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Correspondence

Abnormal morphology of a larva of *Ixodes lividus* Koch, 1844 (Acari: Ixodidae)

Yuri Bykov[1], Aleksandra Yatsuk[2*], Evgeny Kondratev[3], Alexandr Porshakov[3] and Alexandr Matyukhin[2]

1. *Meshchera National Park, Internacionalnaya st., 111, 601501, Gus-Khrustalny, Russia; E-mail: bykov_goos@yahoo.com*
2. *A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninskij prosp. 33, 119071, Moscow, Russia; E-mails: sasha_djedi@mail.ru, amatyukhin53@mail.ru.*
3. *Russian Research Anti-Plague Institute "Microbe", Universytetskaya st., 46, 410005, Saratov, Russia; E-mails: eugene.n.kondratyev@gmail.com, pam_82@mail.ru.*

[*] Corresponding author

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Tick-borne diseases are of growing public health concern and new tick-transmitted pathogens emerge regularly (Zharkov *et al.* 2000; Kernif *et al.* 2016; Salman and Tarrés-Call 2013; Wei *et al.* 2016). Tick studies are necessary to gain a better understanding of tick-borne diseases, but those that focus on morphological variation in sampled ticks (e.g., teratology) are rare. According to the literature data, in *Ixodes persulcatus* (Schulze, 1930) which have a normal structure of the exoskeleton, no more than 3–4 types of pathogenic microorganisms can be simultaneously registered, while in anomalous individuals, 5–7 are often detected, with a higher level of individual infection (Alekseev *et al.* 2008).

The most documented abnormality of ticks is gynandromorphism, when in one organism large parts of the body have a genotype and signs of different sexes (Campana-Rouget 1959; Tovornik 1987; Labruna *et al.* 2000, 2002; Prusinski *et al.* 2015; Larson and Paskewitz 2016; Chitimia-Dobler and Pfeffer 2017; Chitimia-Dobler *et al.* 2017). However, several studies report other types of morphological abnormalities, such as asymmetry, bifurcation, fusion of adanal plates and festoons, atrophy or lack of one or two legs (Campana-Rouget 1959; Latif *et al.* 1988; Guglielmone *et al.* 1999; Estrada-Peña 2001; Serra-Freire and Borsoi 2009; Nowak-Chmura 2012; Slovák and Vidlička 2013; Kar *et al.* 2015; Ren *et al.* 2016; Keskin 2018; Taank *et al.* 2021).

Teratological changes are rare phenomena in ticks and several biological or non-biological factors are accepted as possible causes such as temperature (Buczek 2000), pollution (Zharkov *et al.* 2000), or chemical agents including insecticides (Buczek *et al.* 2013), retinoic acid (Belozerov 2003, 2004), sulfuric acid, and ethyl quinone (Campana-Rouget 1959).

The representatives of the genus *Ixodes* Latreille, 1795 are vectors and reservoirs of diseases in vertebrates. Previously, two cases of abnormal morphology for this genus were found: in a laboratory-reared *Ixodes scapularis* Say, 1821 nymph, (Taank *et al.* 2021), and for the species *I. frontalis* (Panzer, 1798) (Keskin 2018) which had two anuses. Several types of teratology in ticks have been reported in Russia (Zharkov *et al.* 2000; Alekseev and Dubinina 2004; Verzhuckaja *et al.*

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2020).

In the present study, we present morphological anomalies in *Ixodes lividus* Koch, 1844 for the first time.

The examined tick specimens were collected from three colonies of sand martin, *Riparia riparia* (L., 1758) near the villages of Spass-Kupalische (colony N1), Glebovo (colony N2), Klyazminsky (colony N3) in Vladimirskaya oblast in autumn 2022. The nesting material was removed with a modified scraper according to the standard method (Shiranovich *et al.* 1950; Glashchinskaya-Babenko 1956) at the end of the nesting season. Using this method, it was possible to extract most of the nest, part of the sand from the nest chamber and also from the bottom of the burrow tunnel. Material was obtained from 40 nests (11.8% of the total number of nests in the colony) from colony N1, from 25 nests (27.8%) in colony N2 and from 25 nests (33.3%) of colony N3. Nest sampling covered the colony area evenly. The nest material was processed in a Tullgren funnel for 24 hours to remove all ticks (Southwood and Henderson 2000). All specimens were identified to species level using the taxonomic keys by Filippova (1977). In total, 6,892 *Ixodes lividus* larvae were collected from the nest material of sand martins in three colonies. Among them, one larva with teratological changes was found (Fig. 1). Some normal features were retained, such as the number of legs, mouthparts, and scutum. The anomalous larva had a bilobed posterior region and two anal pores. This was the only morphological abnormality that was observed. Thus, in total, 0.01% of all ticks collected in 2022 displayed morphological anomalies.

Figure 1. Micrographs of the *Ixodes lividus* Koch, 1844 – **A.** The normal larva with a single anus; **B.** The larva with two anuses. Scale bars: 100 μm

Morphological anomalies at any developmental stage rarely occur in natural populations of ticks. In our study, morphological anomalies occurred in only 0.01% of collected ticks. The percentage of anomalous specimens studied is concordant with the results of other researchers (Tovornik 1987; Latif *et al.* 1988; Guglielmone *et al.* 1999; Nowak-Chmura 2012). Several tick species have been reported to have malformed morphology including two anal pores (type II by Campana-Rouget 1959 to date, *Amblyomma dissimile* Koch, 1844 (Brumpt 1934), *A. variegatum* (Fabricius, 1794) (Slovák and Vidlička 2013), *Dermacentor reticulatus* Fabricius, 1794 (Slovák and

Vidlička 2013), *Haemaphysalis punctata* Canestrini & Fanzago, 1878 (Campana-Rouget 1959), *H. qinghaiensis* Teng, 1980 (Ren *et al.* 2016), *Hyalomma aegyptium* L., 1758 (Sénevet 1922), *H. anatolicum* (Koch, 1844) (Campana-Rouget 1959a), *H. dromedarii* Koch, 1844 (Campana-Rouget 1959), *I. frontalis* (Keskin 2018), *I. scapularis* (Taank *et al.* 2021), *Rhipicephalus annulatus* (Say, 1821) (Pavlovsky 1939; Keskin 2018), *R. appendiculatus* Neumann, 1901 (Nuttall 1914), *R. decoloratus* Koch, 1844 (Warburton and Nuttall 1909), *R. pulchellus* (Gerstäcker, 1873) (Slovák and Vidlička 2013), *R. sanguineus* (Latreille, 1806) (Warburton and Nuttall 1909; Serra-Freire and Borsoi 2009). This suggests that this anomaly is rare, but constant.

To our knowledge, such teratological changes in *I. lividus* have been reported for the first time with the present study. Although teratologies are rare, it is worth noting that such individuals may be carriers of a greater number of pathogens (Buczek 2000; Zharkov *et al.* 2000; Belozerov 2003, 2004; Alekseev *et al.* 2008; Buczek *et al.* 2013). Local and general anomalies are of great interest for epidemiology.

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