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*Research Article*

# Study of distribution of *Rhipicephalus microplus* ticks in India based on Worldclim temperature and rainfall data through an ecological niche modeling approach

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**Abstract**
*Rhipicephalus microplus* is an important tick infesting livestock, particularly ruminants, and also transmits various economic diseases, viz. babesiosis and anaplasmosis. Considering the economic impact of those diseases and losses incurred due to tick infestations, it is pertinent to appraise the distribution of these tick species regarding climatic backgrounds. The present study aimed to employ a species distribution model for studying distribution patterns of *Rhipicepaus microplus* in India. Important bio-climatic variables *viz* Bio1 (Annual Mean temperature), Bio2 (Mean diurnal range of temperature), Bio12 (Annual precipitation) and Bio15 (Precipitation seasonality) were used for building a model with the help of '*dismo'* R package. The results showed that temperature and precipitation significantly impact the distribution pattern of *R. microplus*. The resultant model indicated that bio 1, i.e. annual mean temperature, has significantly highest influence (0.0212 ± 0.0017; p<0.00001) on the occurrence of these ticks than the effects of bio12 (0.0007±0.0001; p<0.0001) and bio15 (-0.0153±0.0031; p<0.0001); however effects of bio2 (-0.0033±0.0042; p=0.427) was non-significant on its occurrence. The accuracy of this model is adjudged well by its AUC value being 0.874. On visual interpretation of the model maps, it was found that the drier regions comprising parts of Rajasthan, Gujarat and Madhya Pradesh of the country have low suitability as against those with sufficient precipitation. The temperature effects on the survivability of ticks and eggs are linked with the soil types of the country's various regions. The present study is the first attempt to present a distribution model of an important vector of livestock diseases.

**Keywords:** Distribution pattern, Ecological niche model, Generalized linear model, *Rhipicephalus microplus*, Ruminant tick

## INTRODUCTION

The importance of vectors in health sciences has been evident not only due to the direct harm they cause through biting and blood-sucking, yet their potential to transmit several deadly pathogens is much more destructive (Palraj, 2022). Veterinary insects and acarines are responsible for huge economic losses to the dairy and meat industries due to the drop in production due to the harmful effects of vectors on the animals' body (Narladkar, 2018; Ghosh and Nagar, 2014). Those harmful effects include loss of blood and vector potentiality of those insects to transmit various diseases such as bacterial, viral and protozoon (Benedict and Barboza, 2022). Also the changes in behavior of animals and restlessness are attributable to the annoyance and bites of insects and acarines (Smith *et al*., 2022). It has been reported to cause significant loss in milk production due to annoyance by *Culicoides* sp flies (Carpenter *et al*., 2015); however, economic losses attributed to ticks' infestation amounted to not less than 46100 million INR annually in India (Singh *et al*., 2022).
The tick vectors of livestock diseases are of several genera belonging to the Ixodidae family. The important

genera include *Rhipicephalus, Ixodes, Haemaphysalis, Hyalomma*, *Rhipicephalus* spp. of bovines is amongst the most important considering the transmission of several diseases of cattle and other ruminants (Singh *et al*., 2022). *Rhipicephalus annulatus* and *Rhipicephalus microplus* are the most widely reported ticks predominantly observed on cattle however have been reported from other livestock such as buffalo, horses, donkeys, dogs, deer, sheep, and goats (Pound *et al*., 2010; Kumar *et al*., 2020). These ticks are the prime vectors for two of the most economically important bovine protozoon diseases: babesiosis and anaplasmosis (da Silva *et al*., 2018). Even some other infections, such as Cremean Congo Haemorrhagic Fever (CCHF), Lumpy Skin Disease (LSD), Staphylococcosis, Ehrlichiosis have also been reported to be transmitted by those ticks (Okely *et al*., 2022). The abundance of these ticks has been reported to be high in countries with tropical and subtropical climates (Tan *et al*., 2021), where these ticks have always been a cause of concern to their dairy industry (Paules *et al*., 2018). Huge amounts of fiscal have been consumed towards controlling these ticks in those countries and several strategies are being applied globally to achieve its control (Tabor *et al*., 2017). Yet the ability of these ticks to re-emergence has raised concerns among society, for instance, re-emergence of *R. annulatus* in The United States even after its successful eradication program carried out earlier during the first quarter 20th century (Giles *et al*., 2014).

In light of its importance in terms of health concerns to livestock and its compatibility/adjustability to climatic vagaries, studying the distribution patterns of bovine *Rhipicephalus* spp tick in a particular geographic space is necessary. The species distribution modeling (SDM) approach has been considered an effective tool to predict the distribution of particular species in a landscape on the backdrop of influencing ecological factors such as biotic, abiotic, climatic as well as demographics and human interference (Sofaer *et al*., 2019). The utility of SDMs in conservation biology has been widely reported and acknowledged (Camaclang *et al*., 2015; Scott and Jens-Christian, 2018). In agriculture, it was found useful tool to map the historical and predict the future distributions of insect pests by employing various species distribution models (Perennes *et al*., 2023). SDMs' utility in epidemiological studies has been explored though with scattered reports. However, its importance in studying the ecological modeling of vectors and vector-borne diseases has been reviewed by several authors (Carvalho *et al*., 2017; ). In recent years, several studies on the ecological niche modeling of ticks have been conducted throughout the globe to predict the potential distribution of those species (Kopsco *et al*., 2022). In view of the lack of any such report from India, the present study is an attempt to estimate the potential distribution of an important tick vector viz. *Rhipicephalus microplus,* using species distribution modeling approach to identify their suitable niches in India.

## MATERIALS AND METHODS

### Methodology

### Species occurrence data

The worldwide occurrence records of *R. microplus* ticks were obtained from Global Biodiversity Information Facility (GBIF). The occurrence data were downloaded with the help of "*dismo*" package in R and then the data of occurrences were thinned to obtain their geographic locations. The pseudo-absence data were also obtained with the help of the same package as mentioned earlier.

### Environmental data

Data on the various bioclimatic variables were downloaded from the WorldClim website (www.worldclim.org). WorldClim variables hosts' information on climatic data for 1950–2000 in raster format. However, for the present study, only four important variables viz. Bio1 (Annual Mean temperature), Bio2 (Mean diurnal range of temperature), Bio12 (Annual precipitation) and Bio15 (Precipitation seasonality) were used for model building considering the most [potential impact of these variables in the determination of ticks occurrences.

### Species distribution modeling

The ecological niches were determined by using a generalized linear model in "*dismo*" package of R (Hijmans *et al*., 2015). Initially, the data on species occurrences and bioclimatic variables were entered and locations were mapped. Then the model was built using 'glm' command and the comparative contribution of each variable used for modeling was obtained and presented. The model was evaluated with the help of AUC (Area under curve) of the ROC (Receiver operating characteristics) plot. AUC measured in percentages measures model performance and varies from random to perfect discrimination (Swets, 1988; Fawcett, 2006). The final model obtained was then cropped for India, including adjoining sub-continental regions and presented through maps. All the analyses were done with different packages of spatial data analysis and species distribution modeling in R software.

## RESULTS

Overall, 1208 occurrence records were used for the present species distribution model. However, background points, *i.e.* pseudo absence records, were 447 globally. The logistic regression model was fitted with a generalized linear algorithm for the effect of the four important climatic variables on the distribution of *R.*

*microplus*. The results of the model showed that there were significant coefficients associated positively with the variables bio1, bio12 and negatively with bio15 for the distribution of *R. micorplus* species however, as regards bio2 there was a non-significant association (Table 1). It signifies that mean annual temperature and mean annual precipitation had a significant linear relationship with the abundance of *R. microplus* and conversely, precipitation seasonality had a significant yet negative relationship with its distribution. However, mean diurnal range did not significantly affect the determinations of niches for *R. microplus*.

The model was evaluated with the AUC of ROC plot, which returned a value of AUC as 0.874, confirming that the model best fitted for determining the niches of *R. microplus* with climatic variables under the study (Fig. 1). The resultant map of the model was cropped to the extent of India, including adjoining areas of the Indian subcontinent.

The pictorial interpretation of this map revealed that the spread of *R. microplus* was higher in the west and east coastal areas, including those of Chhattisgarh, Orissa, the eastern part of Maharashtra, the south eastern part of Tamil Nadu as well as parts of West Bengal (Fig. 2). Particularly all these areas are primarily characterized by Medium-high to high rainfall. Map also reveals that most of the peninsular part of India is better suitable for propagation and survival ticks, which corresponds to ground realism as these areas hold much of the dairy animal population and exotic or crossbreds predominant among those. However, other areas, such as parts of Rajasthan, Gujarat and Bundelkhand region in the north-central part of India which are characterized by climatic conditions with high temperatures and less rainfall, have been shown to be less suitable for these ticks.

## DISCUSSION

*R. microplus* is a one-host tick widely distributed in tropical and subtropical regions of the world (Spickler, 2022). The results of this study indicated that the Bio1, bio12 and bio15 were the most important predictor vari-

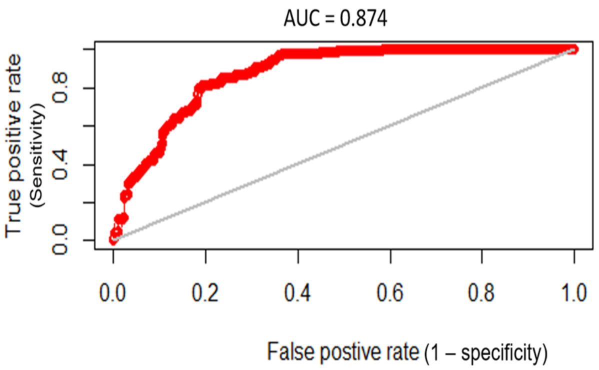


**Fig. 1.** *Receiver operating characteristics plot and area under the curve of the model*

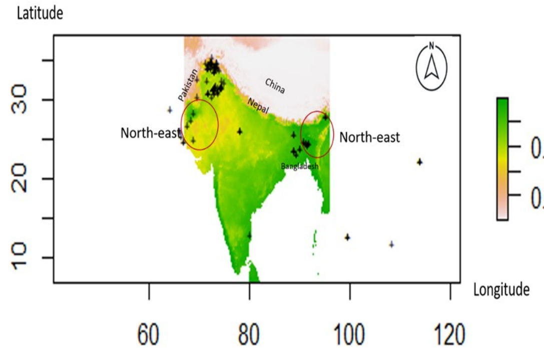


**Fig. 2.** *Spatial distribution of Rhipicephalus microplus in India and Indian subcontinent (X-axis: longitude, Y-axis: Latitude; Suitability index from pink to green, i.e. 0 (not suitable) to 1: most suitable)*

**Table 1.** Results of species distribution model for *Rhipicephalus microplus*

| | | | | | |
|---|---|---|---|---|---|
| **Deviance residuals** | | | | | |
| | **Min** | **1Q** | **Median** | **3Q** | **Max** |
| | -2.99988 | -0.06881 | 0.26576 | 0.55228 | 2.33281 |
| **Coefficients** | | | | | |
| | **Estimate** | **Std. Error** | **z value** | **P (>\|z\|)** | **Significance** |
| (Intercept) | -3.0188003 | 0.6221438 | -4.852 | 1.22e-06 | *** |
| bio1 | 0.0211717 | 0.0016988 | 12.462 | < 2e-16 | *** |
| bio2 | -0.0033957 | 0.0042707 | -0.795 | 0.427 | |
| bio12 | 0.0007023 | 0.0001482 | 4.739 | 2.15e-06 | *** |
| bio15 | -0.0153898 | 0.0031429 | -4.897 | 9.75e-07 | *** |

Signif codes: ‘***’ 0.001; ‘**’ 0.01; ‘*’ 0.05; ‘.’ 0.1; ‘ ’ 1 ables for habitat suitability of *R.microplus*. This tick species preferred habitats with high temperature and high rainfall and these results were in concurrence with the results described earlier wherein the distribution of *R. annulatus* was also found subject to similar enviornmenatl attributes globally (Okely and Al-Khalaf, 2022). The initial model output in the present study has been obtained for distribution of *R. microplus* ticks for entire world which demonstrated highest suitability in North Americas while in South America Brazil, Uruguay, Argentina and Mexico and southern United States. Also sub-Saharan Africa, Western Europe, Southeast Asia and Coastal parts of Australia were also reported highly suitable for propagation of *R. microplus* (Marques *et al*., 2020). As regards distribution of *R.microplus* in India, the areas in northwestern part of the country showed low suitability which may be attributed high degree of temperature (mean annual average of 37.7 ºC) yet very low levels of environmental moistures and overall precipitation (mean annual average of 200-400mm) this area receives throughout the year. However the scattered studies have reported the infestation of these ticks to cattle of these areas *i.e.* from the states of Rajasthan and Gujarat (Kumar *et al*., 2022) which also alarms about possibility of other factors responsible for its presence (Burtis *et al*., 2016). These factors may include cattle density, presence of susceptible host populations, individual hosts' immunity and sometimes may be invasiveness of the tick itself (Asmaa *et al*., 2014; Rehman *et al*., 2017; Patel *et al*., 2019). This is the first study in India which predicted the distribution of *R.microplus* by projecting the results of a generalized linear model (GLM) for species suitability based on occurrence records of this tick throughout the world. The influence of four important bioclimatic factors on the tick occurrence was estimated and suitability across the area was identified. The growth and survivability of ticks and their intermediate stages are subjected to conducive environmental factors such as moisture, humidity, and soil types, which also enfluence the retension of sufficient moisture (Santiago *et al*., 2022). For instance, sandy or arid soils predominant in deserts of Rajasthan and Gujarat, are detrimental to the growth of ticks and survivability of eggs of ticks as the low moisture levels in such soil easily desiccate the eggs and adults stages of ticks (Greenfield, 2011). On the contrary, alluvial and red/ balck soils predominant in peninsular India and the eastern part of India favours the growth (D'Alessandro *et al*., 2014). Several researchers have reported that secreted fatty layers around the eggs laid by female ticks are dissolved earlier in hot and drier climates than in moist and humid climates (Booth, 1992; Sutherst and Bourne, 2006; Ogden and Lindsay, 2016). This phenomenon also supports the findings of the present study depicting the more suitability of tick propagation in the moist and humid areas such as peninsular India and southeastern part of the country (Mondal *et al*., 2013).

Considering the fact that transmission and other epidemiological features of babesiosis and anaplasmosis are contingent on the presence and dispersion of its vector, *i.e. R. microplus* tick; it is pertinent that the same environmental factors are related to these protozoon diseases as they are with tick itself (Jaenson and Lindgren, 2010; Tokarevich *et al*., 2011; Ghosh and Nagar, 2014). Also, some wild reservoir hosts and domestic reservoirs, such as goats are important for the dispersal of this tick species (Khaskheli, 2020). Temperature and rainfall are reported to be the most important driving factors for the distribution of this tick (Estrada-Peña *et al.,* 2006; Sungirai *et al.,* 2018). The laboratory cultivations studies also seconded this fact as this tick prefers warm and humid conditions (De Clercq *et al.,* 2012). Earlier reports also demonstrated that area with high altitudes has low suitability for *R. microplus* distribution, which may be attributed to apparently colder climates in areas unfavorable for eggs of *R. microplus* (Lyanen *et al*., 2008; Sutherst and Bourne, 2006). The present study depicts the first model for this important tick vector from India. However, it has certain limitations also. First, very few sets of bioclimatic variables used for the model building may have constraining outcomes of the model. Secondly, the climate change scenarios have not been considered in the present study. However, these results were useful in identifying the probable expansion of this important tick vector of livestock. The results are also helpful for veterinary epidemiologists in planning preventive control measures.

## Conclusion

It was concluded that the generalised linear model (GLM) for establishing the niches of *R. microplus* ticks in India revealed the significant impact of temperature and rainfall on their distribution. The peninsular part and southeastern region of India were found to be highly suitable for these ticks; however northwestern region of India was found to be less likely suitable for the propagation of these ticks. This is first of its kind attempt to incorporate environmental variables to study the distribution of a vital livestock tick on a national scale. This model may also be improved by incorporating country-specific data and more occurrence points through primary studies.

## Conflict of interest

The authors declare that they have no conflict of interest.

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