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Original article

Ticks (Ixodida: Argasidae, Ixodidae) of Brazil: Updated species checklist and taxonomic keys

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ABSTRACT

Ticks are ectoparasites of great medical and veterinary significance in the neotropical region. In Brazil, they are responsible for enormous economic losses to the livestock industry and also for considerable morbidity and mortality in companion animals and humans. Therefore, recognizing the identity of a given species is important, not only from a biodiversity perspective, but also from the medical and veterinary standpoints. The Brazilian tick fauna is one of the most diverse and well-studied in the neotropical region. In the past few years, several new species were discovered and/or recorded for the first time in this country. The main objectives of this study were to provide an updated list of tick species occurring in Brazil and taxonomic keys for their identification. The updated list of Brazilian ticks includes 70 species, 47 in the family Ixodidae and 23 in the family Argasidae. The genera *Amblyomma* (32 spp.) and *Ornithodoros* (18 spp.) are the most representative. Updated taxonomic keys for the identification of ticks of Brazil are provided. Finally, the medico-veterinary significance of ticks occurring in this country is briefly discussed.

1. Introduction

Ticks are large chelicerate arthropods belonging to the order Ixodida (Keirans, 2009). At one or more developmental stages, ticks are blood-feeding parasites on mammals, birds, reptiles and amphibians. They are common in tropical and subtropical regions, where they are also responsible for considerable losses to the livestock industry (Grisi et al., 2014). Furthermore, ticks can transmit a myriad of disease agents causing significant morbidity and mortality in companion animals and humans (Dantas-Torres et al., 2012a; Dantas-Torres and Otranto, 2016).

To date, the Ixodida includes 956 species (Du et al., 2018; Kwak et al., 2018; Dantas-Torres, 2018; Apanaskevich et al., 2019; Sun et al., 2019; Tomlinson and Apanaskevich, 2019; Venzal et al., 2019), which are included in four families, being three extant [Ixodidae (736 spp.), Argasidae (218 spp.) and Nuttalliellidae (monospecific)] and one extinct [Deinocrotonidae (monospecific)]. A recent comprehensive review of ticks occurring in the southern Cone of South America (Argentina, Chile, Paraguay and Uruguay) listed 62 tick species for this region (Nava et al., 2017). In turn, until 2009, 61 tick species were known to occur in Brazil, including 44 ixodid species and 17 argasid species (Dantas-Torres et al., 2009b). Since then, 12 tick species were described, resurrected or registered for the first time in this country (Labruna and Venzal, 2009; Nava et al., 2010; Dantas-Torres et al., 2012b; Martins et al., 2014; Nava et al., 2014a; Barros-Battesti et al.,

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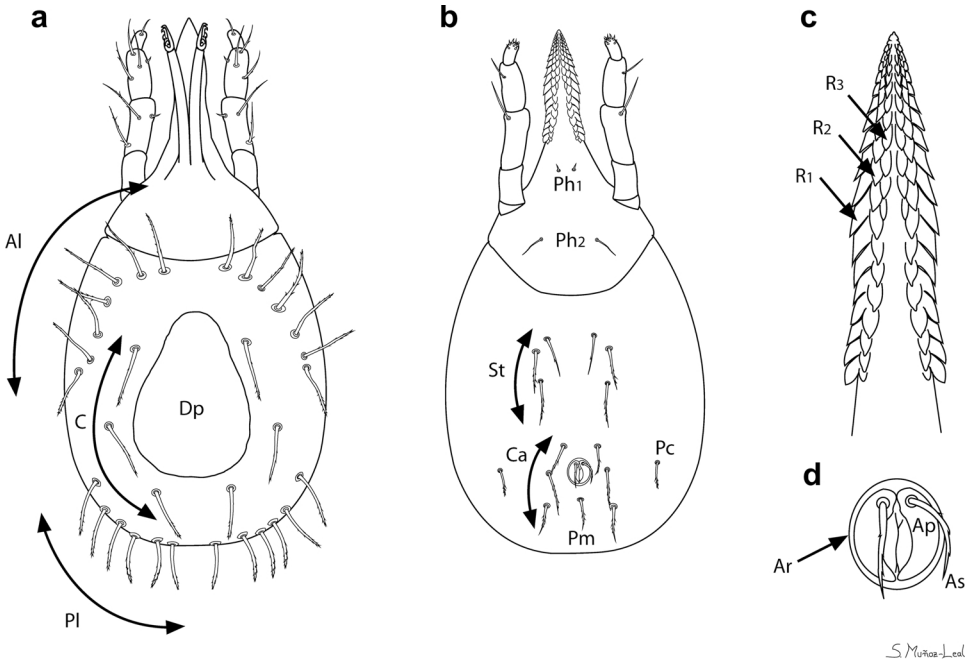

Fig. 1. Schematic drawing of a hypothetical *Ornithodoros* sp. larva, denoting the main morphological characters. a: dorsal view. b: ventral view. c: ventral view of hypostome. d: anal plates. Abbreviations: Al, anterolateral setae; Pl, posterolateral setae; C, central setae; Dp, dorsal plate; Ph1, posthypostomal setae 1; Ph2, posthypostomal setae 2; St, sternal setae; Ca, circumanal setae; Pc, postcoxal setae; Pm, posteromedian seta; R1, first row of denticles; R2, second row of denticles; R3, third row of denticles; Ap, anal plates; As, anal setae; Ar, anal ring.

2015; Krawczak et al., 2015; Labruna et al., 2016; Wolf et al., 2016; Michel et al., 2017; Muñoz-Leal et al., 2017, 2018b, 2018c). Besides, some argasid species included in previous lists are known only from type specimens, which are unavailable in some cases (Barros-Battesti et al., 2013), or currently considered as misidentifications of recently described taxa (Labruna et al., 2016).

As a consequence, not only the list of ticks occurring in Brazil, but also the keys used for their identification became obsolete. In order to fill this gap, the main objectives of this study were to provide an updated list of tick species occurring in Brazil and updated taxonomic keys for their identification. The medical and veterinary significance of ticks occurring in this country is briefly discussed.

2. Material and methods

2.1. Updated list of Brazilian ticks

The current list of tick species occurring in Brazil is an updated version of the list prepared by Dantas-Torres et al. (2009b). In brief, the previous list was prepared after an extensive review of the literature, from 1844 to 2008 (Koch, 1844; Neumann, 1899, 1906; Aragão, 1908a, 1908b, 1908c; Hooker, 1909; Rohr, 1909; Aragão, 1911; Neumann, 1911; Nuttall and Warburton, 1911; Aragão, 1912a, 1912b, 1913, 1918, 1923; Robinson, 1926; Aragão, 1931, 1936; Aragão and Fonseca, 1951, 1952a, 1952b; Fonseca and Aragão, 1952; Aragão and Fonseca, 1953; Fonseca and Aragão, 1953; Aragão and Fonseca, 1961a, 1961b; Barros-Battesti and Knysak, 1999; Evans et al., 2000; Guimarães et al., 2001; Serra-Freire, 2001; Labruna et al., 2002; Guglielmone et al., 2003; Barros-Battesti et al., 2003; Estrada-Peña et al., 2004; Arzua et al., 2005; Barros-Battesti et al., 2005, 2006, 2007; Labruna et al., 2005a; Serra-Freire and Mello, 2006; Voltzit, 2007; Labruna et al., 2008). Herein, we provide an updated list by adding species described (Labruna and Venzal, 2009; Nava et al., 2010; Dantas-Torres et al., 2012b; Barros-Battesti et al., 2015; Krawczak et al., 2015; Labruna et al., 2016; Muñoz-Leal et al., 2017), resurrected (Nava et al., 2014a) or found in Brazil for the first time (Martins et al., 2014; Wolf et al., 2016; Michel et al., 2017; Muñoz-Leal et al., 2018b, 2018c) since the publication of the previous list. Additionally, paratypes (RML-17868) and Brazilian specimens (RML-49606 and RML-49607) of *Ornithodoros stageri* were examined from high-quality photographs kindly taken by Professor Lorenza Beati, curator of the U.S. National Tick Collection.

Noteworthy, two putative new species of the genus *Ornithodoros* have recently been reported to occur in north-eastern Brazil, being one associated with reptiles (Alcantara et al., 2018) and the other with marsupials (Maia et al., 2018). As both taxa remain formally undescribed, they are not included in the current species list. Moreover, one larva identified as *Ornithodoros* cf. *clarki* was recently documented in association with bats in the Caatinga biome (Muñoz-Leal et al., 2018a). Considering its *conferre* status, this species is not included as well.

Tick species nomenclature follows Guglielmone et al. (2010); Guglielmone and Nava (2014), and subsequent species descriptions (Labruna and Venzal, 2009; Nava et al., 2010; Dantas-Torres et al., 2012b; Nava et al., 2014a; Barros-Battesti et al., 2015; Krawczak et al., 2015; Labruna et al., 2016; Muñoz-Leal et al., 2017).

2.2. Taxonomic keys for the identification of Brazilian ticks

After updating the list of ticks occurring in Brazil, we elaborated taxonomic keys for their identification. These keys were prepared by updating and modifying previous keys (Aragão and Fonseca, 1961a; Guimarães et al., 2001; Onofrio et al., 2006, 2009; Martins et al., 2010;

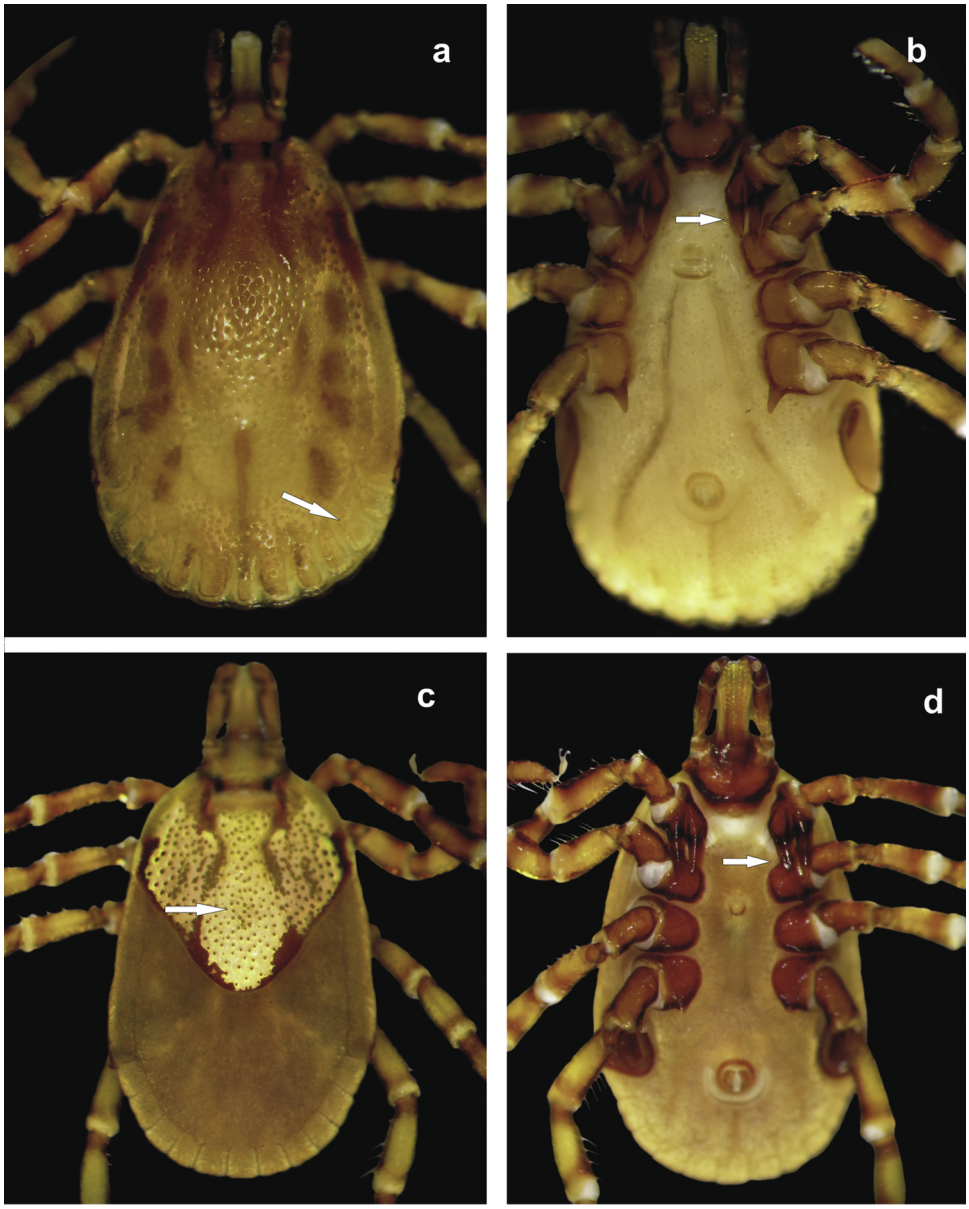

Fig. 2. *Amblyomma aureolatum*. a: male dorsal (magnification 45x). b: male ventral (mag. 45x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the incomplete marginal groove of the male (a), the scutal ornamentation pattern in the female (c), and the long spurs on coxa I in both sexes (b and d).

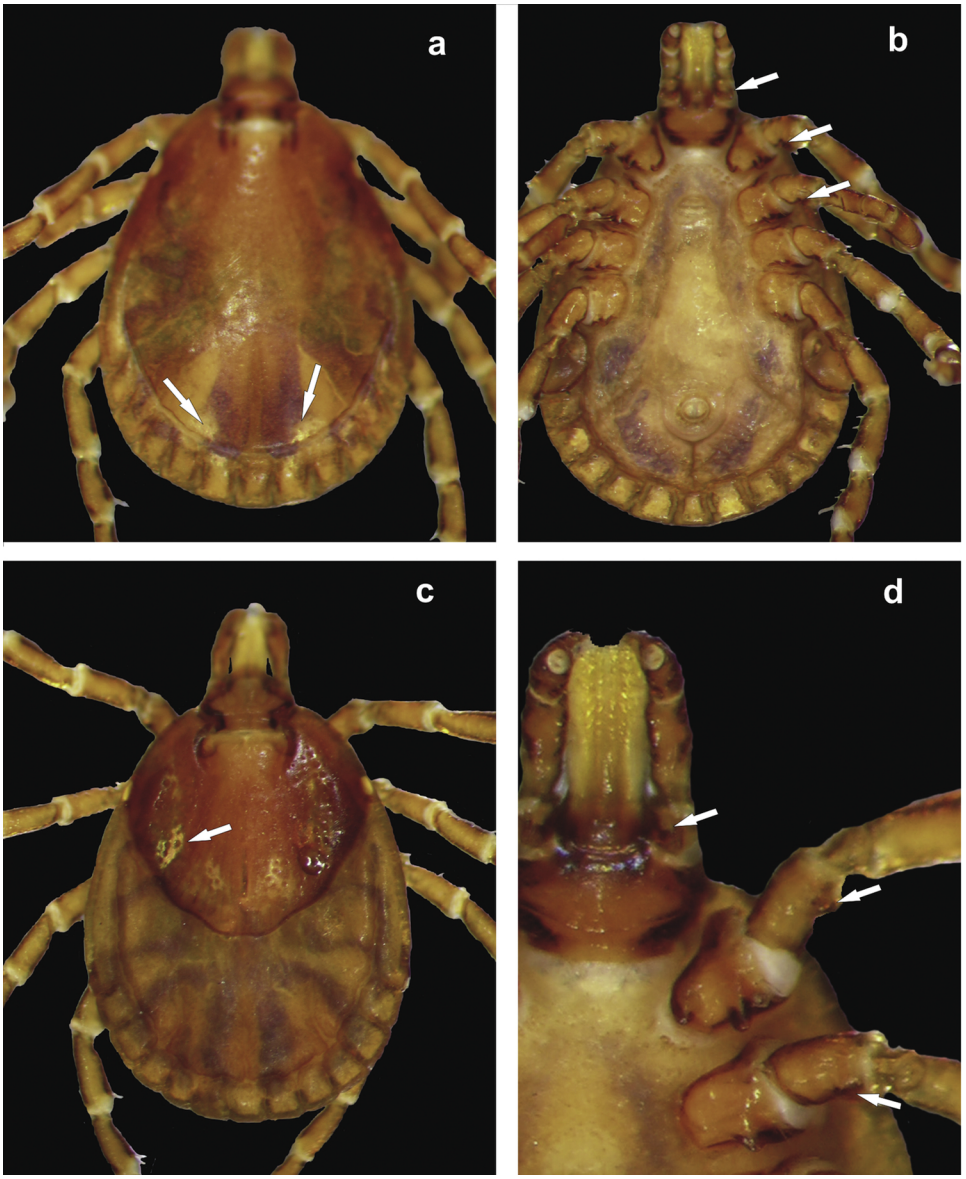

Fig. 3. *Amblyomma auricularium*. a: male dorsal (magnification 50x). b: male ventral (mag. 50x). c: female dorsal (mag. 32x). d: female ventral (mag. 66x). Arrows indicate the scutal ornamentation pattern, represented by two symmetrically disposed spots located at the posterior margin, near the marginal groove in the male (a), and by pale spots in the lateral fields in the female (c). The retrograde spur on palpal article I and the spurs on trochanters in both sexes are also arrowed (b and d).

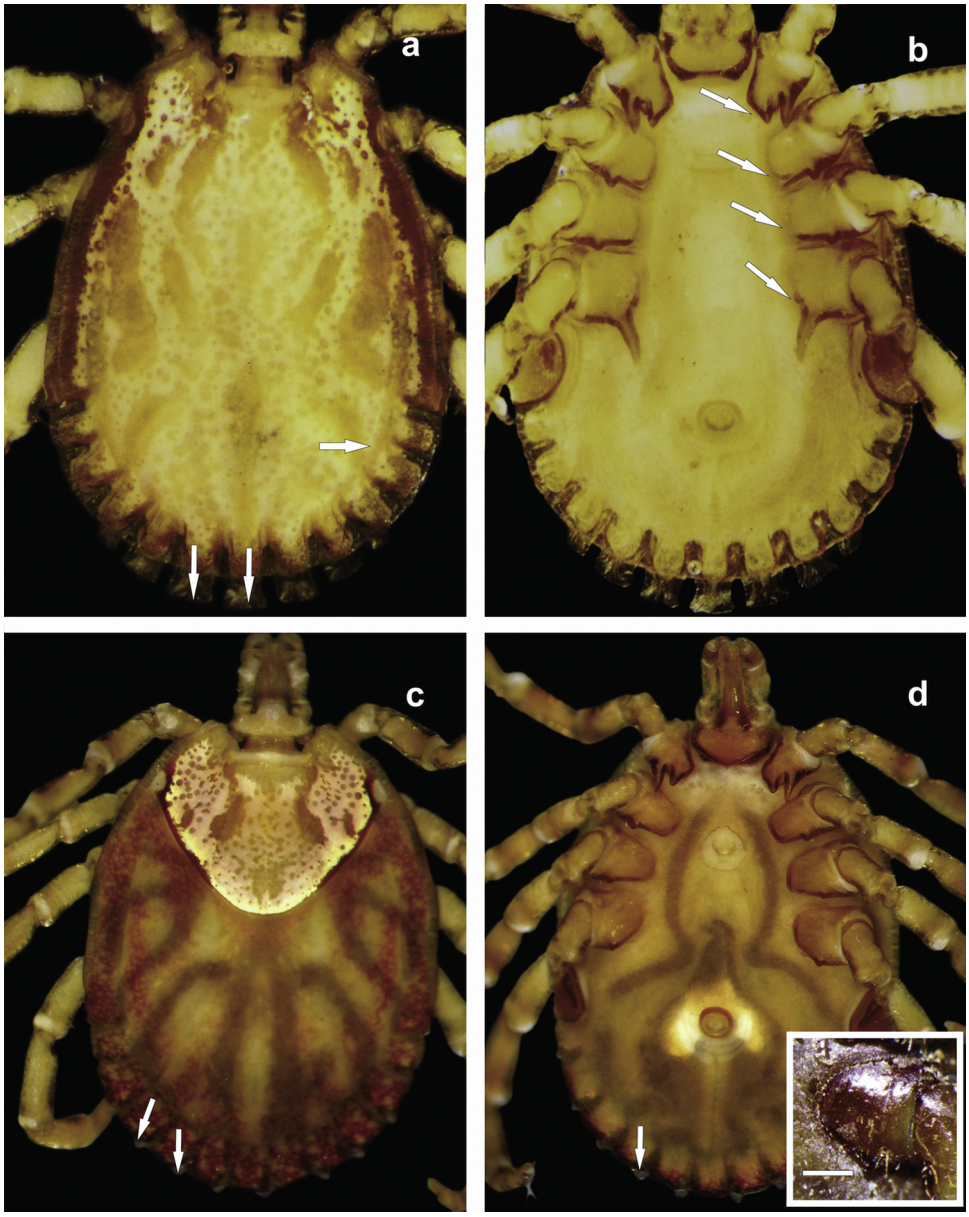

Fig. 4. *Amblyomma brasiliense*. a: male dorsal (magnification 20x). b: male ventral (mag. 20x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x); the close-up image shows the spurs on coxa IV, the internal being reduced to a vestigial ridge (bar = 250 μm). Arrows indicate festoons with sclerotised ventral plates and the marginal groove not surpassing the second festoon in the male (a), spurs on coxa I-IV in the male (b), and festoons with chitinous tubercles in the female (c and d).

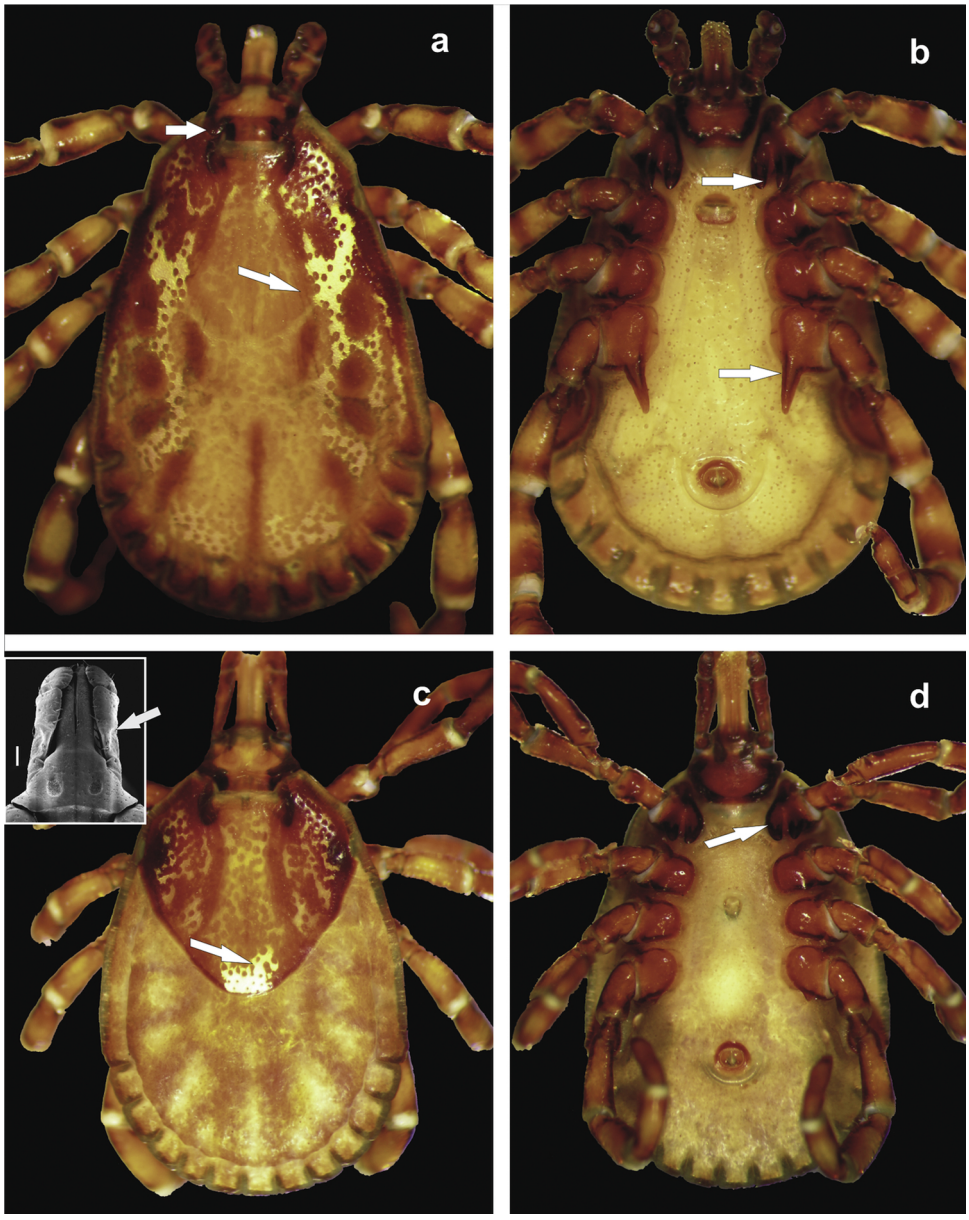

Fig. 5. *Amblyomma calcaratum*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 32x); the SEM image shows the oblique ridge on dorsal aspect of palpal article II (bar = 150 μm). d: female ventral (mag. 32x). Arrows indicate the pronounced cornua (a) and the long spur on coxa IV in the male (b). The scutal ornamentation pattern (a and c) and the spurs on coxa I (b and d) in both sexes are also arrowed.

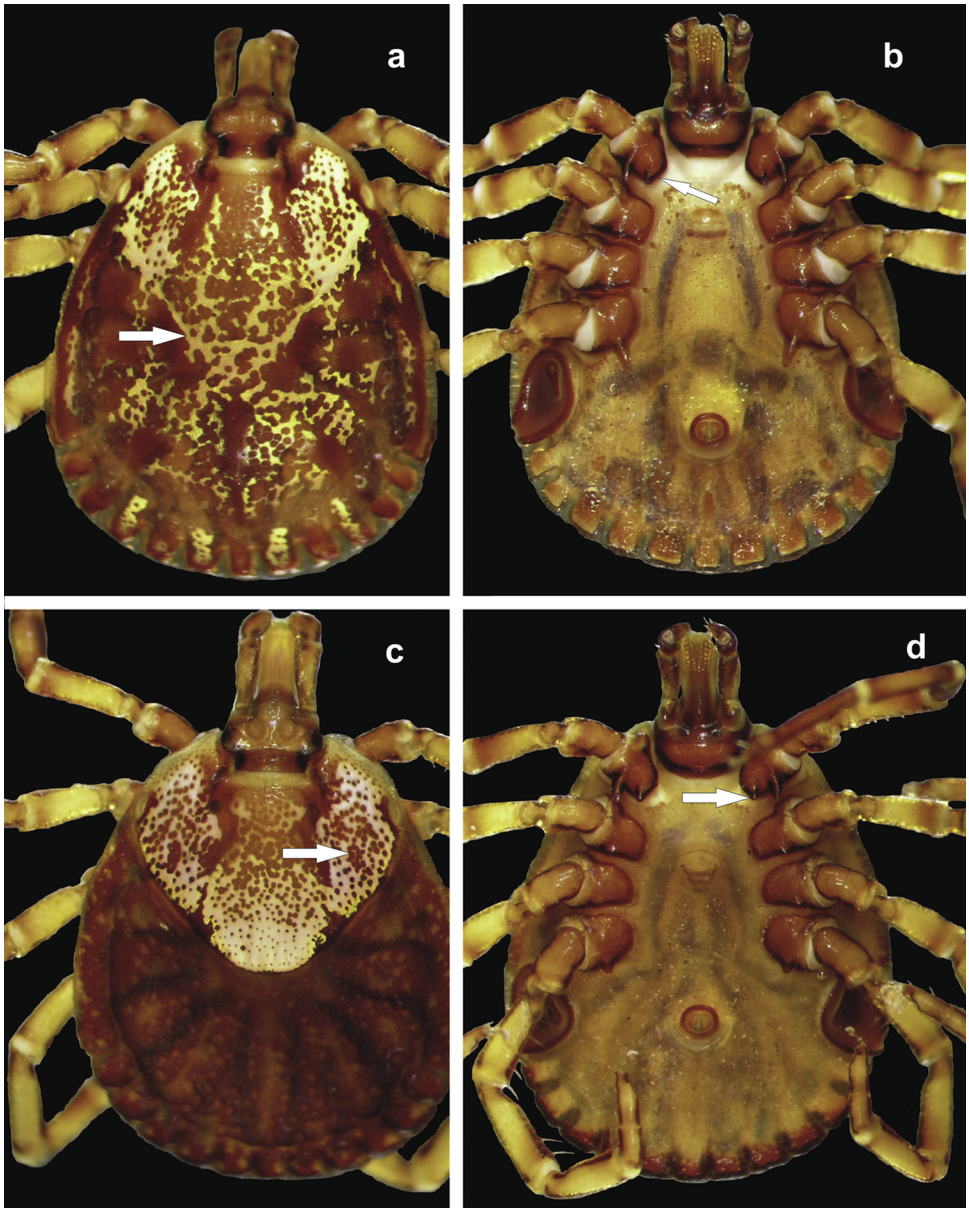

Fig. 6. *Amblyomma coelebs*. a: male dorsal (magnification 32x). b: male ventral (mag. 25x). c: female dorsal (mag. 20x). d: female ventral (mag. 20x). Arrows indicate large punctuations and scutal ornamentation pattern (a and c), as well as spurs on coxa I (b and d) in both sexes.

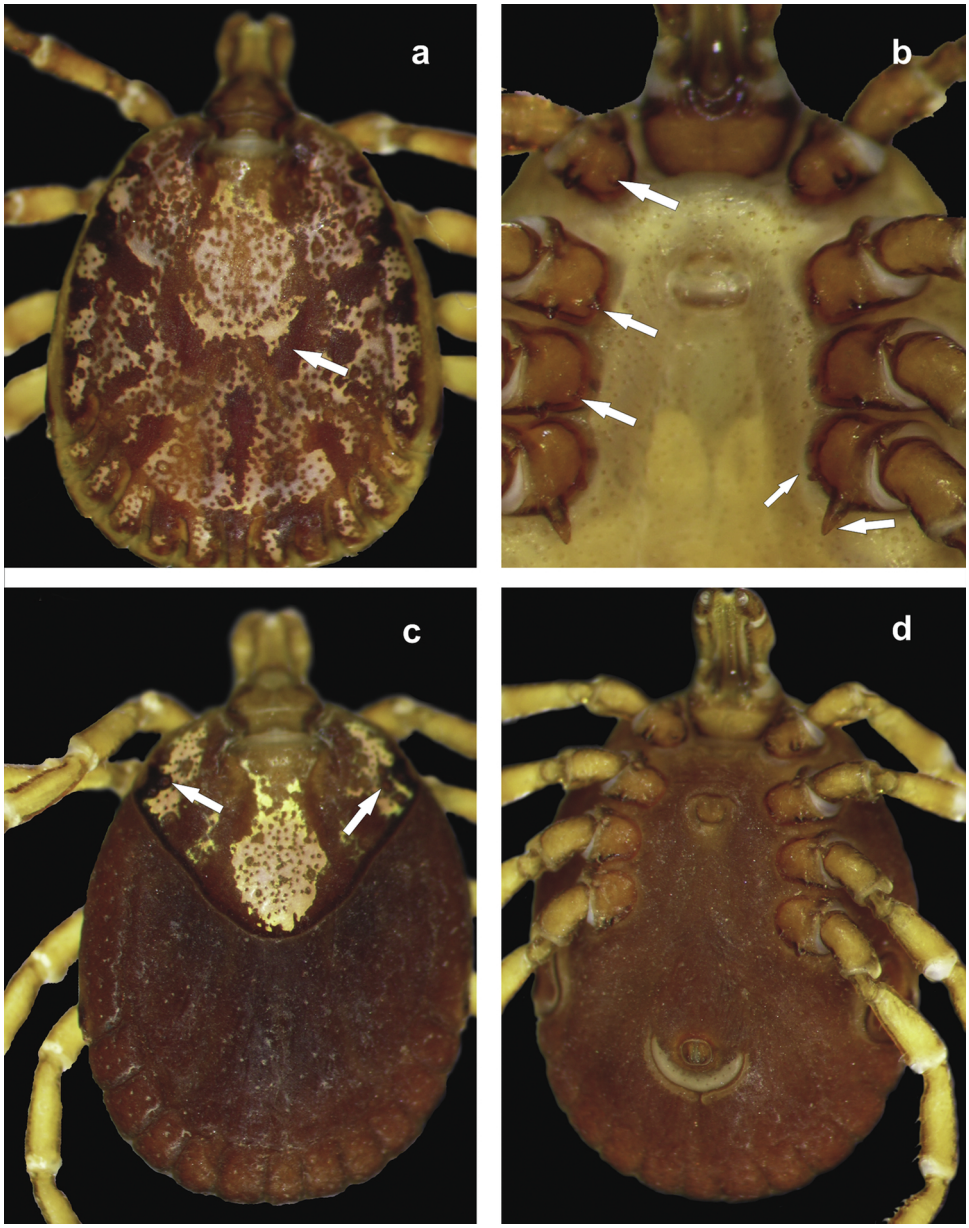

Fig. 7. *Amblyomma dissimile*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 25x). d: female ventral (mag. 32x). Arrows indicate the scutal ornamentation pattern (a) and the spurs on coxa I-IV in the male (b). The large punctations near the eyes of the female are also arrowed (c).

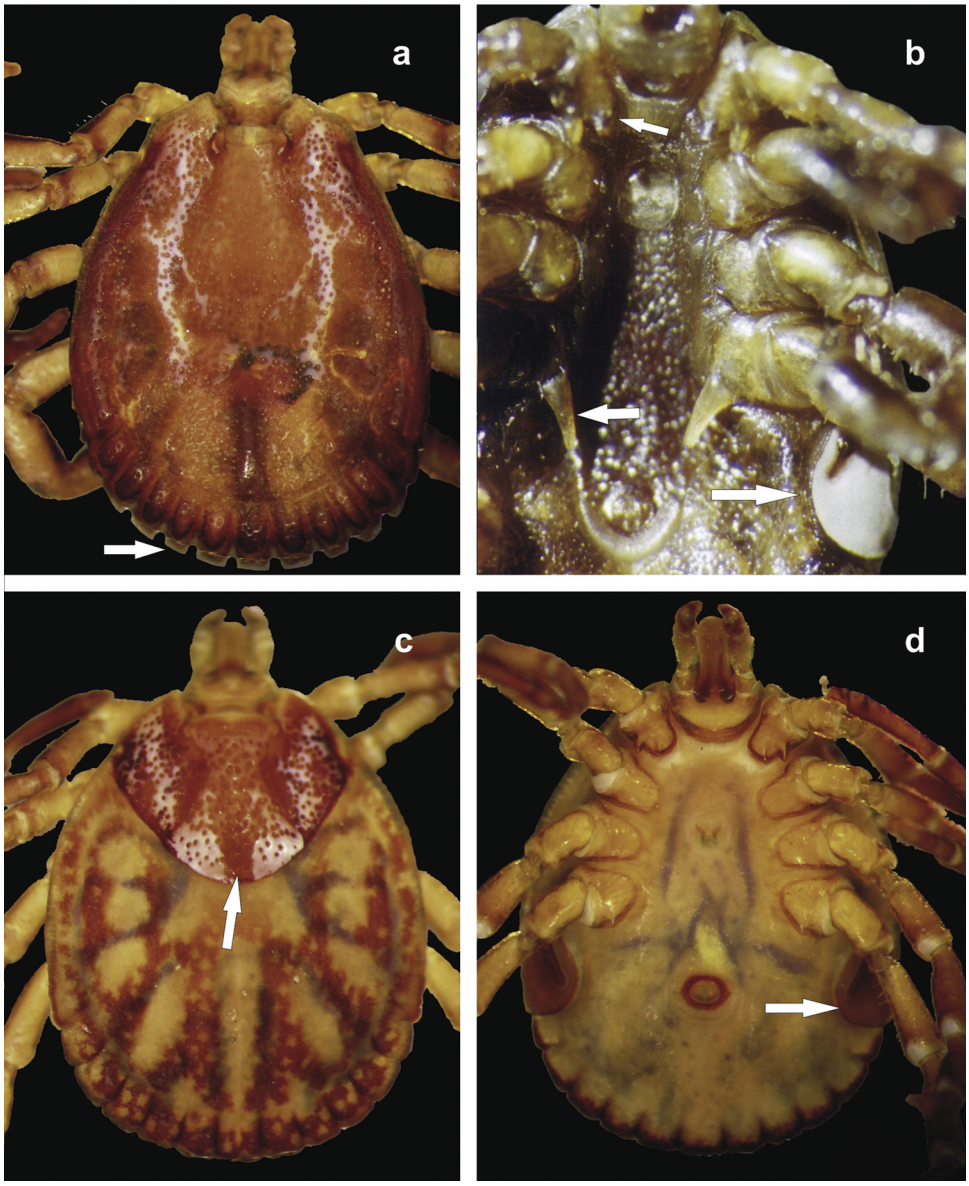

Fig. 8. *Amblyomma dubitatum*. a: male dorsal (magnification 32x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate festoons with the sclerotised ventral plates (a) and the long spur on coxa IV in the male (b), the dark-brown central stripe ending at the posterior margin of scutum in the female (c), and the large spiracular plates in both sexes (b and d). Males and females of *Amblyomma dubitatum* are very similar to *Amblyomma yucumense*. For a proper separation of these species, see illustrations and descriptions by Krawczak et al. (2015).

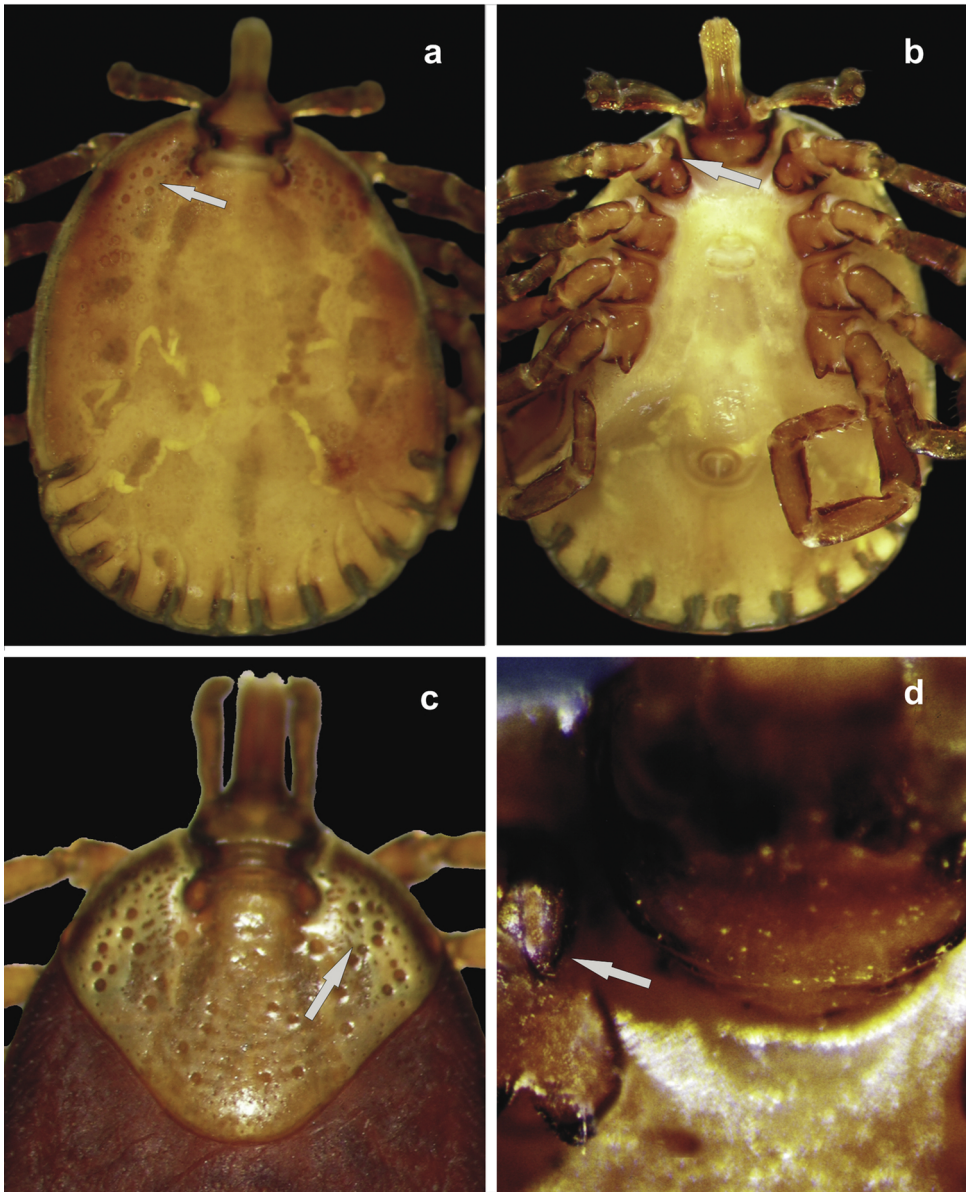

Fig. 9. *Amblyomma fuscum*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 20x). d: female ventral (mag. 80x). Arrows indicate large punctations in the anterolateral portions of the scutum (a and c), and a conspicuous tubercle in the anterior margin of coxa I (b and d) in both sexes.

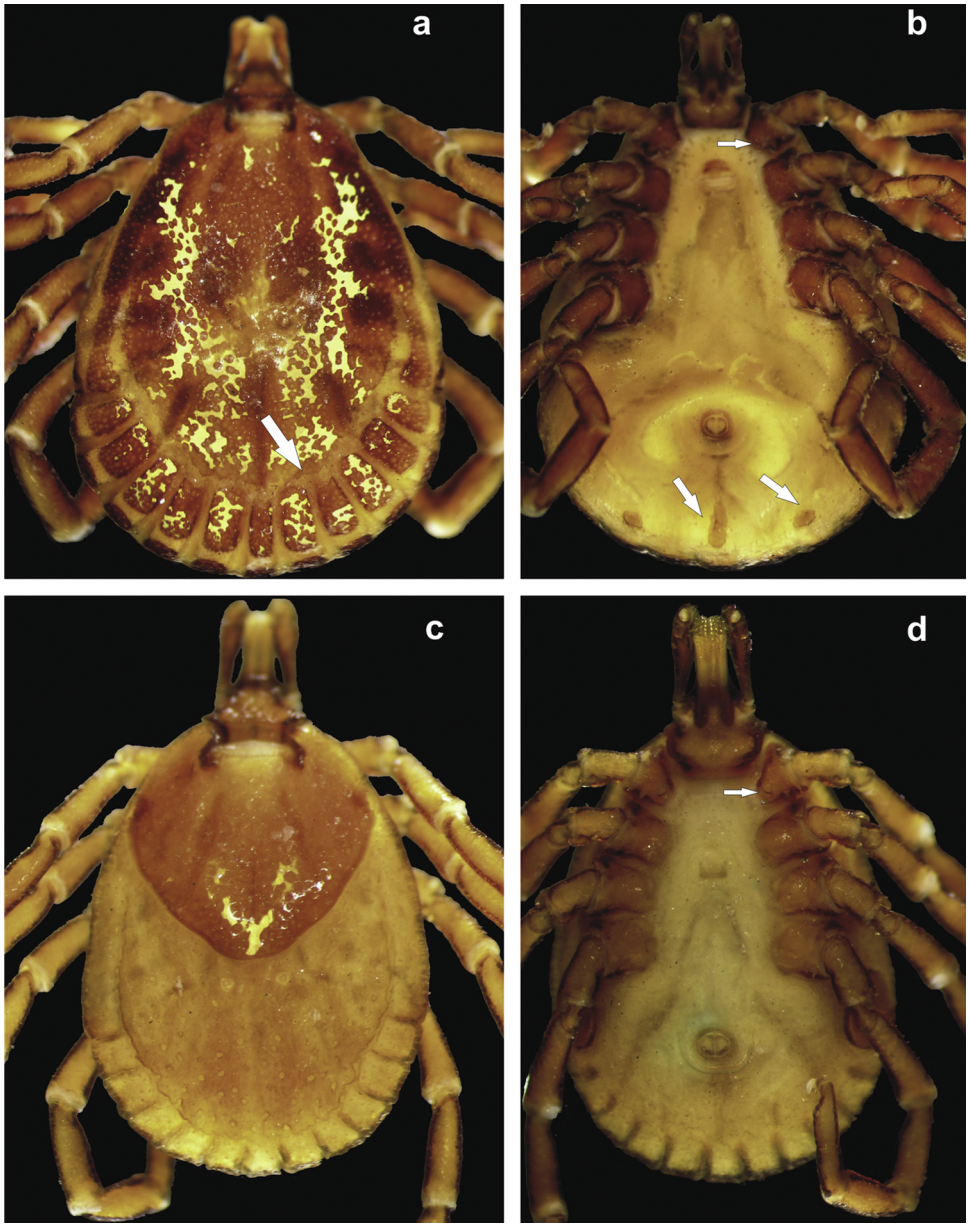

Fig. 10. *Amblyomma geayi*. a: male dorsal (magnification 25x). b: male ventral (mag. 25x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the complete marginal groove (a) and small ventral plates (b) in the male, and the short internal spurs on coxa I in both sexes (b and d).

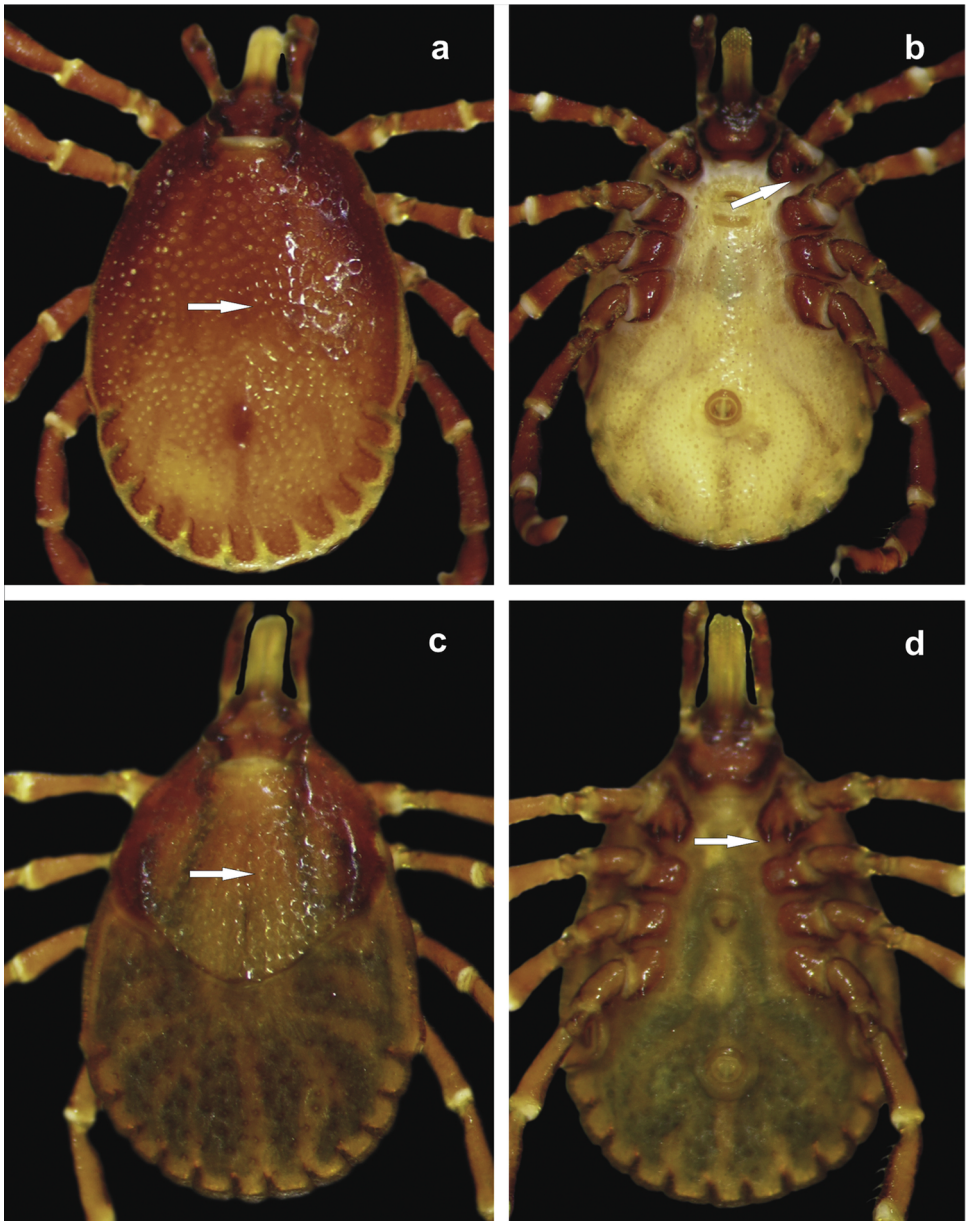

Fig. 11. *Amblyomma goeldii*. a: male dorsal (magnification 25x). b: male ventral (mag. 32x). c: female dorsal (mag. 25x). d: female ventral (mag. 25x). Arrows indicate the inornate scutum (a and c) and the spurs on coxa I (b and d) in both sexes.

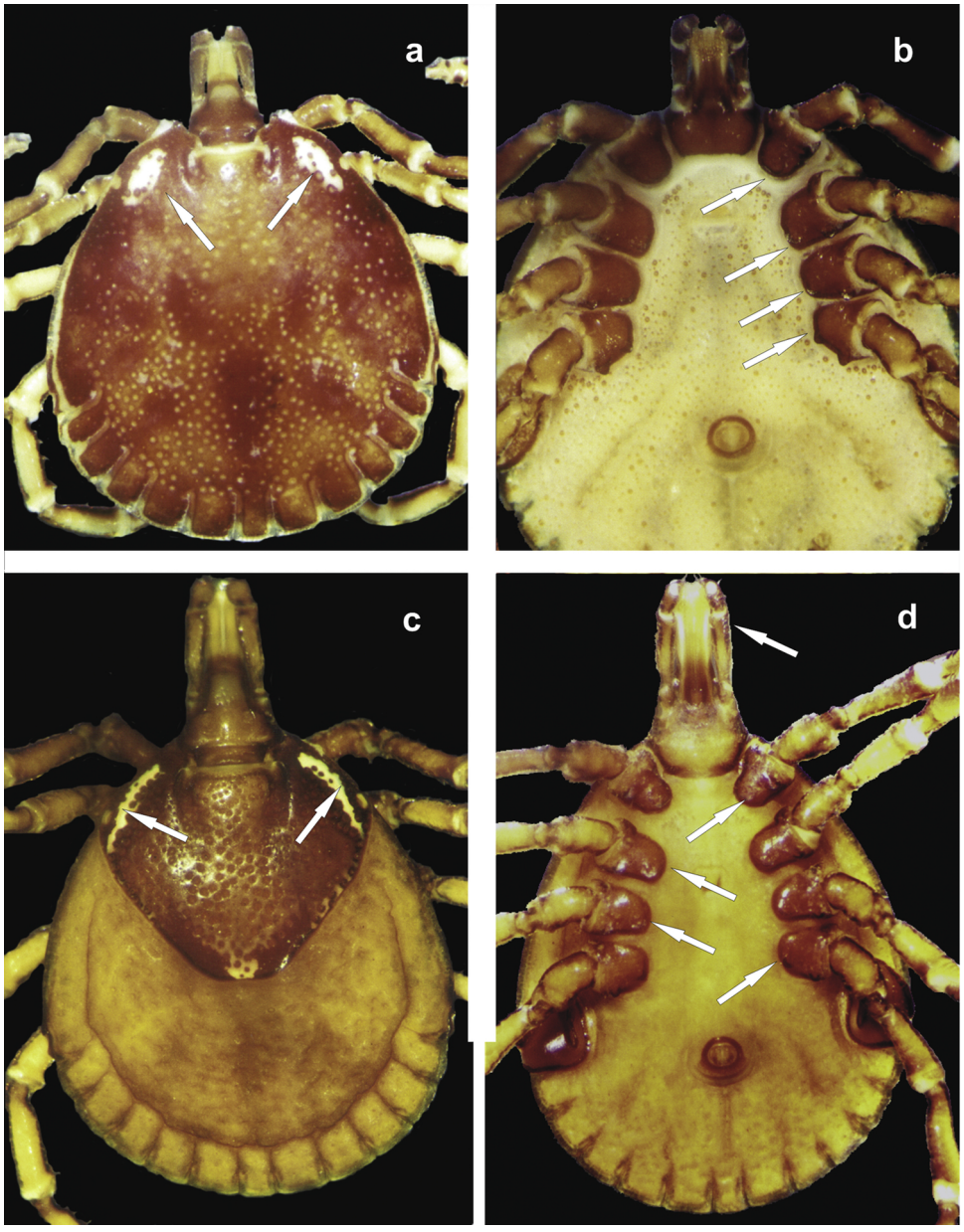

Fig. 12. *Amblyomma humerale.* a: male dorsal (magnification 12,5x). b: male ventral (mag. 16x). c: female dorsal (mag. 12,5x). d: female ventral (mag. 10x). Arrows indicate the characteristic scutal ornamentation pattern (a and c) and the spurs on coxa I-IV in both sexes (b and d). The long rostrum of the female is also arrowed (d).

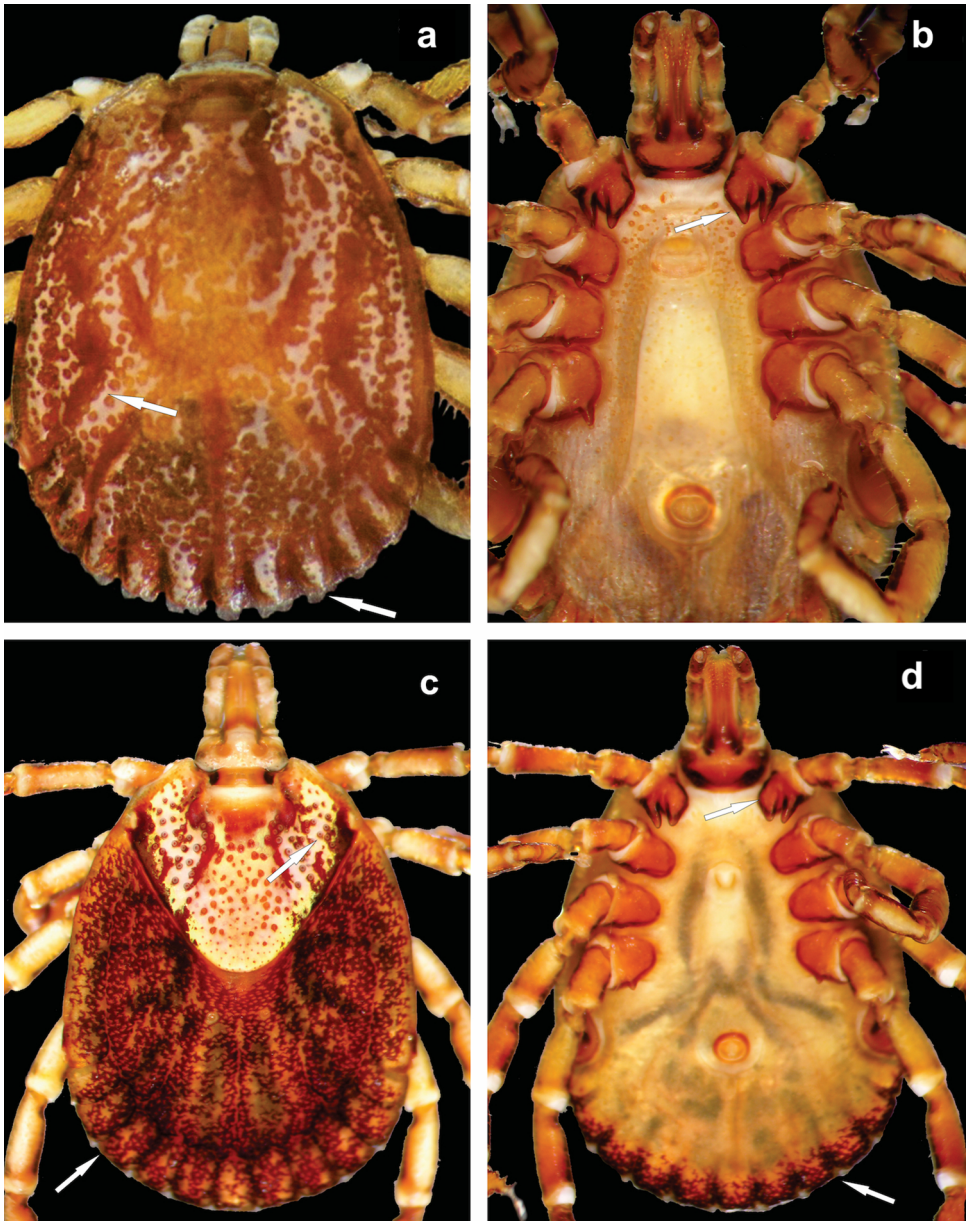

Fig. 13. *Amblyomma incisum*. a: male dorsal (magnification 40x). b: male ventral (mag. 32x). c: female dorsal (mag. 25x). d: female ventral (mag. 25x). Arrows indicate incised festoons in the male (a), the festoons with chitinous tubercles in the female (c and d), large punctations on the scutum (a and c) and spurs on coxa I (b and d) in both sexes.

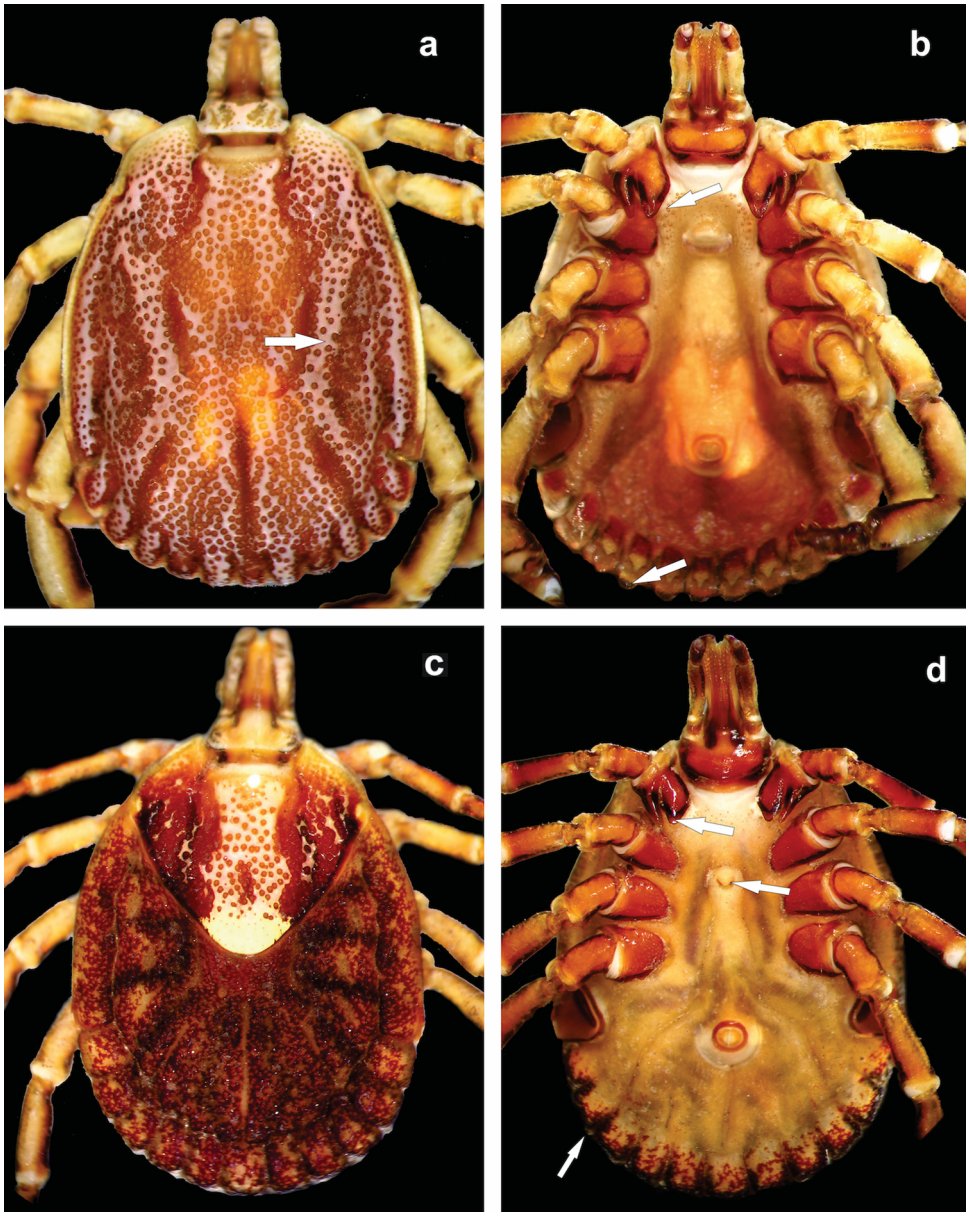

Fig. 14. *Amblyomma latepunctatum*. a: male dorsal (magnification 25x). b: male ventral (mag. 28x). c: female dorsal (mag. 25x). d: female ventral (mag. 28x). Arrows indicate the deep punctations in the male (a) and the spurs on coxa I (b and d) in both sexes, festoons with sclerotised ventral plates in the male (b), and the V-shaped genital aperture and festoons with chitinous tubercles in the female (d).

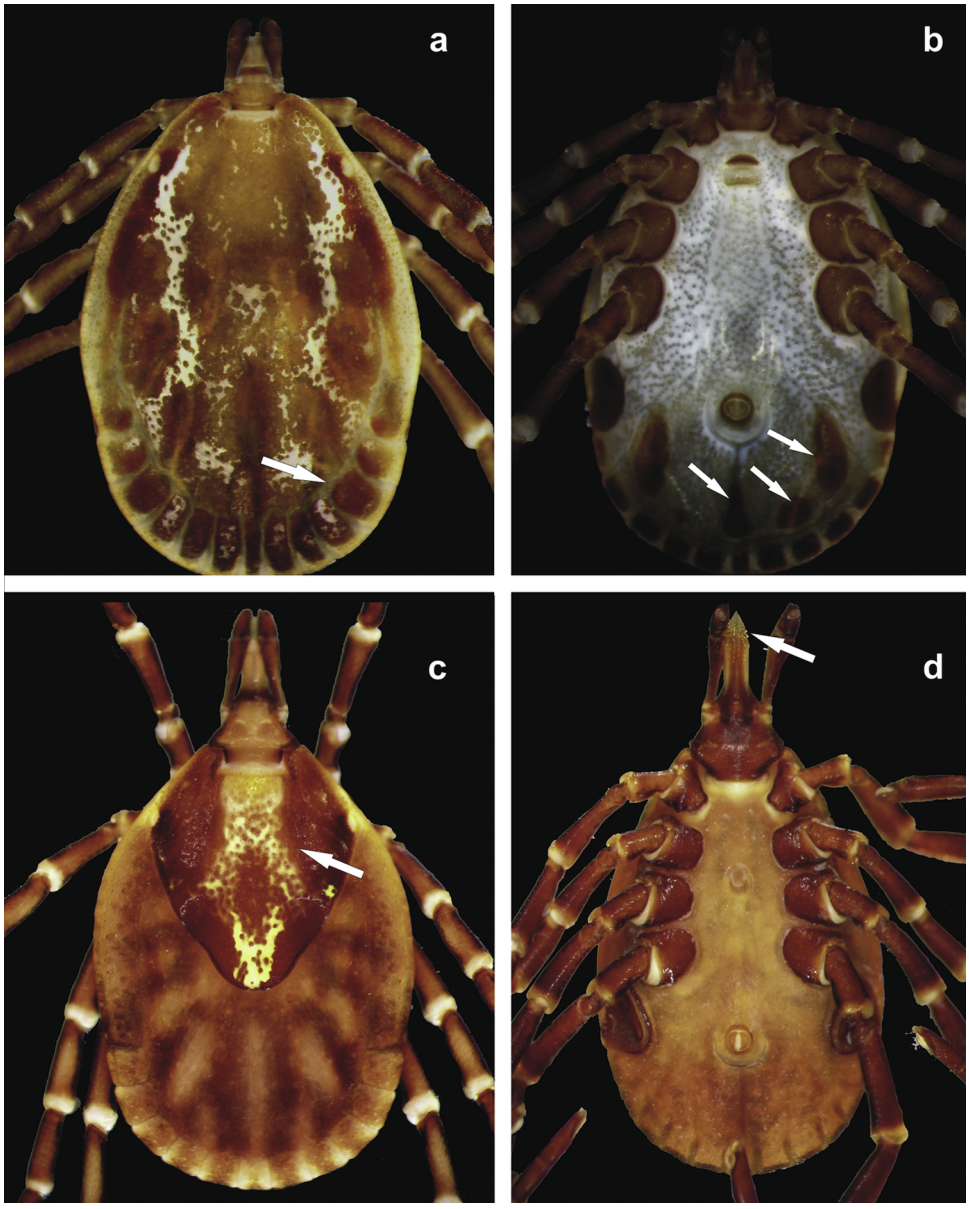

Fig. 15. *Amblyomma longirostre*. a: male dorsal (magnification 25x). b: male ventral (mag. 20x). c: female dorsal (mag. 32x). d: female ventral (mag. 25x). Arrows indicate the incomplete marginal groove (a) and the ventral plates (b) in the male, the scutal ornamentation pattern (c) and the apically pointed hypostome (d) in the female.

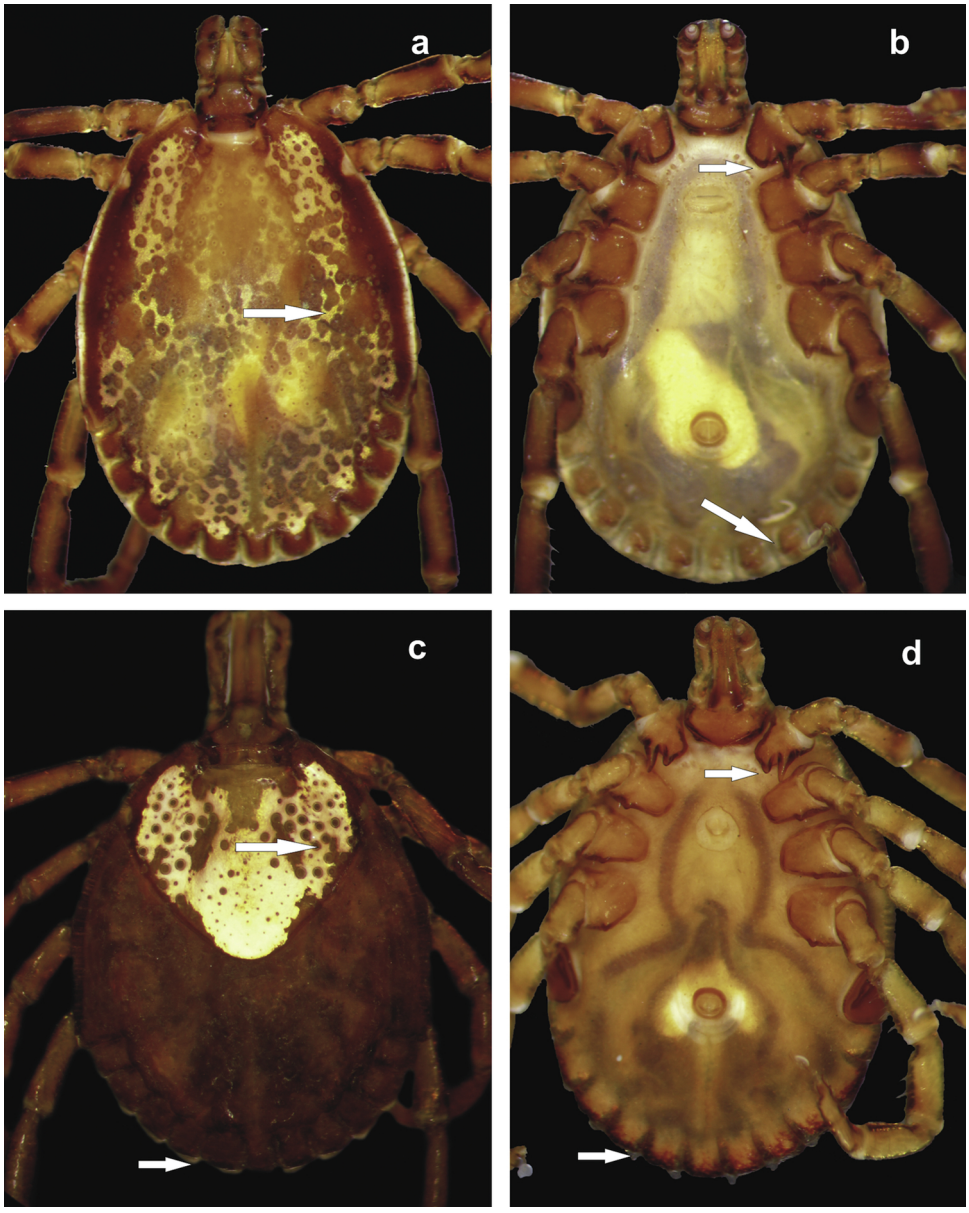

Fig. 16. *Amblyomma naponense*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 40x). d: female ventral (mag. 40x). Arrows indicate deep punctations on the scutum (a and c) and spurs on coxa I (b and d) in both sexes. Festoons with sclerotised ventral plates in the male (b) and with chitinous tubercles in the female (c and d) are also arrowed.

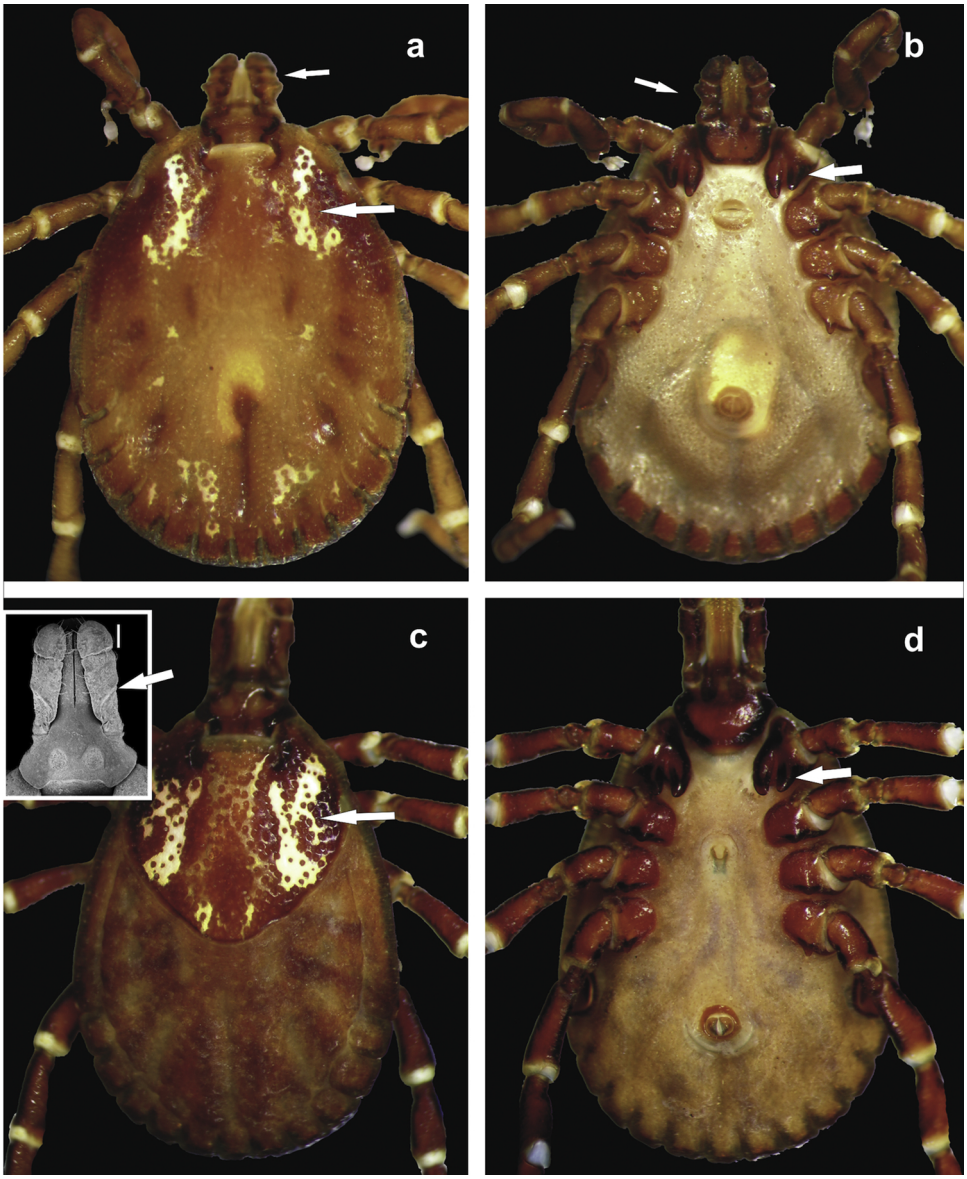

Fig. 17. *Amblyomma nodosum*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x); the SEM image shows the oblique ridge present on dorsal aspect of palpal article II (bar = 150 μm). d: female ventral (mag. 32x). Arrows indicate the short, nodose palps of the male (a and b), the characteristic scutal ornamentation pattern (a and c) and the spurs on coxa I (b and d) in both sexes.

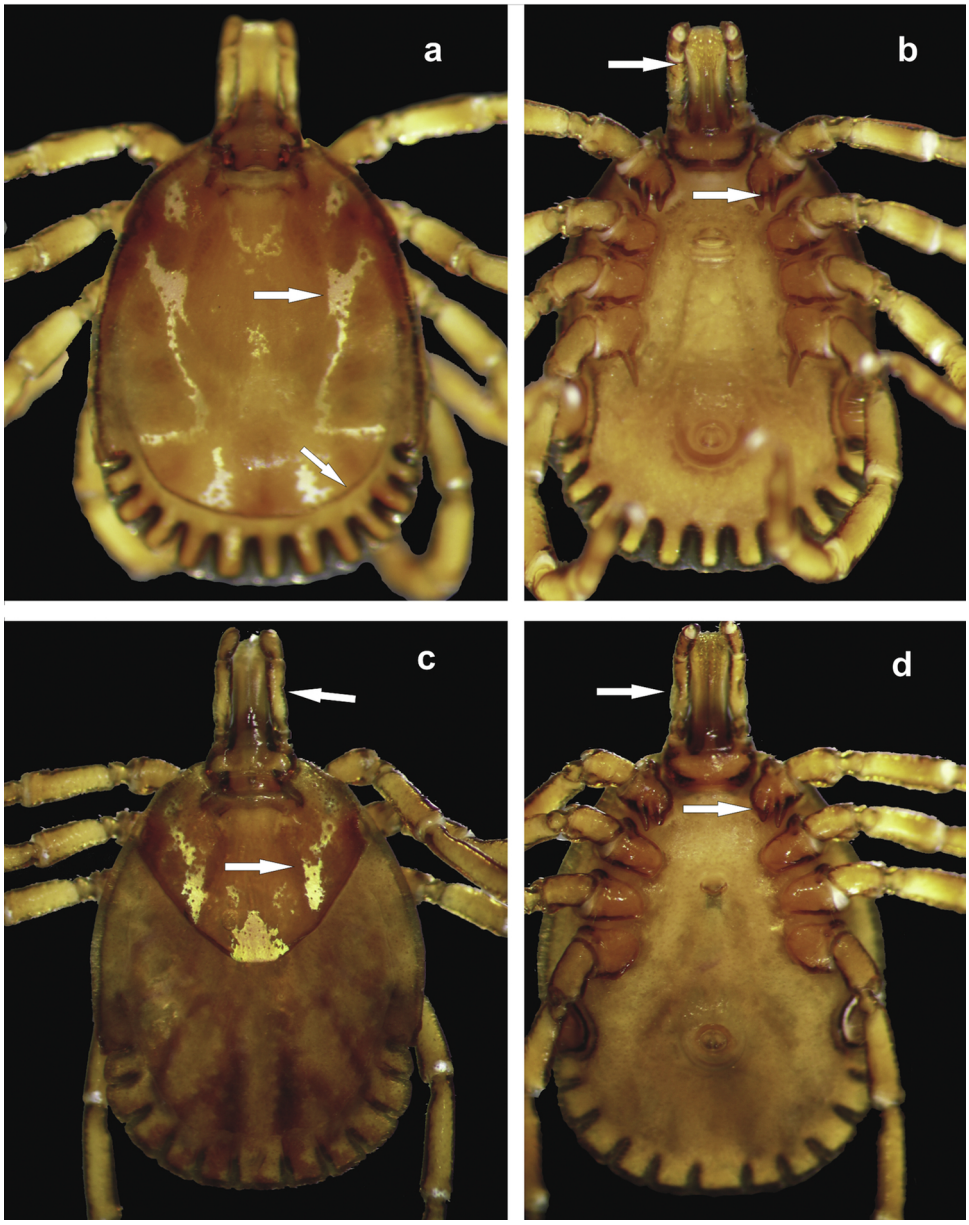

Fig. 18. *Amblyomma oblongoguttatum*. a: male dorsal (magnification 50x). b: male ventral (mag. 50x). c: female dorsal (mag. 40x). d: female ventral (mag. 40x). Arrows indicate the complete marginal groove in the male (a), and the long rostrum (b, c and d), the scutal ornamentation pattern (a and c) and spurs on coxa I (b and d) in both sexes.

Fig. 19. *Amblyomma ovale*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the long spurs on coxa I, with the external spur presenting a sharply pointed tip, slightly curved outward (b and d) in both sexes.

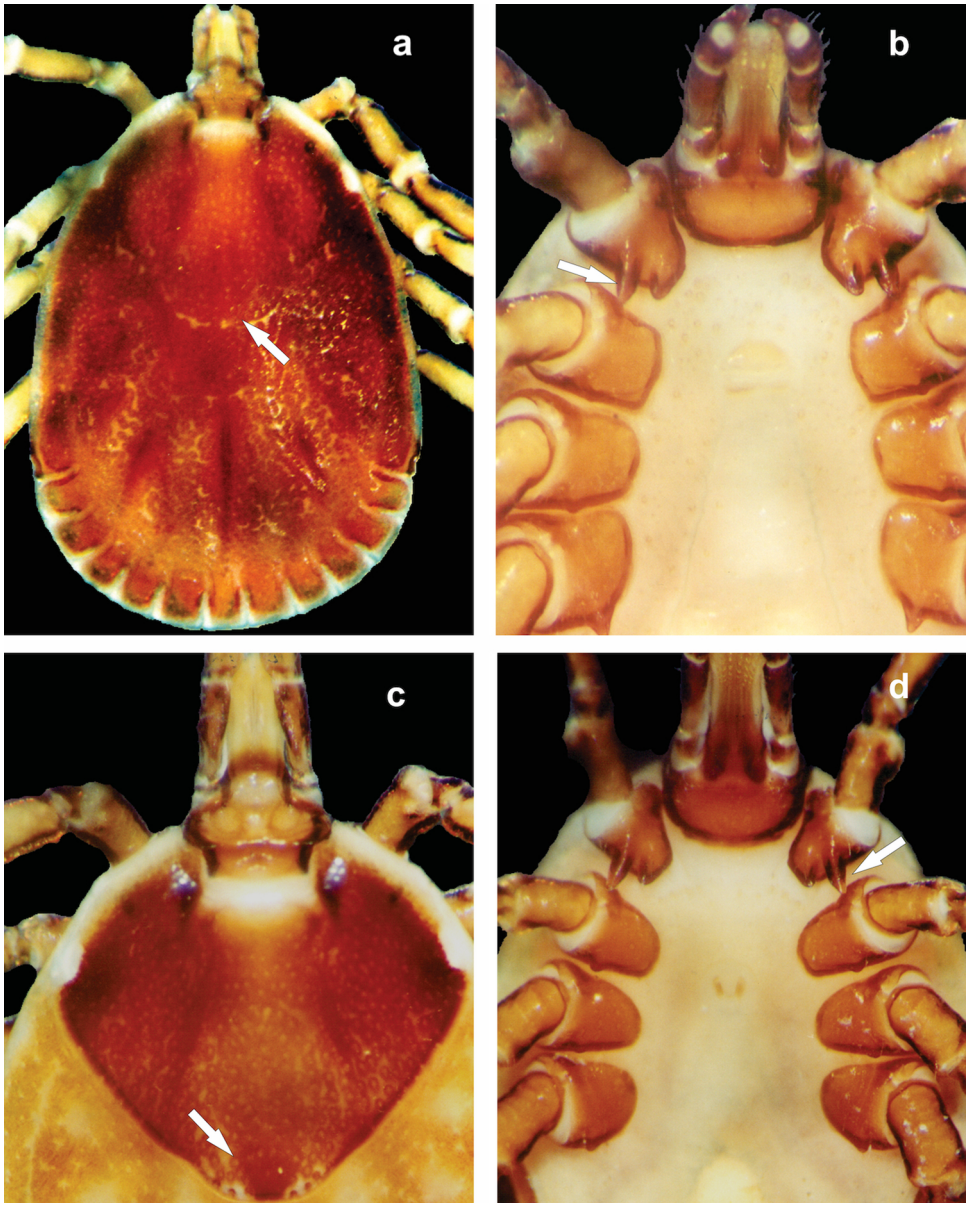

Fig. 20. *Amblyomma pacae*. a: male dorsal (magnification 20x). b: male ventral (mag. 40x). c: female dorsal (mag. 25x). d: female ventral (mag. 25x). Arrows indicate the scutal ornamentation pattern (a and c) and the external spurs on coxa I, with the tip slightly curved outward (b and d) in both sexes.

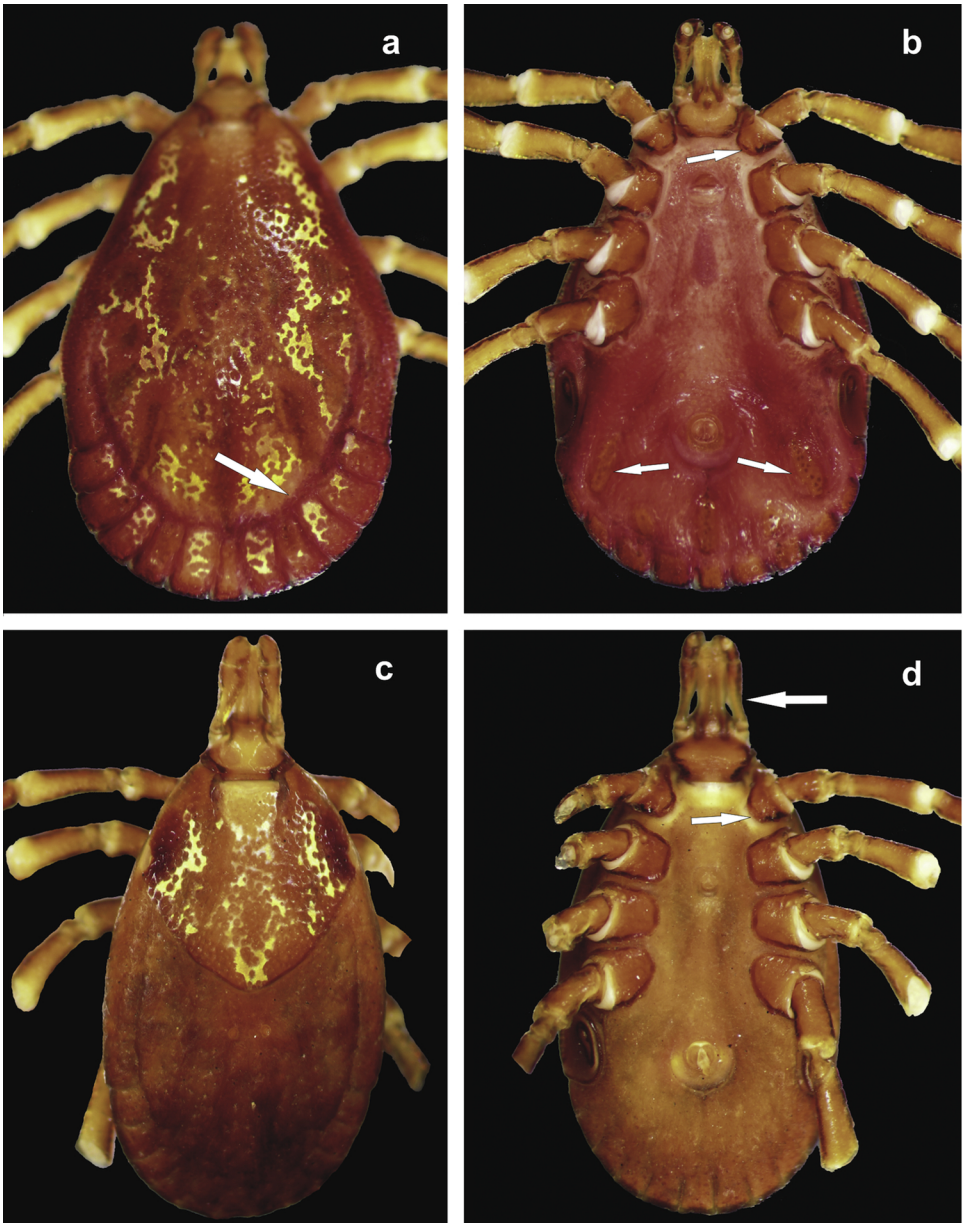

Fig. 21. *Amblyomma parkeri*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the complete marginal groove and the ventral plates in the male (a and b), the long rostrum with hypostome apically rounded in the female (d), and the short spurs on coxa I (b and d) in both sexes.

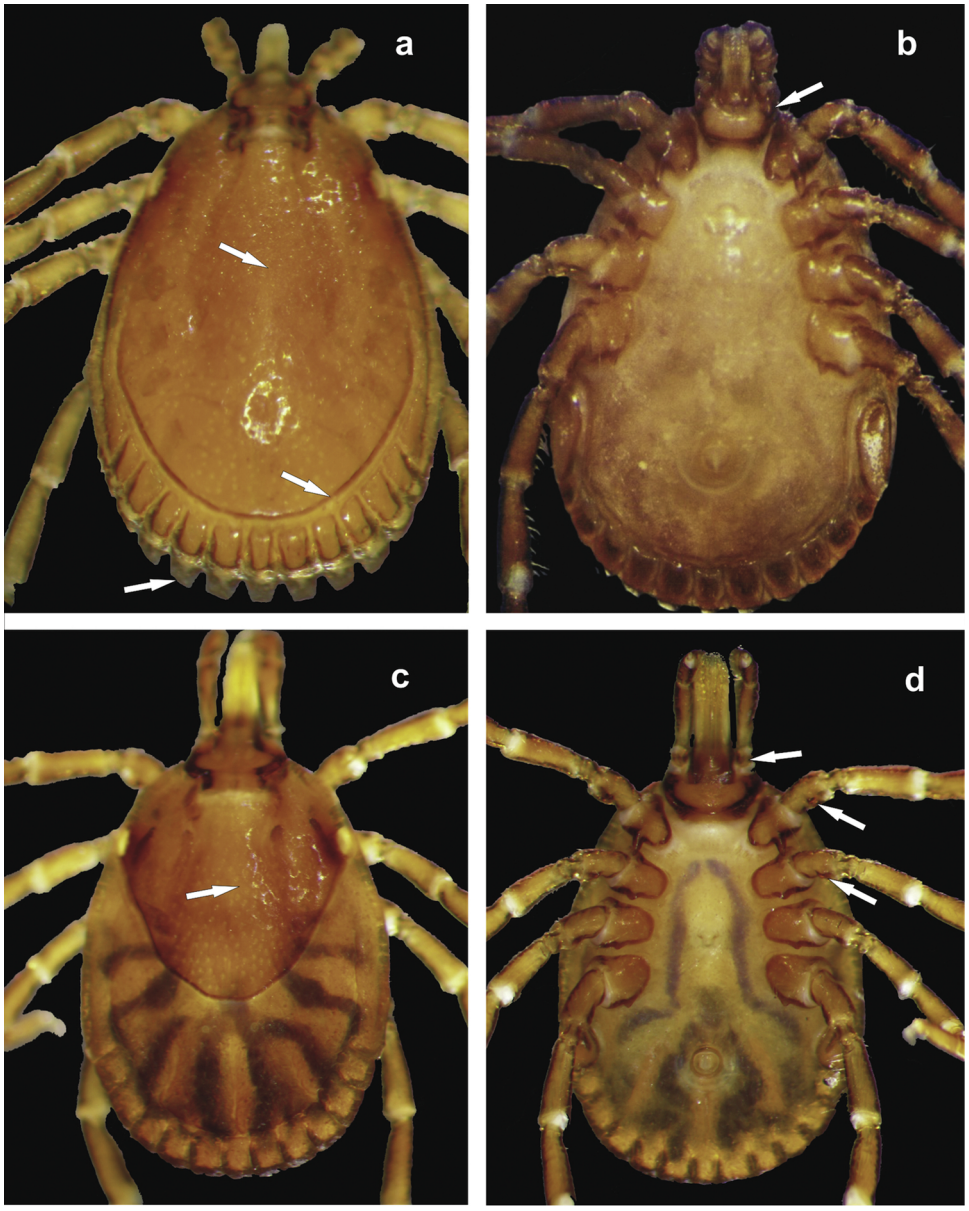

Fig. 22. *Amblyomma parvum*. a: male dorsal (magnification 66x). b: male ventral (mag. 66x). c: female dorsal (mag. 50x). d: female ventral (mag. 50x). Arrows indicate the complete marginal groove and festoons with sclerotised ventral plates in the male (a), the inornate scutum (a and c) and the retrograde spur on palpal article I (b and d) in both sexes. Spurs on the trochanters of the female are also arrowed (d).

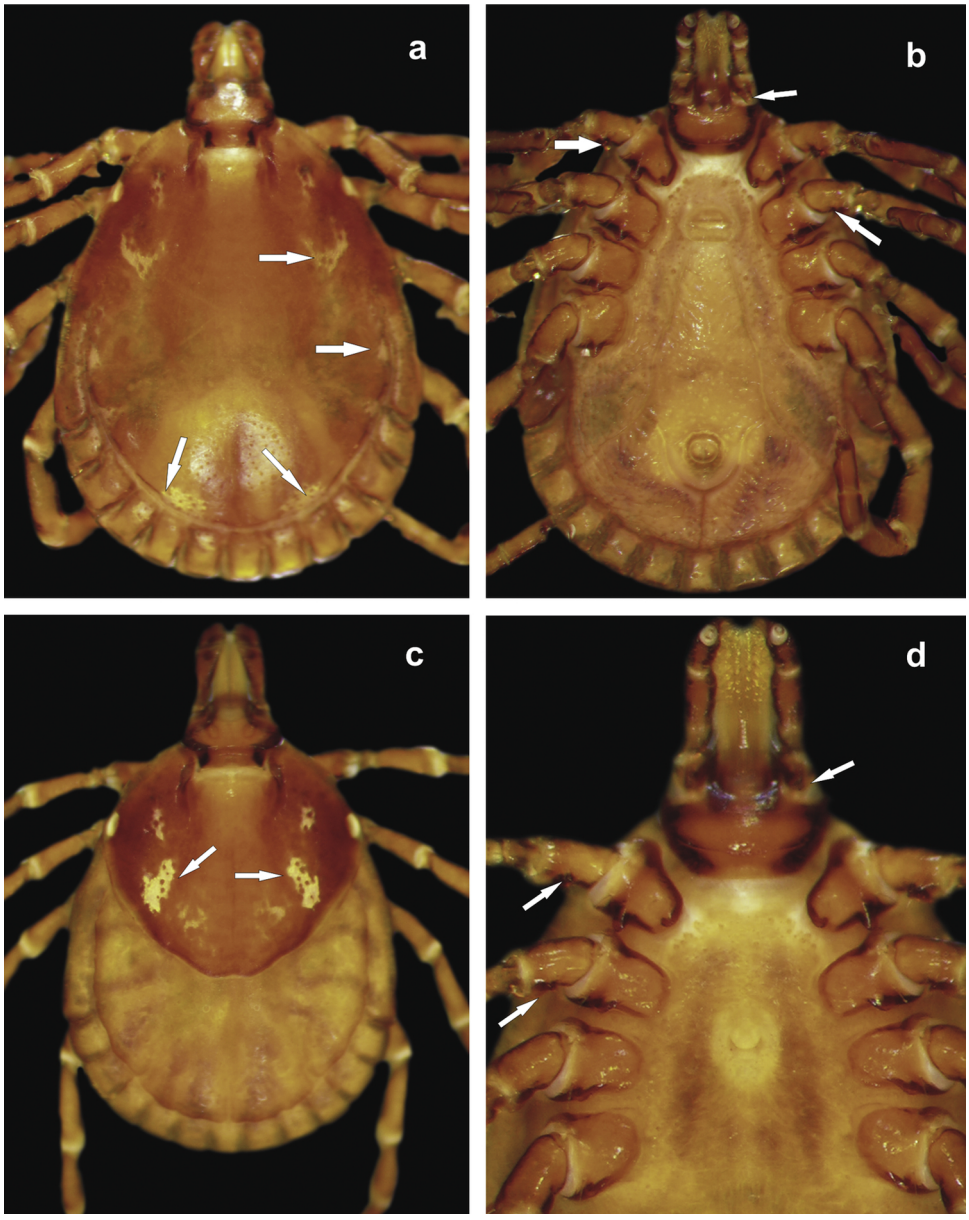

Fig. 23. *Amblyomma pseudoconcolor*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 66x). Arrows indicate the scutal ornamentation pattern (a and c), the retrograde spur on palpal article I (b and d), spurs on the trochanters (b and d) in both sexes.

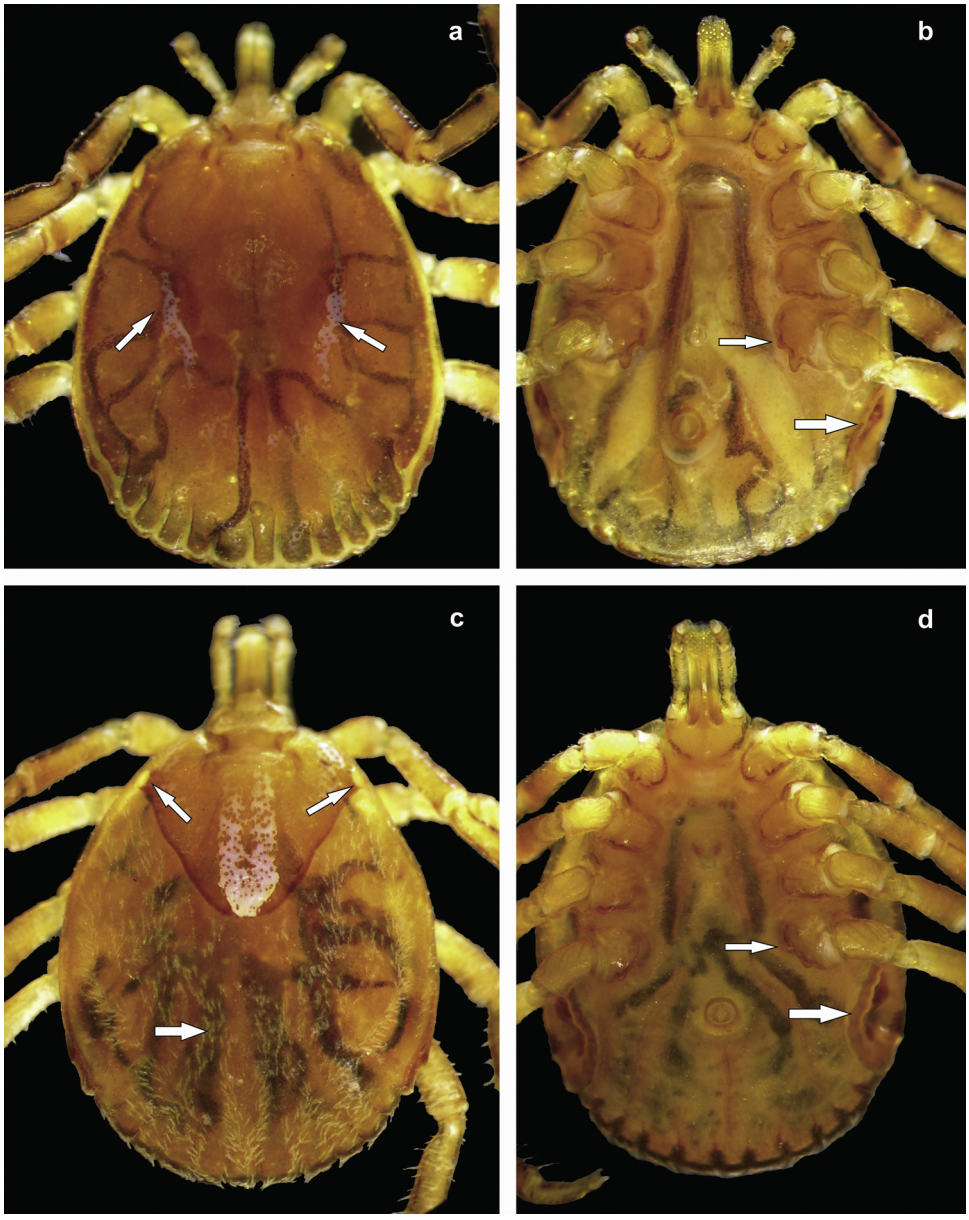

Fig. 24. *Amblyomma romitii*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 25x). d: female ventral (mag. 25x). Arrows indicate the scutal ornamentation pattern in the male (a), convex eyes (c), spurs on coxa IV and festooned spiracular plates in both sexes (b and d). The densely pilose alloscutum of the female is also arrowed (c).

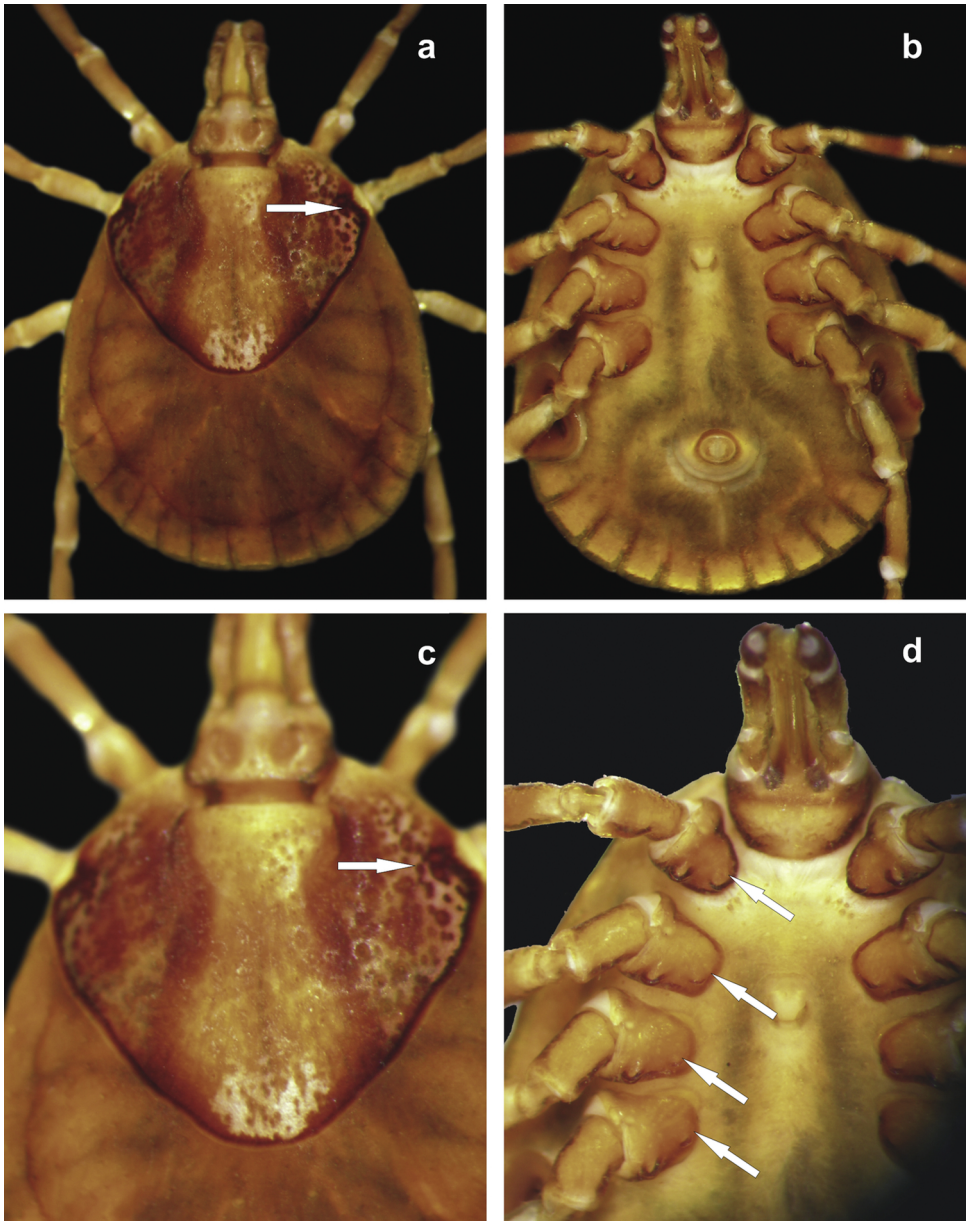

Fig. 25. *Amblyomma rotundatum*. a: female dorsal (magnification 25x). b: female ventral (mag. 20x). c: female close-up of scutum (mag. 50x). d: female close-up of coxal spurs (mag. 50x). Arrows indicate large, deep punctations near the eyes (a and c) and spurs on coxa I-IV (d).

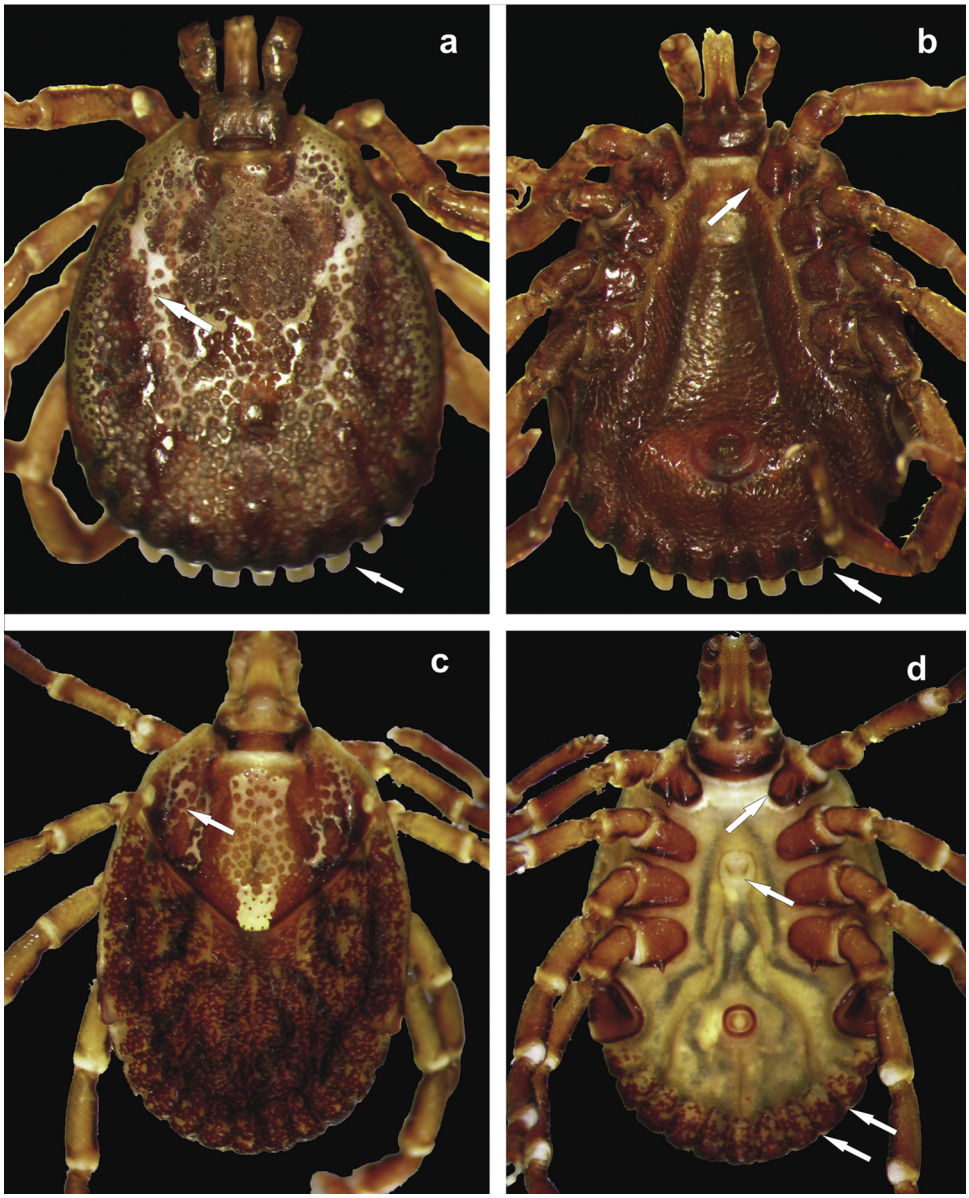

Fig. 26. *Amblyomma scalpturatum*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 20x). d: female ventral (mag. 20x). Arrows indicate festoons with sclerotised ventral plates in the male (a and b), the U-shaped genital aperture and festoons with chitinous tubercles in the female (d), and scutum with distinctly elevated margins (a and c) and spurs of coxa I in both sexes (b and d).

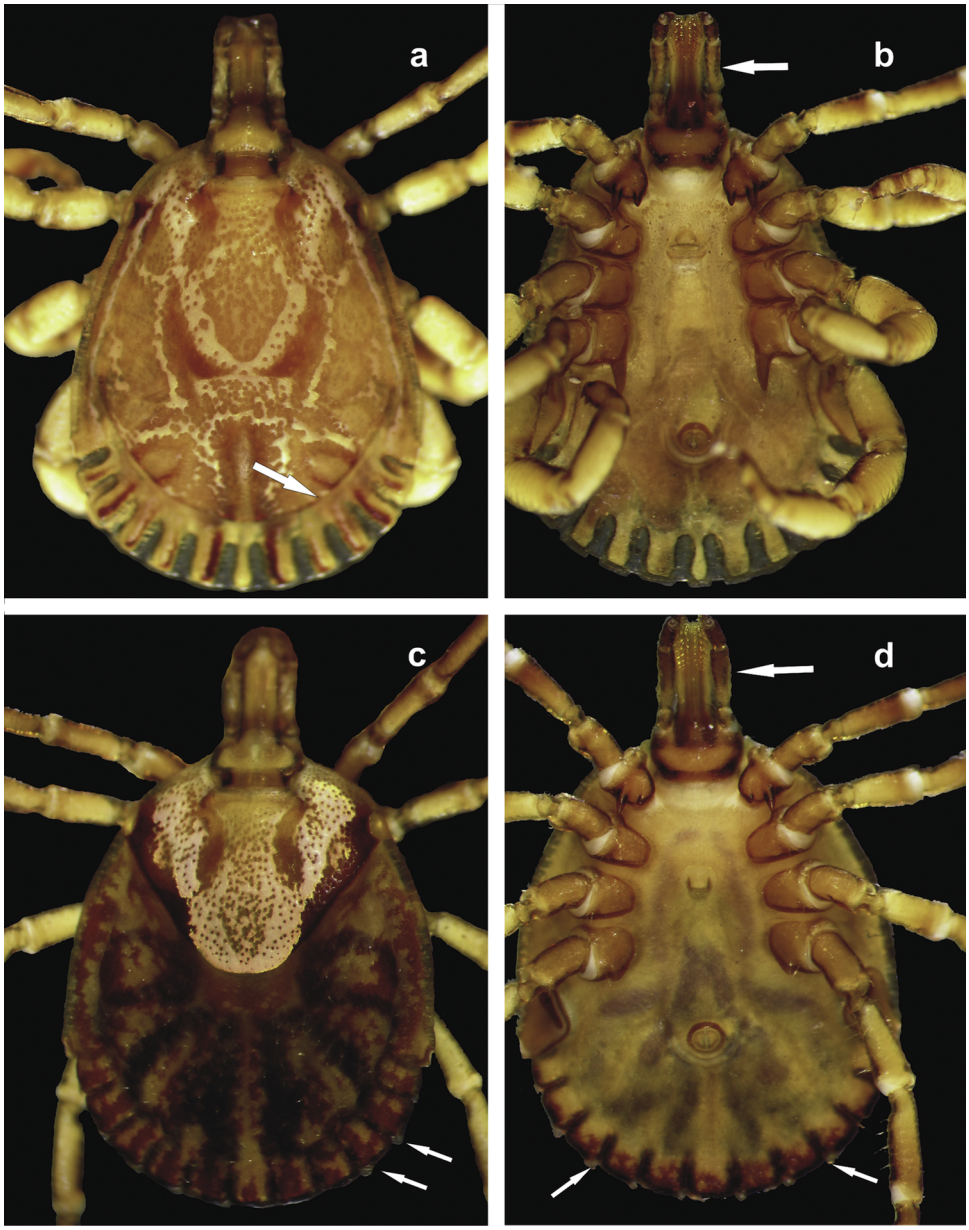

Fig. 27. *Amblyomma sculptum*. a: male dorsal (magnification 32x). b: male ventral (mag. 32x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the complete marginal groove in the male (a), festoons with chitinous tubercles in the female (c and d), and the long rostrum in both sexes. The males of *A. sculptum* and *Amblyomma cajennense* sensu stricto are indistinguishable, whereas the females can be distinguished based on the morphology of the genital aperture (see illustrations in Nava et al., 2014 and Martins et al., 2016).

Fig. 28. *Amblyomma tigrinum*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the scutal ornamentation pattern in the male (a) and female (c), the long spur on coxa IV in the male (b), and the spurs on coxa I in both sexes (b and d).

Fig. 29. *Amblyomma triste*. a: male dorsal (magnification 40x). b: male ventral (mag. 40x). c: female dorsal (mag. 32x). d: female ventral (mag. 32x). Arrows indicate the scutal ornamentation pattern in the male (a) and female (c), and festoons with chitinous tubercles in the female (c and d).

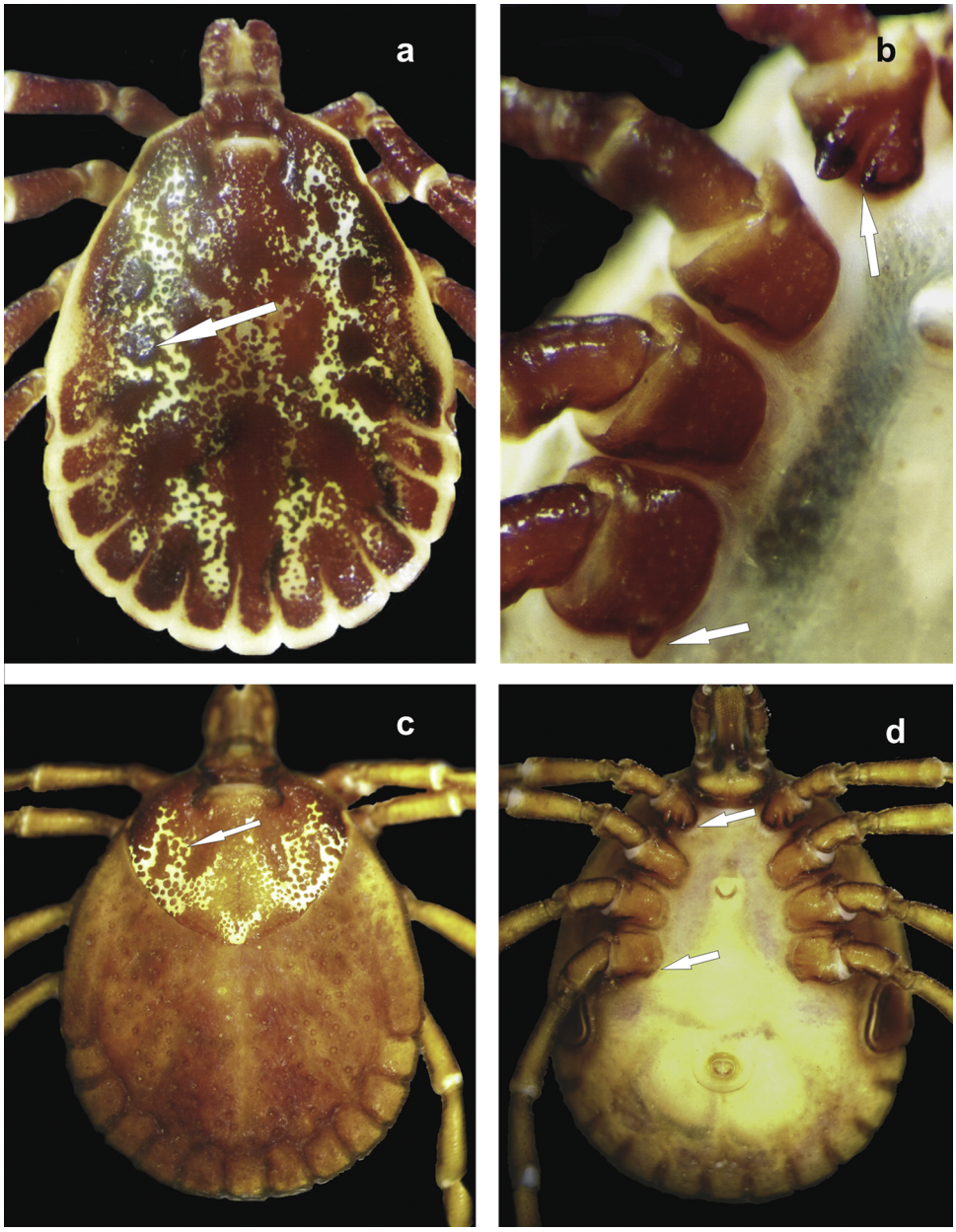

Fig. 30. *Amblyomma varium*. a: male dorsal (magnification 40x). b: male ventral (mag. 63x). c: female dorsal (mag. 20x). d: female ventral (mag. 20x). Arrows indicate the scutal ornamentation pattern in the male (a) and female (c), and spurs on coxa I and IV (b and d) in both sexes.

Table 1
Checklist of tick species of Brazil, with some taxonomic notes.

Family	Genus	Species	Observations
Argasidae Canestrini	*Antricola* Cooley & Kohls	*Antricola delacruzi* Estrada-Peña et al. (2004) *Antricola guglielmonei* Estrada-Peña et al. (2004) *Antricola inexpectata* Estrada-Peña et al. (2004)	Larvae of these species as well as the male of *A. inexpectata* are unknown. *Antricola inexpectata* was described from three females resembling *A. guglielmonei* (Estrada-Peña et al., 2004). We tentatively retain this species as valid, but further study may reveal that it is conspecific with *A. guglielmonei.*
	Argas Latreille	*Argas miniatus* Koch, 1844	
	Nothoaspis Keirans & Clifford	*Nothoaspis amazoniensis* Nava et al., 2010	
	Ornithodoros Koch	*Ornithodoros brasiliensis* Aragão, 1923 *Ornithodoros capensis* Neumann, 1901 *Ornithodoros cavernicolous* Dantas-Torres et al. (2012a) *Ornithodoros faccinii* Barros-Battesti et al., 2015 *Ornithodoros fonsecai* (Labruna and Venzal, 2009) *Ornithodoros guaporensis* Nava et al., 2013 *Ornithodoros hasei* (Schulze, 1935) *Ornithodoros kohlsi* Guglielmone & Keirans, 2002 *Ornithodoros marinkellei* Kohls et al., 1969 *Ornithodoros mimon* Kohls et al., 1969 *Ornithodoros rietcorreai* Labruna et al., 2016 *Ornithodoros peropteryx* Kohls et al., 1969 *Ornithodoros rondoniensis* (Labruna et al., 2008) *Ornithodoros rostratus* Aragão, 1911 *Ornithodoros rudis* Karsch, 1880 *Ornithodoros saraivai* Muñoz-Leal et al., 2017 *Ornithodoros setosus* Kohls et al., 1969 *Ornithodoros stageri* Cooley and Kohls, 1941	The larva of *O. rondoniensis* is unknown. Nymphs of *O. guaporensis*, *O. rondoniensis*, and *O. setosus,* and adults of *O. setosus* are still unknown. Although nymphs of *O. brasiliensis*, *O. fonsecai*, *O. rietcorreai*, *O. rostratus*, *O. rudis*, and *O. stageri* have already been collected or obtained under laboratory conditions (Cooley and Kohls, 1944; Labruna and Venzal, 2009; Barros-Battesti et al., 2012; Ribeiro et al., 2013; Labruna et al., 2016; Muñoz-Leal et al., 2018b), proper morphological descriptions are currently missing. The sole report of *O. stageri* from Brazil refers to unpublished records from the US National Tick Collection mentioned by Jones et al. (1972). These records consist of 19 larvae labelled as *O. stageri* collected from bats (*Noctilio albiventris* and *Nyctinomops laticaudatus*) in Rondônia state in 1964 (RML-49557, RML-49565, RML-49603, RML-49606, RML-49607). Two of us (FDT and SML) had the opportunity to examine high-quality images of larvae from lots RML-49606 and RML-49607, and confirmed that they correspond to *O. stageri*. The remaining lots (RML-49557, RML-49565, RML-49603) contain larvae in ethanol, whose identity needs confirmation.
Ixodidae Murray	*Amblyomma* Koch	*Amblyomma aureolatum* (Pallas, 1772) *Amblyomma auricularium* (Conil, 1878) *Amblyomma brasiliense* Aragão (1908a,b,c) *Amblyomma cajennense* (Fabricius, 1787) *Amblyomma calcaratum* Neumann, 1899 *Amblyomma coelebs* Neumann, 1899 *Amblyomma dissimile* Koch, 1844 *Amblyomma dubitatum* Neumann, 1899 *Amblyomma fuscum* Neumann, 1907 *Amblyomma geayi* Neumann, 1899 *Amblyomma goeldii* Neumann, 1899 *Amblyomma humerale* Koch, 1844 *Amblyomma incisum* Neumann, 1906 *Amblyomma latepunctatum* Tonelli-Rondelli, 1939 *Amblyomma longirostre* (Koch, 1844) *Amblyomma naponense* (Packard, 1869) *Amblyomma nodosum* Neumann, 1899 *Amblyomma oblongoguttatum* Koch, 1844 *Amblyomma ovale* Koch, 1844 *Amblyomma pacae* Aragão, 1911 *Amblyomma parkeri* Fonseca and Aragão, 1952 *Amblyomma parvum* Aragão (1908a,b,c) *Amblyomma pictum* Neumann, 1906 *Amblyomma pseudoconcolor* Aragão (1908a,b,c) *Amblyomma romitii* Tonelli-Rondelli, 1939 *Amblyomma rotundatum* Koch, 1844 *Amblyomma scalpturatum* Neumann, 1906 *Amblyomma sculptum* Berlese, 1888 *Amblyomma tigrinum* Koch, 1844 *Amblyomma triste* Koch, 1844 *Amblyomma varium* Koch, 1844 *Amblyomma yucumense* Krawczak et al., 2015	Larvae of *A. aureolatum*, *A. cajennense*, *A. coelebs*, *A. fuscum*, *A. goeldii*, *A. humerale*, *A. incisum*, *A. latepunctatum*, *A. naponense*, *A. pseudoconcolor*, *A. scalpturatum*, and *A. yucumense* are unknown. The larva described by Famadas et al. (1997) as *A. cajennense* is actually *A. sculptum*, and that described by Amorim and Serra-Freire (1999b) as *A. cooperi* is *A. dubitatum*. The nymph of *A. pictum* is unknown (Guglielmone et al., 2014). We tentatively retain this species as part of the Brazilian fauna, but further data (e.g., the examination of Aragão's type of *A. conspicuum*) would be valuable to confirm this. Ticks previously identified as *A. cajennense* and *A. dubitatum* actually belong to four different taxa, that is, *A. cajennense* sensu stricto and *A. sculptum* in the *A. cajennense* group, and *A. dubitatum* sensu stricto and *A. yucumense* in the *A. dubitatum* group. Further information about the currently known geographical distribution of these species in Brazil may be found elsewhere (Nava et al., 2014a; Krawczak et al., 2015; Martins et al., 2016). The male of *A. auricularium* is considered as inornate (Nava et al., 2017). However, some males from north-eastern Brazil are ornate, with small pale spots, as in *A. pseudoconcolor*. Further research on these tick species in Brazil and other countries where they occur is warranted. Males of *A. rotundatum* are extremely rare and have only been reported from Amazonia (Labruna et al., 2005b; Martins et al., 2014; Silva et al., 2016; Gianizella et al., 2018). Females of this species reproduce by parthenogenesis (Aragão, 1912b).
	Dermacentor Koch	*Dermacentor nitens* Neumann, 1897	
	Haemaphysalis Koch	*Haemaphysalis cinnabarina* Koch, 1844 *Haemaphysalis juxtakochi* Cooley, 1946 *Haemaphysalis leporispalustris* (Packard, 1869)	*Haemaphysalis cinnabarina* has been reported in Brazil over a century ago (Aragão, 1911; Barros-Battesti et al., 2008). The holotype (ZMB 1105) of this species is from Pará, Brazil, and was recently examined by one of us (FDT). The morphological characters of the holotype female fit with the re-description by Hoogstraal (1973). We retain this species as part of the Brazilian tick fauna.
	Ixodes Latreille	*Ixodes amarali* Fonseca, 1935 *Ixodes aragaoi* Fonseca, 1935 *Ixodes auritulus* Neumann, 1904 *Ixodes fuscipes* Koch, 1844 *Ixodes longiscutatus* Boero, 1944 *Ixodes loricatus* Neumann, 1899 *Ixodes luciae* Sénevet, 1940	Some larvae (*I. aragaoi*), nymphs (*I. amarali* and *I. aragaoi*) and males (*I. amarali*, *I. fuscipes*, *I. longiscutatus* and *I. schulzei*) of this genus are unknown. *Ixodes longiscutatus* was recently found (six larvae, 13 nymphs and one female) on rodents in southern Brazil (Michel et al., 2017). It belongs to the subgenus *Haemixodes*, as *Ixodes serrafreirei* Amorim et al., 2003 (*nomen nudum*), a species described from wild rodents in south-eastern

(*continued on next page*)

Table 1 (*continued*)

Family	Genus	Species	Observations
		Ixodes paranaensis Barros-Battesti et al., 2003	Brazil (Amorim et al., 2003). Further study may reveal that *I. serrafreirei* is a synonym of *I. longiscutatus* or even that it is a valid species lacking a valid description.
		Ixodes schulzei Aragão and Fonseca, 1951	
	Rhipicephalus Koch	*Rhipicephalus microplus* (Canestrini, 1888)	*Rhipicephalus sanguineus* sensu stricto, which has recently been redescribed by Nava et al. (2018), is present in southern Brazil. However, in most of the Brazilian territory, a different genetic lineage (the tropical lineage of the *R. sanguineus* group) is found on dogs (Moraes-Filho et al., 2011). Further research is needed to clarify the identity of this taxon.
		Rhipicephalus sanguineus (Latreille, 1806)	

Barros-Battesti et al., 2013; Durden and Beati, 2013). In particular, the key to families and genera of ticks of ticks occurring in Brazil were adapted from Durden and Beati (2013). Although *Otobius megnini* has previously been reported in Brazil, this tick is not considered to be established in this country (Dantas-Torres et al., 2009b). Therefore, the genus *Otobius* is not included.

Otherwise stated (see table footnotes), diagnostic characters for nymphs of the genus *Amblyomma* are essentially according to descriptions by Martins et al. (2010), with the addition of species whose nymphs were described afterwards (*Amblyomma cajennense*, *Amblyomma geayi*, *Amblyomma goeldii*, and *Amblyomma yucumense*). Diagnostic characters for these nymphs are provided according to Martins et al. (2013, 2015, 2016) and Krawczak et al. (2015). It is important to mention that the diagnostic features for the nymph of *A. cajennense* are those provided by Martins et al. (2016) and for the nymph of *Amblyomma sculptum* are those provided by Martins et al. (2010), reported as "*A. cajennense*" (see Martins et al., 2016). Keys to males and females of the genus *Amblyomma* were translated, modified and updated from Aragão and Fonseca (1961a), Guimarães et al. (2001), Onofrio et al. (2006), and Onofrio (2007). Diagnostic characters are provided according to these keys and several other sources (Robinson, 1926; Barros-Battesti et al., 2005, 2007; Estrada-Peña et al., 2005; Labruna et al., 2005a, 2005b, 2009; Onofrio, 2007; Onofrio et al., 2008, 2009; Nava et al., 2014a; Krawczak et al., 2015; Martins et al., 2016; Gianizella et al., 2018; Luz et al., 2018b). Type specimens of *Amblyomma dissimile* (syntype, ZMB 1058), *Amblyomma oblongoguttatum* (holotype, ZMB 1066), *A. rotundatum* (holotype, ZMB 1065), *Amblyomma tigrinum* (holotype, ZMB 1047), *Amblyomma triste* (holotype,ZMB 1046), and *Amblyomma varium* (holotype, ZMB 1055), which are deposited in the Arachnida and Myriapoda Collection of the Museum für Naturkunde, Berlin, Germany, were also recently examined by one of us (FDT). Major modifications in relation to previous keys were the exclusion of *Amblyomma albopictum*, *Amblyomma multipunctum*, and *Amblyomma scutatum*, and the inclusion of *A. sculptum*, *A. yucumense*, and *Amblyomma rotundatum* (in the key for males). Diagnostic characters for the newly included species are provided according to descriptions by Nava et al. (2014a), Krawczak et al. (2015), and Gianizella et al. (2018). For *Amblyomma pictum*, diagnostic characters are according to descriptions by Aragão (1912a) and Robinson (1926).

Otherwise stated, diagnostic characters for males and females of the genus *Ixodes* are essentially according to Onofrio et al. (2009), except for the female of *Ixodes longiscutatus*, whose diagnostic characters are provided according to Boero (1944). Diagnostic characters for males and females of the genus *Antricola* are those provided by Estrada-Peña et al. (2004). For argasid larvae, we elaborated a new key for all species found in Brazil, with the exception of *Ornithodoros rondoniensis*, whose larval stage remains unknown. For a correct use of this key, the specimen should be mounted on a slide, since direct observation precludes the detection of small setae and a detailed appreciation of the hypostome morphology. The method used for mounting argasid larvae using Hoyer's medium is explained elsewhere (Muñoz-Leal et al., 2018a). Diagnostic characters are provided according to original descriptions and/or re-descriptions (Kohls and Clifford, 1964; Kohls et al., 1965, 1969, 1970; Labruna and Venzal, 2009; Nava et al., 2010, 2013; Dantas-Torres et al., 2012b; Barros-Battesti et al., 2015; Labruna et al., 2016; Muñoz-Leal et al., 2017), except for the genus *Antricola* which are according to Jones and Clifford (1972).

2.3. Illustrations

General morphologic characters useful to separate larvae of different argasid species are schematized in Fig. 1. These drawings of a hypothetical *Ornithodoros* sp. larva were prepared by hand drawing slide-mounted specimens observed under an optical microscope. Pencil drawings were then digitalized with an Olympus DP70 digital camera (Olympus Optical, Tokyo, Japan) and manually redrawn into vector lines using Adobe Illustrator CS5 (Adobe Systems Inc., San Francisco, CA, USA).

Illustrations of *Amblyomma* spp. nymphs and *Ixodes* spp. males and females occurring in Brazil are available in the international literature (Onofrio et al., 2009; Martins et al., 2010, 2013, 2015, 2016; Krawczak et al., 2015). However, for *Amblyomma* spp. males and females, apart from individual papers dedicated to particular groups of species, the only comprehensive collection of images is the book *Carrapatos de importância médico-veterinária da Região Neotropical: um guia ilustrado para a identificação de espécies* (Barros-Battesti et al., 2006), which is no longer available, neither in print nor online. Therefore, we reproduced herein the images (Figs. 2–30) of this book with permission of editors and authors of the specific chapter where the images where originally published (Onofrio et al., 2006). We excluded the images of *A. albopictum*, *A. multipuctum*, and *A. scutatum*, considering that these species were excluded from the list of Brazilian ticks (Dantas-Torres et al., 2009b). The figures originally published as *A. cajennense* actually refer to *A. sculptum* (collected in Horto Florestal, São Paulo). Finally, we added a new close-up image to better illustrate the internal spur of coxa IV of the *Amblyomma brasiliense* female, which was unclear in the

Table 2
Key to families and genera of adult ticks found in the neotropical region[a].

1a. Capitulum ventral (in nymphs and adults) or terminal (in larvae). Palpal articles subequal in size, with article IV never recessed into article III. Scutum absent; pseudoscutum (*nothoaspis* or false scutum) present in nymphs and adults of *Nothoaspis*. Dorsal plate usually present in larvae (present in all species found in Brazil). Spiracular plates situated between coxae III and IV in nymphs and adults	**family Argasidae – 2**
1b. Capitulum terminal. Palpal article IV reduced and recessed in article III. Scutum present (podonotal in larvae, nymphs and females, and holonotal in males). Spiracular plates situated posterior to coxa IV in nymphs and adults	**family Ixodidae – 5**
2a. Sutural line present	**genus *Argas*[b]**
2b. Sutural line absent	**3**
3a. Pseudoscutum present	**genus *Nothoaspis*[c]**
3b. Pseudoscutum absent	**4**
4a. Integument tuberculated, sometimes with areas of smooth cuticle Hypostome broad at base and scoop-like	**genus *Antricola***
4b. Integument mammillated (except in *O. marinkellei*, in which it is smooth). Hypostome of various forms, but never scoop-like	**genus *Ornithodoros***
5a. Eyes absent	**6**
5b. Eyes present	**7**
6a. Festoons absent. Anal groove contouring the anus anteriorly	**genus *Ixodes***
6b. Festoons present. Anal groove contouring the anus posteriorly. Palps short, with article II at least as broad as long and extended laterally in most species	**genus *Haemaphysalis***
7a. Palps long, usually longer than basis capituli, with article II longer than broad. Scutum ornate (except in a few species)	**genus *Amblyomma***
7b. Palps short, about as long as basis capituli, with article II as long as broad. Scutum inornate	**8**
8a. Palps extremely short (shorter than hypostome), ridged dorsally and laterally. Anal groove indistinct and festoons absent	**genus *Rhipicephalus*, subgenus *Boophilus***
8b. Palps not extremely short (at least as long as hypostome), not ridged dorsally and laterally. Anal groove distinct and festoons present	**9**
9a. Seven festoons. Basis capituli rectangular dorsally. Spiracular plates subcircular with few large goblet cells	**genus *Dermacentor*, subgenus *Anocentor*[d]**
9b. Eleven festoons. Basis capituli hexagonal dorsally. Spiracular plates with dorsal prolongation and numerous goblet cells. Males with adanal and accessory plates	**genus *Rhipicephalus*, subgenus *Rhipicephalus***

[a] Diagnostic characters are provided according to Keirans (2009) and Durden and Beati (2013). Otherwise stated (see steps 1a and 1b), diagnostic characters are for adults.
[b] Genus represented in Brazil by *A. miniatus*, a parasite of fowl. For morphological details, see Barros-Battesti et al. (2013) and Muñoz-Leal et al. (2017).
[c] Genus represented in Brazil by *N. amazoniensis*, a parasite of bats. For morphological details, see Nava et al. (2010).
[d] Genus represented in Brazil by *D. nitens*, a parasite of equids.

original image published by Onofrio et al. (2006). The female used for this purpose is deposited in the collection "Coleção Acarológica" of the Butantan Institute, São Paulo, Brazil (accession number IBSP-9946).

3. Results

3.1. Updated list of Brazilian ticks

The updated list of tick species found in Brazil contains 70 species, being 47 in the family Ixodidae and 23 in the family Argasidae (Table 1). During the past decade, roughly one tick species was described/recorded in Brazil every year.

Among hard ticks, the genus *Amblyomma* remains as the most representative, with 32 species. We still consider *A. pictum* (considered as a synonym of *Amblyomma conspicuum* Aragão) as part of the Brazilian tick fauna, but it is noteworthy that this species has not been collected/identified in the country in the past 107 years (at that time, as *A. conspicuum*). The hard tick species recently described or recorded in Brazil are *A. sculptum* [resurrected in 2014; formerly regarded as a synonym of *A. cajennense*], *A. yucumense* (originally described in 2015), and *I. longiscutatus* (recently recorded for the first time in 2017).

Among soft ticks, the genus *Ornithodoros* is the most representative, with 18 species. Since 2009, six new argasid species were described (*Nothoaspis amazoniensis*, *Ornithodoros cavernicolous*, *Ornithodoros faccinii*, *Ornithodoros fonsecai*, *Ornithodoros rietcorreai*, and *Ornithodoros saraivai*), three were recorded for the first time (*Ornithodoros guaporensis*, *Ornithodoros kohlsi*, and *Ornithodoros peropteryx*) and one (*Ornithodoros rudis*) had its presence definitely confirmed in this country. We also confirmed the presence of *O. stageri* in Brazil by examining high-quality photographs of slide-mounted larvae collected in 1964 in Rondônia state, northern Brazil (RML-49606 and RML-49607). Noteworthy, three *Ornithodoros* spp. are excluded from the Brazilian tick fauna: *Ornithodoros jul*, *Ornithodoros nattereri*, and *Ornithodoros talaje*. *Ornithodoros jul* and *O. nattereri* have never been collected again after their original description and types are unavailable. Therefore, we consider both *O. jul* and *O. nattereri* to be *nomina nuda*. Finally, current evidence strongly indicates that *O. talaje* does not occur in Brazil (see Discussion). Thus, *O. talaje* is also excluded from Brazilian tick fauna.

3.2. Taxonomic keys for the identification of Brazilian ticks

Updated morphological keys for the identification of families, genera and species of ticks found in Brazil are provided in Tables 2–12 and Figs. 1–30. For genera currently represented in this country by only one species (*Argas*, *Dermacentor*, and *Nothoaspis*), the users of the keys are advised to refer to generic keys (Table 2; see table footnotes). *Argas miniatus* and *N. amazoniensis* are included in the key for larvae of argasid ticks found in the Brazilian territory (Table 12). We judged the inclusion of *N. amazoniensis* in this key particularly relevant, as this species has been found with other bat-associated larvae of the genera *Antricola* and *Ornithodoros* in Brazil.

Some of the keys provided herein are not fully complete, missing one or more species, as the specific developmental stage or sex (only males) may be unknown. For instance, *A. pictum* is not included in the key for nymphs of *Amblyomma*, as the nymph of this species is unknown. Similarly, males of several species of *Ixodes* (*Ixodes amarali*, *Ixodes fuscipes*, *I. longiscutatus*, and *Ixodes schulzei*) remain unknown.

Table 3
Key to nymphs of the genus *Amblyomma* found in Brazil[a].

1a. Coxa I with one spur. Ventral basis capituli with posteriorly directed projections[b]	**2**
1b. Coxa I with two spurs. Ventral basis capituli with lacking posteriorly directed projections	**3**
2a. Coxa I with a broad spur, whose insertion reaches the internal margin of the coxa. Scutum with posterolateral margins sinuous	***A. triste***
2b. Coxa I with a narrow spur, whose insertion does not reach the internal margin of the coxa. Scutum with posterolateral margins regular, not sinuous	***A. tigrinum***
3a. Coxa II with two spurs, the internal very small	**4**
3b. Coxa II with one spur	**5**
4a. Scutum with large, deep punctations uniformly distributed. Hypostome dentition 2/2	***A. humerale***
4b. Scutum with large, deep punctations concentrated in the lateral fields. Hypostome dentition 3/3 in the anterior half and 2/2 in the posterior half	***A. rotundatum***
5a. Cornua present	**6**
5b. Cornua absent	**12**
6a. Festoons with chitinous tubercles	**7**
6b. Festoons lacking chitinous tubercles	**9**
7a. Scutum length < 0.75 mm	***A. brasiliense***
7b. Scutum length > 0.75 mm	**8**
8a. Festoons with conspicuous, whitish chitinous tubercles. Scutum broader than long (breadth/length ratio > 1.3), with posterolateral margins sinuous	***A. incisum***
8b. Festoons with inconspicuous, brownish chitinous tubercles. Scutum slightly longer than broad (breadth/length ratio < 1.3), with posterolateral margins regular, not sinuous	***A. scalpturatum***
9a. Coxa I with internal spur shorter than the spur on coxa II. Coxa IV with a small triangular spur, as long as broad	**10**
9b. Coxa I with internal spur as long as the spur on coxa II. Coxa IV with a small triangular spur, longer than broad	**11**
10a. Dorsal basis capituli hexagonal. Cornua conspicuous	***A. naponense***
10b. Dorsal basis capituli sub-rectangular. Cornua inconspicuous. Idiosoma longilineous	***A. parvum***[c]
11a. Scutum length > 0.8 mm. Cornua conspicuous	***A. latepunctatum***
11b. Scutum length < 0.7 mm. Cornua inconspicuous	***A. oblongoguttatum***[c]
12a. Ventral basis capituli with small posterolateral rounded projections[d]	**13**
12b. Ventral basis capituli lacking small posterolateral rounded projections	**16**
13a. Coxa I with two medium spurs. Eyes located at the level of the posterior third of the scutum. Idiosoma longilineous. Hypostome with apex rounded	***A. ovale***
13b. Coxa I with two short spurs. Eyes located at the level of the scutum midlength	**14**
14a. Hypostome with apex pointed. Scutum extensively shagreened with few large, deep punctations in the lateral fields	***A. longirostre***
14b. Hypostome with apex rounded	**15**
15a. Scutum slightly shagreened, with many large, deep punctations uniformly distributed	***A. parkeri***
15b. Scutum extensively shagreened, with few large, deep punctations in the lateral fields	***A. geayi***
16a. Hypostome dentition 3/3 apically	**17**
16b. Hypostome dentition 2/2 all the way through	**19**
17a. Alloscutum densely pilose. Scutum densely punctate. Spiracular plates with margins slightly festooned. Hypostome dentition 3/3 all the way through	***A. romitii***
17b. Alloscutum not densely pilose. Spiracular plates lacking festooned margins. Hypostome dentition 3/3 apically and 2/2 in the remaining toothed portion	**18**
18a. Scutum with deep punctations concentrated in the lateral fields. Coxa I with two unequal spurs, the external longer than the internal	***A. dissimile***
18b. Scutum with deep punctations uniformly distributed. Coxa I with two subequal spurs	***A. goeldii***
19a. Coxa I with two short, subequal spurs. Dorsal basis capituli pentagonal. Palpal article IV projected apically	***A. fuscum***
19b. Coxa I with two unequal spurs, the external longer than the internal	**20**
20a. Scutum with deep punctations rarely present or, when present, concentrated in the lateral fields	**21**
20b. Scutum moderately punctate, with deep punctations uniformly distributed	**25**
21a. Basis capituli triangular or sub-triangular. Scutum extensively shagreened	**22**
21b. Basis capituli broadly rectangular. Scutum slightly shagreened	**24**
22a. Coxa I with two, stout, contiguous spurs. Idiosoma longilineous	***A. aureolatum***
22b. Coxa I with two, well-separated spurs, the external longer and pointed	**23**
23a. Scutum broader than long (breadth/length ratio > 1.3), with few medium punctations uniformly distributed	***A. nodosum***[e]
23b. Scutum slightly longer than broad (breadth/length ratio < 1.3), with medium-large punctations uniformly distributed, deeper in the lateral fields	***A. calcaratum***[e]
24a. Scutum broader than long (breadth/length ratio > 1.3), with cervical groove extending to near the posterior margin	***A. pseudoconcolor***
24b. Scutum slightly longer than broad (breadth/length ratio < 1.3), with cervical groove extending to the scutum midlength	***A. auricularium***
25a. Coxa I with two spurs, the external twice as long as the internal	**26**
25b. Coxa I with two spurs, the external spur longer than the internal, but not twice as long	**28**
26a. Basis capituli slightly hexagonal. Coxa I with external spur less than twice as long as the spur of coxa II	***A. varium***
26b. Basis capituli rectangular. Coxa I with external spur at least twice as long as the spur of coxa II	**27**
27a. Scutum broader than long (breadth/length ratio > 1.3)	***A. sculptum***[f]
27b. Scutum slightly longer than broad (breadth/length ratio < 1.3)	***A. cajennense***[f]
28a. Cervical groove short, ending as a small shallow, shagreened depression at the level of the posterior margin of the eyes. Scutum with large, deep punctations in both lateral and central fields	***A. coelebs***
28b. Cervical groove long, extended well beyond the posterior margin of the eyes. Scutum with large, deep punctations in the lateral fields and smaller punctations in the central field	**29**
29a. Scutum broader than long (breadth/length ratio > 1.3), with numerous large, deep punctations in the lateral fields, smaller punctations in the intercervical field. Cervical groove deep in its anterior convergent half, and as a shallow large depression on its posterior divergent half	***A. pacae***
29b. Scutum longer than broad (breadth/length ratio < 1.3). Cervical groove deep throughout, lacking a shallow, large depression in its posterior divergent half	**30**
30a. Cervical groove extending to the posterior margin of the scutum; cervical groove length/scutum length ratio 0.65 in average (range, 0.63–0.67 mm)	***A. dubitatum***
30b. Cervical groove extending to near the posterior margin of the scutum; cervical groove length/scutum length ratio 0.51 in average (range, 0.50–0.52 mm)	***A. yucumense***

[a] Diagnostic characters are provided according to the descriptions by Martins et al. (2010, 2013, 2015, 2016) and Krawczak et al. (2015). These references also provide illustrations for all *Amblyomma* nymphs found in Brazil, except *A. pictum* whose nymph is unknown.

[b] Martins et al. (2010) referred to these 'posteriorly directed projections' as 'auriculae'. Nava et al. (2017) defined them as 'ventral processes.

[c] Martins et al. (2010) described the cornua as "minute triangular".

[d] Martins et al. (2010) referred to these "posterolateral projections" as 'auriculae'. Nava et al. (2017) defined them as 'ventral cornua'.

[e] Nymphs of *A. nodosum* and *A. calcaratum* are very similar. Whenever possible, their morphological identification should be confirmed genetically.

[f] Nymphs of *A. sculptum* and *A. cajennense* are very similar. Whenever possible, their morphological identification should be confirmed genetically. Geographical distribution may also be considered when identifying these species (Martins et al., 2016).

Table 4
Key to females of the genus *Amblyomma* found in Brazil[a].

1a. Coxa IV with one spur	**2**
1b. Coxa IV with two conspicuous spurs (except in *A. brasiliense*, in which the internal spur is reduced to a vestigial ridge)	**22**
2a. Hypostome dentition 3/3 (except in *A. dubitatum* and *A. yucumense*, which may present dentition 4/4 in the posterior half)	**3**
2b. Hypostome dentition 4/4 all the way through	**26**
3a. Coxa I with two spurs, the external very long, the external vestigial	**4**
3b. Coxa I with two spurs, the internal not vestigial	**5**
4a. Festoons with chitinous tubercles. Scutum with central, inornate area reaching the posterior margin of the scutum	***A. triste*** (Fig. 29)
4b. Festoons lacking chitinous tubercles. Scutum with central, inornate area not reaching the posterior margin of the scutum	***A. tigrinum*** (Fig. 28)
5a. Trochanters with spurs. Palpal article I with a distinct retrograde, ventral spur	**6**
5b. Trochanters lacking spurs	**8**
6a. Alloscutum setose. Scutum inornate. Punctations numerous, moderately deep, uniformly distributed. Coxa I with two unequal spurs, the external much longer than the internal	***A. parvum*** (Fig. 22)
6b. Alloscutum glabrous. Scutum inornate or ornate	**7**
7a. Scutum inornate or faintly ornate. Coxa I with two short, subequal spurs, the external slightly longer than the internal	***A. auricularium*** (Fig. 3)
7b. Scutum with small pale spots in the lateral fields. Coxa I with two short, unequal spurs, the external much longer than the internal	***A. pseudoconcolor*** (Fig. 23)
8a. Hypostome with apex pointed. Coxa I with two short, unequal spurs, the external longer than the internal	***A. longirostre*** (Fig. 15)
8b. Hypostome with apex rounded	**9**
9a. Coxa I with two spurs, longer than the coxa length	**10**
9b. Coxa I with two spurs, shorter than the coxa length	**11**
10a. Coxa I with external spur slightly longer than the internal spur and with a pointed tip, slightly curved outward. Scutum with a central patch extending from the anterior portion to the posterior margin, where it is more pronounced	***A. ovale*** (Fig. 19)
10b. Coxa I with external spur slightly longer than the internal spur, but lacking a pointed tip, slightly curved outward. Ornamentation extensive, covering most of the scutum, predominantly yellowish in colour	***A. aureolatum*** (Fig. 2)
11a. Festoons with chitinous tubercles	**12**
11b. Festoons lacking chitinous tubercles	**14**
12a. Alloscutum glabrous. Scutum with large punctations concentrated in the intercervical and cervical fields, and small punctations in the posterior field. Ornamentation extensive, covering most of the scutum. Coxa I with two unequal spurs, the external long and pointed, the internal short and distinctly broad	***A. naponense*** (Fig. 16)
12b. Alloscutum setose. Scutum with small punctations, uniformly distributed. Coxa I with two unequal spurs, the external long and pointed, the internal short	**13**
13a. Genital aperture V-shaped	***A. cajennense***
13b. Genital aperture U-shaped	***A. sculptum*** (Fig. 27)
14a. Palpal article II with an oblique ridge in dorsal aspect	**15**
14b. Palpal article II lacking an oblique ridge in dorsal aspect	**16**
15a. Scutum with symmetrically disposed, Y-shaped pale spots in the anterolateral fields and an irregular spot in the posterior field. Palpal article II twice as longer as article III	***A. nodosum*** (Fig. 17)
15b. Scutum with an irregular pale spot in the posterior field. Palpal article II three times as longer as article III	***A. calcaratum*** (Fig. 5)
16a. Ornamentation with pale spots on the cervical and posterolateral fields, separated by a dark-brown central stripe ending at the posterior margin of scutum	**17**
16b. Ornamentation variable, lacking a dark-brown central stripe ending at the posterior margin of scutum	**18**
17a. Coxa I with two short spurs, the internal not extended well beyond the posterior margin of the coxa. Coxae II–III with shallow ridges, which may be inconspicuous. Punctations large and deep, uniformly distributed. Capitulum and ventral idiosoma yellowish or light brown colored	***A. dubitatum*** (Fig. 8)
17b. Coxa I with two moderately long spurs, the internal extended well beyond the posterior margin of the coxa. Coxae II–III with conspicuous, salient ridges. Punctations large and deep, concentrated in the lateral fields. Capitulum and ventral idiosoma dark brown colored	***A. yucumense***
18a. Coxa I with two, very short spurs, the external corresponding to much less than half the coxa length	**19**
18b. Coxa I with two medium spurs, the external about as long as half the coxa length	**20**
19a. Scutum with an irregular, pale yellow V-shaped spot at the posterior margin. Few large punctations in the lateral fields and numerous medium-sized punctations uniformly distributed on the scutum. Hypostome sub-acute (sub-lanceolate)	***A. geayi*** (Fig. 10)
19b. Scutum with pale-yellowish stripes on the central area extending to the posterior margin. Numerous medium-sized punctations uniformly distributed on the scutum. Hypostome apically rounded	***A. parkeri*** (Fig. 21)
20a. Coxa I with two subequal spurs, the external slightly longer than the internal. Ornamentation extensive, covering most of the scutum. Punctations numerous, uniformly distributed	***A. coelebs*** (Fig. 6)
20b. Coxa I with two unequal spurs, the external distinctly longer than the internal. Ornamentation varied, but not covering most of the scutum	**21**
21a. Scutum faintly ornate, with two small, symmetrically disposed, pale spots in the posterior margin. External spur on coxa I with the tip curved outward	***A. pacae*** (Fig. 20)
21b. Scutum with two longitudinal stripes in the lateral fields and a triangular spot in the posterior margin. External spur on coxa I with the tip not curved outward	***A. oblongoguttatum*** (Fig. 18)
22a. Hypostome dentition 3/3	**23**
22b. Hypostome dentition 4/4 (except in *A. romitii*, in which the dentition may vary)	**24**
23a. Scutum triangular, with a large, pale spot, extending from the posterior margin to the midline of the scutum. Coxa I with two short pointed spurs, which are separated from each other by a space larger than the width of the external spur	***A. dissimile*** (Fig. 7)
23b. Scutum cordiform, with a small, pale spot, not extending to the midline of the scutum. Coxa I with two short rounded spurs, separated from each other by a space shorter than the width of the external spur	***A. rotundatum*** (Fig. 25)
24a. Festoons with chitinous tubercles. Ornamentation extensive, covering most of the scutum. Coxa I with two unequal spurs, the external narrower and longer than the internal	***A. brasiliense*** (Fig. 4)
24b. Festoons lacking chitinous tubercles	**25**
25a. Alloscutum setose. Spiracular plates with festooned margins. Scutum with a large, pale spot, extending centrally from the posterior margin up to the intercervical field, and with irregular, less evident pale spots in the lateral fields	***A. romitii*** (Fig. 24)
25b. Alloscutum glabrous. Spiracular plates lacking festooned margins. Scutum with two bright, symmetrically disposed stripes in the scapular fields	***A. humerale*** (Fig. 12)
26a. Festoons with chitinous tubercles	**27**
26b. Festoons lacking chitinous tubercles	**29**
27a. Scutum lacking elevated lateral margins, with relatively larger punctations restricted to the cervical fields. Ornamentation extensive, covering most of the scutum. Coxa I with two long, broad, subequal spurs, the external narrower than the internal	***A. incisum*** (Fig. 13)
27b. Scutum elevated lateral margins, with large punctations, uniformly distributed	**28**
	A. latepunctatum (Fig. 14)

(*continued on next page*)

Table 4 (*continued*)

28a. Genital aperture V-shaped. Coxa I with two long, broad, subequal spurs, the external slightly narrower and longer than the internal. Scutum with slightly elevated margins. Ornamentation consisting of a large spot extending centrally from the posterior margin up to the intercervical field	
28b. Genital aperture U-shaped. Coxa I with two long, broad, unequal spurs, the external narrower and longer than the internal. Scutum with distinctly elevated margins. Ornamentation consisting of a small yellow spot in posterior field and additional pale markings, less pronounced, extending centrally and laterally	***A. scalpturatum*** (Fig. 26)
29a. Scutum inornate. Punctations large, numerous, uniformly distributed	***A. goeldii*** (Fig. 11)
29b. Scutum ornate	**30**
30a. Anterior margin of coxa I with a conspicuous tubercle. Scutum faintly ornate, with few large, punctations, irregularly distributed	***A. fuscum*** (Fig. 9)
30b. Anterior margin of coxa I lacking a conspicuous tubercle	**31**
31a. Scutum with irregular, coppery and greenish spots, in the posterior and lateral fields. Punctations large in the anterior half of the scutum and smaller in the posterior half. Coxa I with two broad, subequal spurs, the external slightly longer than the internal. Legs dark-brown, with rings of pale enamelling. Hypostome dentition 4/4	***A. varium*** (Fig. 30)[b]
31b. Ornamentation extensive, pale-yellow, covering most of the scutum. Punctations large in the lateral fields. Coxa I with two broad spurs, equal in size. Hypostome dentition 4/4	***A. pictum***[c]

[a] Diagnostic characters are provided according to the descriptions by Robinson (1926), Guimarães et al. (2001), Barros-Battesti et al. (2005, 2007), Estrada-Peña et al. (2005), Labruna et al. (2005a, 2009), Onofrio (2007), Onofrio et al. (2006,2008, 2009), Nava et al. (2014a), Krawczak et al. (2015), Martins et al. (2016) and Luz et al. (2018b).

[b] In their re-description, Onofrio et al. (2008) indicated hypostome dentition 4/4 and we agree. As a note, on page 207 of his monograph, Robinson (1926) added the following *corrigendum*: 'Page 207, line 4 from bottom, *in place of* "dentition 3/3" *read* "dentition 3/3–4/4."'.

[c] In his description of *A. pictum*, Neumann (1906) indicated 4/4, whereas in his description of *A. conspicuum*, Aragão (1912a) indicated 3/3, as noticed by Robinson (1926). These species are currently regarded as synonyms (Guglielmone et al., 2014). Some years ago, one of us (VCO) examined a female type (BMNH, 1905.5.21.7) of *A. pictum* at the British Museum of Natural History and confirmed that the hypostome dentition is 4/4 (Onofrio, 2007).

4. Discussion

In the present article, we provide an updated list of tick species occurring in Brazil and taxonomic keys for their identification. It is important to emphasize that these keys do not include complete morphological descriptions for each single species. Therefore, these keys should be used as a guide and, whenever possible, users should double check the preliminary identification using original descriptions and/or re-descriptions: *Amblyomma* (Aragão, 1908a, 1908b, 1908c, 1911; Robinson, 1926; Fonseca and Aragão, 1952; Barros-Battesti et al., 2005, 2007; Estrada-Peña et al., 2005; Labruna et al., 2005a, 2005b, 2009; Onofrio, 2007; Onofrio et al., 2008, 2009; Martins et al., 2010, 2013, 2015, 2016; Nava et al., 2014a; Krawczak et al., 2015), *Dermacentor* (Arthur, 1960), *Haemaphysalis* (Cooley, 1946), *Ixodes* (Dantas-Torres et al., 2009a; Onofrio et al., 2009, 2014), *Rhipicephalus* (Walker et al., 2000), *Antricola* (Estrada-Peña et al., 2004), *Argas* (Kohls et al., 1970), *Nothoaspis* (Nava et al., 2010), and *Ornithodoros* (Kohls et al., 1965, 1969; Labruna et al., 2008; Labruna and Venzal, 2009; Barros-Battesti et al., 2012, 2013, 2015; Dantas-Torres et al., 2012b; Nava et al., 2013; Martins et al., 2014; Labruna et al., 2016; Muñoz-Leal et al., 2017, 2018b).

Amblyomma is the third most speciose genus in the family Ixodidae (Guglielmone et al., 2014), currently represented by 139 species (Dantas-Torres, 2018); 137 if one considers the new monospecific genera *Robertsicus* and *Archaeocroton*, recently proposed for *Amblyomma elaphense* and *Amblyomma sphenodonti*, respectively (Barker and Burger, 2018). Of these, approximately 66 are found in the neotropical region (Guglielmone et al., 2014; Nava et al., 2014a, 2014b, 2017; Krawczak et al., 2015). In Brazil, this genus is currently represented by 32 species (Table 1) (Dantas-Torres et al., 2009b; Martins et al., 2010; Nava et al., 2014a; Krawczak et al., 2015). Herein we provided updated keys for the identification of nymphs, males and females (Tables 2–4). The nymph of *A. pictum* remains unknown (Guglielmone et al., 2003; Barros-Battesti et al., 2006), thus not included in the present key. We tentatively retain *A. pictum* in the Brazilian list, pending comparison with the type of *A. conspicuum*. As discussed elsewhere (Dantas-Torres et al., 2009b), the only report of this species in this country was published over a century ago (Aragão, 1912a).

As far as larvae of *Amblyomma* spp. found in Brazil, the only key available was published 20 years ago and included a limited number of species (Amorim and Serra-Freire, 1999a). Indeed, even if the larval stage of several *Amblyomma* spp. occurring in Brazil have been described in the past decades (Barbieri et al., 2013), the larvae of many species are still unknown. Moreover, the chaetotaxy (arrangement of setae in different parts of the body) and porotaxy (arrangement lyrifissures, small glands, and large wax glands) are very conserved among different species. This complicates the elaboration of dichotomous taxonomic keys for larvae of this genus. Until a reliable morphological key for *Amblyomma* spp. larvae found in Brazil is elaborated, their definitive identification should be based on genetic analyses.

Considering our incipient knowledge on nymphs and adults of *Ornithodoros* spp. found in Brazil, it would seem premature to propose taxonomic keys for their identification. Indeed, nymphal stages and adults of different *Ornithodoros* spp. found in this country are still unknown (see Table 1). Moreover, nymphs and adults of *Ornithodoros* spp. may be difficult to distinguish morphologically. Some exceptions are *O. cavernicolous*, *Ornithodoros marinkellei*, and *O. rondoniensis*, which have unique features that allow their separation at the adult stage (Labruna et al., 2008, 2011; Dantas-Torres et al., 2012b). In the same way, adults of *Ornithodoros brasiliensis* and *Ornithodoros rostratus* may be differentiated based on features of the tarsi I and IV, as illustrated elsewhere (Aragão, 1931; Barros-Battesti et al., 2012). In any case, we have provided herein a key for the identification of larvae of argasid ticks found in the Brazilian territory, including the genus *Antricola*, *A. miniatus*, *N. amazoniensis* and 17 *Ornithodoros* spp. (Table 12). A previous key for

Table 5
Key to males of the genus *Amblyomma* found in Brazil[a].

1a. Marginal groove complete	**2**
1b. Marginal groove incomplete or absent	**14**
2a. Coxa I with two long, pointed, subequal spurs, the internal slightly shorter than the external, which presents a sharply pointed tip, slightly curved outward	***A. ovale*** (Fig. 19)
2b. Coxa I with two spurs of variable length and form, but with external spur lacking a sharply pointed tip, slightly curved outward	**3**
3a. Tibiae II–IV with a spine	**4**
3b. Tibiae II–IV lacking a spine	**5**
4a. Spiracular plates comma-shaped. Festoons lacking chitinous tubercles	***A. tigrinum*** (Fig. 28)
4b. Spiracular plates oval. Festoons with chitinous tubercles	***A. triste*** (Fig. 29)
5a. Ventral plates present	**6**
5b. Ventral plates absent	**7**
6a. Marginal groove with a distinct obtuse angle at the level of spiracular plates, giving the scutum a diamond-like appearance. Length from apices of scapulae to posterior margin of idiosoma > 5.5 mm	***A. geayi*** (Fig. 10)
6b. Marginal groove displaying a rounded angle at the level of spiracular plates, giving the scutum an oval shape. Length from apices of scapulae to posterior margin of idiosoma < 4.5 mm	***A. parkeri*** (Fig. 21)
7a. Trochanters with spurs. Palpal article I with a retrograde, ventral spur	**8**
7b. Trochanters lacking spurs	**10**
8a. Cornua long. Scutum inornate. Coxa I with two unequal spurs, the external longer than the internal	***A. parvum*** (Fig. 22)
8b. Cornua short or indistinct	**9**
9a. Scutum with small, symmetrically disposed pale spots, at the posterior margin, in front of and adjacent to the first festoons. Idiosoma contour broadly oval, widest just posterior to midlength	***A. pseudoconcolor*** (Fig. 23)
9b. Scutum inornate or faintly ornate, with small, symmetrically disposed pale spots at the posterior margin. Idiosoma slightly enlarged posteriorly	***A. auricularium*** (Fig. 3)[b]
10a. Coxa I with two unequal spurs, the external much longer than the internal. Festoons lacking sclerotised ventral plates	***A. cajennense* s.l.** (Fig. 27)[c]
10b. Coxa I with two subequal spurs. Festoons with sclerotised ventral plates	**11**
11a. Coxa I with two narrow, pointed spurs. Coxa IV with a long, narrow spur. Punctations small, more numerous on the ornate areas	***A. oblongoguttatum*** (Fig. 18)
11b. Coxa I with two stout spurs. Coxa IV a moderately long, stout spur	**12**
12a. Scutum with pale stripes in the scapular areas, converging posteriorly to delineate the outline of a pseudoscutum. Punctations numerous, uniformly distributed	***A. coelebs*** (Fig. 6)
12b. Scutum distinctly ornate, with numerous, large, deep punctations uniformly distributed, interposed by dark brown elevated spots lacking punctations	**13**
13a. Coxa I with two separated spurs. Scutum with longitudinal stripes starting at the cervical area, diverging posteriorly at the level of first festoons	***A. dubitatum*** (Fig. 8)
13b. Coxa I with two contiguous spurs. Scutum with major longitudinal stripes starting at the cervical area, diverging posteriorly at the level of first festoons. Presence of a median pale stripe delineating the outline of a pseudoscutum	***A. yucumense***[d]
14a. Marginal groove incomplete	**15**
14b. Marginal groove absent	**20**
15a. Coxa IV with a long, pointed spur and a small internal tubercle. Festoons with sclerotised ventral plates	***A. brasiliense*** (Fig. 4)
15b. Coxa IV with one spur	**16**
16a. Ventral plates present. Coxa I with two short, unequal spurs, the external longer than the internal	***A. longirostre*** (Fig. 15)
16b. Ventral plates absent. Coxa I with two long spurs	**17**
17a. Coxa I with two very long, subequal spurs. Ornamentation extensive, covering most of the scutum. Punctuations numerous, uniformly distributed	***A. aureolatum*** (Fig. 2)
17b. Coxa I with two long, stout spurs, the internal distinctly broader than the external	**18**
18a. Small accessory spur on the anterior margin of coxa I inconspicuous. Festoons with sclerotised ventral plates invariably incised	***A. incisum*** (Fig. 13)
18b. Small accessory spur on the anterior margin of coxa I conspicuous. Festoons with sclerotised ventral plates not invariably incised	**19**
19a. Scutum densely punctate, with large, deep punctations, uniformly distributed. Coxa I with two long spurs, both reaching the succeeding coxa. Festoons with sclerotised ventral plates normally not incised, but some specimens may present some incised sclerotised ventral plates	***A. latepunctatum*** (Fig. 14)
19b. Scutum densely punctate, with large, deep punctations uniformly distributed, interposed by dark brown stripes or spots lacking punctations. Coxa I with two moderately long spurs, normally not reaching the succeeding coxa. Festoons with sclerotised ventral plates not incised	***A. scalpturatum*** (Fig. 26)
20a. Hypostome dentition 3/3	**21**
20b. Hypostome dentition 4/4 (except in *A. romitii*, in which the dentition may vary)	**28**
21a. Coxa IV with two unequal spurs	**22**
21b. Coxa IV with one spur	**23**
22a. Coxa IV with a medium-sized, pointed external spur. Scutum with whitish, copper-coloured ornamentation, covering most of its surface, with posterior branches of limiting spots fused posteriorly, sometimes delineating the outline of a pseudoscutum. Punctations large, numerous, uniformly distributed, interspaced by fine punctations	***A. dissimile*** (Fig. 7)
22b. Coxa IV with a short, rounded external spur. Scutum with pale-orange patches in lateral fields. Punctuations numerous, more densely distributed in anterolateral fields	***A. rotundatum*** (Fig. 25)
23a. Coxa I with internal spur usually shorter than half length of coxa	**24**
23b. Coxa I with internal spur as long as or longer than half length of coxa	**26**
24a. Festoons with tubercles. Ornamentation extensive, covering most of the scutum. Coxa I with two unequal spurs, the external long and narrow, the internal short	***A. naponense*** (Fig. 16)
24b. Festoons lacking tubercles	**25**
25a. Large tick (> 5 mm in length). Scutum distinctly ornate. Coxa I with two subequal spurs, being the external not curved outward. Legs dark-brown, with rings of pale enamelling	***A. varium*** (Fig. 30)
25b. Small tick (< 5 mm in length). Scutum faintly ornate, with limiting spots converging posteriorly toward the median line to delineate the outline of a pseudoscutum. Coxa I with two unequal spurs, the external longer than the internal and with the tip curved outward	***A. pacae*** (Fig. 20)
26a. Palps elongated. Scutum with symmetrically disposed, Y-shaped pale spots in the anterolateral fields and other less pronounced, irregular spots. Coxa I with two moderately long, subequal spurs. Coxa IV with a long spur	***A. calcaratum*** (Fig. 5)
26b. Palps short, nodose. Scutum with two, symmetrically disposed, J-shaped pale spots in the anterolateral fields and other less pronounced, irregular spots. Coxa I with two long, subequal spurs. Coxa IV with a short spur	***A. nodosum*** (Fig. 17)
27a. Coxa IV with one spur	**28**
27b. Coxa IV with two spurs	**30**
28a. Scutum inornate. Punctations medium-large, numerous, uniformly distributed. Coxa I with two stout, subequal spurs	***A. goeldii*** (Fig. 11)

(*continued on next page*)

Table 5 (*continued*)

28b. Scutum ornate	**29**
29a. Coxa I with two short, stout, subequal spurs, the external slightly longer than the internal. Anterior margin of coxa I with a large tubercle. Punctations large, deep, few in number, and situated mainly in the lateral margins, including cervical fields	***A. fuscum*** (Fig. 9)
29b. Coxa I with two short, stout, subequal spurs, and lacking a tubercle in the anterior margin. Punctations small, uniformly distributed	***A. pictum***[c]
30a. Spiracular plates with festooned margins. Coxa IV with two unequal spurs, the external much longer than the internal	***A. romitii*** (Fig. 24)
30b. Spiracular plates lacking festooned margins. Coxa IV with two short, subequal spurs. Scutum with two, symmetrically disposed, spots in the scapular areas	***A. humerale*** (Fig. 12)

[a] Diagnostic characters are provided according to the descriptions by Robinson (1926), Guimarães et al. (2001), Barros-Battesti et al. (2005, 2007), Estrada-Peña et al. (2005), Labruna et al. (2005a, 2005b, 2009), Onofrio (2007), Onofrio et al. (2006, 2008, 2009)Onofrio et al., 2006Onofrio et al., 2006Onofrio et al. (2006, 2008, 2009)Onofrio et al., 2006Onofrio et al., 2006Onofrio et al. (2006, 2008, 2009)Onofrio et al., 2006Onofrio et al., 2006Onofrio et al. (2006, 2008, 2009)Onofrio et al., 2006Onofrio et al. (2006, 2008, 2009)Onofrio et al., 2006Onofrio et al. (2006, 2008, 2009), Nava et al. (2014a), Krawczak et al. (2015) and Gianizella et al. (2018).

[b] *A. auricularium* males from Brazil may present symmetrically disposed pale spots on scutum, as in *A. pseudoconcolor*.

[c] Males of *A. cajennense* and *A. sculptum* cannot be distinguished morphologically (Nava et al., 2014a; Martins et al., 2016), only genetically.

Table 6
Keys to adults of the genus *Haemaphysalis* found in Brazil[a].

1a. Hypostome dentition 3/3. Palpal article III with a short, ventral spur, posteriorly directed. Ventral basis capituli with pointed spurs at the posterolateral angles	***H. leporispalustris***
1b. Hypostome dentition 4/4 or 6/6	**2**
2a. Hypostome dentition 6/6. Palpal article III with a ventral spur, inconspicuous, medially directed	***H. cinnabarina***[b]
2b. Hypostome dentition 4/4. Palpal article III with a ventral spur, conspicuous, posteriorly directed	***H. juxtakochi***

[a] Diagnostic characters are provided according to the descriptions by Nuttall and Warburton (1915) and Hoogstraal (1973).

[b] This rare species has been reported in Brazil over 100 years ago (see comments on Table 1).

Table 7
Keys to females of the genus *Ixodes* found in Brazil[a].

1a. Trochanters I-IV with spurs	**2**
1b. Trochanters I-IV lacking spurs	**3**
2a. Auriculae long, horn-like. Palpal article I with a long internal projection extending to the mid-length of the hypostome. Hypostome dentition 2/2 at the base, 4/4 in the middle and 5/5 near the corona. Cornua pointed, well developed	***I. auritulus***
2b. Auriculae short. Palpal article I with a short internal projection not reaching the mid-length of the hypostome. Cornua blunt	***I. paranaensis***
3a. Scutum twice as long as broad	***I. longiscutatus***
3b. Scutum longer than broad, but not twice as long as broad	**4**
4a. Coxa I with two spurs, the internal sharply pointed and much longer than the external	**5**
4b. Coxa I with two spurs, the internal similar in length or shorter than the external	**6**
5a. Palpal article I with a retrograde, ventral spur. Auriculae long, horn-like	***I. fuscipes***
5b. Palpal article I without a retrograde, ventral spur. Auriculae indicated by slight rounded lateral ridges	***I. aragaoi***[b]
6a. Coxa I with two spurs, the external sharply pointed and much longer than the internal	***I. luciae***
6b. Coxa I with two subequal spurs	**7**
7a. Palps and hypostome short and broad	***I. loricatus***
7b. Palps and hypostome long and narrow	**8**
8a. Porose areas oval, close together. Auriculae pointed, extended laterally. Hypostome arising at level of distal third of palpal article II	***I. schulzei***
8b. Porose areas rounded, far apart. Auriculae rounded. Hypostome arising at level of proximal third of palpal article II	***I. amarali***

[a] Diagnostic characters are provided according to the descriptions by Onofrio et al. (2009), except for *I. longiscutatus* which are according to Boero (1944).

[b] Auriculae described as “short and blunt” in Onofrio et al. (2009) and as “short and slightly pointed” in Onofrio et al. (2014). However, auriculae of *I. aragaoi* females are indicated by slight rounded lateral ridges, as described for *I. pararicinus* (Keirans et al., 1985).

Table 8
Key to males of the genus *Ixodes* found in Brazil[a]. Males of *I. amarali*, *I. fuscipes*, *I. longiscutatus*, and *I. schulzei* are unknown.

1a. Jugular plates present. Palpal articles II and III fused	**2**
1b. Jugular plates absent. Palpal articles II and III not fused	**3**
2a. Jugular plates distinct. Coxa IV with a short internal spur	***I. paranaensis***
2b. Jugular plates indistinct. Coxa IV lacking an internal spur	***I. auritulus***
3a. Coxa I with external spur pointed, at least twice as long as the internal spur	***I. luciae***
3b. Coxa I with external spur shorter or as long as the internal spur	**4**
4a. Coxa I with internal spur, very long, sharply pointed. Ventral basis capituli with three posterior triangular lobes, one median and two lateral. Hypostome crenulate	***I. aragaoi***
4b. Coxa I with internal spur short. Ventral basis capituli lacking three triangular lobes. Hypostome denticulate	***I. loricatus***

[a] Diagnostic characters are provided according to the descriptions by Onofrio et al. (2009).

Table 9
Key to adults of the genus *Rhipicephalus* found in Brazil[a].

1a. Hypostome dentition 3/3. Scutum not densely pilose. Anal groove distinct. Spiracular plates with dorsal prolongation. Genital aperture U-shaped in females. Caudal appendage absent in males	***R. sanguineus* s.l.**[b]
1b. Hypostome dentition 4/4. Scutum densely pilose. Anal groove indistinct. Spiracular plates rounded. Genital aperture not U-shaped in females. Caudal appendage present in males	***R. microplus***

[a] Diagnostic characters are provided according to the descriptions by Walker et al. (2000).
[b] These diagnostic characters encompass ticks belonging to both temperate (= *R. sanguineus* sensu stricto) and tropical lineages (for more details, see Nava et al., 2018). Until a proper morphological definition of the tropical lineage in Brazil is available, *R. sanguineus* s.l. ticks should be characterized genetically, for an unequivocal identification.

Table 10
Key to females of the genus *Antricola* found in Brazil[a].

1a. Spiracular plates large (always greater than 400 μm in diameter), generally visible from above. Dorsum mostly without tubercles or reticulations. Several tufts of 15 or more setae present in the lateral portions of the idiosoma, close to the spiracular plates	***A. delacruzi***
1b. Spiracular plates small (always less than 300 μm in diameter), generally not visible from above	**2**
2a. Several tufts of setae, not well delimited, and never on cuticular thickenings. Dorsal tubercles close to each other, without areas of smooth cuticle. Zone between coxal insertion and genital shield smooth, with a few posterior striations, never with tubercles	***A. guglielmonei***
2b. Three to four tufts of setae near spiracular plates, well delimited in the lateral portion of the idiosoma, located over rounded cuticular thickenings. Dorsal tubercles separated by areas of smooth cuticle. Zone between coxal insertion and genital shield with small tubercles	***A. inexpectata***[b]

[a] Diagnostic characters are provided according to the descriptions by Estrada-Peña et al. (2004).
[b] This species is known from three females only, resembling those of *A. guglielmonei* (Estrada-Peña et al., 2004). Further research may reveal that they are conspecific (see Table 1).

Table 11
Key to males of the genus *Antricola* found in Brazil[a]. The male of *A. inexpectata* is unknown.

1a. Spiracular plate large (always greater than 250 μm in diameter). Dorsum of idiosoma without tubercles or reticulate pattern. Some small areas displaying a reticulate pattern may be visible in the posterolateral portions of the idiosoma, but the whole dorsum is mostly smooth	***A. delacruzi***
1b. Spiracular plate small (always less than 200 μm in diameter). Dorsum of idiosoma with large tubercles partially fused into larger plates in the anterolateral regions, but also with conspicuous individual tubercles	***A. guglielmonei***

[a] Diagnostic characters are provided according to the descriptions by Estrada-Peña et al. (2004).

larvae of argasid ticks included 13 *Ornithodoros* spp. (Barros-Battesti et al., 2013).

As indicated elsewhere (Venzal et al., 2008; Labruna et al., 2014, 2016; Alcantara et al., 2018), records of *O. talaje* from Brazil may actually correspond to misidentifications with other species, which are morphologically similar. Adults of the *O. talaje* group share very similar phenotypes, whereas morphological characters of larvae have successfully used for species delimitation (Venzal et al., 2008). As such, we exclude *O. talaje* from the Brazilian fauna of ticks, since all reports of this species in this country were based on post-larval stages, and thus inconclusive. Noteworthy, this tick was originally described upon material collected in Guatemala, and its presence in South America is currently questioned (Venzal et al., 2008).

The types of *O. jul* are lost (Barros-Battesti et al., 2013) and the sole material that explains its identity correspond to its original description (Schulze, 1940). Notably, the type specimens of *O. jul* were collected inside a bat-inhabited wasp nest and are extremely similar to *Ornithodoros mimon*, also a bat-associated tick. As a thorough comparison between these species is now impossible to perform, solving this taxonomic gap would require new collections of *O. jul* at its type locality (Nova Teutonia, Seara municipality, Santa Catarina state) (Schulze, 1940). As for *O. jul*, the types of *O. nattereri* do not exist in its depository (Vienna Museum, label 86). In this case, the situation is even worse since Warburton (1927) did not specify the type locality in Brazil, so the provenance of the type specimens is impossible to track. Although it has been suggested that *O. nattereri* may actually correspond to *O. rostratus* (Camicas et al., 1998; Guglielmone et al., 2009, 2010; Barros-Battesti et al., 2013), their comparison is now unfeasible. Under these circumstances, we consider both *O. jul* and *O. nattereri* to be *nomina nuda*.

Noteworthy, larvae of two unidentified *Ornithodoros* spp. have been recently reported in Brazil, one on snakes in the Ceará state (Alcantara et al., 2018) and the other on marsupials at Bahia state (Maia et al., 2018). These *Ornithodoros* spp. are considered as two potential new species yet to be formally described and were therefore excluded from our list and taxonomic key. Remarkably, the presence of *Ornithodoros clarki* (referred to as *Ornithodoros* cf. *clarki*) has been tentatively reported for Brazil after the examination of one damaged larva collected from bats inside a hot cave in Pernambuco state (Muñoz-Leal et al., 2018a). However, as noted by these authors, *O. clarki* has never been documented in Brazil and until well-preserved specimens are collected, the diagnosis of this species should remain as tentative.

The morphological identification of some tick species occurring in Brazil may be difficult at one or more developmental stage, especially when dealing with bad preserved, damaged and/or fully engorged specimens. In many instances, a thorough morphological analysis complemented with genetic identification is indispensable. Based on this approach, Muñoz-Leal et al. (2018d) have provided evidence pointing that *Argas persicus*, a species recorded but of doubtful occurrence in Brazil (Dantas-Torres et al., 2009b), is not present in this country. Furthermore, genetic analyses should be used to separate males of *A. cajennense* and *A. sculptum* since they are morphologically indistinguishable and, in some areas, may occur in sympatry (Nava et al., 2014a; Martins et al., 2016). A list of reference DNA sequences for ticks occurring in the southern cone of South America, many of

Table 12
Key to larvae of argasids found in Brazil[a].

1a. Venter with 14 setae (3 pairs of sternal, 3 pairs circumanal and 1 pair anal setae); posteromedian seta absent; dorsum with 25–30 pairs of setae (14 dorsolateral and 11–17 central); dorsal plate circular; palpal article IV longer than other articles; hypostome blunt	***Argas miniatus***
1b. Venter with 15 or more setae; posteromedian seta present or absent; postcoxal pair present or absent; dorsum with 14–29 pairs of setae; dorsal plate never circular; hypostome of various forms	**2**
2a. Three pairs of postcoxal setae; 3–4 circumanal pairs; posteromedian seta present; pulvilli greatly enlarged; dorsal plate pyriform with longitudinal striations	**genus *Antricola*[b]**
2b. One pair of postcoxal setae absent or present	**3**
3a. Five pairs of circumanal setae; posteromedian seta absent; dorsal plate forming an elongated isosceles triangle, with concave posterior margin	***Nothoaspis amazoniensis***
3b. Three pairs of circumanal setae; posteromedian seta present; dorsal plate of various forms	**genus *Ornithodoros* – 4**
4a. Postcoxal setae absent; hypostome rounded	***O. rudis*[c]**
4b. Postcoxal setae present; hypostome of various forms	**5**
5a. Seven pairs of sternal setae; hypostome pointed	***O. saraivai*[d]**
5b. Three pairs of sternal setae; hypostome of various forms	**6**
6a. Hypostome with 2 files of denticles, apically notched	**7**
6b. Hypostome with 2 or more files of denticles, not notched apically	**8**
7a. Posthypostomal seta Ph1 almost two times longer than Ph2, tarsus I wrinkled, exceeding 0.250 mm of length	***O. brasiliensis***
7b. Posthypostomal seta Ph1 almost the same length than Ph2, tarsus I smooth, not exceeding 0.230 mm of length	***O. rostratus***
8a. Dorsal plate triangular in shape	**9**
8b. Dorsal plate of various forms, not triangular	**11**
9a. Posterior margin of basis capituli straight, without cornua-like processes, dorsal plate forming an equilateral triangle, hypostome apically rounded	***O. cavernicolous***
9b. Posterior margin of basis capituli provided with two cornua-like processes laterally, dorsal plate forming an isosceles triangle, hypostome apically pointed	**10**
10a. Dorsum with 27–29 pairs of setae (23–25 dorsolateral and 4 central), posterior margin of dorsal plate notched	***O. setosus***
10b. Dorsum with 13 pairs of setae (7 anterolateral, 3 central and 3 posterolateral), posterior margin of dorsal plate straight or slightly concave	***O. marinkellei***
11a. Dorsal plate oval, elongate	***O. faccinii*[e]**
11b. Dorsal plate pyriform	**12**
12a. Hypostome rounded or blunt	**13**
12b. Hypostome pointed	**14**
13a. Dorsum with 23–25 pairs of setae (7 anterolateral, 4 central and 11 or more posterolateral)	***O. capensis***
13b. Dorsum with 14 pairs of setae (7 anterolateral, 3 central and 4 posterolateral)	***O. mimon*[f]**
14a. Dorsum with 20 pairs of setae (7 anterolateral, 4 central and 9 posterolateral), hypostome > 0.240 mm long	***O. guaporensis***
14b. Dorsum with less than 20 pairs of setae, hypostome < 0.240 mm	**15**
15a. Dorsum with 19 pairs of setae	**16**
15b. Dorsum with less than 19 pairs of setae	**17**
16a. Hypostome with 3 files of denticles in anterior two-thirds	***O. hasei***
16b. Hypostome with 4 files of denticles in anterior two-thirds	***O. stageri***
17a. Dorsum with 17–18 pairs of setae (7 anterolateral, 4 central and 7–8 posterolateral)	***O. kohlsi***
17b. Dorsum with 13–14 pairs of setae	**18**
18a. Hypostome with a bilateral constriction in the middle length of the first row of denticles	***O. peropteryx***
18b. Hypostome lacking a bilateral constriction	**19**
19a. Anal valves conspicuous and leave-shaped, exceeding the margin of anal ring	***O. rietcorreai***
19b. Anal valves not exceeding the margin of anal ring	***O. fonsecai***

[a] Key adapted and expanded from Barros-Battesti et al. (2013). Diagnostic characters are provided according to original species descriptions and re-descriptions.
[b] These diagnostic features of larvae of the genus *Antricola* are provided according to Jones and Clifford (1972). The larvae of *Antricola* spp. found in Brazil are unknown. Therefore, when these larvae are described, these diagnostic features may have to be revised.
[c] Kohls et al. (1965) indicated the presence of 16–21 pairs of dorsal setae (12–14 dorsolateral and 4–7 central). Recently, analysing larvae from north-eastern Brazil, Muñoz-Leal et al. (2018b) indicated the presence of 17–18 pairs of dorsal setae (13 dorsolateral and 4–5 central).
[d] Muñoz-Leal et al. (2017) described the dorsal plate as "pyriform, with irregular margins, wider in the base". The dorsal plate of *O. saraivai* has an irregular shape, with a broad anterior end, sinuous lateral margins, and the widest portion is actually just below the mid-length of the plate, rather than in the base.
[e] Barros-Battesti et al. (2015) stated that the ventral posteromedian seta was absent in most of the larvae, but present in the holotype. In addition, although these authors stated that larval stages of *O. faccinii* are provided by six pairs of dorsal anterolateral setae, Luz et al. (2018a) found specimens with seven pairs. The seventh pair of dorsal anterolateral setae of *O. faccinii* larvae is shorter than the other six pairs and might have been overlooked in the original description.
[f] Kohls et al. (1969) described the presence of 14–15 pairs of dorsal setae (11–12 dorsolateral and 3 central) and venter with 8 pairs plus 1 posteromedian seta. A further re-description of Barros-Battesti et al. (2011) indicated the presence of 13 pairs of dorsal setae (10 dorsolateral and 3 central) and venter with 8–9 pairs plus 1 posteromedian seta. The lack of one dorsal pair of setae stated in Barros-Battesti et al. (2011) is not supported by illustrations and scanning micrographs presented and seems to correspond to a typing mistake.

which are also present in Brazil, may be found elsewhere (Nava et al., 2017).

Several tick species found in Brazil have been documented parasitizing humans in this country or elsewhere in the neotropical region (Guglielmone et al., 2006; Guglielmone and Robbins, 2018). Some of these ticks are proven or putative vectors of rickettsial pathogens, which constitute a major problem in Latin America (Oteo et al., 2014). From 2007 and 2015, 1,245 confirmed cases of spotted fever rickettsiosis were notified in Brazil (Oliveira et al., 2016). Of these, 411 had a fatal outcome, most of which in south-eastern Brazil, where the case-fatality reached 55%. The main vector of *Rickettsia rickettsii* in Brazil is *A. sculptum* (Martins et al., 2016; Ueno et al., 2016; Labruna et al., 2017), but recent studies indicate that the vector role of this tick may vary from region to region (Bitencourth et al., 2016, 2017). The yellow

dog tick *Amblyomma aureolatum* is also involved in the transmission of this agent in the metropolitan region of São Paulo (Ogrzewalska et al., 2012). Other ticks have been found infected by *R. rickettsia* in Brazil. For instance, *R. rickettsii* has been isolated from brown dog ticks (*Rhipicephalus sanguineus* s.l.) in south-eastern Brazil (Pacheco et al., 2011). Even if brown dog ticks may parasitize humans (Dantas-Torres et al., 2006), their role in the epidemiology of spotted fever rickettsiosis in Brazil requires further research (Szabó et al., 2013b). As another example, *Rickettsia parkeri* has been associated with human disease in Brazil and may possibly be transmitted by different *Amblyomma* species, including *Amblyomma ovale* (Szabó et al., 2013a; Nieri-Bastos et al., 2018; Krawczak and Labruna, 2018).

Several tick species have been implicated in the transmission of pathogens to companion animals and livestock. For instance, *Dermacentor nitens* is a vector of *Babesia caballi* to equids, *Rhipicephalus microplus* transmits *Anaplasma marginale*, *Babesia bigemina*, and *Babesia bovis* to cattle, *R. sanguineus* s.l. is a vector of *Ehrlichia canis* and *Babesia vogeli* to dogs, and *A. miniatus* transmits *Borrelia anserina*, the agent of avian borreliosis. Furthermore, *R. microplus* and *A. cajennense* s.l. are regarded as vectors of *Theileria equi* to equids (Nava et al., 2017), whereas *A. aureolatum* and *A. ovale* are proven vectors of *Rangelia vitalii* and *Hepatozoon canis*, respectively, to dogs. Argasid ticks such as *O. brasiliensis* are extremely aggressive to animals and humans, being responsible for cases of tick toxicosis in Brazil (Reck et al., 2013). Recently, *O. rietcorreai* was reported to produce toxicosis in humans as well (Oliveira et al., 2018) and the human-pathogenic *Borrelia venezuelensis* was isolated and molecularly characterized from an *O. rudis* female collected in the north-eastern part of the country (Muñoz-Leal et al., 2018b). More information about ticks of medical and veterinary significance in Brazil may be found in reference textbooks and literature reviews (Guimarães et al., 2001; Barros-Battesti et al., 2006; Marcondes, 2009, 2017; Szabó et al., 2013b; Dantas-Torres and Otranto, 2014; Martins, 2018).

5. Conclusions

In conclusion, we provided an updated list of ticks found in Brazil and updated taxonomic keys for their identification. The list of tick species found in this country is certainly expected to grow in the forthcoming years. Meanwhile, the taxonomic keys proposed herein may be updated in the future, remaining as an important source for studies on ticks and tick-borne pathogens in the Brazilian territory and surrounding countries.

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