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Ticks in Australia: endemics; exotics; which ticks bite humans?

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At least 71 species of ticks occur in Australia; a further 33 or so species are endemic to its neighbours, New Guinea and New Zealand. The ticks of Australia and other parts of Australasia are phylogenetically distinct. Indeed, there are at least two lineages of ticks that are unique to Australasia: the genus Bothriocroton Klompen, Dobson & Barker, 2002; and the new genus Archaeocroton Barker & Burger, 2018. Two species of ticks that are endemic to Australia are notorious for feeding on humans: (i) *Ixodes holocyclus*, the eastern paralysis tick, in eastern Australia; and (ii) *Amblyomma t. triguttatum* triguttatum, the ornate kangaroo tick, in Western Australia, at one place in South Australia, and in parts of Queensland. Three of the other endemic species of ticks that feed on humans in Australia are also noteworthy: (i) *Bothriocroton hydrosauri*, the southern reptile tick, which is a vector of Rickettsia bonei (Flinders Island spotted fever); (ii) *Haemaphysalis novaeguineae*, the New Guinea haemaphysalis; and (iii) *Ornithodoros capensis*, the seabird soft tick. Here, we present images of female *Ixodes holocyclus*, *Amblyomma t. triguttatum*, *Bothriocroton hydrosauri* and *Haemaphysalis novaeguineae* and our latest maps of the geographic distributions of *Ixodes bolocylus*, *Amblyomma t. triguttatum* and *Bothriocroton hydrosauri*. None of the five exotic species of ticks in Australia typically feed on humans.

The Australian tick fauna
At least 71 species of ticks are known in Australia: 57 hard ticks (family Ixodidae) and 14 soft ticks (family Argasidae)\(^1\). Five of these 71 species of ticks were brought to Australia by humans and thus might be called exotic: (i) *Argas persicus*, the poultry tick; (ii) *Otobius megnini*, the spinose ear tick, a recent introduction, probably in the ears of horses; (iii) *Haemaphysalis longicornis*, the bush tick, which occurs in much of east Asia; (iv) *Rhipicephalus sanguineus*, the brown dog tick, a worldwide species; and (v) *Rhipicephalus (Boophilus) australis*, the Australian cattle tick. Barker and Walker\(^3\) has detailed species accounts for these five ticks.

Australia has a special place in the history of hard ticks (Ixodidae). Indeed, the hard ticks\(^4\)–\(^6\), soft ticks and nutallielid ticks\(^7\) may have first lived in Australia, or more accurately, that part of the super continent Gondwana that became Australia, as early as the Devonian era (362–409 million years ago). Accordingly, six of the eight subfamilies of ticks (Ixodidae) are endemic to Australia: Argasinae,
Bothriocrotinae, Amblyomminae, Haemaphysalinae, Ixodinae and the Ornithodorinae. Furthermore, there are at least three lineages of ticks that are unique to Australasia: (i) the sub-family Bothriocrotinae Klompen, Murrell & Barker, 2002 from Australia and New Guinea; (ii) the Australasian Ixodes lineage; and (iii) the genus Archaeocroton Barker & Burger, 2018, which was made for the tick of the tuatara, a singular lizard, from New Zealand.

Which ticks bite humans in Australia?

None of the five exotic species of ticks in Australia typically feed on humans. Two of the 66 species of ticks that are endemic to Australia are, however, notorious for feeding on humans or may often be found crawling on them: (i) Ixodes holocyclus, the eastern paralysis tick, in eastern Australia; and (ii) Amblyomma t. triguttatum, the ornate kangaroo tick, in Western Australia, at one place in South Australia, Innes National Park on Yorke Peninsula where it was recently introduced (refer to commentary and references), and in parts of Queensland. These two ticks will be considered in detail in the present paper. Of the three other endemic species of ticks that may feed on humans in Australia: (i) Bothriocroton hydrosauri, the southern reptile tick, is a vector of Rickettsia honei (Flinders Island spotted fever); (ii) Haemaphysalis novaeguineae, the New Guinea haemaphysalid, which, although restricted to the far north of Australia and the Island of New Guinea is noteworthy because it is known to be a vector of R. honei strain marmionii, which caused a fatality in a patient admitted to Townsville General Hospital in late 2016; and (iii) Ornithodoros capensis, the seabird soft tick, that will feed on humans and domestic poultry given the opportunity. O. capensis is known to carry a large number of viruses although none of these have been confirmed to infect humans (see commentary).

Ixodes holocyclus, the eastern paralysis tick

I. holocyclus (Figure 1) is known as the eastern paralysis tick since most cases of tick paralysis in eastern Australia in domestic animals, wildlife and humans are caused by this tick. I. holocyclus is also known as the scrub tick in Queensland, particularly in North and Far North Queensland. The name scrub tick echoes

Figure 1. Ixodes holocyclus, the eastern paralysis tick; Amblyomma triguttatum triguttatum, the ornate kangaroo tick; Bothriocroton hydrosauri, the southern reptile tick; and Haemaphysalis novaeguineae, the New Guinea haemaphysalid.
the apparent predilection of *I. bolocylus* for the edges of wet-forests (‘scrub’).

**Geographic distribution and hosts:** *Ixodes bolocylus* is strictly constrained to the east coast of Australia (Figure 2) despite the tick having been carried by domestic dogs, cattle, horses and people to many other parts of Australia that appear to be superficially suitable, such as Melbourne and Perth (SC Barker, E Teo and D Barker, unpublished data). *I. bolocylus* is considered to be catholic in its feeding habits. Indeed, *I. bolocylus* has been recorded from 34 species of mammals and seven species of birds3, but whether it feeds successfully on all of these species is another question. Where *I. bolocylus* is abundant, it will be found on most of the species of mammals present, but the bandicoots *Isoodon macrourus* and *Perameles nasuta* have been considered the principal hosts in southeastern Queensland since at least 197512. These bandicoots may carry many ticks. It seems that reasonable numbers of *I. macrourus* and *P. nasuta* are required for populations of *I. bolocylus* to persist from one tick season to another in southeastern Queensland12 but this is probably not the case in other parts of the geographic range of *I. bolocylus* where there seem to be large numbers of ticks but few if any bandicoots (SC Barker and D Barker, unpublished data).

**Illnesses in humans associated with I. bolocylus:** The toxins of this tick seem to be the most potent of all tick-toxins with at least 20 fatalities13: there have been comparable numbers of fatalities from red-back spiders (*n* = 18) and funnel-web spiders (*n* = 13)13. Thankfully, deaths from the bite of *I. bolocylus* are now rare due to the advent of intensive care-units in regional hospitals and expert medical treatment. The illnesses that *I. bolocylus* has been associated with include Australian multi-system disorder, post-infection fatigue, autoimmune disease, paralysis, allergies (particularly to the bites of larvae), Queensland Tick Typhus (*Rickettsia australis*), mammalian meat-allergy and tick anaphylaxis; Graves and Stenos14 reviewed these illnesses. Barker15 hypothesised that *I. bolocylus* may be a link in the transmission of Hendra virus from bats to horses to humans; this hypothesis has not yet been tested.

**Amblyomma triguttatum triguttatum,**
the ornate kangaroo tick

Although known as a kangaroo tick, *A. t. triguttatum* (Figure 1) will feed on humans; it is one of four subspecies of *A. triguttatum* (see Barker et al.1).

**Geographic distribution and hosts:** The geographic distribution of *A. t. triguttatum* has two parts: eastern Australia and western Australia (Figure 3). *A. t. triguttatum* is primarily a tick of kangaroos (genus *Macropus*). *A. t. triguttatum* is also common on wild (feral) pigs in Australia16. Of a sample of 88 grey kangaroos, *Macropus giganteus*, in southeast Queensland, 84% were infested with *A. t. triguttatum*; 97% of all these ticks were found in the ears16. McCarthy17 also found that *A. triguttatum* prefers to attach in the ears of kangaroos, sheep and cattle, sheep and cattle. No other species of ticks were found on these kangaroos16.

**Illnesses in humans associated with A. t. triguttatum:** *A. t. triguttatum* is vector of the spotted fever organism, *Rickettsia gravesi*16.
So far this *Rickettsia* has been found only in *A. triguttatum* taken from feral pigs (*Sus scrofa*)\(^1\) and humans\(^2\) in Western Australia. Owen *et al.*\(^2\) suggested that the geographic distribution of *R. gravesii* may coincide with that of *A. triguttatum* (possibly the subspecies *A. t. triguttatum* – inferred by us from the known geographic distribution of *A. t. triguttatum* (Figure 3)). *A. t. triguttatum* is also a vector of *Coxiella burnetii*, the aetiological agent of Q fever\(^4\). Pearce and Grove\(^2\) described the local skin reactions of 175 soldiers who were bitten by *A. triguttatum* (probably *A. t. triguttatum*). Moorhouse\(^2\) also reported local skin reactions, which he described as allergic dermatitis, in humans bitten by *A. triguttatum* (possibly the subspecies *A. t. triguttatum* – inferred by us from the known geographic distribution of *A. t. triguttatum* (Figure 3)).

Figure 3. The geographic distributions of *Amblyomma triguttatum triguttatum*, the ornate kangaroo tick, and *Bothriocroton hydrosauri*, the southern reptile tick.
**Bothriocroton hydrosauri**, the southern reptile tick

Although known as the southern reptile tick, *B. hydrosauri* (Figure 1) will, however, feed on humans.

**Geographic distribution and hosts:** The geographic distribution of *B. hydrosauri* (Figure 3) is very well known. In South Australia, at Bundey Bore Station, north-east of Adelaide, the distribution of *B. hydrosauri* has been mapped to a scale of metres. The main host of *B. hydrosauri*, in much of South Australia at least, is *Tiliqua rugosa* (sleepy lizard). Nonetheless, *B. hydrosauri* will, given the opportunity, attach to and feed on humans, cattle and horses.

**Illnesses in humans associated with** *B. hydrosauri:* *B. hydrosauri* is the arthropod-host of *R. honei* on Flinders Island, Tasmania and mainland-Tasmania. *R. honei* causes Flinders Island spotted fever in humans. Flinders Island spotted fever is typically a relatively mild disease; no deaths have been reported although a patient in Nepal had severe illness. *R. honei* has been isolated from the blood of patients with chronic illness, including fatigue, from Melbourne, Victoria, and Adelaide, South Australia, but it is not known whether or not *R. honei* was causally related to the illness. *R. honei* was not detected by PCR nor cell culture in the blood of *Tiliqua rugosa* (southern blue-tongue lizard), *Austrelaps superbus* (copperhead snakes) nor *Notechis scutatus* (tiger snake), but more than 60% of *B. hydrosauri* from those lizards and snakes were PCR-positive or cell culture-positive for *R. honei*. So, *R.honei* is apparently sustained in populations of *B. hydrosauri* on Flinders Island by vertical, trans-ovarial transmission. That is, *R. honei* infects the eggs of *B. hydrosauri* in situ and thus the next generation of *B. hydrosauri* become infected with *R. honei*, without feeding on an infected vertebrate. So apparently, vertebrates are not needed for the survival of *R. honei* on Flinders Island, and probably elsewhere. Furthermore, horizontal transmission, that is transmission between the arthropod-host (tick) and the vertebrate-host (lizards and snakes), has not yet been demonstrated experimentally for *R. honei* although there are confirmed cases of infection with *R. honei* in people who had been bitten by ticks from Iron Range, Cape York Peninsula, Queensland (*H. novaeguineae*); and Nepal (species of tick unknown).

Flinders Island spotted fever is now known from three continents: (i) Australia (Flinders Island, Tasmania; mainland Tasmania; and South Australia); (ii) Asia (Thailand; Orchid Island, Taiwan; Nepal); and (iii) North America (Texas) confirmed tick-hosts of *R. honei* are: (i) *B. hydrosauri* from Flinders Island and mainland Tasmania; Cooma, New South Wales; and Bundy Bore Station, South Australia; (ii) *Haemaphysalis novaeguineae* (*R. honei* strain marimonii) from Iron Range, Queensland; (iii) *Ixodes granulatus* from *Rattus rattus* (black rat) from Thailand (adult ticks but not yet from larval or nymphal *I. granulatus*); and (iv) *Amblyomma cajennense* from cattle from Texas, USA.

**Where to next?**

We still need cytochrome *c oxidase subunit I* (COXI) and Internal Transcribed Spacer (ITS2) rRNA nucleotide sequences for most of the Australian ticks. These sequences will help non-experts to identify quickly ticks, particularly larvae and nymphs. We also need to know where exactly *H. novaeguineae*, the New Guinea haemaphysalid, lives in northern Australia, and how abundant it is there.

**Conflicts of interest**

The authors declare no conflicts of interest.

**Acknowledgements**

We sincerely thank Julianne Waldock (Western Australian Museum) for identifying many *Amblyomma tritigatum* to subspecies for our map. We also thank Brodie Foster and Wil McGuire for expert and creative images of ticks, our Honours student Melanie Vial who pioneered map-making in our laboratory, our undergraduate research students, Samuel Kelava, Ernest Teo, Semira Hailu and Truc Le, for help with the geographic distributions of Australian ticks, and Jordan Clough for expert work on a troublesome tick image. This research did not receive any specific funding.

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15. Barker, S.C. (2003) The Australian paralysis tick may be the missing link in the taxonomy and biology of Australasian ticks. Dayana is a PhD candidate at the School of Veterinary Sciences, University of Queensland, Australia. He is a specialist in ticks and other ectoparasites; he has worked on ticks and other ectoparasites at the University of Queensland for 27 years.

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