G Model
ACTROP 3390 1–10
ARTICLE IN PRESS
Acta Tropica xxx (2014) xxx–xxx
Contents lists available at ScienceDirect
Acta Tropica
journal homepage: www.elsevier.com/locate/actatropica

Characterising African tick communities at a wild–domestic interface using repeated sampling protocols and models

Q1 Eve Miguel[a,b,c,*], Thierry Boulinier[b], Michel de Garine-Wichatitsky[a,c], Alexandre Caron[a,c,d], Hervé Fritz[e], Vladimir Grosbois[a]

[a] Cirad–ES,AGIRs, (Animal et Gestion Intégrée des Risques/Animal and Integrated Risk Management), Montpellier, France
[b] CNRS–Centre d'Ecologie Fonctionnelle et Evolutive - UMR 5175, Montpellier, France
[c] Cirad–ES, AGIRs–RP-PCP, Harare P.O. Box 1378, Zimbabwe
[d] Mammal Research Institute, University of Pretoria, Pretoria, South Africa
[e] CNRS–Laboratoire de Biométrie et Biologie Evolutive UMR 5558, UCB Lyon Villeurbanne, France

ARTICLE INFO

Article history:
Received 25 November 2013
Received in revised form 23 May 2014
Accepted 27 May 2014
Available online xxx

Keywords:
Africa
Aggregation
Drag sampling
Host diversity
Site occupancy modelling

ABSTRACT

The sharing of habitat by wild and domestic animals may result in pathogen transmission, notably via ectoparasite vectors such as ticks. Interfaces between protected and communal lands constitute sharp transitions between areas occupied by host communities that are extremely contrasted in terms of composition, diversity and density. Empirical characterizations of tick communities and of their vertebrate hosts are strongly relevant for understanding the mechanisms leading to disease transmission between wild and domestic animals. In the present study we aimed at depicting the pattern of spatial variation in the density of immature ticks at such an interface located in Zimbabwe. At the end of the 2011 rainy season, we applied a hierarchical repeated protocol to collect ticks. We used the drag-sampling method in the vegetation surrounding water pans used by ungulates in 3 distinct landscape compartments (i.e. national park, mixed compartment and communal lands) characterized by a differential use by wild and domestic hosts. We combined generalized linear mixed models with site occupancy models to (1) assess tick aggregation levels at different spatial scales, (2) identify and disentangle factors which influence the density and probability of tick detection, and (3) compare robust estimations of tick densities among the landscape compartments. Ticks belonging to the *Amblyomma* and *Riphicephalus* genuses were found to be the most abundant. At small scale, ticks were more often detected in the afternoon and were more abundant close to water pans for *Amblyomma* and *Riphicephalus* genuses. *Riphicephalus spp*. density was also higher in grassland and bushland vegetation types as compared to woodland vegetation type. At large scale, for the three detected genuses, presence and density probabilities were much higher near water pans located in the communal lands as compared to the national park and mixed compartment. Given that host community's diversity is much lower in the communal areas than in the two other landscape compartments, these results are compatible with a dilution effect but not sufficient to demonstrate this effect without additional studies. Up to date, it is the first utilization of these rigorous sampling and statistical modelling methodologies to estimate tick density or presence in African ecosystem simultaneously at large and small scales.

1. Introduction

The growth of global human population and of per capita consumption has led over the last fifty years to an important increase in the total area dedicated to the production of agricultural products in developing countries (Green et al., 2005; Gibbs et al., 2010). At the same time, concerns about the erosion of natural ecosystems and of biodiversity have motivated the creation and the expansion of protection areas for nature conservation with the support of integrated conservation and rural development investment made by national governments and international donor agencies (Wittemyer et al., 2008). These trends in land use and conservation and development policies have resulted in the fast growth of human and livestock populations living at the edge of wildlife

* Corresponding author at: Cirad AGIRs - Animal et Gestion Intégrée des Risques - TA C 22/E Campus International de Baillarguet - 34398 Montpellier cedex 5 France. Tel.: +33 0 4 67 59 39 74; fax: +33 0 4 67 59 37 54.
E-mail addresses: eve.miguel@cirad.fr, eve.miguel@gmail.com (E. Miguel).

http://dx.doi.org/10.1016/j.actatropica.2014.05.019
0001-706X/© 2014 Published by Elsevier B.V.

protection areas in Africa and Latin America (Wittemyer et al., 2008).

The situation of Southern Africa where the creation of Transfrontier Conservation Areas is currently ongoing is emblematic of this phenomenon and requires addressing the coexistence of rural communities and wildlife (Andersson et al., 2012). Such coexistence is problematic because the direct or indirect interactions among wild animals, domestic animals and humans resulting from the exploitation of the same habitats and resources generates a number of conflicting interferences including competition for pasture and water (e.g. Baudron et al., 2011), crop damages (e.g. Guerbois et al., 2012), predation of livestock (e.g. Butler, 2000) and transmission of infectious diseases between wildlife, livestock and humans (e.g. Miguel et al., 2013). Many livestock diseases such as foot-and-mouth disease, bovine tuberculosis, brucellosis, rift valley fever and theileriosis circulate at interfaces between communal lands and protected areas in Southern Africa. Their possible maintenance in wildlife populations could compromise their control in livestock through standard veterinary measures such as vaccination and dipping against tick-borne diseases (Caron et al., 2013). In addition some of these pathogens such as brucellosis, rift valley fever or bovine tuberculosis are zoonotic. As a consequence they also put local human populations at risk of outbreaks and, because human populations are globally connected, they also represent a global public health concern (Jones et al., 2013). Understanding the mechanisms of pathogen transmission at interfaces between communal and conservation areas is crucial to address these local and global risks.

Wild and domestic ungulates can be hosts for the adult and for the immature stages of the 3 tick genus commonly detected in austral Africa, *Rhipicephalus spp.*; *Hyalomma spp.* and *Amblyomma spp.* (Table 1a) (Walker et al., 2013) and several pathogens infecting livestock and wild ruminants in Southern Africa are transmitted by such ticks (Grard et al., 2011). For instance the protozoan *Theileria parvas* is the causative agent of Theleriosis and is mainly transmitted by *Rhipicephalus appendiculatus* and *R. zambeziensis* ticks (Latif et al., 2002) while the bacterium *rickettsia Cowdria ruminantium* is the causative agent of Heartwater and is transmitted by *Amblyomma spp.* ticks (Uilenberg et al., 1993). Empirical characterizations of communities of ticks and identification of the biotic and abiotic factors influencing their composition and density at interfaces between protected and communal lands is thus strongly relevant for understanding the mechanisms leading to disease transmission between wild and domestic animals. Moreover, at these interfaces host diversity varies sharply over short distances with wild host communities being usually more diverse than domestic host communities, while abiotic factors such as meteorological conditions or soil composition are relatively homogeneous. Investigations of tick communities at such interfaces can thus provide insights on the influence of host diversity on parasite abundance; a relevant topic regarding health regulatory functions of biodiversity and natural ecosystems (Hails and Ormerod, 2013).

However, investigations of the distribution of parasites such as ticks can be hampered by low and heterogeneous detection probabilities (McClintock et al., 2010) implying that observed counts are biased estimations of true abundances (Royle et al., 2005). It is thus crucial to use sampling strategies and analytical approaches that minimize these biases. Field protocols where sites or hosts are repeatedly sampled within short time periods (Bailey et al., 2004) and statistical models specifically designed to be fitted to the resulting data allow simultaneous estimation of detection probabilities and abundance (MacKenzie, 2005; Mackenzie and Royle, 2005). Such methods have however been rarely used so far in disease ecology studies (McClintock et al., 2010; Restif et al., 2012). Another characteristic of parasites such as ticks is that their distribution on hosts or in the environment is often aggregated (Boulinier et al., 1996; Elston et al., 2001), which can have significant implications for the estimations of parameters of populations and communities (Petney et al., 1990).

In the present study we investigated tick densities at an interface between protected and communal lands in Zimbabwe. We implemented a hierarchical repeated tick sampling protocol in three landscape compartments located respectively on the communal side occupied almost exclusively by domestic ungulates, on the protected side occupied exclusively by wild ungulates and on the transition zone between these two sides which is used both by wild and domestic ungulates (hereafter referred to as "mixed compartment"). We combined generalized linear mixed models with site occupancy models to (1) assess tick aggregations at different spatial scales, (2) identify and disentangle the factors which influence the density or the probability of detections of ticks, and (3) compare robust estimations of tick densities in the different landscape compartments.

2. Materials and methods

2.1. Study areas

The study was carried out in Hwange National Park (HNP), Zimbabwe (35 K 484826E; 794130S) and adjacent communal lands. HNP and its surroundings are characterized by a dry savannah ecosystem where water is a key resource for all vertebrate populations (Valeix, 2011). Three tick sampling compartments were defined (Fig. 1): inside the national park where wildlife is protected and only wild ungulate hosts occur (i.e. Main Camp area); in the mixed compartment between communal lands and the national park where both wild and domestic ungulate hosts co-occur (i.e. Chezhou and Mabale); and in communal lands located relatively far away from the national park (i.e. 30–40 km: Tinde) where almost exclusively domestic ungulate hosts occur. The mixed compartment is characterized by a mixture of land uses and a large diversity of ungulates (domestic and wild) that are potential tick hosts. Altitude in the area is around 1100 m and the rainfall is slightly below 600 mm per year (see word.climate.com). The seasonal climatic pattern is characterized by a rainy season from mid-November to March followed by a cold dry season between April and July and a hot dry season from August to mid-November (see world.climate.com). Vegetation consists in a woodland–bushland savanna dominated by *Colophospermum mopane*, *Combretum spp.*, *Acacia spp.* and *Baikiaea spp. d* (Rogers, 1993). Water pans constitute the main surface water and are scattered over the landscape inside and outside the national Park. Water pans density is higher inside the national park, with 0.25 water pans per km^2 (in the area of interest) (Valeix, 2011), than in the mixed compartment, with 0.08 water pans per km^2 (personal census of water pans and boreholes). Although no water pan density estimation is available for the Tinde communal land, we are aware of several water pans available for domestic hosts in this area. Human activities in the communal areas essentially consist in subsistence farming with small-scale livestock production. Small herds are bred extensively with on average 12 heads of cattle and small ruminants (goats and a few sheep) per herd (Department of Veterinary Services, Cross Dete, Zimbabwe, 2011). Cattle were treated during our study period with an acaricide (Amitraz diluted in pools called 'diptank') at the following frequencies: 4 times/month from January to March, 2 times/month from April to September, one time/month in October and November and 3 times for December. The rainy season was identified by the local veterinary services as the most risky in terms of tick infestation.

Wildlife abundance and diversity inside Hwange National Park are relatively high (see data in Fig. 1 for the beginning of the dry season – confidence intervals are provided in (Chamaille-Jammes et al.,

Please cite this article in press as: Miguel, E., et al., Characterising African tick communities at a wild–domestic interface using repeated sampling protocols and models. Acta Trop. (2014), http://dx.doi.org/10.1016/j.actatropica.2014.05.019