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On the Bionomics of the *Ixodes (Pholeoixodes) hexagonus* Leach, 1815 in Slovenia (Yugoslavia)

O bionomiji klopa *Ixodes (Pholeoixodes) hexagonus* Leach, 1815 v Sloveniji

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Descriptors: Ixodes hexagonus / Slovenia

Abstract. Data on geographical and seasonal distribution of 554 tick specimens identified as *Ixodes (Pholeoixodes) hexagonus* Leach are presented. They are found only on hedgehogs and some carnivores or as free, unfed specimens on walls and in the crevices of caves, mostly in Slovenia, but also in some other parts of Yugoslavia. The infestation intensity of all investigated hóst-animals, the associations of *I. hexagonus* with other tick species present and the developmental duration of several *I. hexagonus* stages under laboratory conditions are shown. The possible relationship between *I. hexagonus* and the tick-borne encephalitis virus is discussed.

Deskriptorji: Ixodes hexagonus / Slovenija

Izvleček. Prikazani so podatki o geografski in sezonski distribuciji 554 klopov, determiniranih kot *Ixodes (Pholeoixodes) hexagonus* Leach, najdenih izključno le na ježih in nekaterih zvereh, v prostem, nenasesanem stanju pa po stenah in špranjah jamskih habitatov, večinoma v Sloveniji, vendar tudi v nekaterih drugih predelih Jugoslavije. Avtorica pokaže na intenzivnost infestacije zajedenih živali, na asociacije *I. hexagonus* z drugimi vrstami klopov na le-teh, na dolžino razvoja posameznih stadijev *I. hexagonus* v laboratorijskih razmerah ter govori o morebitni povezavi *I. hexagonus* z virusom klopnega meningoencefalitisa.

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Introduction

The tick *Ixodes hexagonus* Leach is a young species and this is probably the reason for its rather high degree of morphological variability. Some researchers quote 15 identified species of the subgenus *Pholeoixodes* for central Europe, of which 9 species were found as parasites of mammals and 6 of birds (BABOS 1964). All *Pholeoixodes* species identified are closely related to each other and they have many common, hardly distinguishable, morphological features. *I. hexagonus* and a very small number of *Ixodes canisuga* Johnston were the only species which we could segregate and identify in the material collected in Slovenia (Yu) in spite of its obvious morphological variability. Our identification was supported by Dr. Harry Hoogstraal and Dr. Hilda Y. Wassef (NAMRU-3, Cairo).

According to STREISSLE (1961a, 1961b), the tick *I. hexagonus* plays a part in the circulation of the tick-borne encephalitis (TBE) virus in regions it inhabits in Europe as well. *I. hexagonus* is able to transmit the TBE virus to its offspring transovarially, to infect a laboratory mouse with bite, to transmit the virus transstadially and to attack man.

I. hexagonus has already been registered in Yugoslavia (OSWALD 1940, 1941) and pointed out as a constituent part of *Ixodidae* fauna in regions where TBE occurs (TOVORNIK 1970). Greater attention was devoted to this species in an unpublished work prepared for Research Community of Slovenia (TOVORNIK 1981).

In this paper, 554 *I. hexagonus* ticks are analysed in detail. Data on the geographical distribution of *I. hexagonus* that reflect its horizontal and vertical distribution are given; the relationship of the species to host animals is ascertained and the associations of *I. hexagonus* with other tick species in the different zoogeographical regions of Yugoslavia presented. The development of *I. hexagonus* under laboratory conditions is observed and the growth structure of our specimens given.

Methods of work and material

The great majority of *I. hexagonus* ticks were handed to us for treatment by the executive curator of the Slovene Museum of Natural Sciences in Ljubljana, Savo Brelih. Some of ticks remained in the possession of the Department for Human and Sanitary Virology of the Institute for Hygiene, Epidemiology and Laboratory Diagnostics in Ljubljana. Ticks found in underground caves were identified and returned to the Slovene Academy of Arts and Sciences, Postojna (Dr. Tone Novak).

Glass Petri plates or large plastic tubes, closed by foam rubber or cellulose stoppers, were used for the maintenance of live cultures of ticks.

Results of work

1) Breeding of *I. hexagonus* in the laboratory

The results of the laboratory breeding of two related hygrophilic species of ticks, *I. hexagonus* and *Ixodes ricinus* Linné, are shown in table 1. Our experimental data are complemented with data cited for the growth of *I. hexagonus* in laboratory conditions by other researchers (ARTHUR 1951, NOSEK et al 1967, HONZAKOVA 1971).

Table 1.: *The development in the laboratory (20 °C; RH)*
Tabela 1.: *Razvoj v laboratoriju (20 °C; RH)*

	Lastna opazovanja; Own observations;		Arthur (1951); *I hexagonus*	Nosek et al. (1967); *I. hexagonus*	Honzakova (1971); *I. hexagonus*
	I. ricinus	*I. hexagonus*			
Oplojena samica; čas preovipozicije; The fertilized female; preoviposition time	6—14 dni (52) days	15—12 dni days	12—14 dni (7—31) days		11—16 dni days
ovipozicija the oviposition	(3) 20—35	16—30	19—15		
izleženje larv po; hatching of larvae in	43—60 (97)	35—45	52—25		
larva sesa; the larva sucks	2—5	3—7 (miš; mouse)	3—6		4—8 (miš, mouse) 5—18 (jež; hedgehog)
metamorfoza larve; metamorphosis of the larva	50—75	15—30	23—60		7—31 (24—31)
nimfa sesa; the nymph sucks	3—6		5—7		8—9 (miš; mouse) 6—14 (jež; hedgehog)
metamorfoza nimfe; metamorphosis of the nymph	(40) 50—55	25—40	20—25—77	19	32—44
samica sesa; the female sucks	10—14		8—16	nekaj tednov; some weeks	8—13

2) Dimensions of fed females of *I. hexagonus*

Fed females can reach rather large proportions. The length of the fully engorged females collected from hedgehogs was found to be within the range of 0.7 and 1.1 cm, and the width between 0.3 and 0.7 cm. The majority of females in our material were 0.7 cm long (35%), followed by 0.9 cm long females (30%), and those measuring 0.8 cm and 1.0 cm (15% respectively). The biggest females of all were 1.1 cm long and 0.7 cm wide and were found only individually. As regards width, 80% of females measured either 0.4 or 0.5 cm. Females of 0.6 and 0.7 cm wide are rare, as are the narrowest ones of 0.3 cm.

All the measured females were fully fed with blood and were therefore able to lay eggs. The size of the egg-sac laid by females is however, primarily dependent on the size of the female.

3) Distribution of *I. hexagonus*

a) Geographical distribution

a-1) Horizontal distribution

The places where the *I. hexagonus* tick has been found are shown in figure 1. Our data were recorded on the cartogram UTM for Slovenia, where one point for each 10 km UTM quadrant is given, regardless of the actual number of finding places. Discovery sites in other parts of Yugoslavia are shown separately, in the small drawing.

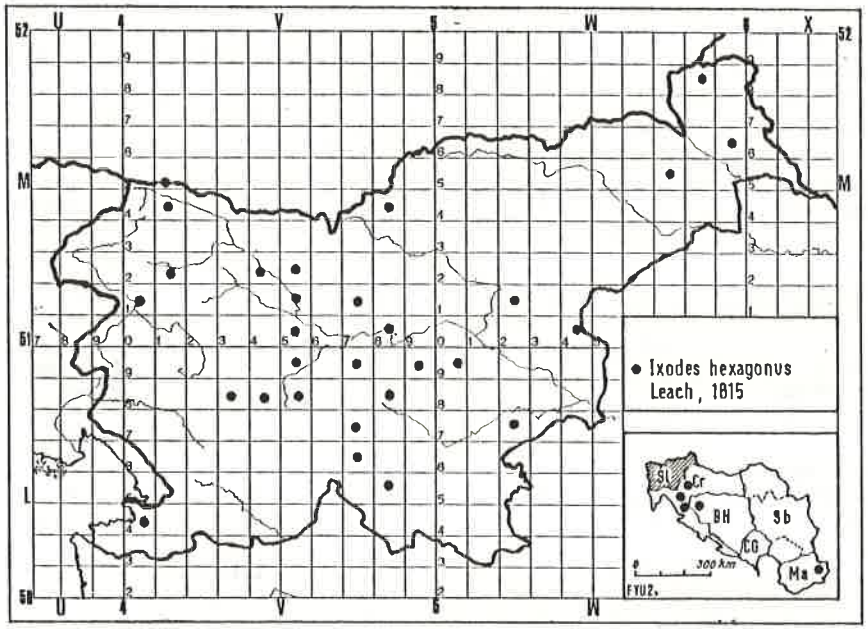

Figure 1.: *Places in Slovenia (Yu) where Ixodes hexagonus has been found*
Slika 1.: *Nahajališča Ixodes hexagonus v Sloveniji*

a-2) Vertical distribution

The height above sea-level of the sites where *I. hexagonus* has been found is given in the figure 2. According to our data the *I. hexagonus* tick mainly inhabits lowland and hilly areas, although it also occurs higher in the mountains, at up to 1000 metres above sea-level. The higher sites are rather the exception for our material than the rule, although *I. hexagonus* is ecologically strictly bound to cave habitats, which are also common higher in the mountains.

b) Seasonal distribution

I. hexagonus was collected on hosts throughout the calendar year, even during the coolest months. This phenomenon is the direct consequence of the way of life led by the tick in

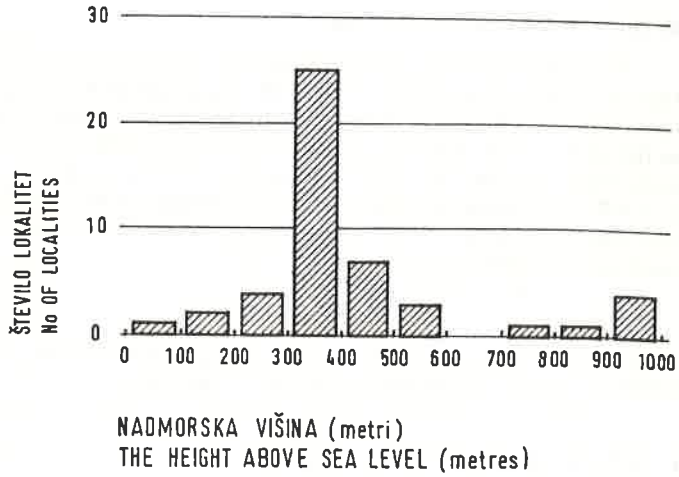

Figure 2.: *Ixodes hexagonus: height above sea level*
Slika 2.: *Ixodes hexagonus glede na nadmorsko višino*

pits and caves, where its free forms do not depend directly on atmospheric circumstances. The connection between the hosts found infested with *I. hexagonus* and the month when the animals were captured or ticks collected, is presented in figure 3. Ticks treated in this paper were gathered during the period 1954—1979.

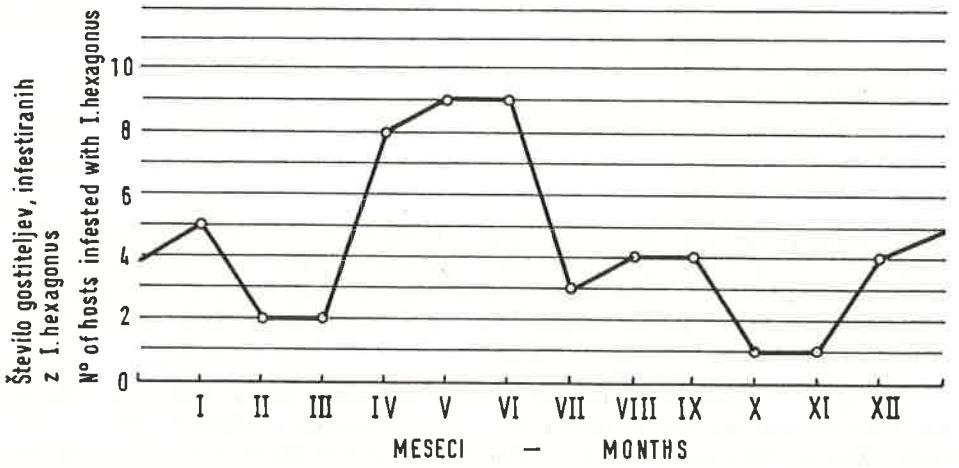

Figure 3.: *Ixodes hexagonus: seasonal infestation of hosts*
Slika 3.: *Ixodes hexagonus glede na sezonsko infestacijo gostiteljev*

) Hosts of the tick *I. hexagonus*

The host animals on which *I. hexagonus* was found and which are consequently classified with regular hosts for this tick species, are presented in table 2. All the tick material gathered is labelled with basic data, which are presented in tables for clarity. In table 3, as well as the data on hosts and the number of parasitizing ticks within each species and development stage, the place and date of collection, UTM co-ordinates, altitude of finding place and collectors' names are given. All the collaborators who collected ticks and identified the host animals while in the field, are quoted and each name is abbreviated to make it easier to record in the table.

able 2.: *Animals found to be infested with* ***I. hexagonus*** *in Slovenia (Yu)*
abela 2.: *Živali, ki smo jih našli infestirane z* ***I. hexagonus*** *v Sloveniji*

INSECTIVORA

rinaceidae: *Erinaceus roumanicus*: jež, hedgehog;

. CARNIVORA

elidae: *Felis silvestris*: divja mačka, wild cat;
Felis domestica: domača mačka, domestic cat;

anidae: *Canis lupus*: volk, wolf;
Canis familiaris: pes, dog;
Vulpes vulpes:: lisica, fox;

lustelidae: *Martes martes*: kuna zlatica, pine marten;
Martes foina: kuna belica, stone marten;
Mustela putorius: dihur, polecat;
Meles meles: jazbec, badger;
Lutra lutra: vidra, otter;

I. ARTIODACTYLA:

Bos taurus: domače govedo, cattle.

AF — Barbič Franc; BrS — Brelih Savo; DjB — Djulić Beatrica; DoJ — Dovič Janez; DžG - Džukić Georg; GrJ — Gregori Janez; IgK — Igallfy Kosta; KrB — Kryštufek Boris; LeF - Leben Franc; LeA — Lesinger Andrija; NoT — Novak Tone; PeB — Petrov Boris; PrS - Pretner Egon; RuC — Rucner Dragutin; SiI — Sivec Ignac; ŠmA — Šmuc Alojz; ToD — ɔvornik Danica; TvN — Tvrtković Nikola.

12 species of mammals, 67 animals in number, are among typical hosts for *I. hexagonus*. These animals, and the parasitizing ticks, are systematically arranged in table 4. In this ble 1,000 ticks are considered, presented in absolute and relative numerical figures accorng to their hosts. The tick, *Ixodes pari Leach* (=Ixodes frontalis Panzer), which is a typil parasite of birds, was found by chance on a stone marten. A graphical analysis of all the 000 ticks collected that are shown in the tables, is also given. The infestation of one species

Table 3.: *The list of the material collected*
Tabela 3.: *Seznam zbranega materiala*

Živali-gostitelji; Host-animals	Št živali; No. of animals;	Kraj ulova; Place of capture;	UTM koord.; UTM co-ord.	Nadmorske višine; sea level;	Datum: Date:	Legit:	Klopi po vrstah in stadijih; Species and stage of tick;
1	2	3	4	5	6	7	8
Er. europaeus (det. B. Djulić)	2	Brač	XJ30		7. 1967	DjB	H. marginatum: 8 Ny, 3 La;
Er. europaeus	2	Brač	XJ30		7. 1967	DjB	H. marginatum: 9 Ny, 19 La;
Er. europaeus	1	Brač	XJ30		7. 1967	DjB	H. marginatum: 2 Ny, 3 La;
Er. roumanicus	1	Orjen, Črna gora	CNo1		1968	PeB	I. ricinus: 1 ♀;
Er. roumanicus	1	Valandovo, Ulanci	FL27		6. 4. 1968	BrS;	Rh. sanguineus: 2 ♂; H. marginatum: 1 Ny;
Er. roumanicus	1	Beltinci	WM96	177 m	16. 7. 1969	PeB, BrS;	I. hexagonus: 2 ♀, 5 Ny, 39 La;
Erinaceus roumanicus	1	Razvala, Velika Kapela	WK29	884 m	16. 8. 1969	PeB, BrS;	I. hexagonus: 4 Ny;
Er. romanicus	1	Beltinci	WM96	177 m	16. 7. 1969	PeB, BrS;	I. hexagonus: 2 ♀, 5 Ny, 39 La;
Er. roumanicus	1	Vilusi, Črna gora	CNo3	ca 700 m	9. 8. 1970	BrS	I. ricinus: 1 Ny, 1 La; H. punctata: 2 Ny, 15 La; D. marginatus: 19 Ny, 4 La;
Er. roumanicus	1	Ljubljana,	VL59	300 m	6. 6. 1971		I. hexagonus: 10 Ny, 2 La; I. ricinus; 1 ♀, 14 Ny, 4 La;
Er. roumanicus	1	Medvode	VM51	340 m	4. 5. 1975	KrB	I. hexagonus: 2 ♀, 1 Ny; I. ricinus: 3 ♀, 1 ♂, 1 Ny;
Er. roumanicus	1	Kranj, Žeje	VM42	430 m	20. 4. 1976	KrB	I. hexagonus: 6 Ny;
Er. roumanicus	1	Medvode	VM51	340 m	4. 5. 1976	KrB	I. hexagonus: 1 Ny; I. ricinus: 3 Ny;
Er. roumanicus	1	Medvode	VM51	340 m	17. 5. 1976	KrB	I. hexagonus: 5♀;
Er. roumanicus	1	Kranj	VM52	385 m	3. 5. 1977	KrB	I. hexagonus: 4 Ny, 2 La;
Er. roumanicus	1	Medvode	VM51	340 m	15. 5. 1978	KrB	I. hexagonus: 2 ♀; I. ricinus: 14 ♂, 8 ♀;
Er. roumanicus	1	Vrhovci	VM50	300 m	15. 6. 1979	ToD	I. hexagonus: 10 ♀; I. ricinus: 10 ♀, 30 Ny, 10 La;
Er. roumanicus	1	Vrhovci	VM50	300 m	22. 6. 1979	ToD	I. hexagonus: 12 ♀, 20 Ny, 4 La; I. ricinus: 30 ♀, 10 Ny;
Er. roumanicus	1	Vrhovci	VM50	300 m	20. 9. 1979	ToD	I. hexagonus: 1 ♂, 16 La; I. ricinus: 2 ♀, 8 Ny, 20 La;
Felis silvestris	1	Ribnica	VL76	441 m	30. 6. 1964		I. hexagonus: 1 Ny; I. ricinus: 4 Ny;
Felis domestica	2	Vrhnika	VL48	ca 320 m	7. 11. 1973		I. hexagonus: 2 Ny; I. ricinus: 2 ♂, 10 ♀, 8 Ny, 4 La;
Canis lupus	1	Kočevje,	VL85	460 m	25. 6. 1963		I. hexagonus: 1 Ny; I. ricinus: 2 ♀, 2 Ny;
Canis lupus	1	Cazin	WK77		10. 3. 1972	LeF	I. ricinus: 2 ♂;
Canis familiaris	1	Grad, Goričko, Prekmurje;	WM88	200—300 m	2. 7. 1954	ToD	I. hexagonus: 6 ♀, 9 Ny, 15 La;
Canis familiaris	1	Portorož	VL93	30 m	15. 7. 1955	ToD	R. sanguineus: 2 ♂, 8 ♀;
Canis familiaris	1	Javor	VL79	520 m	20. 6. 1969	BrS	I. hexagonus: 3 ♀, 5 La; I. ricinus: 19 Ny, 7 La;

Živali-gostitelji; Host-animals	Št. živali; No. of animals;	Kraj ulova; Place of capture;	UTM koord.; UTM co-ord.	Nadmorske višine; sea-level;	Datum: Date:	Legit:	Klopi po vrstah in stadijih; Species and stage of tick;
1	2	3	4	5	6	7	8
Canis familiaris	1	Vače	VM80	ca 600 m	13. 5. 1973		I. hexagonus: 2 ♀, 3 Ny; I. ricinus: 2 ♂, 18 ♀, 15 Ny;
Canis familiaris	1	Ljubljana	VM50	300 m	10. 4. 1974	ToD	I. ricinus: 3 ♂, 4 ♀; R. sanguineus: 1 ♀;
Canis familiaris	1	Umag	UL93	2 m	27. 5. 1978		R. sanguineus: 15 ♂, 20 ♀;
Canis familiaris	1	Lukovica	VM71	320 m	26. 5. 1979	ToD	I. hexagonus: 2 ♀, 2 Ny; I. ricinus: 4 ♀ 5 Ny;
Vulpes vulpes	1	Medvode	VM51	340 m	1. 3. 1956	BaF	I. hexagonus: 1 ♀, 9 Ny, 24 La;
Vulpes vulpes	1				1959		I. hexagonus: 2 Ny, 2 La;
Vulpes vulpes	1	Rakitna	VL58	ca 900 m	10. 3. 1960	BrS	I. hexagonus: 6 ♀, 20 Ny, 10 La; I. ricinus: 7 ♂ 6 ♀;
Vulpes vulpes	1	Ribnica	VL76	441 m	13. 1. 1965	BrS	I. hexagonus: 1 ♀;
Vulpes vulpes	1	Dekani	VL04	10 m	20. 12. 1965	BrS	I. hexagonus: 1 ♀; I. ricinus: 1 ♀;
Vulpes vulpes	1	Šmarna gora	VM50	ca 600 m	25. 12. 1966	DoJ	I. ricinus: 7 ♀; (vse pod kožo — all under the skin);
Vulpes vulpes	1	Laze	VM00		21. 1. 1968	DoJ	I. ricinus: 9 ♀; (vse pod kožo — all under the skin);
Vulpes vulpes	1	Štajersko	WM		21. 1. 1968		I. hexagonus: 6 Ny, 11 La;
Vulpes vulpes	1	Dobrepolje	VL77	ca 300 m	13. 6. 1969	ŠmA	I. hexagonus: 13 ♀, 6 Ny, 1 La;
Vulpes vulpes (juv.)	1	Zakovšek	VL38	ca 600 m	12. 6. 1977		I. ricinus: 1 ♀;
Vulpes vulpes	1	Hodoš	WM98	ca 200 m	14. 1. 1978	LeA	I. canisuga: 3 ♀;
Vulpes vulpes	1				1979		I. hexagonus: 1 Ny; I. ricinus: 1 Ny;
Martes martes	1	Dugo selo, Zagreb;	WL97	ca 200 m	5. 4. 1959	IgK	I. hexagonus: 1 ♀; I ricinus: 1 ♀;
Martes martes	1	Mirna na Dolenjskem	WL09	ca 300 m	28. 4. 1969	BrS	I. hexagonus: 1 ♀; I. ricinus: 1 ♀;
Martes martes	1	Litija	VM80	240 m	1. 12. 1972	BrS	I. hexagonus: 1 ♀; I. ricinus: 1 ♀;
Martes foina	1	Kresnice pri Litiji;	VM80	240 m	4. 4. 1965	BrS	I. hexagonus: 1 Ny; I. ricinus: 1 Ny;
Martes foina	1	D. Klada, Velebit;	VK96		1975	TvN	I. pari: 1 ♀;
Mustela nivalis	1	Paračin	EP36		16. 4. 1972	DžG	I. ricinus: 1 ♂, 1 Ny;
Mustela nivalis	1	Dojran	FL46		27. 11. 1975	PeB	I. ricinus: 3 ♀, 2 Ny;
Mustela putorius	1	Vrhnika	VL48	ca 320 m	26. 4. 1956	LeF	I. hexagonus: 1 ♀, 18 Ny, 41 La; I. ricinus: 3 Ny;
Mustela putorius	1	Borovnica	VL58	ca 320 m	18. 2. 1957	LeF	I. hexagonus: 5 Ny, 1 La;
Mustela putorius	1	Borovnica	VL58	ca 320	3. 2. 1959	LeF	I. hexagonus: 1 Ny;
Mustela putorius	1	Ljubljana, Šiška;	VM50	ca 300 m	5. 8. 1962		I. hexagonus: 6 Ny, 15 La;
Mustela putorius	1	Kočevje,	VL85	460 m	12. 4. 1964		I. hexagonus: 6 ♀, 46 Ny, 2 La;
Mustela putorius	1	Miklavž, Gorjanci;	WL27	965 m	13. 8. 1967	PeB	I. hexagonus: 2 Ny;

Živali-gostitelji; Host-animals	Št. živali; No. of animals;	Kraj ulova; Place of capture;	UTM koord.; UTM co-ord.	Nadmorske višine; sea-level;	Datum: Date:	Legit:	Klopi po vrstah in stadijih; Species and stage of tick;
1	2	3	4	5	6	7	8
Mustela putorius	1	Vrhnika	VM14	ca 320 m	24. 6. 1965		I. hexagonus: 2 Ny;
Mustela putorius	1	Krma, Julijske Alpe;	VM14	890—1100 m	19. 8. 1967		I. hexagonus: 11 Ny, 7 La;
Mustela putorius	1	Borovnica, Barje;	VL58	ca 320 m	3. 10. 1973	LeF	I. hexagonus: 6 Ny; I. ricinus: 3 La;
Meles meles	1	Prevoje pri Lukovici;	VM71	ca 300 m	29. 6. 1964	BrS	I. hexagonus: 4 ♀, 6 Ny; I. ricinus: 2 ♀;
Meles meles	1	Kočevje	VL85	460 m	6. 8. 1964		I. hexagonus: 2 ♀;
Meles meles	1	Višnja gora	VL88	ca 320	7. 5. 1965		I. hexagonus: 1 Ny;
Meles meles	1	Vrhnika	VL48	ca 320 m	26. 4. 1967	LeF	I. hexagonus: 1 ♀, 1 Ny;
Meles meles	1	Vrhnika	VL48	ca 320 m	24. 4. 1969	LeF	I. hexagonus: 2 ♀, 2 Ny;
Meles meles	1	Srednji vrh, Karavanke;	VM15	960 m	18. 4. 1975	GrJ	I. hexagonus: 1 ♀, 1 Ny;
Meles meles	1	Dobrnič	VL99	ca 350 m	29. 8. 1978	ŠmA	I. hexagonus: 8 Ny;
Lutra lutra	1	Bihać,	WL66	ca 400 m	25. 1. 1972	LeF	I. hexagonus: 2 Ny, 1 La;
Bos taurus	1	Bohinj	VM12	530 m	10. 9. 1959		I. hexagonus: 8 ♀, 15 Ny;
Rastlinje / Vegetation:							
Helleboreto--Pinetum		Vrhovine, Rakitna;	WK16		18. 9. 1961	RuD	I. hexagonus: 1 ♀, 1 Ny;
Podzemske jame Underground caves:							
		Gustav Jakob Höhle, Laichingen;			5. 1965	PrE	I. hexagonus: 1 ♂, 1 Ny;
		Zadlaška jama, Tolmin;	VM01		8. 5. 1966	PrE	I. hexagonus: 1 ♀;
		Vzhodna Makedonija;			26. 6. 1966	PrE	I. hexagonus: 1 ♀;
		Gruska jama, Kozje;	WM40		18. 7. 1978	SiI NoT	I. hexagonus: 3 ♂;
		Jama Karančuka, Peca Črna na Koroškem;	VM84		5. 1. 1979	NoT	I hexagonus: 2 ♂;
		Fantovska jama, Štore, Bojanski vrh;	WM21		8. 7. 1978	NoT	I. hexagonus: 1 ♀;

Table 4.: *Ixodid ticks from hosts typical for the species I. hexagonus*
Tabela 4.: *Iksodidni klopi z gostiteljev, karakterističnih za vrsto I. hexagonus*

Tipični gostitelji / Typical hosts	St. / No.	Klopi po vrstah (abs./%) / Ticks — species (abs/%)								Vsi klopi: / All ticks	Povpr. klopi: / Average ticks	Povprečno I. hexagonus; / Average I. hexagonus
		I. ric.	I. pari*	I. hex	I. canis	Haem. p.	Derm. marg.	Rhip. sang.	Hy. marg.	Absol./ %		
1. Erinaceus roumanicus	20	182/18,2		148/14,8		17,/1,7	23/2,3	2/0,2	45/4,5	417/41,7	20,9	7,4
2. Felis silvestris	1	4/0,4		1/0,1						5/0,5	5,0	1,0
3. Felis domestica	2	24/2,4		2/0,2						26/2,6	13,0	1,0
4. Canis lupus	2	6/0,6		1/0,1						7/0,7	3,5	0,5
5. Canis familiaris	7	77/7,7		47/4,7				46/4,6		170/17,0	24,3	6,7
6. Vulpes vulpes	12	32/3,2		114/11,4	3/0,3					149/14,9	12,4	9,5
7. Martes martes	3	3/0,3		3/0,3						6/0,6	2,0	1,0
8. Martes foina	2	1/0,1	1/0,1	1/0,1						3/0,3	1,5	0,5
9. Mustela putorius	9	6/0,6		170/17,0						176/17,6	19,6	18,9
10. Mustela nivalis	2	7/0,7								7/0,7	7,0	0
11. Meles meles	7	2/0,2		29/2,9						31/3,1	4,4	4,2
12. Lutra lutra	1			3/0,3						3/0,3	3,0	3,0
Vsi — All	67	344 34,4%	1 0,1%	519 51,9%	3 0,3%	17 1,7%	23 2,3%	48 4,8%	45 4,5%	1000 100%		

* the tick of birds
* klop ptičev

of animal was taken as a concluded totality, i.e. 100%, and all animals are ranged according to the successive reduction of the percentage value of infestation with *I. hexagonus*. (Fig. 4).

The mean infestation values of specific host species with *I. hexagonus* are shown on the graph of figure 5. These mean infestation values show, (like figure 4), a significant decrease from the level of infestation of the polecat to that of the stone marten: polecat, hedgehog, fox, dog, badger, otter, wild cat, domestic cat, pine marten, wolf, stone marten.

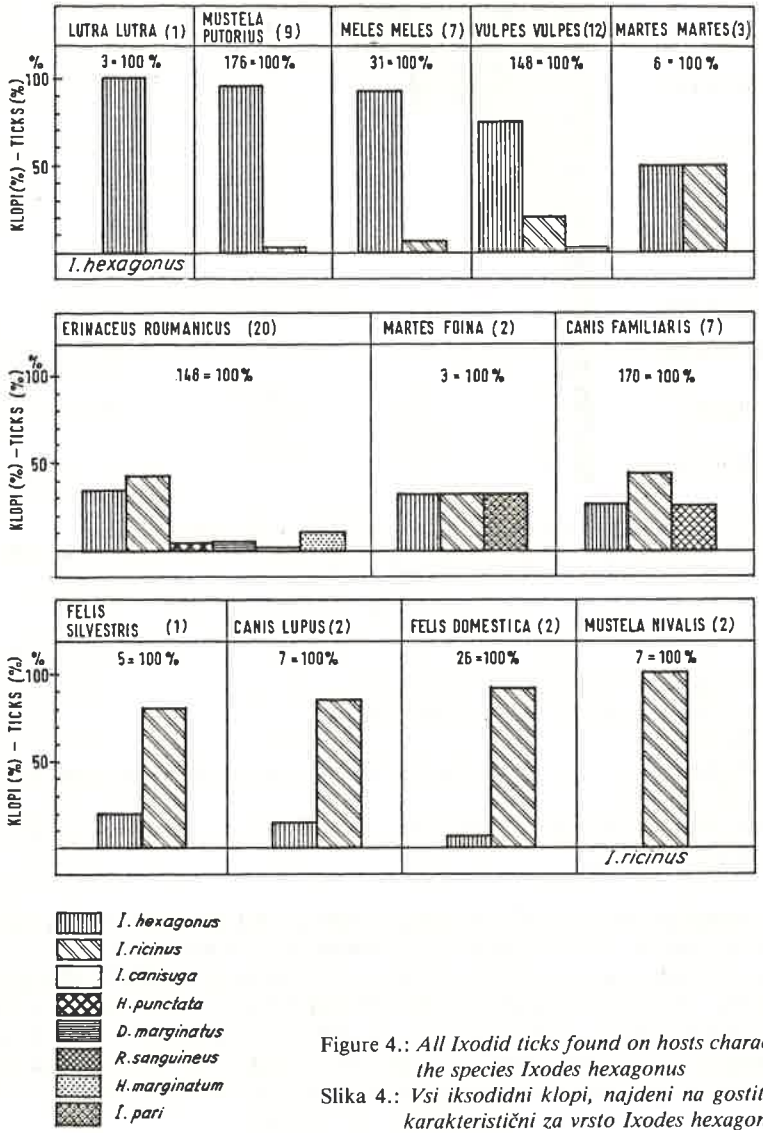

Figure 4.: *All Ixodid ticks found on hosts characteristic for the species Ixodes hexagonus*
Slika 4.: *Vsi iksodidni klopi, najdeni na gostiteljih, ki so karakteristični za vrsto Ixodes hexagonus.*

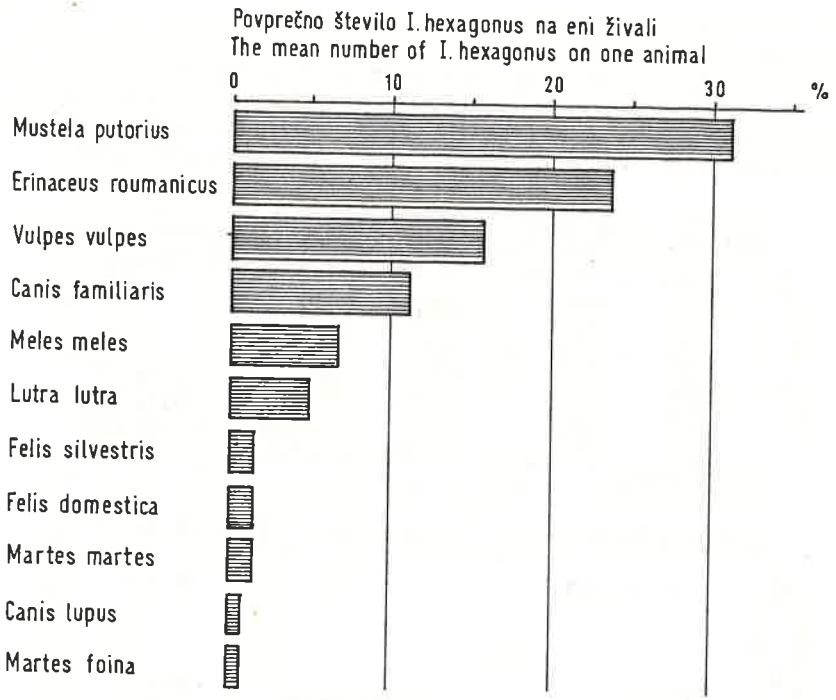

Figure 5.: *Ixodes hexagonus: mean infestation value of characteristic hosts*
Slika 5.: *Ixodes hexagonus glede na povprečno vrednost infestacije karakterističnih gostiteljev*

5) Ticks

Origin of all ticks treated in the paper (1,035):
1) from hosts characteristic for *I. hexagonus* (1000);
2) from cattle (23);
3) from underground caves, typical habitat for this cavicol species, where it was found free on the walls (10) and
4) from vegetation, caught with an insect net, which is not the usual way of capturing *I. hexagonus* (2).

The numerical presentation of 1,035 ticks, including *I. hexagonus* and concomitant species, is given in table 5. 554 of identified ticks belong to the species *I. hexagonus*, and its growth structure with regard to individual hosts is shown in detail in table 6. Altogether 107 (19,2%) adults, 249 (45,1%) nymphs and 198 (35,7%) larvae of this species were found.

Those mammal species which in Slovenia are most intensively parasitized by *I. hexagonus*, are emphasized in the extra graph in figure 6. We compare four species — fox, polecat, hedgehog, badger — and the *I. hexagonus* ticks on them, considering developmental stages.

Table 5.: *Tick species bound with I. hexagonus in relation to common hosts.*
Tabela 5.: *Vrste klopov, povezane z I. hexagonus, glede na skupne gostitelje.*

Vrste klopov — Tick species	abs.	%
1. *Ixodes ricinus* Linné, 1746;	344	33,2
2. *Ixodes pari* Leach, 1813 (*I. frontalis* Panzer, 1795);	1	0,1
3. *Ixodes hexagonus* Leach, 1815;	554	53,6
4. *Ixodes canisuga* Johnston, 1849;	3	0,3
5. *Haemaphysalis punctata* Canestrini et Fanzago, 1877;	17	1,6
6. *Dermacentor marginatus* Sulzer, 1776;	23	2,2
7. *Rhipicephalus sanguineus* Latreille, 1804	48	4,6
8. *Hyalomma marginatum* Koch, 1844.	45	4,4
Vsi — All	1035	100%

Table 6.: I hexagonus: stages of development
Tabela 6.: I hexagonus glede na stadije razvoja

Živali-gostitelji; Host animals	Klopi — Ticks			
	Odrasli; Adults abs./%	Nimfe; Nymphs abs./%	Ličinke; Larvae abs./%	Vsi; All abs./%
1. *Erinaceus roumanicus*	1 ♂ 33 ♀ /6,1%	51/9,2%	63/11,4%	148/26,7%
2. *Felis silvestris*		1/0,2		1/0,2
3. *Felis domestica*		2/0,4		2/0,4
4. *Canis lupus*		1/0,2		1/0,2
5. *Canis familiaris*	13/2,4	14/2,5	20/3,6	47/8,5
6. *Vulpes vulpes*	22/4,0	44/8,0	48/8,6	114/20,6
7. *Martes martes*	3/0,5			3/0,5
8. *Martes foina*		1/0,2		1/0,2
9. *Mustela putorius*	7/1,2	97/17,5	66/11,9	170/30,7
10. *Meles meles*	10/1,8	19/3,4		29/5,2
11. *Lutra lutra*		2/0,4	1/0,2	3/0,5
12. *Bos taurus*	8/1,4	15/2,7		23/4,1
13. Vegetacija; vegetation	1/0,2	1/0,2		2/0,4
14. Jame; caves	6 ♂ 3 ♀/1,6	1/0,2		10/1,8
Vsi; all	107/19,2	249/45,1	198/35,7	554/100%
	7(1,2%) samci — males; 100(18,0%) samice — females			

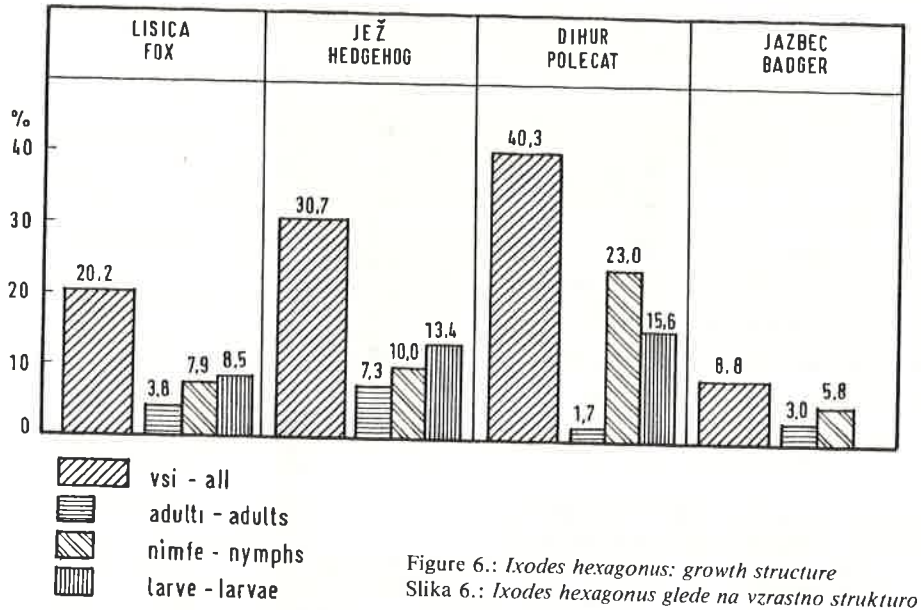

Figure 6.: *Ixodes hexagonus: growth structure*
Slika 6.: *Ixodes hexagonus glede na vzrastno strukturo*

Discusion

The results of our work clearly show that *I. hexagonus* is a rather specific species in its relationship to hosts and has boundaries, beyond which in normal conditions it does not reach. This contradicts observation made by OSWALD (1940, 1941) who draws a parallel between *I. hexagonus* and *I. ricinus* due to its supposed omni-host characteristic. He remarks that adult forms of *I. hexagonus* feel equally at home on carnivora, herbivora and omnivora, as well as on man, and he describes the adult form of *I. hexagonus* as a tick without a preference host, yet makes no mention of immature stages. Our entire collection consists of thousands of ticks of all stages and species, originating from the widest circle of hosts, a great number being merely identified and then used for virus isolation, or some other purpose. But in all this multitude of ticks, *I. hexagonus* was found in significant numbers only on hedgehogs, polecats, foxes, dogs and badgers; we have evidence from only a few martens, one otter and two young wolves, but *I. hexagonus* was found on them, despite a minimal degree of infestation. In contrast, we did not find *I. hexagonus* at all on roe-deer, in spite of collecting numerous specimens, and only once on cattle, although hundreds of cattle were screened. We are also of the opinion that researchers who claim that *I. hexagonus* are very often found as parasites of small mammals are mistaken too. Very probably the larvae of *I. hexagonus* have in fact been larvae of *I. trianguliceps* (Birula), which is a frequent parasite of small mammals.

Researchers abroad have already tested the majority of those host animals on which our *I. hexagonus* was found for susceptibility to the TBE virus.

RADDA et al. (1969a) proved in the laboratory that both foxes and weasels can be easily infected with the TBE virus by ticks. Both animals develop viremia, which exceeds the threshold level necessary for infecting new generations of ticks. It is interesting that it was not possible to suck the nymphs of *I. ricinus* on the badger in the laboratory, for we only found 3 females of this tick on the 7 badgers examined. In laboratory experiment, the badger did not react to the TBE virus to a sufficient degree either. RADDA et al. (1969b) succeeded, however, in proving the exeptional succeptibility to the TBE virus of the polecat, which also readily disseminates infected ticks into its environment. It is worth mentioning that polecats, which in our material are at the top of the scale for infestation with *I. hexagonus*, are numerous in Slovenia. The polecat is found from lowland habitats to mountain slopes; it readily frequents human dwellings and even invades the periphery of our biggest towns.

Van TONGEREN (1959) was the first to demonstrate the transmission of the TBE virus to hedgehogs by ticks. A model of alimentary infection for the hedgehog was set up by KOŽUCH and NOSEK (1964). After being fed with infected mice, the hedgehogs developed viremia, followed by an intensive development of antibodies. If a hedgehog falls into hibernation during the time of autumnal viremia, the virus persists until the spring, when the same hedgehog shows a considerable degree of post-hibernation viremia, which is of course a new opportunity for intensive vernal infection of vector ticks. NOSEK and GRULICH (1967) isolated the TBE virus from the blood of a hedgehog captured in the mountainous area of Tribeč in Czechoslovakia. As well as reacting positively to the TBE antigen, the hedgehogs in experiments carried out by Austrian researchers reacted positively to Q fever, Sindbis virus, West Nile, herpes virus, ornithosis, toxoplasmosis and listeriosis (SIXL et al. 1973). They found four *I. ricinus* ticks on a hedgehog to be spontaneously infected with rickettsia *Coxiella burneti*.

Dogs and cats are significant indicators of arboviruses, and a dog can even develop a full clinical picture of TBE (STÜNZNER et al. 1973). Among 173 dogs examined, 39,5%, i.e. 69 animals, were positive for TBE virus, and from 21 cats, 9 sera reacted positively against TBE with a titre of 1:10 to 1:1280.

The majority of animals classified as preference hosts of the *I. hexagonus* tick in Slovenia in all probability also participate in the circulation of the TBE virus in their natural habitats. We can therefore safely conclude that, in addition to the *I. ricinus* tick, the *I. hexagonus* tick is another species which disseminates the TBE virus among those animals on which it lives as a parasite in significant numbers. In Germany *I. hexagonus* is considered as a regular ubiquitous parasite of man in natural habitats, especially in fields and the gardens of urban settlements (HOFFMANN 1973).

I. hexagonus is still far less frequent in Slovenia than *I. ricinus*, and we are convinced that it is not an ubiquitous species, because it is a typical member of pholeophilous fauna. It is harder to collect than the species *I. ricinus*. These are probably some of the reasons why, up to the present, no successful experiment isolating the TBE virus from *I. hexagonus* caught directly in natural habitats has been performed anywhere, according to the literature available.

Conclusions

1) The *I. hexagonus* tick has been found in Slovenia and also in other parts of Yugoslavia on strictly specific host species. As elsewhere in Europe, the significant hosts of *I. hexa-*

gonus are the hedgehog *(Erinaceidae)* and carnivora, especially *Mustelidae* and *Canidae*.

2) Out of typical hosts treated, 67 in number, the most intensively infested were polecat *(Mustela putorius)*, hedgehog *(Erinaceus roumanicus)*, dog *(Canis familiaris)*, fox *(Vulpes vulpes)*, and badger *(Meles meles)*, on which 508, i.e. 91.7% of all the *I. hexagonus*, kept in our collection (554) were found. The remaining 46 (8.3%) *I. hexagonus* found came from the other animals and from natural habitats.

3) Polecats and hedgehogs show the highest mean infestation value of *I. hexagonus* of all the examined animals.

4) The growth structure of *I. hexagonus* in our material was defined with relation to the following: 107 (19.2%) adults, 249 (45.1%) nymphs and 198 (35.7%) larvae. On some hosts, the larvae of *I. hexagonus* are more numerous than the adult forms (hedgehog, fox), on others (badger, cattle) there are no larvae at all. The nymphs were found on practically all the hosts treated.

5) It was found that the *I. hexagonus* tick lives all over Slovenia and also in other parts of Yugoslavia, mainly in areas between 300 and 500 m above sea level. It was discovered in great numbers, mostly on specific hosts and is a rather frequent tick in Slovenia. *I. hexagonus* was found during all months of the year regardless of the cool winter period.

6) *I. hexagonus* is a cavicol species and is found living free on walls in dens and underground caves, where we were able to ascertain it in its adult forms but only exceptionally as a nymph.

7) The developmental cycle of *I. hexagonus* in Slovenia can not be completed in one calendar year, as already uncontinous phases of development observed in the laboratory have reached a time period of from 3.6 to 5.7 months. The larvae of *I. hexagonus* could feed normally on laboratory white mice and on man. The development of the *I. ricinus* tick has — given equal developmental phases and standard laboratory conditions — lasted from 6.0 to 8.1 months, i.e. a longer period than for *I. hexagonus*.

8) In parallel to our bionomic findings regarding *I. hexagonus*, which are being presented for the first time in Yugoslavia, we are discussing virus research elsewhere in Middle Europe.

9) On the basis of what we have ascertained we behave that, in Slovenia as well, *I. hexagonus* is involved in disseminating the TBE virus among animals on which it regularly lives as a parasite.

10) Therefore in Slovenia a specific, additional circulation system for the TBE virus exists, which is firmly established between *I. hexagonus* and its regular hosts.

11) The above circulation system of the TBE virus in Slovenia opens into a much broader circle of hosts via *I. ricinus*. The *I. ricinus* tick is namely the only concomitant species for the *I. hexagonus* tick on all of its regular hosts in Slovenia and is certainly also the principal TBE virus disseminator.

12) In other parts of Yugoslavia, the hosts significant for *I. hexagonus* are not parasitized only by the *I. ricinus* tick but also by some other tick species.

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Dr. Harry Hoogstraal and Dr. Hilda Y. Wasef (NAMRU-3, Cairo, Egypt) confirmed the identification of some ticks.

The graphs were drawn by senior technician Vladimir Drnovšek.

Summary

Among the 1,035 *Ixodid* ticks treated in this article, 554 specimens belong to the species *Ixodes (Pholeoixodes) hexagonus* Leach which was taken:

1) — from 67 animals explicitly belonging to the *Insectivora* and *Carnivora* (519); 2) — from cattle probably accidentally infested (23); 3) — from walls and slits in underground caves (10); 4) — from ground vegetation (2). 11 species of *Insectivora* and *Carnivora* were established as regular host animals of *I. hexagonus* in Slovenia (Yu): hedgehog, wild and domestic cat, wolf, dog, fox, pine-marten, stone-marten, polecat, badger, otter. The greatest number *I. hexagonus* 91,7%(508) was found on the polecat *(Mustela putorius)*, hedgehog *(Erinaceus roumanicus)*, dog *(Canis familiaris)*, common fox *(Vulpes vulpes)* and badger *(Meles meles)*. Only 8,3%(46) of *I. hexagonus* identified, belonged to the remaining host animals and natural habitats.

I. hexagonus extends through practically the whole of Slovenia, mostly in regions between 300 and 500 metres above sea level. It is active on host-animals and in underground caves throughout the year and its developmental cycle spans more than a year. All ticks found on host-animals typical for the *I. hexagonus* and identified in our article, come from one of 8 *Ixodid* species. The tick *Ixodes ricinus* Linné is the only species found accompanying *I. hexagonus* in Slovenia, and it lives as a significant parasite on all investigated animals, except on the badger on which only an insignificant number of adults of *I. ricinus* were found.

In our opinion *I. hexagonus* is one more tick species involved in disseminating the tick-borne encephalitis (TBE) virus among animals on which it regularly lives as a parasite. The *I. hexagonus* tick and its regular host-animals represent a specific additional circulation system of TBE virus in their mutual habitats in Slovenia. Undoubtedly, the role of *I. hexagonus* is considerably reduced when compared to the species *I. ricinus*, which is a much more active, ubiquitous and omni-host species, and remains the leading disseminator of the TBE virus in favourable habitats in Slovenia.

Povzetek

Od 1035 klopov, ki jih obravnavamo v članku, pripada 554 klopov vrsti *Ixodes (Pholeoixodes) hexagonus* Leach. — Klopa *I. hexagonus* smo ugotovili 1.) na 67 gostiteljih, ki pripadajo izključno le žužkojedom *(Insectivora)* in zverem *(Carnivora)* (519); 2.) na govedu, ki je bilo po vsej verjetnosti naključno infestirano (23); 3.) po stenah in v špranjah podzemeljskih

jam (10); 4.) na prizemni vegetaciji (2). Žužkojedi in zveri, na katerih smo do danes že našli *I. hexagonus* in smo jih opredelili za redne gostitelje tega klopa v Sloveniji (Ju), pripadajo 11 vrstam, ki so jež, divja in domača mačka, volk, pes, lisica, kuna zlatica, kuna belica, dihur, jazbec, vidra. Najintenzivneje infestiran v našem materialu je dihur *(Mustela putorius)*, sledijo mu jež *(Erinaceus roumanicus)*, domači pes *(Canis familiaris)*, navadna lisica *(Vulpes vulpes)* in jazbec *(Meles meles)*. Na pravkar navedenih živalih smo našli 91,7% (508) od vseh determiniranih *I. hexagonus*, na druge dejavnike, vključno na gostiteljske živali in na naravne habitate, odpade le 8,3% (46) vseh identificiranih *I. hexagonus*. *I hexagonus* je razširjen praktično po vsej Sloveniji, večinoma v območjih med 300 in 500 metri nadmorske višine in je na gostiteljih in v podzemeljskih jamah aktiven vse leto. Razvojni ciklus *I. hexagonus* se tudi v Sloveniji raztegne na večletno obdobje. Klopi, ki smo jih našli na gostiteljih, karakterističnih za *I. hexagonus*, in smo jih za naš članek determinirali, pripadajo 8 vrstam iksodid. V Sloveniji smo na navedenih gostiteljih ugotovili kot edino spremljevalno vrsto za *I. hexagonus* le klopa *Ixodes ricinus Linné*, ki je signifikantno zajedal vse obravnavane živali, z izjemo jazbeca. Na jazbecu smo našli posamične adultne oblike *I. ricinus*, številčno popolnoma nesignifikantne.

Po naših ocenah je tudi *I. hexagonus* aktivno udeležen pri razsejavanju virusa klopnega meningoencefalitisa (KME) med svojimi rednimi gostitelji, s katerimi predstavlja specifični dodatni sistem kroženja virusa KME v njihovem skupnem naravnem okolju. Vloga *I. hexagonus* pri razsejavanju virusa KME pa je nedvomno pomaknjena v senco mnogo številnejše in bolj aktivne vrste ubikvitarnega in glede gostiteljev malo izbirčnega klopa *I. ricinus*, ki še vedno ostaja na čelu razsejevalcev virusa KME v Sloveniji.

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