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Original article

On the possible role of ticks in the eco-epidemiology of *Coxiella burnetii* in a Mediterranean ecosystem

Lucía Varela-Castro[a], Carla Zuddas[a,b], Nieves Ortega[b], Emmanuel Serrano[a,c], Jesús Salinas[b], Joaquim Castellà[d], Raquel Castillo-Contreras[a], João Carvalho[a,c], Santiago Lavín[a], Gregorio Mentaberre[a,e,*]

[a] *Wildlife Ecology & Health group (WEH) and Servei d'Ecopatologia de Fauna Salvatge (SEFaS), Departament de Medicina i Cirurgia Animals, Universitat Autònoma de Barcelona (UAB), Bellaterra, Barcelona, Spain*
[b] *Departamento de Sanidad Animal, Facultad de Veterinaria, Universidad de Murcia, Campus de Espinardo, Murcia, Spain*
[c] *Departamento de Biologia & CESAM, Universidade de Aveiro, Campus Universitário de Santiago, Aveiro, Portugal*
[d] *Departament de Sanitat i d'Anatomia Animals, Àrea de Sanitat Animal, Universitat Autònoma de Barcelona (UAB), Bellaterra, Barcelona, Spain*
[e] *Departament de Ciència Animal, Escola Tècnica Superior d'Enginyeria Agraria (ETSEA), Universitat de Lleida (UdL), Lleida, Spain*

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ABSTRACT

Ruminant livestock is the main reservoir of *Coxiella burnetii* (*Cb*), but little is known about the role of wildlife and ticks in its epidemiology. The Iberian ibex (*Capra pyrenaica,* Schinz 1838) population of "Ports de Tortosa i Beseit" (NE Spain) suffers intense tick infestations and low reproduction rates. This study aims to (1) assess the relationship between infection in ibexes (detection of serum antibodies and/or of *Cb* DNA in tissues) and *Cb* DNA presence in ticks hosted by the same ibexes; and (2) identify *Cb* associated risk factors. Between 2011 and 2015, serum (n = 130), spleen (n = 72), lymph node (n = 89) and tick (n = 669) samples from 134 hunter-harvested ibexes were collected. Antibody detection was performed by ELISA and *Cb* DNA presence was assessed by PCR. Potential risk factors were assessed with regression tree models. Although 30% of the ibexes (39/130; 95%*CI*, [10%–29.8%]) had antibodies, *Cb* DNA was detected in only 9.8% of the ibexes (11/112; 95%CI [7.6%–27.25%]). The prevalence of *Cb*-carrier ticks averaged 10% and exceeded 20% for the genus *Haemaphysalis*. However, lacking correlation between infection in ibexes and their ticks does not support tick-to-ibex transmission or vice versa. Tree modelling points to host, population and environmental factors as drivers of *Cb* infection in ticks and suggests connections with the domestic cycle. The percentage of *Cb*-carrier ticks detected is noteworthy. Along with heavy tick infestations, it suggests vector potential for these tick species, especially for the genera *Rhipicephalus* and *Haemaphysalis*. Since vector competence has not been assessed in these tick species, a classic vector role cannot be proposed nor discarded, but promoter factors of vector capacity occur. In addition, the risk of tick-borne infection through tick excreta should not be neglected. While the airborne route is the preeminent route for *Cb* infection, ticks' contribution to *Cb* epidemiology deserves further attention.

1. Introduction

Q fever is a worldwide zoonotic disease caused by the bacterium *Coxiella burnetii* (*Cb*). It has captured increasing attention due to its impact on human health (Jado et al., 2012; Tilburg et al., 2012). Because *Cb* is an airborne disease, inhalation is considered the main route of transmission (Rodolakis, 2006; Woldehiwet, 2004). After primary multiplication in the host's regional lymph nodes (Babudieri, 1959), *Cb* can be found in several organs, including the spleen (Baca and Paretsky, 1983) and liver (Woldehiwet, 2004). Ruminant livestock is the main reservoir, with abortion, stillbirth (sheep and goat) and infertility (cattle, see Ruiz-Fons, 2012) the most common symptoms. Hence, bacteria shedding through faeces, urine, vaginal mucus, birth products and milk takes place mainly during parturition (Roest et al., 2012; Rousset et al., 2009).

Although wildlife and ticks may be involved in Q fever maintenance and transmission (OIE, 2010), little is known about the wild cycle of *Cb* (Ruiz-Fons et al., 2010). *Cb* has been described not only in wild

* Corresponding author at: Wildlife Ecology & Health group and Servei d'Ecopatologia de Fauna Salvatge, Departament de Medicina i Cirurgia Animals, Facultat de Veterinària, Universitat Autònoma de Barcelona, E-08193, Bellaterra, Barcelona, Spain.
E-mail address: gregorio.mentaberre@uab.cat (G. Mentaberre).

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ungulates (González-Barrio et al., 2015a; Ruiz-Fons, 2012), but also in lagomorphs (Astobiza et al., 2011; González-Barrio et al., 2015b) and rodents (Ruiz-Fons, 2012). Moreover, more than 40 species of ticks have been found infected with *Cb* (Baca and Paretsky, 1983); collected either from vegetation (Bonnet et al., 2013; Toledo et al., 2009) or from domestic and wild hosts (Bennett et al., 2011; Ioannou et al., 2011), low, medium and high prevalences have been described in several genera (Duron et al., 2015). Thus, they could play a role in Q fever epidemiology.

Tick-to-animal experimental transmission of *Cb* has been demonstrated (Široký et al., 2010), but the exact route of infection (e.g., via tick saliva or by inhalation of tick faeces, see Rehácek and Brezina, 1968) and the vector role of ticks is still under debate (Sprong et al., 2012). Adult female ticks can spread *Cb* with their copiously produced faeces at the time of feeding (Maurin et al., 1999; Philip, 1948). Domestic animals living in close contact are prone to infection by inhalation; however, ticks may play a significant role in the transmission of *Cb* among wild vertebrates (Maurin et al., 1999). Therefore, the investigation of *Cb* at the wildlife-tick interface is a welcome step forward to better understand its epidemiology.

The "Ports de Tortosa i Beseit" rock massif (PTiB, henceforth) hosts one of the largest Iberian ibex (*Capra pyrenaica,* Schinz 1838) populations on the Iberian Peninsula (Pérez et al., 2002). This population suffers from intense tick parasitisation (see Fig. 1) and low reproductive rates. This outcome may be caused by abortive pathogens, including *Cb*. Moreover, sympatry with domestic ruminants occurs in this area, and thus connections between the domestic and wild cycles of *Cb* may exist. We took advantage of this scenario to (1) study the relationships between infection signs in ibexes (detection of antibodies and/or Cb DNA) and *Cb* DNA presence in ticks hosted by the same ibexes and (2) to identify *Cb*-associated risk factors.

2. Materials and methods

2.1. Study area

This study was carried out in PTiB, northeastern Spain (40°48′28″N, 0°19′17″E, Fig. 2). The study area covers approximately 35,050 ha. At a coarse scale, a typical Mediterranean forest prevails in the PTiB. The most common habitats are pine and oak forests with dense scrublands (Generalitat de Catalunya, 2014).

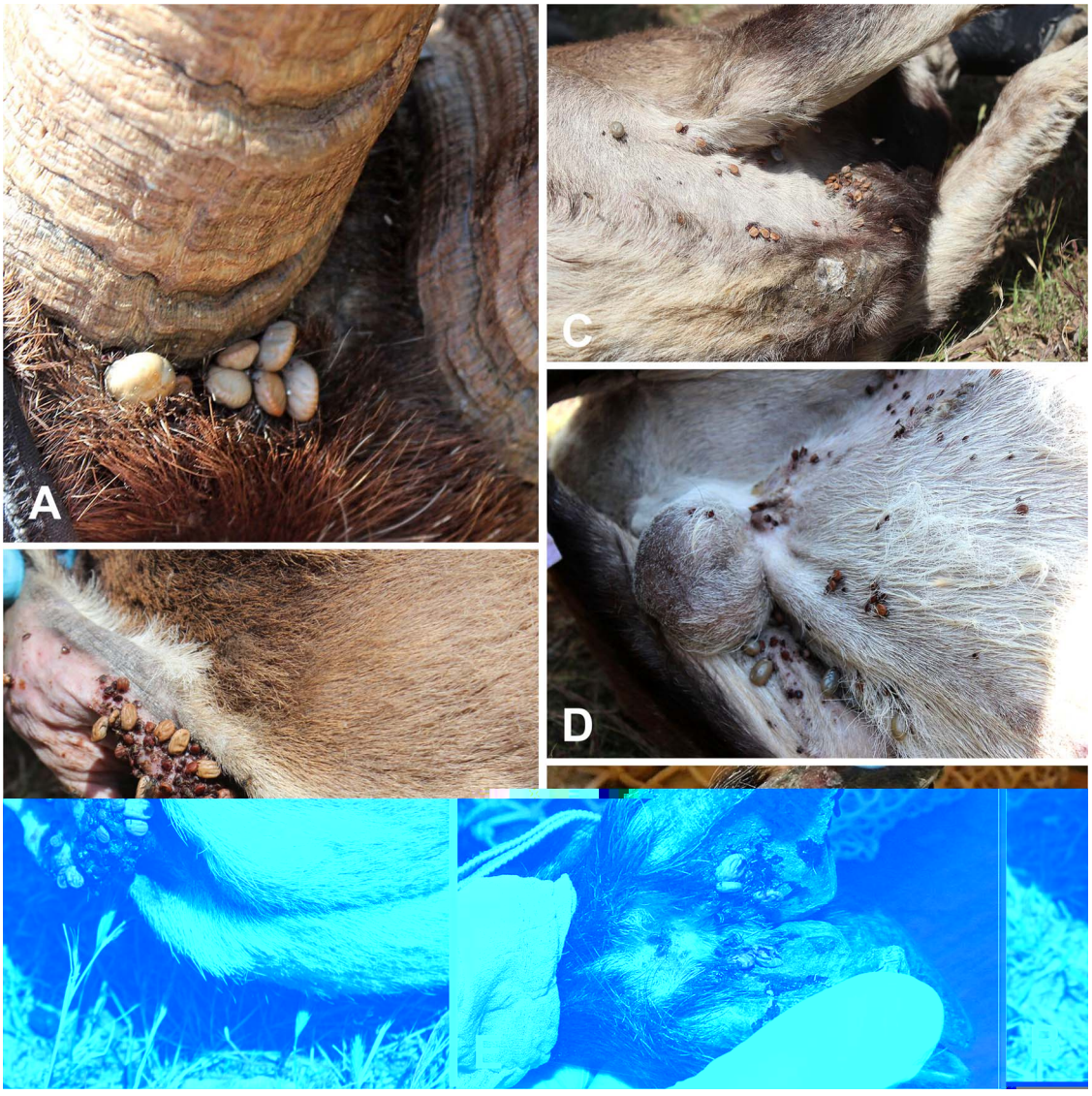

Fig. 1. Ticks parasitizing ibexes in several anatomical regions including (A) horn base, (B) perineum, (C) armpit, (D) inguinal zone and (E) interdigital space. Tick bites, related inflammation and, likely, wounds self-inflicted through scratching resulting in abraded skin.