Ticks and mites parasitizing free-ranging reptiles in Austria - with an identification key to Central European herpetophagous Acarina

Field studies conducted in Central Europe revealed that up to 75 % of the free-living reptile specimens were parasitized by hard ticks of the family Ixodidae (HAKLOVÁ-KOCÍKOVÁ et al. 2014), whereas, the presence of mites was infrequently reported, thus questioning the common occurrence of mite infestations among free-ranging reptiles in Central Europe. In contrast, captive reptiles can significantly be harassed by parasitic mites and occasionally by ticks (unpublished reports of veterinarians). Commonly, these parasites are objects of abhorrence and precipitant extermination, however, their significance as a part of the indigenous fauna or as regulators of host populations are hardly ever considered.

Ticks and mites are both small arachnids in the subclass Acarina. Ticks differ morphologically from other acarine taxa merely by the position of the spiracles and their larger body size. All ticks are blood-feeding, permanent ectoparasites of terrestrial vertebrates. They are referred to as herpetophagous if they feed on amphibians or reptiles without any recognizable damage to the parasite. Almost all such ticks are members of the family Ixodidae. In contrast, herpetophagous mites are distributed over at least five families. At the utmost, two developmental stages in a mite's life cycle are parasitic; some mite species being blood-sucking ectoparasites, others skin-mining endoparasites, which attack terrestrial and aquatic hosts, e.g., newts. The majority are stenoxenous parasites, i. e., they commonly feed on one or very few host taxa only and, in urgent need of food, can attack a small number of further host species. On the contrary, an euryxenous parasite feeds on a broad range of host species even-handedly. Almost all Austrian hard ticks are three-host ticks, they detach regularly from their host for the moult after blood-sucking. In many species each developmental stage prefers a varying set of hosts, the herpetophagous blood-suckers being usually found among the juvenile Ixodidae developmental stages (SERVICE 1986; LUCIUS & LOOS-FRANK 1997; KOLONIN 2004).

Acarine species now indigenous to Central Europe must have established at least one replicating and self-sustaining population in that region, irrespective of their auto- or allochthonous origin. Prior requirement for the establishment of a founder population by an incoming parasite is the permanent availability of suitable hosts, whereas convenient habitats and most environmental factors are second-rank. Large numbers of exotic ticks and parasitic mites are displaced by imported host animals and returning migratory birds which carry adhered hard ticks over long distances. However, peregrine species cannot establish viable populations without the creation of suitable habitats by man. The artificial conditions in vivaria and outdoor pet facilities are substantially promoting the acclimation of non-native parasites (NOWAK 2010). The popularity of keeping exotic herpetological taxa as pets has led to multiple opportunities for invasive acarine parasite species, and some have evidently perceived their chance (Table 1).

The latest revision of the Austrian tick fauna was done almost 30 years ago (RADDA et al. 1986), indigenous herpetophagous mites have never been emphasized. The following key was provided to facilitate the identification of Acarina associated with reptiles in Central Europe:

A - Mites and hard ticks, gross classification

1a	Acarina with six legs, spiracles lacking	2
1b	Acarina with eight legs	3
2a	Length < 0.1 mm	*Ophionyssus* larva (not feeding)
2b	Length > 0.6 mm	hard tick larva
3a	Length > 0.8 mm; spiracles present; mouthparts forming a clearly distinguishable capitulum	4
3b	Length 0.18 mm to 0.5 mm; mouthparts directed straight forward; with a truncate dorsal shield covering the podonotal region	6

4a	Genital aperture undeveloped; no porose areas on capitulum; length < 2 mm	hard tick nymph
4b	Genital aperture developed; dorsal surface covered with a scutum; length > 1.5 mm	5
5a	Scutum covers only a small portion of the back, its uncovered parts are softer and extensible; capitulum with two porose areas	female hard tick
5b	Scutum covers the whole back; capitulum usually without porose areas	male hard tick
6a	Genital aperture small, atrophied; dorsal shield covers less than half of the back	*Ophionyssus* protonymph
6b	Genital aperture vast; dorsal shield longer than half of the back, divided or entire, if entire with less than 16 pairs of setae	*Ophionyssus* female
6c	Genital aperture vast; dorsal shield entire, longer than half of the back, with more than 15 pairs of setae	*Ophionyssus* male

B - Hard ticks; according to Nosek & Sixl (1972), revised by the author

Larvae

1a	Anal grooves embracing the anus anteriorly	*Ixodes ricinus*
1b	Anal grooves embracing the anus posteriorly	2
2a	Eyes present; palpi long	*Hyalomma aegyptium*
2b	Eyes absent; palpi short, conical; second palpal articles collectively wider than basis capituli	3
3a	Second palpal article wider than basis capituli	*Haemaphysalis concinna*
3b	Second palpal article not as wide as basis capituli, protruding laterally; basis capituli oblong, curved at both sides	*Haemaphysalis parva*
3c	Second palpal article not protruding laterally; basis capituli semicircular	*Haemaphysalis inermis* (feeds on *Lacerta agilis*)

Nymphs

1a	Anal grooves embracing the anus anteriorly; no eyes; capitulum and palpi long	2
1b	Anal grooves embracing the anus posteriorly; festoons present	3
2a	Coxae I, II with posterior margins covered with folds of cuticle; scutum without cervical grooves	*Ixodes trianguliceps*
2b	External spurs on coxae present; scutum nearly circular with cervical and lateral grooves; basis capituli about as long as broad	*Ixodes ricinus*
3a	Eyes present; scutum ovalo-rhomboid in outline; hypostome and palpi long; basis capituli subtriangular	*Hyalomma aegyptium*
3b	Eyes absent; palpi short, conical; second articles of palpi collectively wider than the basis capituli; coxae with spurs	4
4a	Second palpal article wider than basis capituli; basis capituli with sides rounded, no cornua	*Haemaphysalis concinna*
4b	Second palpal article not as wide as basis capituli; basis capituli oblong dorsally	5
5a	Palpi not salient laterally; basis capituli with cornua	*Haemaphysalis inermis* (feeds on *Lacerta viridis*)
5b	Basis capituli without cornua	*Haemaphysalis parva* (feeds on *Lacerta agilis*)

Females (*I. ricinus*, *H. inermis* and *H. aegyptium* only)

1a	Anal grooves embracing the anus anteriorly; eyes absent; festoons absent; capitulum and palpi long	*Ixodes ricinus* (isolated reports)
1b	Anal grooves embracing the anus posteriorly	2
2a	Submarginal eyes and coalesced festoons present	*Hyalomma aegyptium*
2b	Eyes absent; 9-11 festoons present, unclear when engorged; palpi not salient laterally, not wider than basis capituli	*Haemaphysalis inermis*

Males (*H. inermis* and *H. aegyptium* only)

1a	Submarginal eyes and coalesced festoons present	*Hyalomma aegyptium*
1b	Eyes absent; 9-11 festoons present; palpi not salient laterally, collectively not wider than basis capituli	*Haemaphysalis inermis* (found on *Lacerta viridis*)

C - Parasitic stages of European *Ophionyssus* mites; according to Moraza et al. (2009)

Protonymphs

1a	Pygidial shield with 3 pairs of setae, transversely subcircular, 63 µm x 75 µm; podonotal shield 204 µm x 192 µm	*Ophionyssus natricis*

1b	Pygidial shield with 2 pairs of setae	2
2a	Pygidial shield as long as wide, 84 µm x 81 µm, four times narrower than podonotal shield (213 µm x 180 µm)	*Ophionyssus saurarum*
2b	Pygidial shield wider than long, 54 µm x 72 µm; podonotal shield 192 µm x 168 µm	*Ophionyssus lacertinus*

Females

1a	Dorsal shield divided into a large anterior and minute pygidial shield; podonotal shield with 10 pairs of setae, 300 µm x 276 µm	*Ophionyssus natricis*
1b	Dorsal shield entire, shortened, with 13-15 pairs of setae	2
2a	Peritremes extending to anterior margin of coxae II; dorsal shield 690 µm x 260 µm with 14-15 pairs of setae; anal shield 160 µm x 84 µm	*Ophionyssus lacertinus*
2b	Peritremes approximately extending to anterior third of coxa II; dorsal shield 670 µm x 192 µm with 13 pairs of setae; anal shield 105 µm x 75 µm	*Ophionyssus saurarum*

Males

1a	Sternogenital shield with 3 pairs of setae; dorsal shield 528 µm x 264 µm with 16 pairs of setae; peritremes extend to anterior margin of coxae III	*Ophionyssus saurarum* (nonfeeding)
1b	Sternogenital shield with 2 pairs of setae; dorsal shield with more than 16 pairs of setae	2
2a	Dorsal shield 204 µm x 240 µm with 17 pairs of setae; peritremes extend to anterior margin of coxae III; more than 10 pairs of ventral setae	*Ophionyssus natricis*
2b	Dorsal shield 516 µm x 250 µm with 23 pairs of setae; peritremes extend to posterior margin of coxae II; 7 pairs of ventral setae	*Ophionyssus lacertinus*

No tick or mite species is known to parasitize amphibians in Central Europe, not even accidentally. The reasons for this are the non-survival of anurophilic, tropical *Amblyomma* ticks under Central European climate conditions on one hand (SIMMONS & BURRIDGE 2000), and the rarity of large terrestrial accumulations of adult amphibians, the hosts of chigger mites, on the other.

Keeping and breeding of *Testudo* tortoises, however, are very common activities in Austria. Based on an earlier estimation (HASSL 2004), tortoises are living in more than 10.000 Austrian households. Usually small herds of them are kept in outdoor-facilities. In some suburban areas the abundance of *Testudo* spp. is higher than it is in the wild. By this, sufficiently large populations of suitable hosts became available to establish transalpine populations of the mediterranean tick species *Hyalomma aegyptium* (LINNAEUS, 1758). Considering the absence of tick control by traders and purchasers (NOWAK 2010), long-standing allochthonous populations of this tick species seem to be in place. This tick species was detected in Middle Europe (Styria) for the first time more than forty years ago (SIXL 1971) and is diagnosed in local live stocks of tortoises during parasitological screenings now and again (unpublished data). It is a strictly stenoxenous species, feeding on *Testudo* only. This three-host tick acts as an endophilic species in Central Europe, remaining in the synanthropic resting caverns of the hosts. But it is unknown where exactly the moults take place and where and how the ticks infest the tortoises. Only adults of *Testudo graeca* LINNAEUS, 1758 seem to fit entirely the tick's requirements as a host. Possibly only unusually cavernophilous members or populations of this tortoise are ideal hosts (CALISIR et al. 2002; ŠIROKÝ et al. 2009). The seasonal activity of the host population is presumably responsible for the fluctuation in the tick's abundance (ŠIROKÝ et al. 2009; GEMEL & HÖRWEG 2011). Nevertheless the crucial needs for the survival of this tick are obviously met in some Central European anthropogenic turtle habitats.

Ixodes ricinus (LINNAEUS, 1758) is long known as an extremely euryxenous tick. Larvae and nymphs attack terrestrial mammals, birds and reptiles likewise. This tick is a free-ranging and outdoor feeding acarine, inhabiting scrub forest edges in humid valley plains (Fig. 1). If *I. ricinus* attacks reptiles, it prefers animals with permanent ground contact of the belly. Lizards seem to be a common host of this tick species in certain regions, e.g., the Spessart

Table 1: Ticks and mites parasitizing on free-ranging reptiles in Austria. +++ - frequently, ++ - regularly, + - rarely.

Acarina species	Parasitic stages	Hosts	In Austria this species is	It attacks man	Reference
Ixodes ricinus LINNEAEUS, 1758	larva, nymph	Larva: *Lacerta agilis* LINNEAEUS, 1758; *Lacerta viridis* (LAURENTI, 1768); *Zootoca vivipara* (LICHTENSTEIN, 1823). Nymph: *Lacerta agilis*; *Lacerta viridis*; *Zootoca vivipara*, *Anguis fragilis* LINNEAEUS, 1758; *Coronella austriaca* LAURENTI, 1768; *Zamenis longissimus* (LAURENTI, 1768); *Natrix natrix* (LINNEAEUS, 1758), probably a misidentified host	autochthonous	+++	PFOSER 1948; SIXL et al. 1971
Ixodes (*Exopalpiger*) *trian-guliceps* BIRULA, 1895	nymph	*Zootoca vivipara*, maybe a rare case of herpetophagy	autochthonous	no	SIXL et al. 1969 1971
Haemaphysalis concinna KOCH, 1844	nymph	*Podarcis muralis* (LAURENTI, 1768); *Lacerta viridis*; *Zamenis longissimus*	autochthonous	++	PFOSER 1948; SIXL et al. 1969
Hyalomma aegyptium LINNAEUS, 1758	larva, nymph, adult	stenoxen: *Testudo graeca*, LINNAEUS, 1758; maybe also: *Testudo marginata* SCHOEPF, 1789; unlikely: *Testudo hermanni* GMELIN, 1789	introduced by pet trade, in synanthropic habitats, origin Mediterranean region	no	SIXL 1971
Ophionyssus natricis (GERVAIS, 1844)	protonymph, adult	captive snakes, occasionally captive Agamidae, possibly free-ranging reptiles in synanthropic habitats	in synanthropic habitats only, maybe an invasive species, presently cosmo-politan, origin unknown	++	no citable reference, diagnostic reports of veterinarians
Ophionyssus lacertinus (BERLESE, 1892)	protonymph, adult	Lacertidae: *Podarcis muralis*, *Lacerta viridis*; maybe in synanthropic or artificial habitats only	unknown; reports from Great Britain, Italy, the Netherlands	+	no reference
Ophionyssus saurarum (OUDEMANS, 1901)	protonymph, female adult	Lacertidae: *Iberolacerta horvathi* (MÉHELY, 1904), *Podarcis muralis*, *Lacerta viridis*, *Lacerta agilis*, *Zootoca vivipara*	probably autochthonous, widespread in Europe	?	no reference

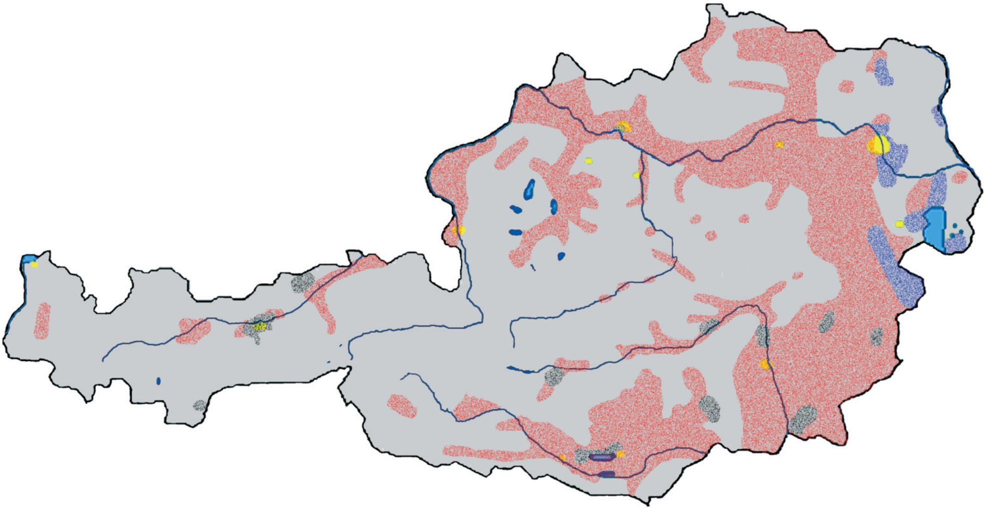

Fig. 1: Known distribution (finely dotted) of the hard tick species in Austria.
Ixodes ricinus LINNAEUS, 1758 (red), *Ixodes trianguliceps* BIRULA, 1895 (black)
and *Haemaphysalis concinna* C. L. KOCH, 1844 (blue). Lakes in dark blue, capitals in yellow.

Mountains in Germany (JANSEN 2002), and may be infested by more than 100 ticks at a time (MALKMUS 1995). It is still unknown whether the reptilian blood suffices the nutrient needs of this tick for successful moulting or egg-production.

This widespread tick species is replaced in moist habitats by the marsh or vole tick, *Ixodes* (*Exopalpiger*) *trianguliceps* BIRULA, 1895. Similar to its lacertilian host, *Zootoca vivipara* (LICHTENSTEIN, 1823), this tick is more sensitive to aridity than other species of the genus and bound to habitats with high relative humidity. In Austria the tick and the lizard can live at high altitudes (Fig. 1), the tick up to 2,400 m a.s.l., in young forest plantations, clearings, moors, and extensively used and well structured meadows and pastures. The tick is considered a specialized blood-feeder on mice and shrews (SIXL et al. 1969), but its biology is largely unknown. The marsh tick has only once been found parasitizing a reptile (*Zootoca vivipara*), in Poland (NOWAK-CHMURA & SIUDA 2012). So parasitism of this tick species on a reptile may be seen as an occasional event.

The bush tick, *Haemaphysalis concinna* C. L. KOCH, 1844, is the typical xerothermophilic tick of ruminant pastures. This species is autochthonous in, but probably restricted to the east of Austria (Fig. 1). It prefers warm, dry habitats, particularly sheep and cattle grazing grounds, but also thin forests with dense undergrowth. Usually it feeds on terrestrial mammals, but in case of starvation, lizards and even snakes are accepted by the nymphs (HASSL 2003). Some other Central European *Haemaphysalis* species are well known to feed on reptiles, but they were not located in Austria.

The existence of herpetophagic mites in the untouched wild of Central Europe was never confirmed. In their natural alien habitats outside vivaria, their abundance is usually low (NOWAK 2010). Although there are at least ten genera of mites feeding on reptiles worldwide, the integration of a peregrine mite into a local biocenosis seems to be intricate. One species of herpetophagic mite, *Ophionyssus saurarum* (OUDEMANS, 1901), is considered to be autochthonous, feeding on Lacertidae only (BECK & PANTCHEV 2006). *Ophionyssus natricis* (GERVAIS, 1844) and *O. lacertinus* (BERLESE, 1892) are strongly associated with keeping reptiles in vivaria, optionally they live in synanthropic and artificial habitats outside the facility. It is unknown whether the free-ranging populations of these species were established or promoted by forsaking their hosts or by relocating host populations or by reducing predator populations. These mite species might be invasive species in the stage of dissemination, or overlooked for a long time and misdiagnosed autochthonous animals. There is a singular report of *O. natricis* mites "existing in nature" in Egypt (YUNKER 1956).

Some Central European ticks are very effective vectors of tick-borne pathogens to man (SIXL & NOSEK 1972; RADDA et al. 1986). But there is only one tick-borne etiologic agent associated with reptiles, the bacterium *Borrelia lusitaniae* LE FLECHE et al., 1997, which is one of several local pathogens causing Lyme borreliosis in man. It is transstadially transmitted by *I. ricinus*, but not transovarially, which is why the tick cannot serve as reservoir for the bacterium. In Central Europe, the lacertids *Lacerta agilis* LINNAEUS, 1758 and *Podarcis muralis* (LAURENTI, 1768) are considered the most important reservoir hosts (RICHTER & MATUSCHKA 2006). In habitats with rich syntopic populations of both *I. ricinus* and lizards, there is a high probability of *B. lusitaniae* spirochetes occurring. By entering such habitats the risk of acquiring a Lyme disease is considerable to man.

A well-known example of a tick-borne reptilian disease is the infection of *Testudo graeca* LINNAEUS, 1758 and *Testudo marginata* SCHOEPFF, 1782 with *Hemolivia mauritanica* (SERGENT & SERGENT, 1904). In the Maghreb and Middle East countries, this apicomplexan parasite was detected in the erythrocytes of these tortoises with prevalences of up to 92 % (ŠIROKÝ et al. 2009). Vector and definitive host of this parasite are *H. aegyptium* ticks only; the infection occurs via tick ingestion. It is unknown whether the tortoises pick up non-attached ticks during nibbling inside their rest caverns or remove ticks from infested congeners in an act of concerted grooming.

Less-known examples of mite-borne reptilian diseases are the infections of lizards with *Karyolysus latus* SVAHN, 1975 and *K. lacazei* LABBÉ, 1894. Both species are indigenous, intracellular blood parasites, they are characterized by a transstadial and a transovarial transmission in gamasid mites (Gamasoidea). *Ophionyssus saurarum* mites are used as vector, reservoir and definitive host, the mites must be ingested to infect the lizards. It is believed that hard ticks can take the mite's place, to explain the frequent presence of *Karyolysus* in spite of the low abundance of mites (HASSL 2003; HAKLOVÁ-KOCÍKOVÁ et al. 2014). The consequences of such infections to the dynamics of lizard populations are unknown. PANTCHEV (2005) stated that *Ophionyssus natricis* transmits the nosocomial bacterium *Aeromonas hydrophila* (CHESTER, 1901), causing a haemorrhagic septicaemia in pet snakes and gastroenteritis in man, which is not commonly accepted.

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