkey and Russia [1,12]. *Haemaphysalis erinacei* is an endophilic tick that lives in the nests or burrows of its hosts [28]. This tick is often found on stone marten (*Martes foina*), least weasel (*Mustela nivalis*) and red fox (*Vulpes vulpes*) [28].

5. Conclusions

This study recorded seven species of hard ticks (Ixodidae) in underground habitats of 138 caves in 13 regions of Croatia (Table 2, Figure 3). Previous findings of four tick species were confirmed, while three tick species were recorded for the first time in underground habitats. The genus *Ixodes* was the most abundant with five species, while the other genera: *Haemaphysalis*, and *Hyalomma* were represented by one species each. Two endophilic hard ticks, *I. vespertilionis* and *I. hexagonus* were the

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most abundant species in the collected sample with 91.97%, followed by *I. frontalis* as typical ornithophiles ticks with 3.28%. The other four species of hard ticks accounted for only 4.75%. Only *I. vespertilionis* was recorded during all 12 months of the year, *I. hexagonus* was recorded in nine months, *I. frontalis* in four months, while the other species were collected over a shorter period. The species *I. lividus* is has been recorded as new to the Croatian fauna, bringing the total number of recorded hard tick species in Croatia to 28. Findings of hard ticks in underground habitats of Dinarides, according to their wide range ectoparasite of a specific host species, can be used as indicators for vertebrate fauna occurring in the caves. In that way, most abundant species, *I. vespertilionis* indicate bats (Chiroptera) occurring in the caves, particularly for four species as primary hosts: greater mouse-eared bat (*Myotis myotis*), and three *Rhinolophus* species: Mediterranean horsehoe bat (*R. euryale*), greater horsehoe bat (*R. ferrumequinum*) and lesser horsehoe bat (*R. hipposideros*). Connection of individual bats and/or bat colonies occurring in the caves and finding of hard ticks in the same caves, can be object for further integral analyses. In the same way, finding the second most abundant species, *Ixodes hexagonus,* can indicate occurring of members of families Mustelidae, such as martens (*Martes* sp.) or some Canidae, but also for some bat species, such as *M. myotis* and *R. ferrumequinum.* Also, individual specimens of hard ticks in caves, can be tested for some potentially zoonotic pathogens vectors, specifically for bats, because bat ticks could be a potential link between bats and non-bat hosts and may help spread diseases between them [52].

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Appendix A

Appendix A.1

Table A1. List of sampling sites for hard ticks in underground habitats in Croatia.

Ord. Nr.	Region/Locality/Village/Protected area/ Mountain/Municipality/or city/Island	UTM mark
	PANNONIAN RANGE	
	Slavonia	
1.	Uviraljka, Papuk NP, Velika	YL 03
2.	Jazavčeva špiljica, Kovačica, Jankovac, Papuk NP, Čačinci	YL 14
3.	Jančikin guz, Jankovac, Papuk NP, Čačinci	YL 14
4.	Jama na mrežarima, Mrežarski rust, Jankovac, Papuk NP, Čačinci	YL 14
5.	Suhodolska jama, Suhodol, Jankovac, Papuk NP, Čačinci	YL 14

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6.	Špilja papučkog pračovjeka, Sokolina, Jankovac, Papuk NP, Čačinci	YL 14
7.	Jelenova špilja, Sokolina, Jankovac, Papuk NP, Čačinci	YL 14
8	Sokolina špilja, Gornji Vrhovci, Papuk NP, Čačinci	XL 93
9.	Brunina špilja, Jovanovica, Papuk NP, Voćin	XL 95
	SUPRADINARIC RANGE	
	NW Croatia (Croatian Zagorje area)	
10.	Žutnica, Strahinjščica Mt., Krapina	WM 61
11.	Rana Peć, Jelavica, Žutnica, Strahinjščica Mt., Krapina	WM 61
12.	Vilska Luknja, Goleš, Zagora, Strahinjščica Mt., Radoboj	WM 71
	NW Croatia (Varaždin area)	
13.	Vihra špiljica, potok Kamenica (Filićev dom), Kameničko Podgorje, Ravna Gora Mt., Lepoglava	WM 81
14.	Jelovec jama, Cimer plac, Ravna Gora Mt., Lepoglava	WM 81
15.	Zdenec pri Ciglaru, Ciglari, Ravna Gora Mt., Klenovnik	WM 82
16.	Cerjanska špilja, Cerjani, Ravna Gora Mt., Klenovnik	WM 82
17.	Špilja u Bukevju, Bukevje, Ivanščica Mt., Ivanec	WM 82
	Medvednica Mountain	
18.	Veternica, Veroško rebro, Gornji Stenjevec, Medvednica Mt., Zagreb	WL 77
19.	Židovske jame, Medvednica Mt., Gornja Stubica	WL 79
	ADRIATIC & DINARIC RANGE	
	Žumberak Mountain	
20.	Obreški Grič, Obrež Vivodinski, Žumberak Mt., Ozalj	WL 35
21.	Milićka jama; Kuljaji, Žumberak Mt., Ozalj	WL 35
22.	Rakička špilja, Pilatovci Žumberak Mt., Ozalj	WL 35
23.	Jamina, Bučari, Donji Oštrc, Žumberak Mt.	WL 35
24.	Ponor Vrulje, Cerovica, Žumberak Mt., Samobor	WL 35
25.	Dolača, Drašči vrh, Žumberak Mt.	WL 36
26.	Rogovac, Žumberak Mt.	WL 37
27.	Provala, Sošice, Žumberak Mt.	WL 37
28.	Bedara, Tihočaj, Žumberak Mt., Samobor	WL 57
	Pokuplje	
29.	Gugečka špilja, Gornje Dubrave, Ogulin	WL 11
30.	Ledenica u Čazinki, Donje Dubrave, Ogulin	WL 11
31.	Vrelić špilja, Donje Dubrave, Ogulin	WL 11
32.	Sušica ponor, Rebića Glavica, Donje Dubrave, Ogulin	WL 11
33.	Kuštrovka, Popovo Selo, Trošmarija	WL 21
34.	Danetska špilja, Dani, Bosiljevo	WL 22
35.	Jankonka jama, Hrsine, Bosiljevo	WL 22
36.	Ledenica u Špeharima, Špehari, Bosiljevo	WL 22
37.	Dragina peć na Dobri, Gabrk, Podumol, Bosiljevo	WL 22
38.	Jama u kanjonu Dobre ispod Gabrka, Podumol, Bosiljevo	WL 22

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39.	Špilja kod Podumolskog mlina, Podumol, Bosiljevo	WL 22
40.	Vodena jama, Kolići, Generalski Stol	WL 22
41.	Paveća špilja, Soline, Generalski Stol	WL 22
42.	Lipa na Protulipi, Lipa, Generalski Stol	WL 22
43.	Zvonečka II, brdo Lipnik Griče Gornje, Ribnik	WL 24
44.	Jama Đot, brdo Lipnik, Ribnik	WL 24
45.	Pivnica jama, Sela Žakanjska, Žakanje	WL 35
46.	Hrenov Grič, Kamanje	WL 35
47.	Kozjača špilja, Kamanje	WL 35
48	Vrlovka špilja, Kamanje	WL 35
	Banovina	
49.	Bajića špilja 1,3, Pecka, Perna, Topusko	WL 61
50.	Velika špilja, Perna, Petrova Gora Mt., Topusko	WL 61
51.	Gradusa špilja, Sjeverovac, Sunja	XL 22
	Kordun	
52.	Rebička špilja, kanjon Tounjčice, Tounj	WL 30
53.	Tounjčica špilja, Tounj	WL 30
54.	Jama Mandelaja, Oštarije, Josipdol	WL 20
55.	Markova špilja, Mateško Selo, Generalski Stol	WL 31
56.	Matešićeva špilja, Mateško selo, Generalski Stol	WL 31
57.	Mikića jama, Perjasica, Barilović	WL 31
58.	Jama u Steljnici, Lučica, Siča, Barilović	WL 32
59.	Vodena špilja, Siča, Barilović	WL 32
60.	Špilja Gvozdenica, Krnjak	WL 42
61.	Bezdanica kod Barilovića, Barilović	WL 42
62.	Jopićeva špilja, Krnjak	WL 42
63.	Jama pod Debelom glavom, Hrvatski Blagaj, Slunj	WL 40
64.	Kutarčeva špilja, kanjon Korane, Slunj	WK 49
65.	Jama 4 psa, Gnojnice, Cetingrad	WL 50
66.	Vukovićeva špilja, Gnojnice, Cetingrad	WL 50
67.	Špilja ispod Drežnik grada, Drežnik Grad, Rakovica	WK 57
68.	Adios špilja, Kordunski Ljeskovac, Rakovica	WK 58
69.	Kojina jama, Mašvina, Rakovica	WK 58
70.	Baraćeva gornja špilja, Nova Kršlja, Rakovica	WK 58
	Lika	
71.	Siničić špilja, Brinje	WK 08
72.	Bobića pećina, Mlakva, Donji Kosinj, Perušić	WK 25
73.	Čardačina jama, Mlakva, Poljane, Donji Kosinj, Perušić	WK 25
74.	Horvatova špilja, HE Sklope, Donji Kosinj, Perušić	WK 25
75.	Mramornjača, Petranović Draga, Donji Kosinj, Perušić	WK 25
76.	Pećina u Čakovcu, Mlakva, Bobići, Donji Kosinj, Perušić	WK 25

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77.	Šojića pećina, Podjelar, Gornji Kosinj, Perušić	WK 25
78.	Amidžina pećina, PP Grabovača, Perušić	WK 34
79.	Sitvukova pećina, Sitvuk, PP Grabovača, Perušić	WK 34
80.	Medina pećina, PP Grabovača, Perušić	WK 34
81.	Rogić špilja, Klanac, Gospić	WK 23
82.	Špilja 2 u kanjonu Jadove, Lovinac	WK 51
83.	Šupljara špilja, jezero Kozjak, Plitvice Lakes NP, Korenica	WK 55
84.	Špilja Milke Trnine, jezero Kozjak, Plitvice Lakes NP, Korenica	WK 55
85.	Mračna pećina, kanjon Korane, Plitvice Lakes NP, Korenica	WK 55
86.	Mračnjača špilja, Plitvice Lakes NP, Korenica	WK 55
87.	Jama na Vršiću, Kuselj, Plitvice Lakes NP, Korenica	WK 55
	Istria	
88.	Rabakova špilja, Ročko polje, Roč, Buzet	VL 22
89.	Radota jama, Vodice, Jelovice, Ćićarija Mt., Lanišće	VL 23
90.	Pećina pod Stržen, Stržen, Brgudac, Ćićarija Mt., Lanišće	VL 32
91.	Jama kod Raspadalice, Ćićarija Mt., Lanišće	VL 32
92.	Klanjčeva peć, Brest pod Učkom, Učka Mt., Lupoglav	VL 32
93.	Jama pod Križ, Semići, Učka Mt., Lupoglav	VL 32
94.	Grnjača špilja, Lovranska Draga, Grnjač, Učka Mt., Lovran	VL 41
95.	Špilja kod Premanture, Premantura, Medulin	VK 16
	Kvarner Bay	
96.	Čampari jama, Petrićevi, Cres, Cres Island	VK 57
97.	Galatkovićeva jama, Krasica, Bakar	VL 61
98.	Špilja Biserujka, Čižići, Rudine, Dobrinj, Krk Island	VK 69
99.	Špilja iznad Jamine Drage, Lopar, Rab island	VK 76
100.	Jamice Plogar, Mundanije, Rab, Rab Island	VK 85
101.	Zagorska peć, Novi Vinodolski	VK 98
	Velebit Mountain	
102.	Lužina špilja, Mali Vaganac, Paklenica NP, Južni Velebit, Starigrad	WK 32
103.	Manita peć, Velika Paklenica, Paklenica NP, Južni Velebit, Starigrad	WK 31
104.	Topla pećina, Kaštel Žegarski, Južni Velebit, Jasenice	WJ 68
105.	Plitka peć, Plitki dolovi, Čabrići Gornji, Kaštel Žegarski, Velebit NP, Obrovac	WJ 68
106.	Kusa, Manastirska luka, Krupa, Velebit NP, Obrovac	WJ 79
	Pounje	
107.	Rastovača špilja, kanjon Slap, Srb, Plješivica Mt., Gračac	WK 73
	Dalmatia	
108.	Golubnjača špilja, Žegar, Bukovica	WJ 68
109.	Rudnik Jukići, Razvođe, Oklaj, Promina	WJ 86
110.	Krčić špilja, Topoljski buk, Knin	WJ 97
111.	Rudelića špilja, Vukovići, Vrlika	XJ 16
112.	Gospodska špilja, Četnici, Vrlika	XJ 17

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113.	Vodena peća, Bajagić, Sinj	XJ 34
114.	Sedrena špilja iza mlina, Bilušića buk, NP Krka, Šibenik	WJ 86
115	Stražbenica, Vrpolje, Šibenik	WJ 83
116.	Trojama, Mosor Mt., Dugopolje	XJ 22
117.	Vranjača, Kotlenice, Mosor Mt., Dugopolje	XJ 32
118.	Jama pod Osojem, Nevistine stine, Donja Brela, Biokovo Mt., Brela	XJ 50
119.	Drinova 2, Bartulovići, Biokovo Mt., Brela	XJ 50
120.	Mala jama u Bratušu, Bratuš, Biokovo Mt., Baška Voda	XJ 50
121.	Krjava 2, Velo brdo, Biokovo Mt., Makarska	XH 69
122.	Jama za Supinom, Supin, Gornje Tučepi, Biokovo Mt., Tučepi	XH 69
123.	Baba špilja, Štedovac, Gornje Tučepi, Biokovo Mt., Tučepi	XH 69
124.	Velika Prdaljka, Alerići, Poljica Kozička, Vrgorac	XH 98
125.	Velika špilja kod Antunovića, Kozica, Šibenik Mt., Vrgorac,	XH 98
126	Rudnik od Vore, Kostirna, Vis, Vis Island	WH 96
127.	Jezero na Gatuli, Komiža, Biševo Island	WH 95
	Dalmatia (Dubrovnik area)	
128.	Pišurka, Korčula, Korčula Island	XH 75
129.	Jakasova špilja, Žrnovo, Korčula, Korčula Island	XH 75
130.	Samograd špilja, Račišće, Korčula, Korčula Island	XH 75
131.	Crno jezero, Ponikve, Ston, Pelješac	YH 14
132.	Medviđa Ropa, Skrivena Luka, Lastovo, Lastovo Island	XH 53
133.	Jama u Zadubravici, Riđica, Dubrovačko primorje	YH 34
134.	Špilja u ogradi, Trnova, Dubrovačko primorje	YH 34
135.	Špilja pod Gromačkom vlakom, Gromača, Dubrovačko primorje	BN 53
136.	Špilja na vrh Krčevina, Orašac, Gromača, Dubrovačko primorje	BN 53
137.	Banova ljut, Ljubač, Dubrovačko primorje	BN 53
138.	Jama Bezdan, Komaji, Konavle	BN 71

Appendix A.2

Table A2. List of recorded hard tick species in underground habitats in Croatia.

1. *Haemaphysalis erinacei* Pavesi, 1884 **Region:** Dalmatia (Dubrovnik area) **County:** Dubrovnik-Neretva Records: Špilja na vrh Krčevina, Orašac-Gromača, Dubrovnik 21.VI.2009 K. Miculinić leg. (1♂), 9.X.2009 H. Cvitanović leg. (1♀), (ADIPA).
2. *Hyalomma marginatum* Koch, 1844 **Region:** Dalmatia (including the Dubrovnik area) **County:** Split-Dalmatia Records: Jama za Supinom, Supin, Gornje Tučepi, Biokovo Mt., Tučepi 15.VIII.2012 R. Ozimec leg. (1♂), (ADIPA).
3. *Ixodes frontalis* (Panzer, 1798)

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Region: Slavonia

County: Virovitica-Podravina, Požega-Slavonia

Records: Jančikin guz, Jankovac, Papuk NP, Čačinci 25.X.2008, R, Ozimec, H. Cvitanović leg. (1♂); Sokolina špilja, Gornji Vrhovci, Papuk NP, Čačinci 25.X.2008, N. Raguž leg. (2♂); Jazavčeva špiljica, Kovačica, Jankovac, Papuk NP, Čačinci 22.IX.2010, M. Lukić leg. (1♂); Jelenova špilja, Sokolina, Jankovac, Papuk NP, Čačinci 13.VIII.2015, N. Kuharić leg. (1♂); Špilja papučkog pračovjeka, Sokolina, Jankovac, Papuk NP, Čačinci 14. VIII. 2015, N. Kuharić leg. (1♂) (ADIPA).

Region: Istria

County: Istria

Records: Klanjčeva peć, Brest pod Učkom, Učka Mt., Lupoglav 6.XI.2006 H. Cvitanović leg. (1♂), (ADIPA).

Region: Dalmatia

County: Split-Dalmatia

Records: Mala jama u Bratušu, Bratuš, Biokovo Mt., Baška Voda 11.X.2018 T. Tursić leg. (2♂), (ADIPA).

4. *Ixodes hexagonus* Leach, 1815

Region: Slavonia

County: Virovitica-Podravina, Požega-Slavonia

Records: Brunina špilja, Jovanovica, Papuk NP, Voćin 22.IX.2010, A. Komerički leg. (1♀); Sokolina špilja, Gornji Vrhovci, Papuk NP, Čačinci 19.VII.2024, M. Lukić leg. (1♀), (ADIPA).

Region: NW Croatia **(**Croatian Zagorje and Varaždin area)

County: Varaždin, Krapina-Zagorje

Records: Zdenac pri Ciglaru, Ciglari, Ravna Gora Mt., Klenovnik 15.V.2006, M. Pavlek leg. (2♂), H. Cvitanović leg. (1♀), 26.V.2007, F. Kljaković-Gašpić leg. (2♂), H. Cvitanović leg (1♀), 18.X.2008, E. Domina leg. (1♀, 2♂); Špilja u Bukevju, Bukevje, Ivanščica Mt., Ivanec 18.X.2008, R. Ozimec leg. (1♂); Rana peć, Jelavica, Žutnica, Strahinjčica Mt., Krapina 10.XI.2009, R. Ozimec leg. (1♀), (ADIPA).

Region: Žumberak

County: Karlovac

Records: Obreški Grič, Obrež Vivodinski, Ozalj 16.XI.2002, R. Ozimec leg. (1♀), (ADIPA).

Region: Pokuplje

County: Karlovac

Records: Ledenica u Čazinki, Donje Dubrave, Ogulin 15.VI.2008 leg. J. Bedek (1♂); Gugečka špilja, Gornje Dubrave, Ogulin 17.VI.2008 leg. R. Ozimec (1♀); Dragina peć na Dobri Grabrk, Podumol, Bosiljevo 18.VI.2008 H. Cvitanović leg. (1♂); Paveća špilja, Soline, Generalski Stol 18.VI.2008 R. Ozimec leg. (1♀); Kuštrovka, Popovo Selo, Trošmarija 27.VIII.2008 R. Ozimec leg. (1♀); Danetska špilja, Dani, Bosiljevo 12.V.2009 A. Komerički leg. (1♂); Sušica ponor, Rebića Glavica, Donje Dubrave, Ogulin 14.V.2009 leg. A. Komerički (1♂); Pivnica jama, Sela Žakanjska, Žakanje 5.VI.2009 H. Cvitanović leg. (1♂); Kozjača špilja, Kamanje 7.VI.2009 H. Cvitanović leg. (1♂), K. Miculinić leg. (1♂); Hrenov Grič, Kamanje 1.II.2015, H. Cvitanović leg. (1♀), (ADIPA).

Region: Kordun

County: Karlovac

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Records: Špilja ispod Drežnik grada, Drežnik Grad, Rakovica 28.IV.2004 I. Franjković leg. (1♂); Rebička špilja, kanjon Tounjčice, Tounj 27.VIII.2004 J. Bedek and H. Cvitanović leg (1♂), (ADIPA).

Region: Velebit Mt.

County: Zadar

Records: Topla pećina, Kaštel Žegarski, Južni Velebit, Jasenice 25.II.2008 R. Ozimec leg. (1♀), (ADIPA).

Region: Dalmatia (including the Dubrovnik area)

County: Šibenik-Knin

Rudnik Jukići, Razvođe, Oklaj, Promina 9.VII.2020 R. Ozimec leg. (1♀), (ADIPA).

County: Dubrovnik-Neretva

Records: Špilja u ogradi, Trnova, Dubrovačko primorje 16.X.2011 R. Ozimec leg. (1♀)

5. ****Ixodes lividus* **Koch, 1844

Region: NW Croatia (Varaždin area)

County: Varaždin

Records: Zdenac pri Ciglaru, Ciglari, Ravna Gora Mt., Klenovnik 15.V.2006, H. Cvitanović leg. (1♀), 26.V.2007, F. Kljaković-Gašpić leg. (1♂), 18.X.2008, F. Kljaković-Gašpić leg. (1♀), (ADIPA).

6. ***Ixodes ricinus*** **(Linnaeus, 1758)**

Region: NW Croatia (Croatian Zagorje and Varaždin area)

County: Varaždin, Krapina-Zagorje

Records: Zdenac pri Ciglaru, Ciglari, Ravna Gora Mt., Klenovnik 26.V.2007, F. Kljaković-Gašpić leg. (5♂); Vilska Luknja, Goleš, Zagora, Strahinjčica Mt., Radoboj 16.V.2009, R. Ozimec leg. (1♂); Rana Peć, Jelavica, Žutnica, Strahinjčica Mt., Krapina 16.V.2009, A. Komerički leg. (1♀), (ADIPA).

7. ***Ixodes vespertilionis*** **Koch, 1844**

Region: Slavonia

County: Virovitica-Podravina, Požega-Slavonia

Records: Ponor Uviraljka, Papuk NP, Velika 19.VII.2004, H. Bilandžija leg. (1♂), 21.IX.2010, M. Lukić leg. (1♂); Suhodolska Jama, Suhodol, Jankovac, Papuk NP, Čačinci 24.X.2008, R. Ozimec leg. (2♂); Jama na mrežarima, Mrežarski rust, Jankovac, Papuk NP, Čačinci 10.VIII.2015, H. Višić leg. (1♀), (ADIPA).

Region: NW Croatia (Croatian Zagorje and Varaždin area)

County: Varaždin, Krapina-Zagorje

Records: Cerjanska špilja, Cerjani, Ravna Gora Mt., Klenovnik 9.I.2002 R. Ozimec leg. (2♂), 15.V.2006 M. Pavlek leg. (3♂, 1n), R. Ozimec (1♀); Vihra špiljica, potok Kamenica, (Filićev dom), Kameničko Podgorje, Ravna Gora Mt., Lepoglava 13.V.2006, H. Cvitanović leg. (1♂); Zdenac pri Ciglaru, Ciglari, Ravna Gora Mt., Klenovnik 26.V.2007, H. Cvitanović leg. (1♂), 18.X.2008 E. Domina leg. (1n); Jelovec jama, Cimerplac, Ravna Gora Mt., Lepoglava 28.V.2007, F. Kljaković-Gašpić leg. (1♀); Vilska Luknja, Goleš, Zagora, Strahinjščica Mt., Radoboj 16.V.2009, R. Ozimec leg. (2♀,2n), A. Komerički leg. (1n), (ADIPA).

Region: Medvednica Mt.

County: Krapina-Zagorje, Zagreb

Records: Židovske jame, Medvednica Mt., Gornja Stubica 23.IV.2005, R. Ozimec leg. (2♂); Veternica, Veroško rebro, Gornji Stenjevec, Medvednica Mt., Zagreb 31.V.2009, D. Bakšić leg. (1♂),

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25.XI.2012, R. Ozimec leg. (1♂), 30.VIII.2013, R. Ozimec leg. (2♂), 1.XII.2016, R. Ozimec leg. (2♂), -, M. Jagić (1♂), (ADIPA).

Region: Žumberak

County: Zagreb, Karlovac

Records: Špilja Provala, Sošice, Žumberak 2.II.1997, R. Ozimec leg. (1♂); Rogovac, Žumberak 18.I.1998, T. R leg. (1♂); Jamina Bučari, Donji Oštrc, Žumberak 19.IV.1998, R. Ozimec leg. (1♂), 17.X.1999, R. Ozimec leg. (1♂), 2.XI.2002, R. Ozimec and T. Rubinić leg. (1♂); Špilja Rakička, Pilatovci, Žumberak, Ozalj 20.IX.2002, R. Ozimec and T. Rubinić leg. (1♀, 1n); Ponor Vrulje, Cerovica, Žumberak, Samobor 3.XI.2002. R. Ozimec and T. Rubinić leg. (1♂); Jama Milićka, Kuljaji, Žumberak, Ozalj 26.IV.2003, R. Ozimec leg. (1♀); Špilja, Dolača, Drašči vrh, Žumberak 12.XII.2004, M. Pavlek leg. (1♂); Bedara, Tihočaj, Žumberak, Samobor 18.XII.2005 M. Pavlek leg. (1♂), (ADIPA).

Region: Pokuplje

County: Karlovac

Records: Pivnica jama, Sela Žakanjska, Žakanje -, 1993, H. Cvitanović leg. (1♂), 12.VII.1998, R. Ozimec leg. (2♂), 18.III.2009, H. Cvitanović leg. (1♂), M. Lukić leg. (2♂), 5.VI. 2009, K. Miculinić leg. (1♂), 13.VIII.2017, D. Basara leg. (1♀), D. Belavić leg. (1♂); Jankonka jama, Hrsine, Bosiljevo 16.I.1999 R. Ozimec leg. (1♀), 2.IV.2000 R. Ozimec and H. Cvitanović leg. (1♂); Jama u kanjonu Dobre ispod Gabrka, Podumol, Bosiljevo 24.VI.2008 H. Cvitanović leg. (1♂), 26.VIII.2008 M. Pavlek leg. (1♂), M. Lukić leg. (1♂), 8.XII.2008 K. Miculinić leg. (1♂), 12.V.2009 M. Lukić leg. (1♂), A. Kirin leg. (1♂), 6.IX.2009 H. Cvitanović leg. (1♂), M. Lukić leg. (1♂); Dragina peć na Dobri Gabrk, Podumol, Bosiljevo 18.VI.2008 H. Cvitanović leg. (1♀, 1♂), 8.XII.2008 H. Cvitanović leg. (1♂), 3.X.2009 R. Baković leg. (2♂); Lipa na Protulipi, Lipa, Generalski Stol 21.VI.2008 R. Baković leg. (1♂); Vodena jama, Kolići, Generalski Stol 9.V.2009 leg. A. Kirin (1♂), 10.V.2009 leg. M. Lukić (1♂); Špilja kod Podumolskog mlina, Podumol, Bosiljevo 14.V.2009 A. Krin leg. (2♂); Kuštrovka, Popovo Selo, Trošmarija 14.II.2009 M. Pavlek leg. (2♂); Zvonečka II, brdo Lipnik, Griče Gornje, Ribnik 19.III.2009, H. Cvitanović leg. (1♂), -, H. Cvitanović leg. (2♂); Jama Đot, Lipnik, Ribnik 20.III.2009 leg. J. Bedek (1♀); Vrelić špilja, Donje Dubrave, Ogulin 14.V.2009 leg. J. Bedek (1♂); Ledenica u Špeharima, Špehari, Bosiljevo 24.V.2009 M. Lukić leg. (1♂); Hrenov Grič, Kamanje 1.II.2015, H. Cvitanović leg. (1n); Vrlovka špilja, Kamanje 22.XII.2015, R. Ozimec leg. (2♂), 21.VII.2016, H. Cvitanović leg. (1♀), (ADIPA).

Region: Banovina

County: Sisak-Moslavina

Records: Bajića špilja 1, Pecka, Perna, Topusko 26.II.2009 N. Gruborović leg. (1♂, 1♀), R. Ozimec and P. Rade leg. (1♀), 5.VI.2002 K. Badovinac leg. (1♂); Gradusa špilja, Sjeverovac, Sunja 6.III.2009 R. Ozimec leg. (1♂); Bajića špilja 3, Pecka, Perna, Topusko 7.III.2009 H. Cvitanović and N. Matoš leg. (1♂), (ADIPA).

Region: Kordun

County: Karlovac

Records: Špilja Tounjčica, Tounj 14.IV.1997 H. Cvitanović leg (1♂), 15.II.2009 M. Pavlek leg. (1♂); Špilja Gvozdenica, Krnjak 9.XII.1997 R. Ozimec leg. (1♂); Jopićeva špilja, Krnjak 21.I.1998 R. Ozimec leg. (1♂), 6.IV.1999 R. Ozimec leg. (2♂); Matešićeva špilja, Mateško selo, Generalski Stol 23.IV.1998 R. Ozimec leg. (2♂, 1n); Markova špilja, Mateško Selo, Generalski Stol 16.I.2000 H.

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Cvitanović leg. (1♂); Bezdanica kod Barilovića, Barilović 16.V.1999 H. Cvitanović leg. (1♂); Kojina jama, Mašvina, Rakovica 27.VI.1999 H. Cvitanović leg. (1♂); Jama 4 psa, Gnojnice, Cetingrad -, 2001 H. Cvitanović leg. (1♂); Vukovićeva špilja, Gnojnice, Cetingrad 3.XI.2001 H. Cvitanović leg. (1♂), 5.V.2002 H. Cvitanović leg. (1♀); Vodena špilja, Siča, Barilović 19.V.2002 H. Cvitanović and K. Badovinec leg. (1♂); Baraćeva gornja špilja, Nova Kršlja, Rakovica 15.VI.2003 D. Hamidović leg. (1♂); Jama Mandelaja, Oštarije, Josipdol 17.IV.2004 M. Lukić leg. (1♂); Jama pod Debelom glavom, Hrvatski Blagaj, Slunj 1.V.2004 M. Pavlek leg. (1♂), 11. XI. 2017 D. Belavić leg. (1♀); Kutarčeva špilja, kanjon Korane, Slunj 25.V.2008 J. Bedek leg. (1♂); Mikića jama, Perjasica, Barilović 24.I.2010 leg. H. Cvitanović (1♂); Jama u Steljnici, Lučica, Siča, Barilović 6.I.2014 N. Cvitanović leg. (1♂); Adios špilja, Kordunski Ljeskovac, Rakovica 1.IX.2018 D. Basara leg. (1♂), (ADIPA).

Region: Lika

County: Lika-Senj

Records: Mramornjača, Petranović Draga, Donji Kosinj, Perušić 30.V.1999 R. Ozimec leg. (1♂), 22.XI.2016 R. Ozimec leg. (1♂); Špilja 2 u kanjonu Jadove, Lovinac 4.XII.2002 H. Cvitanović leg. (1♀); Šupljara špilja, jezero Kozjak, Plitvice Lakes NP, Korenica 24.IX.2005 M. Pavlek leg. (1♂); Špilja Milke Trnine, jezero Kozjak, Plitvice Lakes NP, Korenica 24.IX.2005 R. Ozimec leg. (1♀); Mračna pećina, kanjon Korane, Plitvice Lakes NP, Korenica 24.IX.2005 M. Pavlek leg. (2♂), R. Ozimec leg. (1♂), M. Lukić leg. (1♀); Sinčić špilja, Brinje 7.X.2006 M. Pavlek leg. (1♂); Rogić špilja, Klanac, Gospić 25.VII.2007 M. Pavlek leg. (1♂); Mračnjača špilja, Plitvice Lakes NP, Korenica 14.VII.2008 H. Cvitanović leg. (1♂); Sitvukova pećina, Sitvuk, PP Grabovača, Perušić 8.VIII.2014 J. Bedek leg. (1♂); Amidžina pećina, PP Grabovača, Perušić 11.V.2014 L. Kekelj leg. (1n), 11.V.2014 K. Cindrić leg. (1♂); Bobića pećina, Mlakva, Donji Kosinj, Perušić 13.IV.2016 R. Ozimec leg. (2♂); Čardačina jama, Mlakva Poljane, Donji Kosinj, Perušić 26.VIII.2016 D. Basara leg. (1♀), 30.IX.2016 D. Basara leg. (1n); Pećina u Čakovcu, Mlakva, Bobići, Donji Kosinj, Perušić 26.VIII.2016 H. Cvitanović leg. (1♂), 23.XI.2016 R. Ozimec leg. (1♂); Horvatova špilja, HE Sklope, Donji Kosinj, Perušić 27.VIII.2016 G. Polić leg. (1♂); Šojića pećina, Podjelar, Gornji Kosinj, Perušić 27.IX.2016 R. Ozimec leg. (2♀); Poljakova špilja, HE Sklope, Donji Kosinj, Perušić 28.IX.2016 R. Ozimec leg. (1♂); Medina pećina, PP Grabovača, Perušić 16.X.2017 leg. D. Basara (1♂); Jama na Vršiću, Kuselj, Plitvice Lakes NP, Korenica 17.X.2020 D. Basara leg. (1♂), (ADIPA).

Region: Istria

County: Istria, Primorje-Gorski Kotar

Records: Jama kod Raspadalice, Ćićarija Mt. Lanišće 11.V.2002 R. Ozimec leg. (1♂); Špilja kod Premanture, Premantura, Medulin 13.VII.2004 M. Pavlek leg. (1♂); Rabakova špilja, Ročko polje, Roč, Buzet 4.VII.2005 M. Lukić leg. (1♂), 6.VII.2010 R. Ozimec leg. (3n), 26.XI.2010 S. Polak leg. (4♂), R. Ozimec leg. (1♂); Grnjača špilja, Lovranska Draga, Grnjač, Učka Mt. Lovran 24.VI.2009 J. Bedek leg. (1♂), M. Lukić leg. (1♀, 1n); Pećina pod Stržen, Stržen, Brgudac, Ćićarija Mt. Lanišće 27.VI.2009 J. Bedek leg. (1♂); Jama pod Križ, Semići, Učka Mt. Lupoglav 27.VI.2009 M. Lukić leg. (1♂), 4.VI.2010 M. Lukić leg. (1♂); Radota jama, Vodice, Jelovice, Ćićarija Mt., Lanišće 27.XI.2010 S. Polak leg. (6♂), R. Ozimec leg. (1♂), (ADIPA).

Region: Kvarner Bay

County: Primorje–Gorski Kotar

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Records: Galatkovićeva jama, Krasica, Bakar 13.X.1996 G. Polić leg. (1♂); Jamice Plogar, Mundanije, Rab, Rab Island 17.V.1997 R. Ozimec leg. (2♂); Špilja iznad Jamine Drage, Lopar, Rab Island 18.V.1997 R. Ozimec leg. (1♀); Čampari jama, Petrićevi, Cres, Cres Island 8.IV.2001 R. Ozimec and B. Jalžić leg. (2♂); Špilja Biserujka, Čižići, Rudine, Dobrinj, Krk Island 26.V.2009 R. Ozimec and P. Rade leg. (1♀), 17.III.2011 R. Ozimec leg. (1♂); Zagorska peć, Sjeverni Velebit, Novi Vinodolski 25.V.2018 D. Basara leg. (1♂), (ADIPA).

Region: Velebit Mt.

County: Zadar, Lika-Senj

Records: Manita peć, Velika Paklenica, Paklenica NP, Južni Velebit, Starigrad 7.VI.2006 M. Pavlek leg. (1♂); Lužina špilja, Mali Vaganac, Paklenica NP, Južni Velebit, Starigrad 9.VI.2006 M. Pavlek leg. (1♂); Kusa, Manastirska luka, Krupa, Velebit PP, Obrovac 1. VIII. 2006 R. Ozimec leg (1♀); Plitka peć, Plitki dolovi, Čabrići Gornji, Kaštel Žegarski, Velebit NP, Obrovac 2.V.2009 R. Baković leg (1♂), (ADIPA).

Region: Pounje

County: Zadar

Records: Rastovača špilja, kanjon Slap, Srb, Plješivica Mt., Gračac 21.VI.2005 J. Bedek leg. (1♂), (ADIPA).

Region: Dalmatia (including the Dubrovnik area)

County: Split-Dalmatia, Dubrovnik-Neretva, Zadar, Šibenik-Knin

Records: Rudnik od Vore, Kostirna, Vis, Vis Island 8.I.2000 R. Ozimec leg. (2♂); Baba špilja, Štedovac, Gornje Tučepi, Biokovo Mt., Tučepi 27.IV.2002 R. Ozimec leg. (2♂), 5.XI.2009 H. Cvitanović leg. (1♂), 17.XI.2011 D. Basara leg. (1♂); Krjava 2, Velo brdo, Biokovo Mt., Makarska 24.III.2003 R. Ozimec leg (1♂), 27.X.2006 S. Nižetić leg. (1n), 2.VI.2023 D. Basara leg. (1♂); Jama pod Osojem, Nevistine stine, Donja Brela, Biokovo Mt., Brela 28.X.2003 J. Bedek leg. (1♀); Špilja pod Gromačkom vlakom, Gromača, Dubrovnik 2.XI.2003 J. Bedek leg. (1♂); Rudelića špilja, Vukovići, Vrlika 22.VIII.2004 M. Pavlek leg. (1♂); Golubnjača špilja, Žegar, Bukovica 9.I.2005 H. Bilandžija leg. (1♂), M. Pavlek leg. (1♀), J. Bedek leg (1♂), 2.VIII.2006 M. Pavlek leg. (1♂), R. Ozimec leg. (1♀), 24.II.2008 H. Cvitanović leg. (1♂); Stražbenica, Vrpolje, Šibenik 29.III.2005 J. Bedek leg. (1♂); Trojama, Mosor Mt., Dugopolje 6.V.2005 R. Ozimec leg. (1♂); Gospodska špilja, Četnici, Vrlika 14.VIII.2005 M. Pavlek leg. (1♂); Jezero na Gatuli, Komiža, Biševo Island 2.X.2005 R. Ozimec leg. (1♂); Vodena peća, Bajagić, Sinj 4.II.2006 M. Pavlek leg. (1♂); Vranjača, Kotlenice, Mosor Mt., Dugopolje 1. VIII. 2007 H. Bilandžija leg. (1♂), M. Lukić leg. (1♂); Medviđa Ropa, Skrivena Luka, Lastovo, Lastovo Island 3.III.2008. Manger and Drčelić leg. (1♂,1n); Jama u Zadubravici, Riđica, Dubrovnik 31.III.2008 R. Ozimec leg. (1♂); Banova ljut, Ljubač, Dubrovnik 31.X.2008 H. Cvitanović leg. (1♂), 11.IV.2011 R. Ozimec leg. (1♂); Jakasova špilja, Žrnovo, Korčula, Korčula Island 16.III.2010 R. Ozimec leg. (2♀); Crno jezero, Ponikve, Ston, Pelješac 14.IV.2011 I. Njunjić leg. (1♂); Jama Bezdan, Komaji, Konavle 13.VIII.2011 M. Kajinić leg. (1n); Velika Prdaljka, Alerići, Poljica Kozička, Vrgorac, 6.XI.2015 Ž. Marunčić leg. (1♂), M. Horvatin leg. (1♂); Sedrena špilja iza mlina, Bilušića buk, NP Krka, Šibenik 24.VI.2018 R. Ozimec leg. (1♂); Krčić špilja, Topoljski buk, Knin 26.VII.2018 R. Ozimec leg. (1♂); Pišurka, Korčula, Korčula Island 4.XII.2018 R. Ozimec leg. (1♂); Samograd špilja, Račišće, Korčula, Korčula Island 7.XII.2018 R. Ozimec leg. (1♂); Velika špilja kod Antunovića, Kozica, Biokovo Mt., Vrgorac 4.VI.2019 R. Ozimec and I. Vuković leg. (1♂); Drinova

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2, Bartulovići, Biokovo Mt., Brela, 6.VI.2019 R. Ozimec and I. Vuković leg. (2♂); Jama pod Bilušin vrhom, Žrnovo, Korčula, Korčula Island 11.XI.2019 K. Vučinić Bračić leg. (1♂); Jama za Supinom, Supin, Gornje Tučepi, Biokovo Mt., Tučepi 4.VII.2022 D. Basara and P. Rade leg. (1♂), (ADIPA).

References

1. Hekimoglu, O.; Elverici, M.; Yorulmaz, T. A survey of hard ticks associated with cave dwelling mammals in Turkey. *Ticks Tick Borne Dis*. **2022**, 13, 6. 102008. https://doi.org/10.1016/j.ttbdis.2022.102008.
2. Cull, B.; Pietzsch, M.E.; Hansford, K.M.; Gillingham, E.L.; Medlock, J.M. Surveillance of British ticks: An overview of species records, host associations, and new records of *Ixodes ricinus* distribution. *Ticks Tick Borne Dis*. **2018**, 9, 605-614. https://doi.org/10.1016/j.ttbdis.2018.01.011.
3. Defaye, B.; Moutailler, S.; Pasqualini, V.; Quilichini, Y. A Systematic Review of the Distribution of Tick-Borne Pathogens in Wild Animals and their Ticks in the Mediterranean Rim between 2000 and 2021. *Microorganisms* **2022**, 10, 1858. https://doi.org/10.3390/microorganisms10091858
4. Kapo, N.; Zuber Bogdanović, I.; Gagović, E.; Žekić, M.; Veinović, G.; Sukara, R.; Mihaljica, D.; Adžić, B.; Kadriaj, P.; Cvetkovikj, A.; Djadovski, I.; Potkonjak, A.; Velo, E.; Savić, S.; Tomanović, S.; Omeragić, J.; Beck, R.; Hodžić, A. Ixodid ticks and zoonotic tick-borne pathogens of the Western Balkans. *Parasit. Vectors* **2024**, 17, 2-23. https://doi.org/10.1186/s13071-023-06116-1.
5. Dantas-Torres, F.; Chomel, B.B.; Otranto, D. Ticks and tick-borne diseases: a One Health Perspective.*Trends Parsitol.* **2012**, 28, 437-446. https://.doi.org/10.1016/j.pt.2012.07.003.
6. Sándor, A.D.; Domsa, C.; Péter, Á.; Hornok, S. Ixodid ticks of Western Palearctic bats: ecology, host-parasite relationships, geographic distribution and zoonotic importance. *Front. Vet. Sci.* **2025**, 12, 1517704, https://doi.org/10.3389/fvets.2025.1517704.
7. Ciebiera, O.; Grochowalska, R.; Łopińska, A.; Zdunjak, P.; Strzala, T.; Jerzak, L. Ticks and spirochetes of the genus *Borrelia* in urban areas of Central-Western Poland. *Exp. Appl. Acarol.* **2024**, 93, 421-437. https://doi.org/10.1007/s10493-024-00932-5.
8. Hansford, K.M.; Wheeler, B.W.; Tschirren, B.; Medlock, J.M. Questing *Ixodes ricinus* ticks and *Borrelia* spp. In urban green space across Europe: A review. *Zoon. Pub. Health* **2022**, 69, 153-166. https://doi.org./10.1111/zph.12913.
9. Hansford, K.M.; Gillingham, E.L.; Vaux, A.G.C.; Cull, B.; McGinely, L.; Catton, M.; Wheeler, B.W.; Tschirren, B.; Medlock J.M. Impact of green space connectivity on urban tick presence density and *Borrelia* infected ticks in different habitats and seasons in three cities in Southern England. *Tick Ticks Borne Dis.* **2023**, 14, 1-14. https://doi.org/10.101016/j.ttbdis.2022.102103.
10. Rubel, F.; Dautel, H.; Nijhof, A.M.; Kahl, O. Ticks in the metropolitan area of Berlin, Germany. *Ticks Tick-Borne Dis*. **2022**, 13, 102029.
11. Krčmar, S.; Matak, P.; Krčmar, L.; Nikolić, K. Diversity of Hard Ticks (Acari: Ixodidae) Fauna on Green Habitats of Urban Areas in Eastern Croatia. *Pathogens* **2025a**, 14, 1010. https://doi.org/10.3390/pathogens14101010.
12. Turbanov, I.S.; Turbanova, A.A.; Yatsuk, A.A.; Kondratev, E.N.; Lunina, G.A.; Matyukhin, A.V. New data on hard ticks (Ixodida: Ixodidae) from the caves of Crimea and the Caucasus. *Acarina* **2025**, 33, 189–193. https://doi: 10.21684/0132-8077-2025-33-2-189-193.
13. Weigand, A.; Zaenker, S.; Weber, D.; Schaper, S.; Bröker, M.; Zaenker, C.; Chitimia-Dobler, L. Tick findings from subterranean environments in the Central German Uplands and Luxembourg reveal a predominance of male *Ixodes hexagonus*. *Exp. Appl. Acarol.* **2023**, 89, 461–473. https://doi.org/10.1007/s10493-023-00795-2.
14. Jurković-Žilić, D.; Gagović, E.; Naletilić, Š.; Beck, R. Tick borne pathogens in ruminant horses and tick in Croatia. In proceedongs 11th Ticks and Tick-borne Pathogens Conference. The Center for Genetic Engineering and Biotechnology (CIGB). Havana, Cuba 1.09.-6.09.2024.
15. Pintur, K.; Beck, R.; Gagović, E.; Dumić, T.; Slijepčević, V.; Fabijanić, N. Preliminary research of tick infestation on pheasants (*Phasianus* sp.) in the Republic of Croatia. In proceedings „Veterinarski dani 2025". Znanstveno-stručni skup s međunarodnim sudjelovanjem. Split, Hrvatska 7.11.-9.11.2025.

16. Ozimec, R. Arachnida (Croatia). In *Encyclopaedia Biospeologica*; Gottstein-Matočec, S., Juberthie, C., Decu, V., Eds.; Société de Biospéologie, Moulis, France, 2001; pp. 2257-2262.
17. Ozimec, R. Acarina. In *An overview of the cave and interstitial biota of Croatia*; Gottstein Matočec, S. Eds.; Natura Croatica, Zagreb, Croatia, 2002; 11,/Suppl.1, pp. 57-59. https://hrcak.srce.hr/32761.
18. Bedek, J.; Gottstein Matočec, S.; Jalžić, B.; Ozimec, R.; Štamol, V. Catalogue of Cave Type Localities of Croatian Fauna *Nat. Croat*. **2006**, 15, 1-154. https://hrcak.srce.hr/31056.
19. Ozimec, R.; Bedek, J.; Gottstein, S.; Jalžić, B.; Slapnik, R.; Štamol, V.; Bilandžija, H.; Dražina, T.; Kletečki, E.; Komerički, A.; Lukić, M.; Pavlek, M. Red book of Croatian cave dwelling fauna. 1st ed.; Ministry of Culture, State Institute for Nature Parotection Republic of Croatia, Zagreb, Croatia, 2009; pp. 1-371.
20. Girometta, U. Prilog poznavanju troglobijske i troglofilne faune Dalmacije uz geomorfološke bilješke o istraženim špiljama i jamama. (Fauna cavernarum Dalmatie). *Program Vel. Gimnaz. Spljet* **1914**, 1, 1–16.
21. Langhoffer, A. Fauna hrvatskih pećina (spilja) 2. (Fauna cavernarum Croatie II). Prirodoslovna istraživanja Hrvatske i Slavonije. *JAZU* **1915**, 7, 1-22.
22. Willmann C. Neue Milben aus Höhlen der Balkanhalbinsel, gesammelt von Prof. Dr. K. Absolon. Zool. Anz. **1940a**, 129, 213–218.
23. Willmann C. Neue Milben aus Höhlen der Balkanhalbinsel, gesammelt von Prof. Dr. K. Absolon (2. Mittgl.). *Zool. Anz.* **1940b**, 130, 209–218.
24. Willmann C. Die Acari der Höhlen der Balkanhalbinsel. *Biosp. Balc*. **1941**, 8,1–80.
25. Vlahović, I.; Tišljar, J.; Velić, I.; Matičec, D. Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics. Palaeogeography, Palaeoclimat.,Palaeoecol. **2005**, 220, 333-360. https://doi.org/10.1016/j.palaeo.2005.01.011.
26. Hillyard, P. Ticks of North-west Europe. In *Synopses of the British Fauna (New Series)*; Kermack, D.M., Barnes, R.S.K., Crothers, J.H., Eds.; The Linnean Society of London and the Estuarine and Coastal Sciences Association: Shrewsbury, UK, 1996; pp. 1-178.
27. Estrada-Peña, A.; Bouattour, A.; Camicas, J.-L..; Walker, A. Ticks of Domestic Animals in the Mediterranean Region. A Guide to Identification of Species, 1st ed.; University of Zaragoza, Zaragoza, Spain, 2004; pp. 1-130.
28. Estrada-Peña, A.; Mihalca, A.D.; Petney, T.N. Ticks of Europe and North Africa: A Guide to Species Identification, 1st ed.; Springer International Publishing: Cham, Switzerland, 2017; pp.1-403.
29. Hornok, S.; Sándor, A.D.; Beck, R.; Farkas, R.; Beati, L.; Kontschán, J.; Takács, N.; Földvári, G.; Silaghi, C.; Meyer-Kayser, E.; Hodžić, A.; Tomanović, S.; Abdullah, S.; Wall, R.; Estrada- Peña, A.; Duscher, G.G.; Plantard, O. Contributions to the phylogeny of *Ixodes* (*Pholeoixodes*) *canisuga*, *I.* (*Ph.*) *kaiseri*, *I.* (*Ph.*) *hexagonus* and a simple pictorial key for the identification of their females. *Parasit. Vectors* **2017**, 10, 1-12. https://doi.org/10.1186/s13071-017-2424-x.
30. Hornok, S.; Lesiczka, P.; Warbroek, T.; van den Bosch, T.J.M.; Pitó, A.; Keve, G.; Takács, N.; Kontschán, J.; Sándor, A.D. Comparison and complete mitogenomes of two morphologically similar but ecologically different tick species *Ixodes arboricola* and *Ixodes lividus* (subgenus *Pholeoixodes*). *Tick Tick Borne Dis*. **2026**, 17,102589. https://doi.org/10.1016/j.ttbdis.2025.102589.
31. Michalik, J.; Wodecka, B.; Liberska, J.; Dabert, M.; Postawa, T.; Piksa, K.; Stańczak, J. Diversity of *Borrelia burgdorferi* sensu lato species in *Ixodes* ticks (Acari: Ixodidae) associated with cave-dwelling bats from Poland and Romania. *Ticks Tick Borne Dis*. **2020**, 11, 101300. https://doi.org/10.1016/j.ttbdis.2019.101300.
32. Tovornik. D. *Ixodes* (*Eschatocephalus*) *vespertilionis* Koch, 1844 (Arachn., Ixodidae) regarding its specific hosts and natural habitats (Slovenia, Yugoslavia). *Acta Entomol. Jugosl.* **1990a**. 23, 15-28.
33. Hornok, S.; Kontschán, J.; Kováts, D.; Kovács, R.; Angyal, D.; Görföl, T.; Polacsek, Z.; Kalmár, Z.; Mihalca, A.D. Bat ticks revisited: *Ixodes ariadnae* sp. nov. and allopatric genotypes of *I. vespertilionis* in caves of Hungary. *Parasit. Vectors* **2014**, 7, 202. https://doi: 10.1186/1756-3305-7-202.
34. Krčmar, S. Hard ticks (Acari, Ixodidae) of Croatia. *ZooKeys* **2012**, 234, 19-57. https://doi.org/10.3897/zookeys.234.3658.
35. Antolović, J.; Flajšman, E.; Frković, A.; Grgurev, M.; Grubešić, M.; Hamidović, D.; Holcer, D.; Pavlinić, I.; Vuković, M.; Tvrtković, N. Red book of Mammals of Croatia. 1st ed.; Ministry of Culture, State Institute for Nature Protection, Republic of Croatia, Zagreb, 2006, pp. 1-122.

 doi:10.20944/preprints202602.1718.v1

36. Tovornik, D. On the bionomics of the *Ixodes* (*Pholeoixodes*) *hexagonus* Leach, 1815 in Slovenia (Yugoslavia). *Biol. Vestn.* **1987**, 35, 101-120.
37. Piksa, K.; Górz, A.; Nowak-Chmura, M.; Siuda, K. The patterns of seasonal activity of *Ixodes vespertilionis* (Acari: Ixodidae) on *Rhinolophus hipposideros* in nursery colonies. *Ticks Tick Borne Dis*. **2014**, 5, 69-74. https://doi.org/10.1016/j.ttbdis.2013.08.006.
38. Tovornik, D. Data on ticks *Ixodes frontalis* (Panzer, 1798) and *Ixodes arboricola* Schulze et Schlottke, 1929 found on birds in Yugoslavia. *Biol. Vestn.* **1991**, 39, 157-164.
39. Trilar, T. Ticks (Acarina: Ixodidae) on birds in Slovenia. *Acrocephalus* **2004**, 25, 213-216.
40. Keve, G.; Sándor, A.D.; Hornok, S. Hard ticks (Acari: Ixodidae) associated with Birds in Europe: review of literature data. *Front. Vet. Sci*. **2022**, 9, 928756. https://doi.org/10.3389/fvets.2022.928756.
41. Krčmar, S.; Vucelja, M.; Pezzi, M.; Boljfetić, M.; Margaletić, J.; Bjedov, L. Comparison of Hard Tick (Acari: Ixodidae) Fauna in Natural and Anthropogenic Habitats in Croatia. *Insects* **2025b**, 16, 1027. https://doi.org/10.3390/insects16101027.
42. Gray, J.S.; Dautel, H.; Estrada-Peña, A.; Kahl, O.; Lindgren, E. Effects of Climate Change on Ticks and Tick-Borne Diseases in Europe. *Interdisc. Perspect. Infect. Dis*. **2009**, 1-12 pages https://doi:10.1155/2009/593232.
43. Gray, J.; Kahl, O.; Zintl, A. What do we still need to know about *Ixodes ricinus*? *Ticks Tick Borne Dis.* **2021**, 12, 101682. https://doi.org/10.1016/j.ttbdis.2021.101682.
44. Medlock, J.M.; Hansford, K.M.; Bormane, A.; Derdakova, M.; Estrada-Peña, A.; Claude George, J.; Golovljova, I.; Jaenson, T.G.T.; Jensen, J.K.; Jensen, P.M.; Kazimirova, M.; Oteo, J.A.; Papa, A.; Pfister, K.; Plantard, O.; Randolph, S.E.; Rizzoli, A.; Santos-Silva, M.M.; Sprong, H.; Vial, L.; Hendrickx, G.; Zeller, H.; Bortel, W.V. Driving forces for changes in geographical distribution of *Ixodes ricinus* ticks in Europe. *Parasit. Vectors* **2013**, 6, 1-11. https://doi.org/10.1186/1756-3305-6-1.
45. Hradzilová, K.; Lesiczka, P.M.; Bardon, J.; Vyroubalová, Š.; Šimek, B.; Zurek, L.; Modrý, D. Wild boar as a potential reservoir of zoonotic tick-borne pathogens. *Ticks Tick Borne Dis*. **2021**, 12, 101558. https://doi.org/10.1016/j.ttbdis.2020.101558.
46. Tovornik D. The significance of the birds (Aves) as the hosts and disseminators of Ixodid Ticks (Yugoslavia). *Biol. Vestn.* **1990b**, 38, 77-108.
47. Keve, G.; Sándor, A.D.; Hornok, S. A review on the role of birds as disseminators of ticks, with special emphasis on *Hyalomma* species and Crimean-Congo haemorrhagic fever virus. *Ticks Tick Borne Dis*. **2025**, 16, 102535. https://doi.org/10.1016/j.ttbdis.2025.102535.
48. de la Fuente, J.; Estrada-Peña, A.; Cabezas-Cruz, A.; Brey, R. Flying ticks: anciently evolved associations that constitute a risk of infectious disease spread. *Parasit. Vectors* **2015**, 8, 1-11. https://doi.org/10.1186/s13071-015-1154-1.
49. Matulaityte, V.; Paulauskas, A.; Bratchikov, M.; Radzijevskaja, J. New record of *Rickettsia vini* in *Ixodes lividus* ticks from Lithuania. *Ticks Tick Borne Dis*. **2020**, 11, 3. https://doi.org/10.1016/j.ttbdis.2020.101372.
50. Mikačić, D. Ticks in the litorral belt of Yugoslavia III. Distribution and dynamics of species in the course of the year. *Vet. Arhiv* **1965**, 35, 155-170.

51. Giupponi, C.; Jourdan-Pineau, H.; Bernard, C.; Blanda, V.; Bourquia, M.; Bru, D.; Cabezón, O.; Carrera-Faja, L.; Espunyes, J.; Gottlieb, Y.; Joly-Kukla, C.; Malandrin, L.; Mechouk, N.; Mihalca, A.D.; Pollet, T.; Saengram, P.; Torina, A.; Valcárcel, F.; Vatansever, Z.; Vial, L.; Zahri, A.; Verheyden, H.; Huber, K. Tracking invasion events: phylogeography of *Hyalomma marginatum* in the Mediterranean basin with a focus on Southern France. *Parasit. Vectors* **2025**, 18, 407. https://doi.org/10.1186/s13071-025-06927-4.
52. Szentiványi, T.; Takács, N.; Sándor, A.D.; Péter, Á.; Boldogh, S.A.; Kováts, D.; Foster J.T.; Estók, P.; Hornok, S. Bat-associated ticks as a potential link for vector-borne pathogen transmission between bats and other animals. *PLoS Negl. Trop. Dis*. **2024**, 18, e0012584. https://doi.org/10.1371/journal.pntd.0012584