Veterinary Parasitology: Regional Studies and Reports 14 (2018) 41–49

Contents lists available at ScienceDirect

Veterinary Parasitology: Regional Studies and Reports

journal homepage: www.elsevier.com/locate/vprsr

Original Article

Modelling the distribution of *Rhipicephalus microplus* and *R. decoloratus* in Zimbabwe

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ARTICLE INFO

Keywords:
Rhipicephalus (Boophilus)
Modelling
Habitat suitability
Zimbabwe

ABSTRACT

Species distribution modelling is a very useful tool in vector management. Ticks are vectors of various pathogens which cause serious problems in livestock production in tropical countries. They have a high dispersal potential which is mainly facilitated by the movement of animals from one area to another. In light of the observed geographic expansion of *Rhipicephalus microplus* in Zimbabwe, we used species distribution modelling techniques to identify areas which may provide suitable habitats for the occurrence of this invasive tick species as well as the autochthonous *Rhipicephalus decoloratus*. Our results suggest that, despite the geographic expansion of *R. microplus*, climate will continue to be a limiting factor for the further expansion of this tick species. We expect its distribution to be restricted to the most favourable areas in the eastern and northern parts. The greater part of Zimbabwe is suitable for *R. decoloratus*, although in areas where *R. microplus* occurs, displacement of the former by the latter will be expected to occur. A heterogeneous climate, unregulated movement of cattle and episodic droughts are suggested to be possible factors for the continued existence of *R. microplus* and *R. decoloratus* in Zimbabwe and the partial displacement.

1. Introduction

The invasive tick species *Rhipicephalus microplus* is regarded as the most important cattle tick in the world (Giles et al., 2014). Having originated from South East Asia, *R. microplus* has spread globally, and is now found in most tropical and subtropical countries (Estrada-Peña et al., 2006a). The invasiveness of this tick species has been largely attributed to its high reproductive capacity characterised by a short life cycle, its high adaptability to changing environments, its increasing resistance to chemical acaricides and the fact that it is a one host tick benefitting from cattle movement for spreading efficiently (Barrè and Uilenberg, 2010). The introduction of this species in an area becomes a concern to disease control authorities as not only does it cause production losses in cattle but it transmits the more pathogenic form of bovine babesiosis (*Babesia bovis*) which may be a threat to indigenous non-immune cattle (De Clercq et al., 2012). Even more, the opportunities for keeping the more superior temperate breeds in these areas is jeopardised as these are more susceptible to *B. bovis* infections (Madder et al., 2011).

Control strategies for invasive vector species involve identifying risk areas within which these species can potentially establish upon introduction (Estrada-Peña, 1999). Thereafter, areas deemed suitable for the tick species but not yet invaded may be put under surveillance with constant inspection for the presence of ticks (Hahn et al., 2016). On the other hand, tick eradication programmes may be organised targeting isolated areas where the tick species is currently established and thus preventing its potential spread to areas that may provide the right environmental conditions for survival and proliferation (Wilson, 1996). For tick species, these are climate, vegetation and availability of suitable hosts (De Clercq et al., 2013; Estrada-Peña, 2008). During the parasitic phase, the host provides all resources required for tick development, but during the pre- and post-parasitic phases, favourable

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https://doi.org/10.1016/j.vprsr.2018.08.006
Received 14 April 2018; Received in revised form 26 August 2018; Accepted 28 August 2018
Available online 29 August 2018
2405-9390/

climatic conditions and vegetation patterns are essential. It has been proposed that of these factors, climate is the most limiting factor for tick distribution (Cumming, 2002).

An exhaustive review of the habitat suitability models developed for *Rhipicephalus microplus* ticks has been published by Wang et al. (2017). For these and other tick species, a common approach in modelling species distribution is the use of a generalised linear model (GLM) for presence and absence data together with environmental variables as predictors of species occurrence (Hijmans and Elith, 2016). Data on weather and climate are routinely obtained from weather stations around the world or from satellite imagery. For climate data, the WorldClim dataset is often used and sensors like the Moderate Resolution Imaging Spectroradiometer (MODIS) are useful in gathering environmental data (De Clercq et al., 2015). The final output of species modelling is a suitability map which shows a degree of suitability for each pixel, where values close to '1' indicate the areas that are highly suitable and values close to '0' indicate the areas that are unsuitable for the occurrence of a species.

Previous studies in Zimbabwe suggested a complete displacement of *R. decoloratus* by *R. microplus* in eastern Zimbabwe (Mason and Norval, 1980). Other studies suggested that because of the 1981–1984 drought experienced in Zimbabwe, *R. microplus* could have completely disappeared in Zimbabwe (Norval et al., 1992). Later studies however showed that the tick was present in the east and north east parts of the country (Katsande et al., 1996). In other countries *R. microplus* has been reported to displace *R. decoloratus* (Berkvens et al., 1998; De Clercq et al., 2012; Nyangiwe et al., 2013; Tønnesen et al., 2004). Recently, an expansion in the geographic range of *R. microplus* was reported by Sungirai et al. (2017) and in contrast with earlier studies, they observed a partial displacement of the more drought-tolerant *R. decoloratus* by the former.

The expansion in the range of *R. microplus* and the possible displacement of *R. decoloratus* raises two questions: (i) Are there other areas in Zimbabwe where climatic conditions are suitable for *R. microplus* to exist, survive and reproduce and where the species is not presently reported? and (ii) do the two tick species *R. microplus* and *R. decoloratus* share the same ecological niche in Zimbabwe? This study therefore seeks to model the habitat suitability of these competing tick species, the autochthonous *R. decoloratus* and the invasive *R. microplus,* and to determine whether their niche overlaps. Previous papers have predicted the habitat suitability of these two tick species on a continental scale (Estrada-Peña et al., 2006a) using tick records from 1900 to 1990 (Cumming, 1999). However, as more recent tick occurrence data became available, we felt it necessary to update these species distribution maps. This will be important to understand the ecology of these two tick species and particularly for *R. microplus* to provide the forecast of its distribution changes. From a management point of view it will also provide a platform to allow animal health authorities to evaluate the control programmes in place (Hahn et al., 2016).

2. Materials and methods

2.1. Study area and tick data

The country of Zimbabwe is situated in southern Africa, neighbouring Botswana in the west, Zambia in the north, Mozambique in the east and South Africa in the south. The climate is tropical, but can vary locally due to large differences in relief over a short range. The Zambezi valley to the north is hot and arid, and the eastern plateau is rather cool with relatively high annual rainfall. Overall, the main vegetation cover is savannah (miombo woodland), and tropical forests occur where the climate allows (Gambiza and Nyama, 2000). The country is divided into five agro-ecological regions on the basis of temperature and rainfall, ecological regions 1 and 2 being referred to as the Highveld, region 3 as the Middleveld while region 4 and 5 are referred to as the Lowveld (Norval et al., 1994).

This study used data of *R. microplus* and *R. decoloratus* ticks collected in Zimbabwe during a survey conducted on cattle at communal dipping tanks from September 2013 to May 2015. The details on sample collection are described in detail by Sungirai et al. (2017). Briefly, using the formula of Thrusfield (2005) whereupon a dip tank prevalence of 50% was assumed, 384 dipping tanks were to be sampled throughout the country. This translated to sampling around 77 dipping tanks per ecological region, although the figure varied depending on the respective size and the total number of dipping tanks in the region. Due to this and other logistical reasons explained by Sungirai et al. (2017), sampling was done at 322 dipping tanks throughout the country. A sampling frame of the dipping tanks in each region was obtained from the department of Veterinary Services of Zimbabwe, random numbers were generated using Microsoft Excel as many as the number of dipping tanks and the order of assigned random numbers was used to select the dipping tanks in each region. Ecological region three had the most dipping tanks sampled (109), followed by region four (76), region five (65), region two (55) and region one (17). At each dipping tank, at least five heavily tick infested cattle were sampled for ticks targeting all the predilection sites i.e. the base of tail, perianal region, perineum, legs, axillae, hooves, udder, scrotum, belly, dewlap, head and ears. The name of the dipping tank, geographic co-ordinates, date of collection were collected. The ticks and the labels were stored in specimen bottles with 70% ethanol and were identified in the laboratory using morphological keys (Walker et al., 2003). *Rhipicephalus microplus* ticks were found at 32% (103/322) of the dipping tanks while *R. decoloratus* ticks were found at 62% (200/322) of the dipping tanks. *Rhipicephalus decoloratus* showed a nearly uniform presence throughout the country, while *R. microplus*' distribution was limited to sub-regions in the eastern part of the country.

2.2. Environmental variables

The predictor variables used in the study were the 19 bioclimatic variables (Table 1) obtained from the WorldClim dataset which is an interpolated dataset of temperature and precipitation data obtained from weather stations for the period 1950–1990 (Hijmans et al., 2005). Other predictor variables were the mean, minimum and maximum values of the Normalised Difference Vegetation Index (NDVI) for the period January 2013–December 2015 obtained by remote sensing from the MODIS sensor downloaded at a 1 km spatial resolution (Justice et al., 1998). Monthly NDVI values were averaged into mean, maximum and minimum NDVI values for each dip tank. The NDVI is a measure of photosynthetic activity which reflects available moisture on the ground (Randolph, 2010), its values range from −1 to +1, with negative values indicating water while values close to zero indicate bare soil and values closer to one indicate a lot of greenness.

2.3. Model building

We used the procedure described by Cumming (1999) to develop models to predict the habitat suitability of the two tick species. In this procedure logistic regression is done with the environmental predictor variables and it is realised that the multicollinearity of the variables will not affect the predictive performance of the model (Cumming, 1999). The main effects of autocorrelation are on co-efficient values rather than on predicted probabilities (Cumming, 2002) hence the former will not be interpreted in this paper since there was no correction for collinearity. The presence-absence data for both tick species was divided into a training set (75%) for model calibration and a test set (25%) for model evaluation. First, univariate logistic regression was done using a generalised linear model (GLM) with the "binomial logit" link function to test the association between each variable and tick occurrence. Variables which were significantly correlated ($p \leq .05$) with tick presence were retained as potential predictors for habitat suitability (Table 1). With these, multivariate logistic regression analyses were