Supplementary Information

Mapping ticks and tick-borne pathogens in China

Zhao et al.

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Supplementary Notes

Supplementary Note 1: The integrated database for tick species and tick-borne pathogens

Through literature review, we found a total of 8,953 references, 3,859 in English and 5,094 in Chinese, which met our search criteria. With consensus of two independent reviewers, 605 publications met our study inclusion criteria and were used for data extraction, of which 324 reported detection of tick-borne agents (Supplementary Fig. 44).

After pooling data from all sources, we obtained an integrated database of 7,344 tick records, and 2,060 tick-borne pathogen records. For tick genus, we assembled 1,943, 1,738, 1,163, 1,069, 1048, 193, 112, 68, and ten occurrence records for *Heamaphysalis, Dermacentor*, *Ixodes*, *Rhipicephalus*, *Hyalomma, Argas, Amblyomma*, *Ornithodoros*, and *Anomalohimalaya*, respectively. Supplementary Data 1 shows the numbers of occurrence counties used in our analyses for each tick species.

Supplementary Note 2: The locations of each specific agent in ticks in mainland China

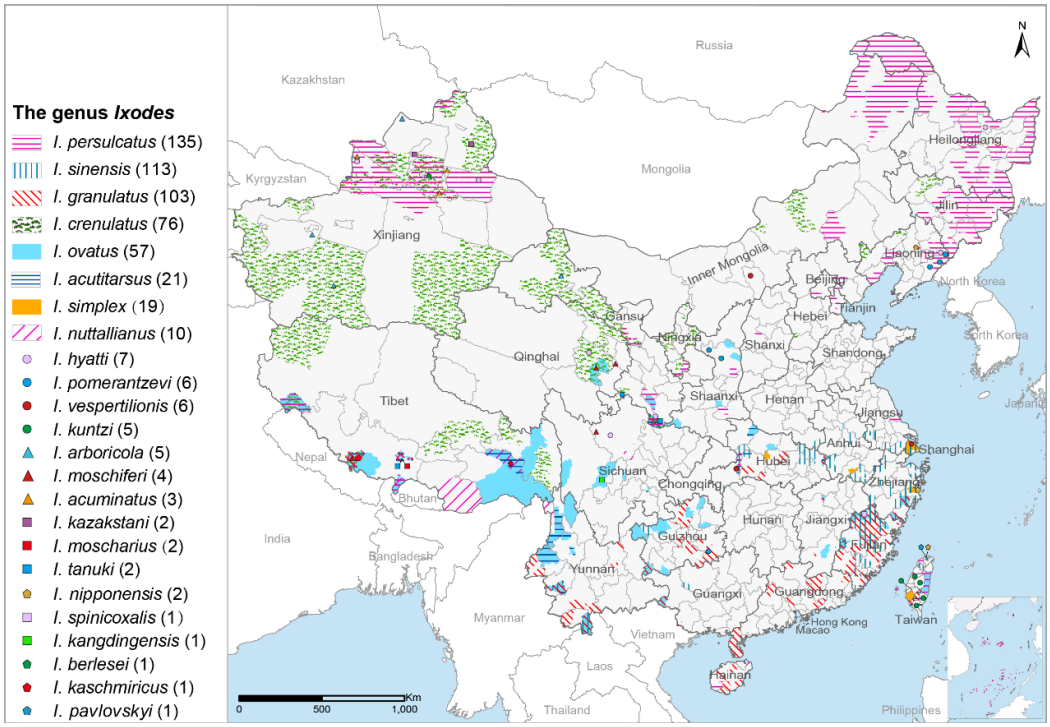
We georeferenced and mapped recorded locations with positive detection of 103 tick-borne agents from 54 tick species in China, including 22 *Rickettsia* species, 18 *Anaplasmataceae*, 12 *Borrelia*, 18 *Babesia* spp., seven *Theileria*, 19 viruses, seven bacteria including *Coxiella burnetii, Francisella tularensis, Colpodella* spp., *Bartonella* spp., *Alcaligenes faecalis, Brucella abortus* and *Brucella melitensis* (Fig. 3). Altogether, 22 species or subspecies of *Rickettsia* were detected from 28 species of ticks, with *R. raoultii, R. heilongjiangensis*, and *R. sibirica* being the most common species detected from ticks in mainland China (Supplementary Fig. 35). A total of 18 species or subspecies in the *Anaplasmataceae* were detected from 26 species of ticks,

the distribution of which covers a wide range of forest areas in northeastern, northwestern and northern China, as well as some areas in central and southern China (Supplementary Fig. 36). *Borrelia*, the earliest reported tick borne pathogens in China, had a high frequency of literature reporting. Altogether 12 species of *Borrelia* were detected from 31 tick species, mainly distributed in the forest areas of northeastern, northwestern, and central-southern China. *B. burgdorferi* sensu stricto and *B. garinii* were the two most commonly seen species of *Borrelia*, both of which were detected in a variety of tick species (Supplementary Fig. 37). Eighteen *Babesia* species were detected in 20 tick species, which were mainly distributed in pastoral or semi-pastoral areas of northeastern, northwestern and central China. It is interesting to note that, despite the rich variety of *Babesia* species, their geographic distribution was rather limited. Except for *Ba. microti*, most *Babesia* species were reported only in local areas (Supplementary Fig. 38). Seven *Theileria* species were detected from 13 tick species mainly in northwestern and central-eastern China, and *T. annulate* appeared to the most common species. Two other species, *B. persica* and *B. latyshevyi*, were only detected from the tick species of *O. papillipes* and *O. tartakovskyi*, spatially confined to the Xinjiang Uygur Autonomous Region in northwestern China (Supplementary Fig. 39). Seven bacteria were detected from 18 tick species. *F. tularensis* and *C. bumetii*, were detected from five and 14 tick species respectively, which were distributed in forest patches across northeastern and northwestern China (Supplementary Fig. 40). Nineteen viruses were detected from 20 tick species. TBEV was mainly detected from five tick species in northeastern and northwestern China, with *I. persulcatus* as the dominant host tick species. CCHFV was exclusively detected from *Hy. asiaticum* in the Xinjiang Uygur Autonomous Region of northwestern China. SFTSV was detected from four tick species (*Ha. longicornis*, *Ha.*

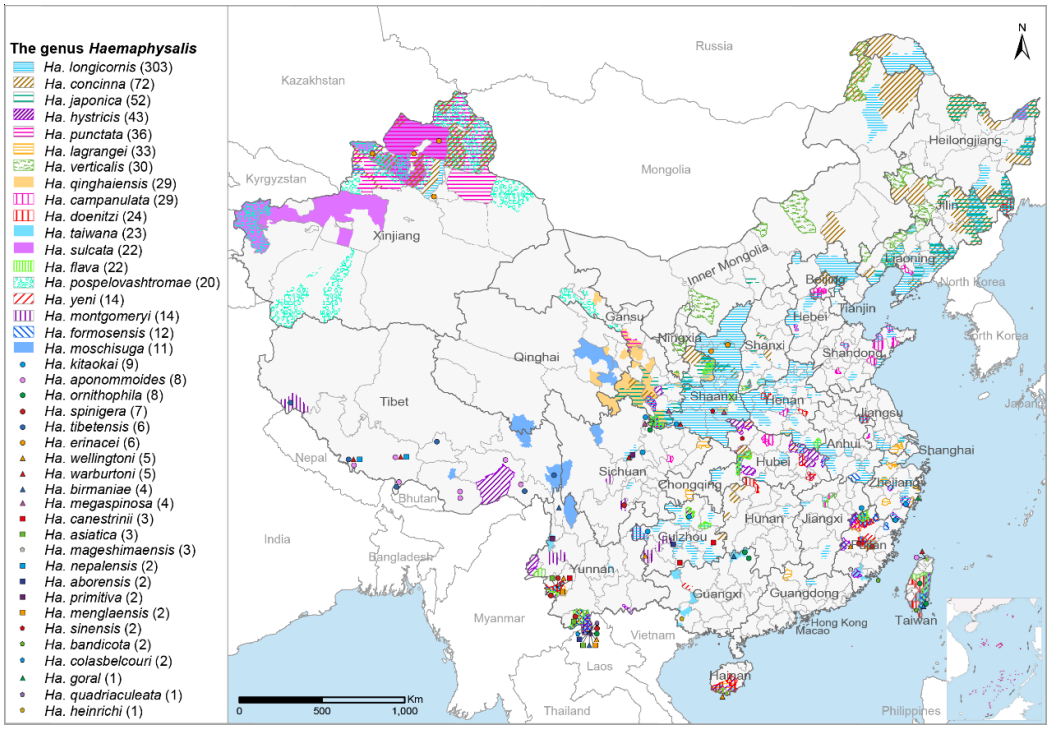
concinna, *R. sanguineus* and *R. microplus*) in its ecological niches in eastern and central China (Supplementary Fig. 41).

Supplementary Figures:

Supplementary Fig. 1 The spatial distribution of the 1,134 counties with at least one record of ticks (yellow) from 1950 to 2018, China. Source data are provided as a Source Data file.

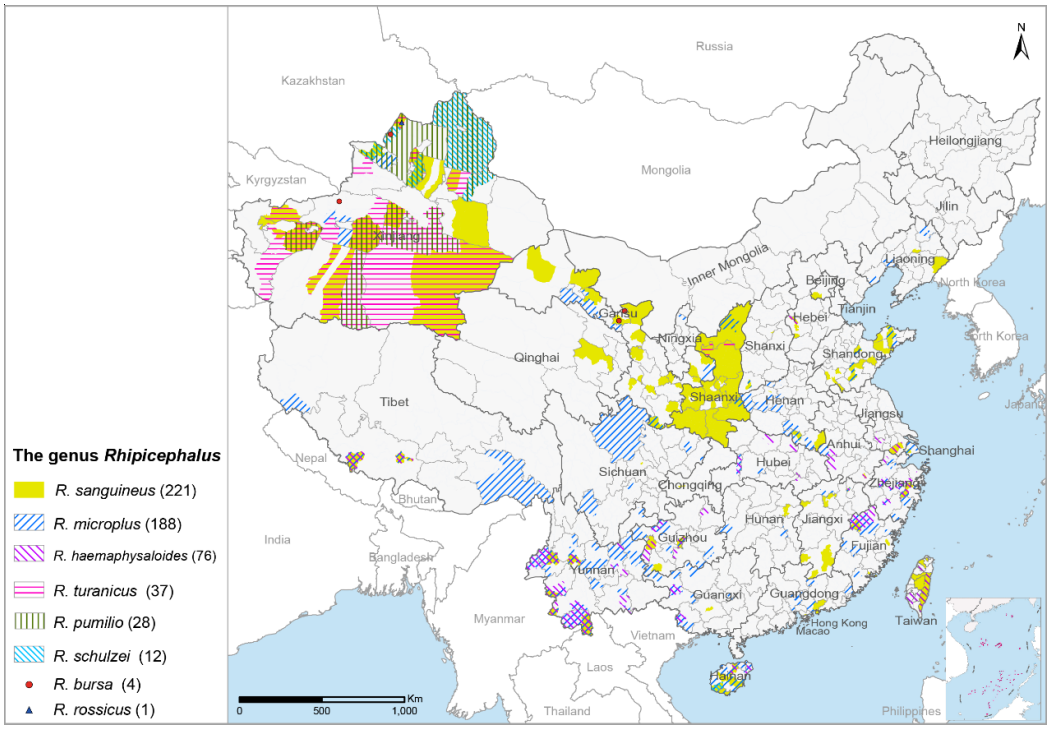


Supplementary Fig. 2 The spatial distribution of the tick genus *Ixodes* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.

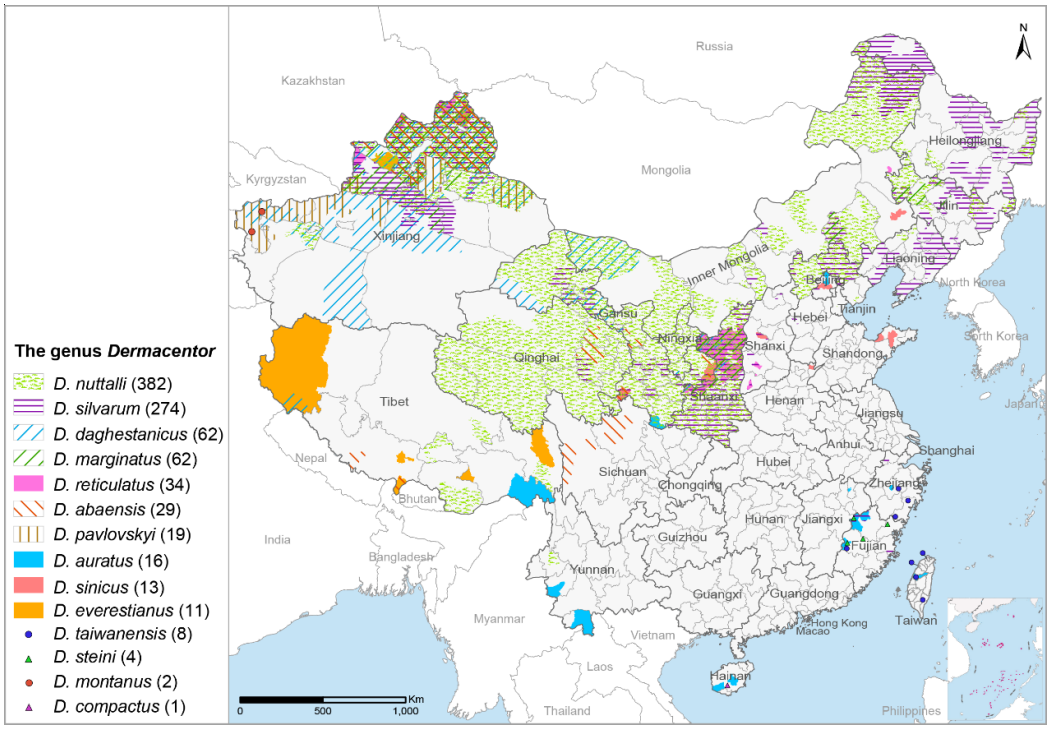


Supplementary Fig. 3 The spatial distribution of the tick genus *Haemaphysalis* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.

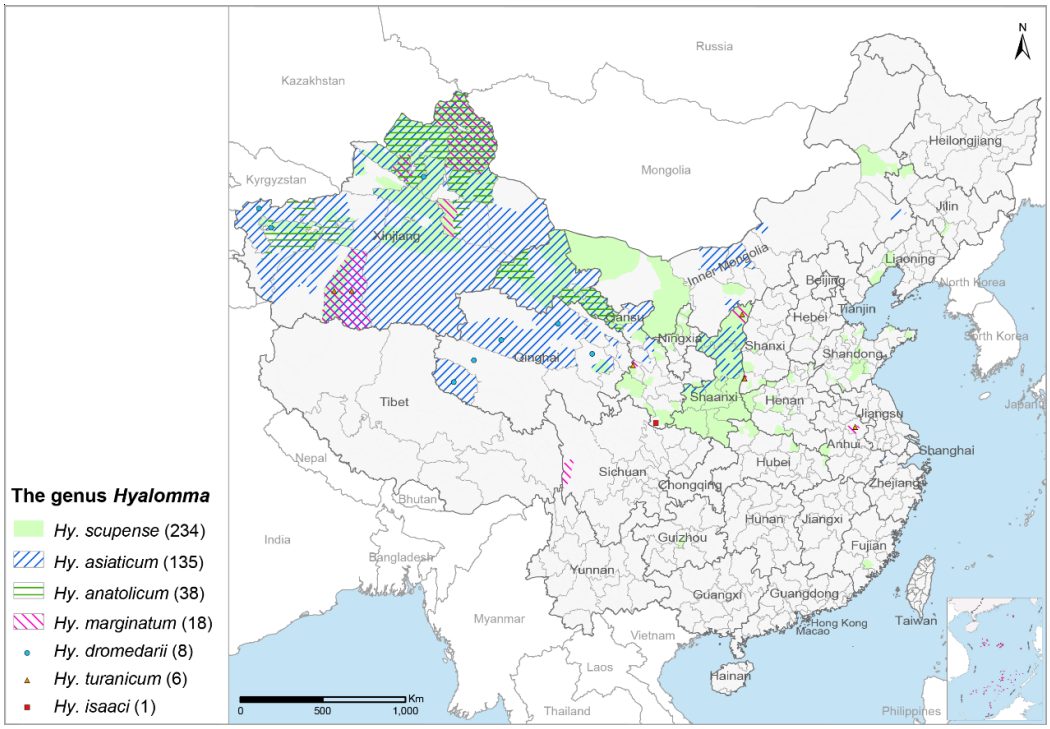
Supplementary Fig. 4 The spatial distribution of the tick genus *Amblyomma* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



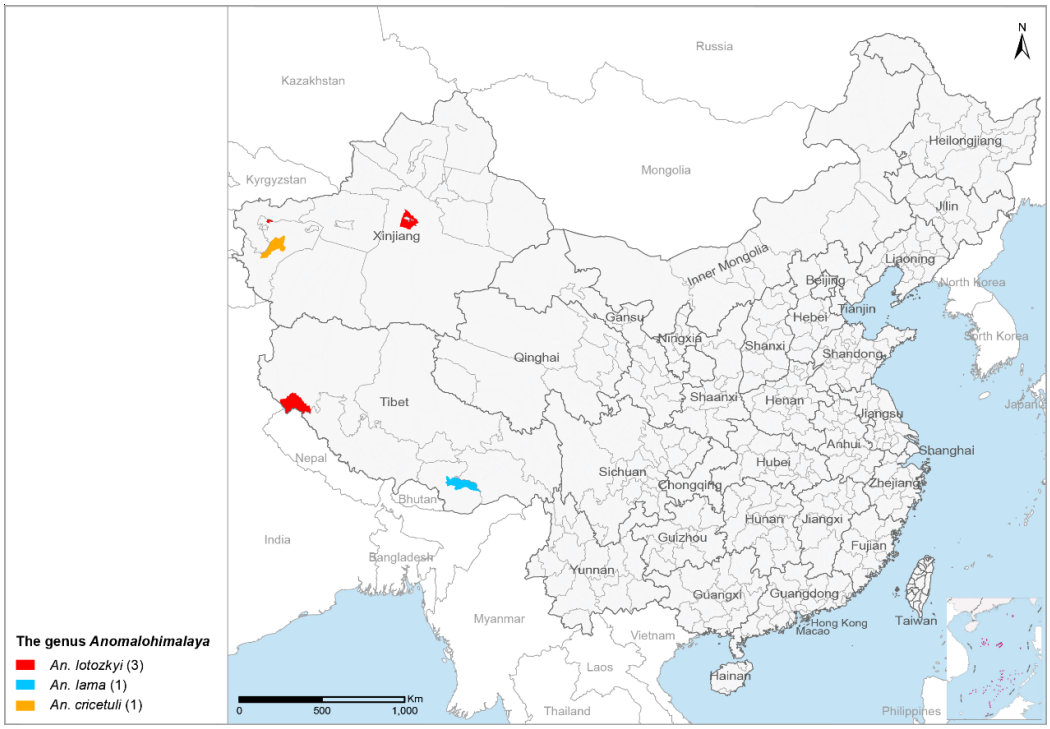
Supplementary Fig. 5 The spatial distribution of the tick genus *Rhipicephalus* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



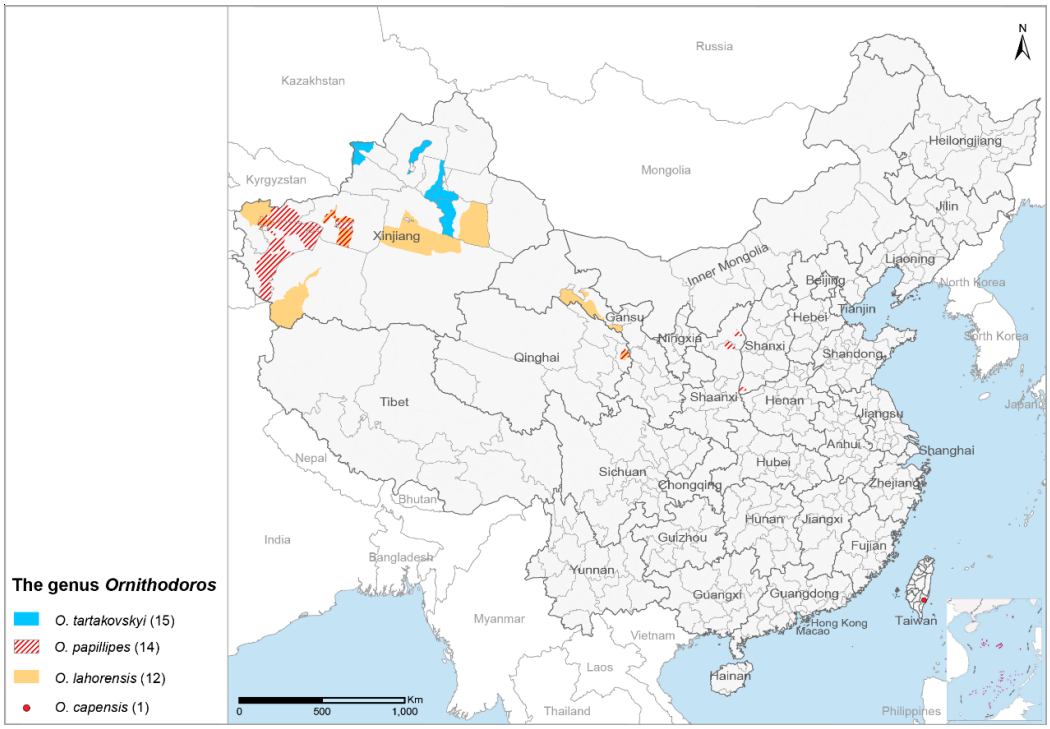
Supplementary Fig. 6 The spatial distribution of the tick genus *Dermacentor* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



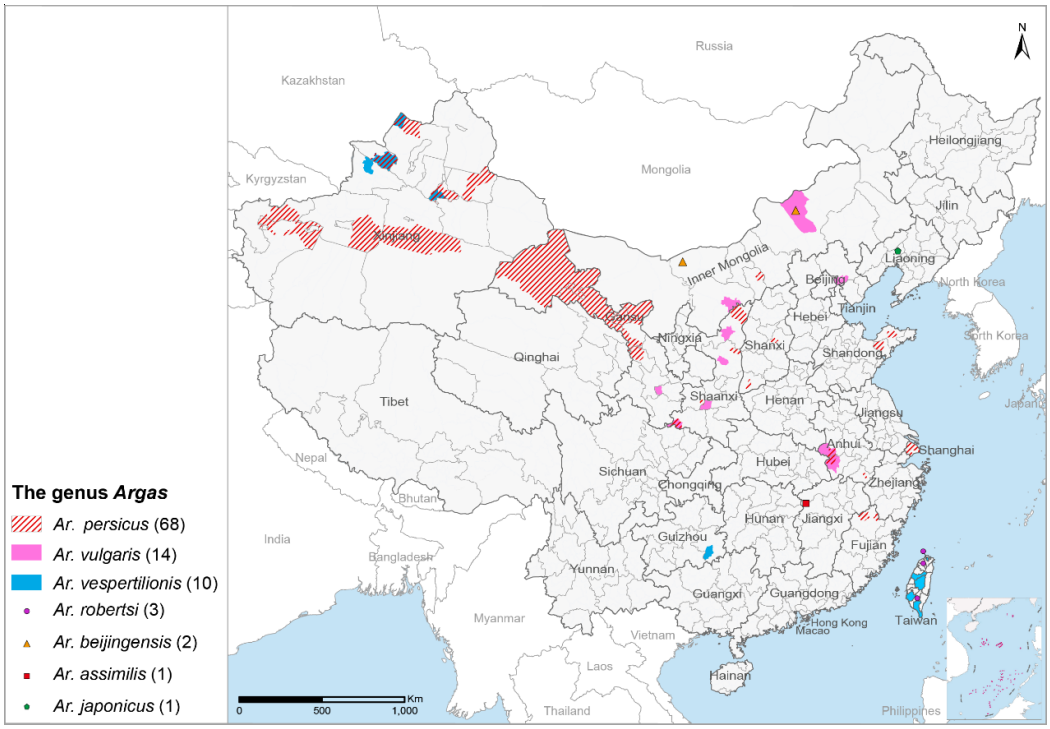
Supplementary Fig. 7 The spatial distribution of the tick genus *Hyalomma* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



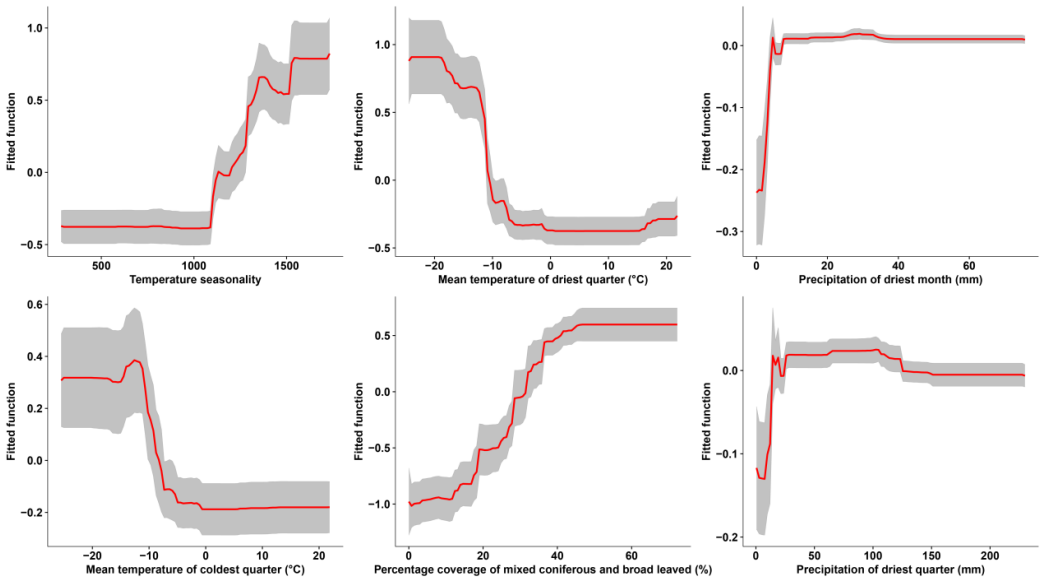
Supplementary Fig. 8 The spatial distribution of the tick genus *Anomalohimalaya* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



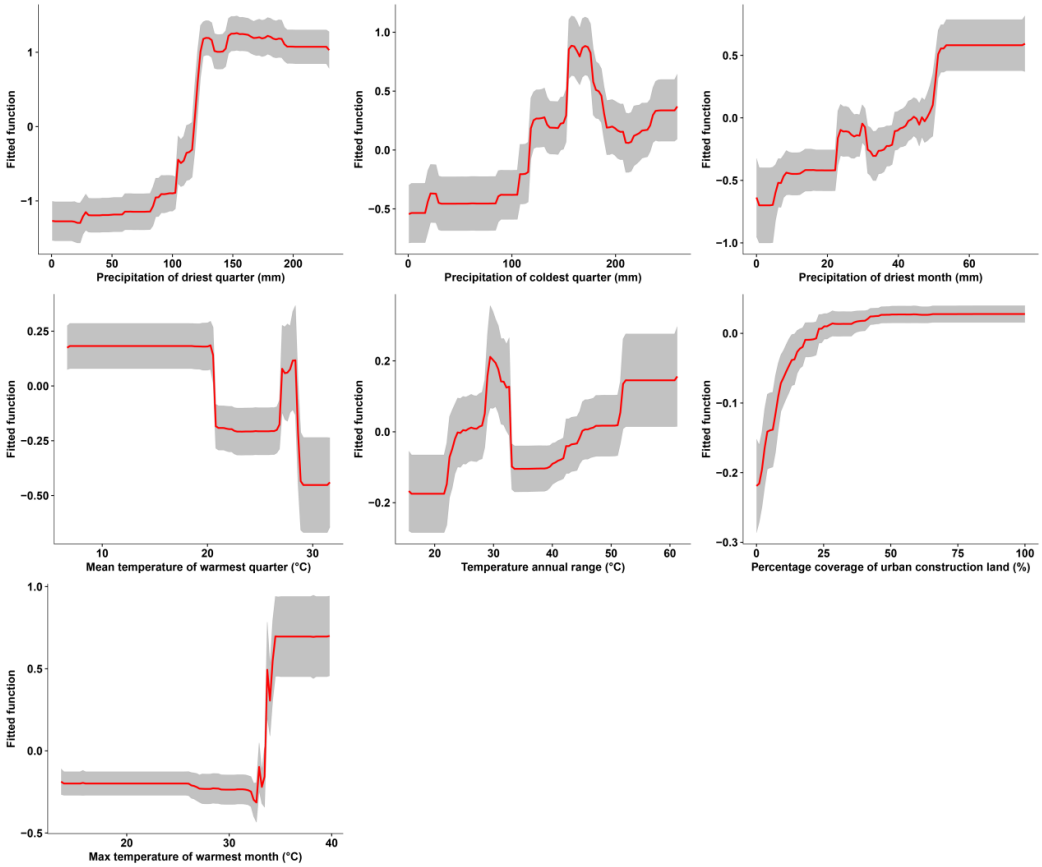
Supplementary Fig. 9 The spatial distribution of the tick genus *Ornithodoros* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



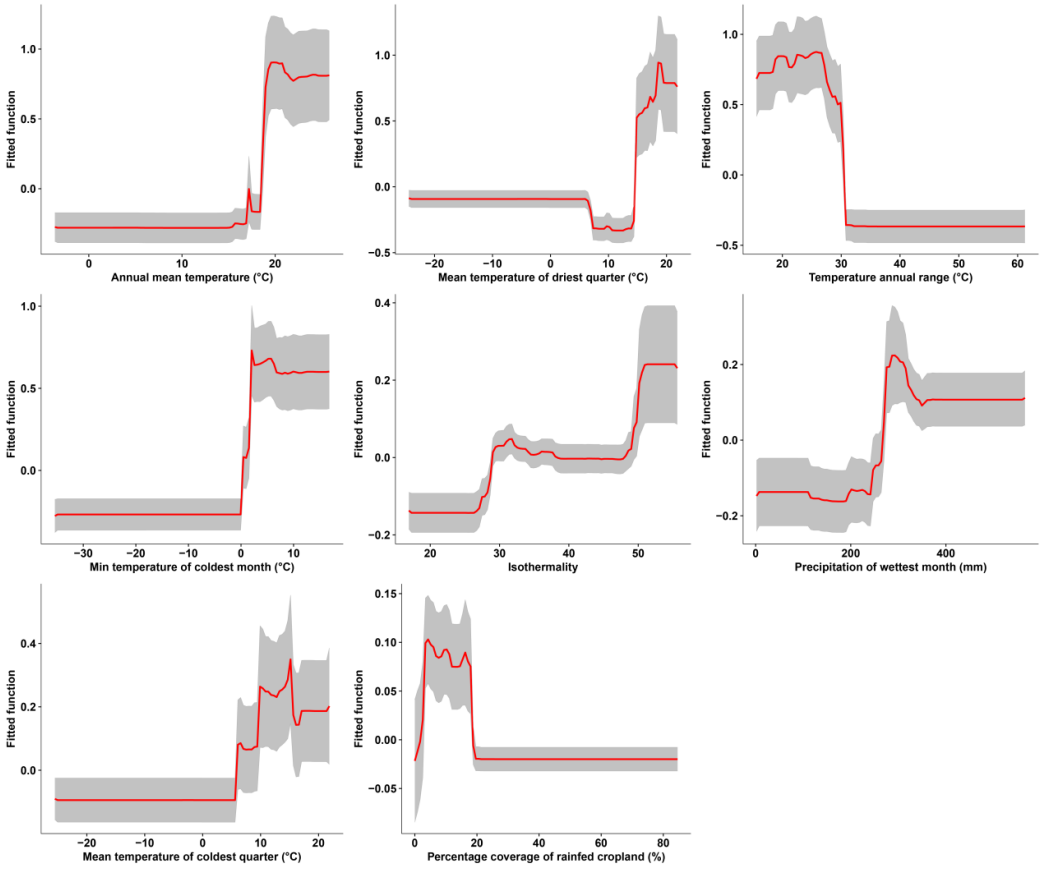
Supplementary Fig. 10 The spatial distribution of the tick genus *Argas* recorded at the county level from 1950 to 2018 in China. Source data are provided as a Source Data file.



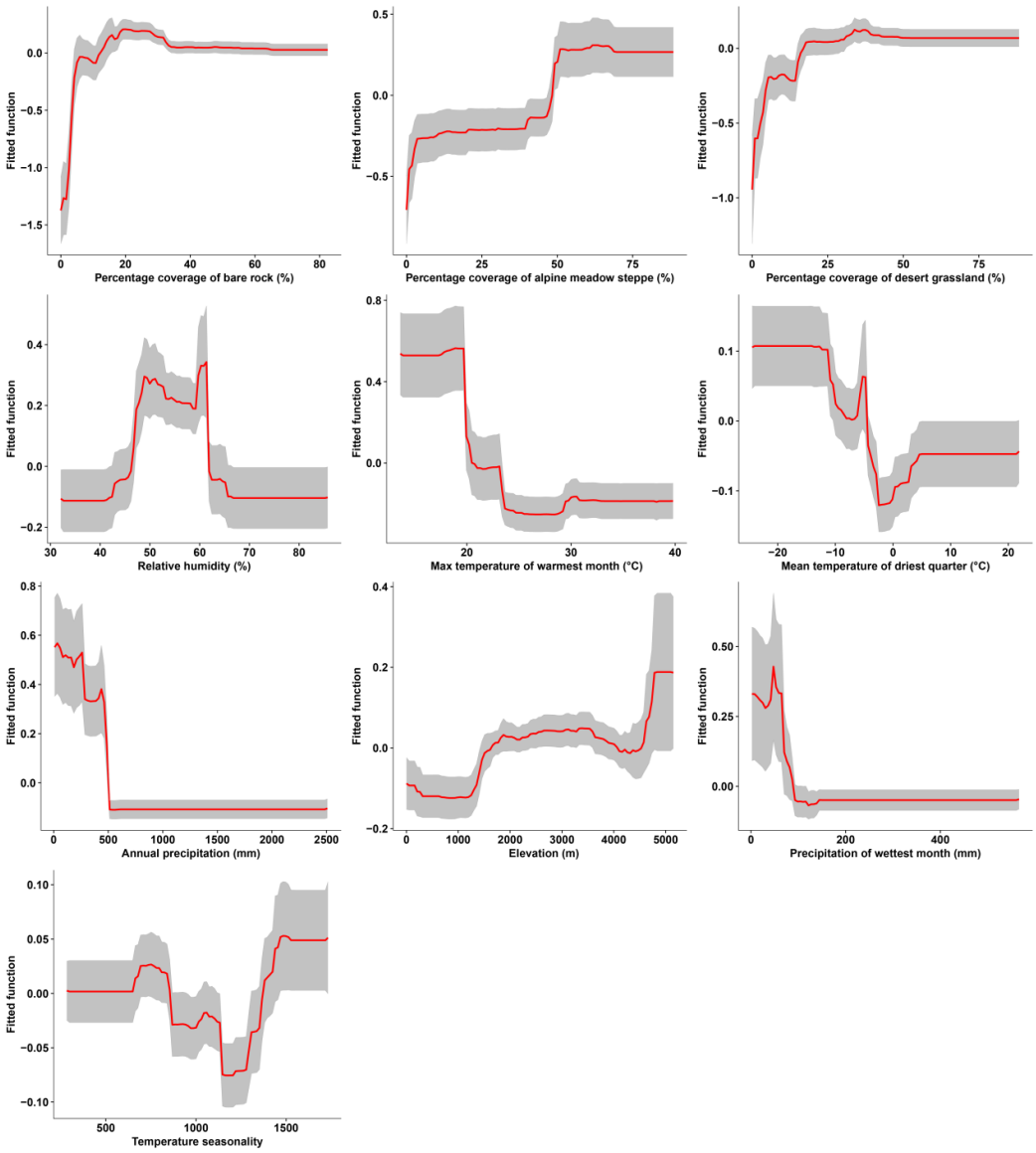
Supplementary Fig. 11 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *I. persulcatus* based on the ensemble of BRT models.



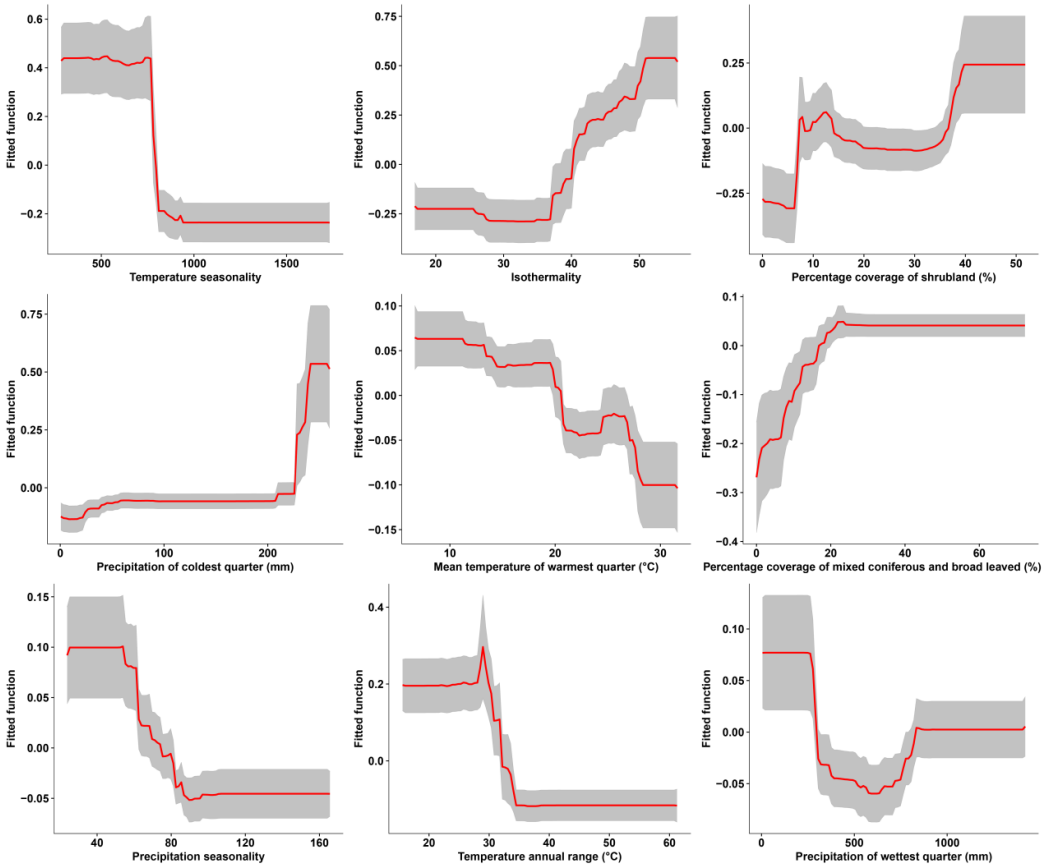
Supplementary Fig. 12 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *I. sinensis* based on the ensemble of BRT models.



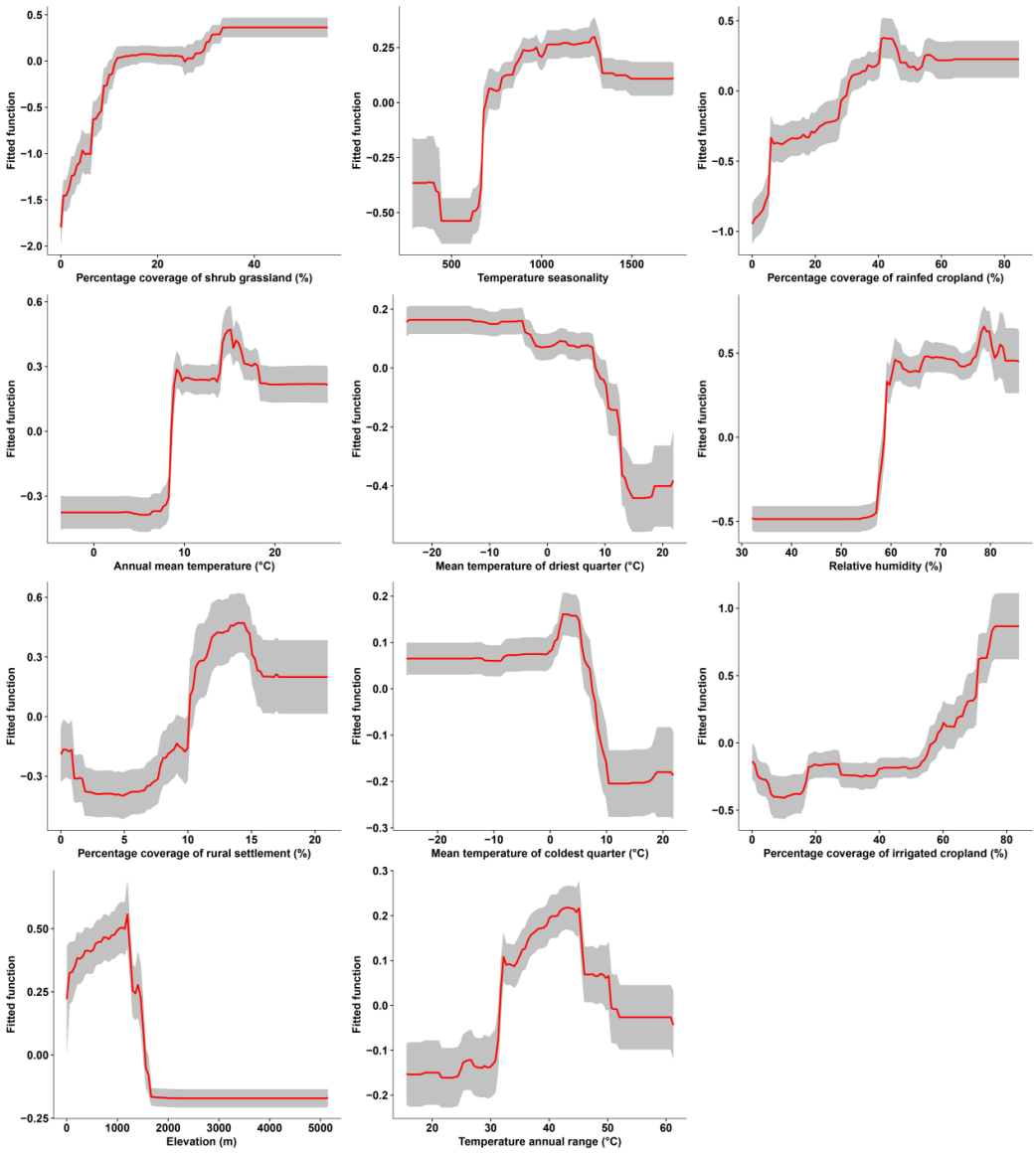
Supplementary Fig. 13 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *I. granulatus* based on the ensemble of BRT models.



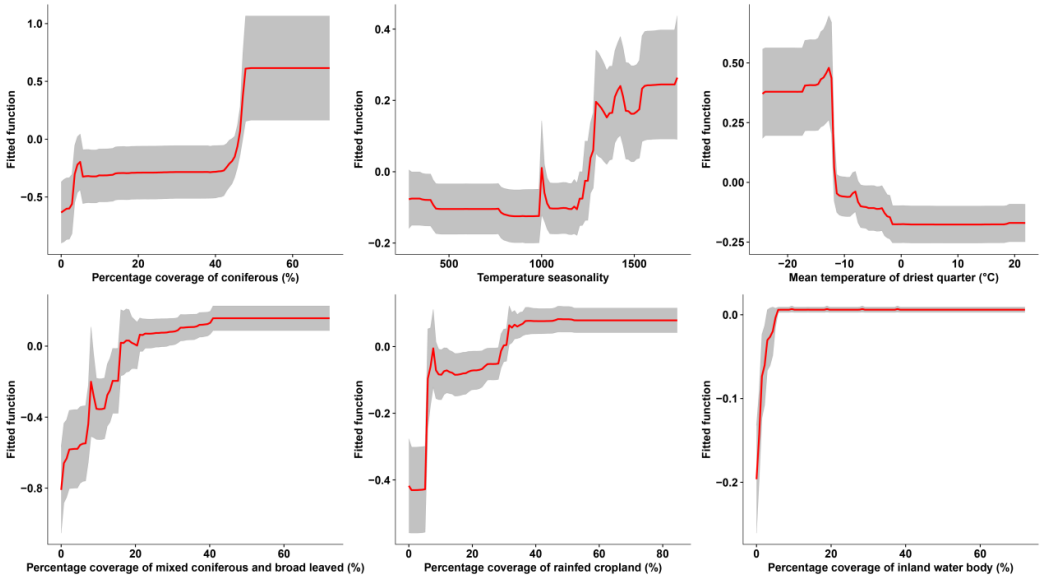
Supplementary Fig. 14 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *I. crenulatus* based on the ensemble of BRT models.



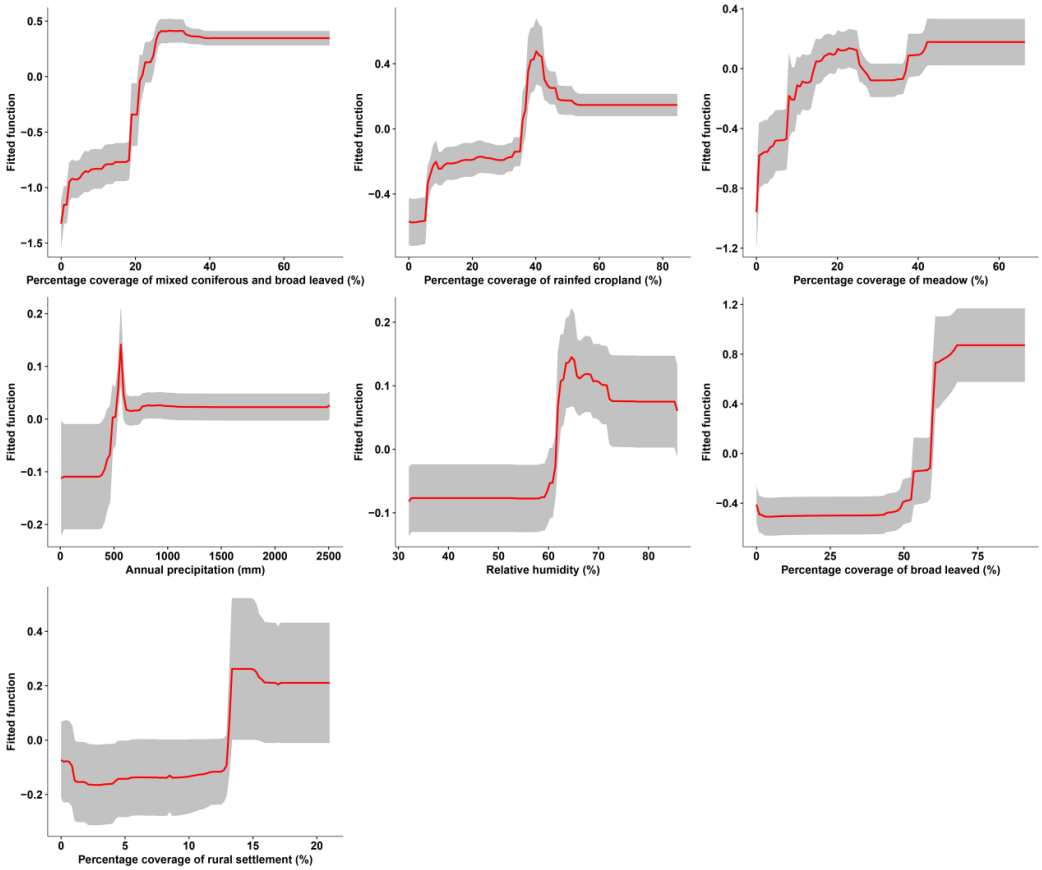
Supplementary Fig. 15 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *I. ovatus* based on the ensemble of BRT models.



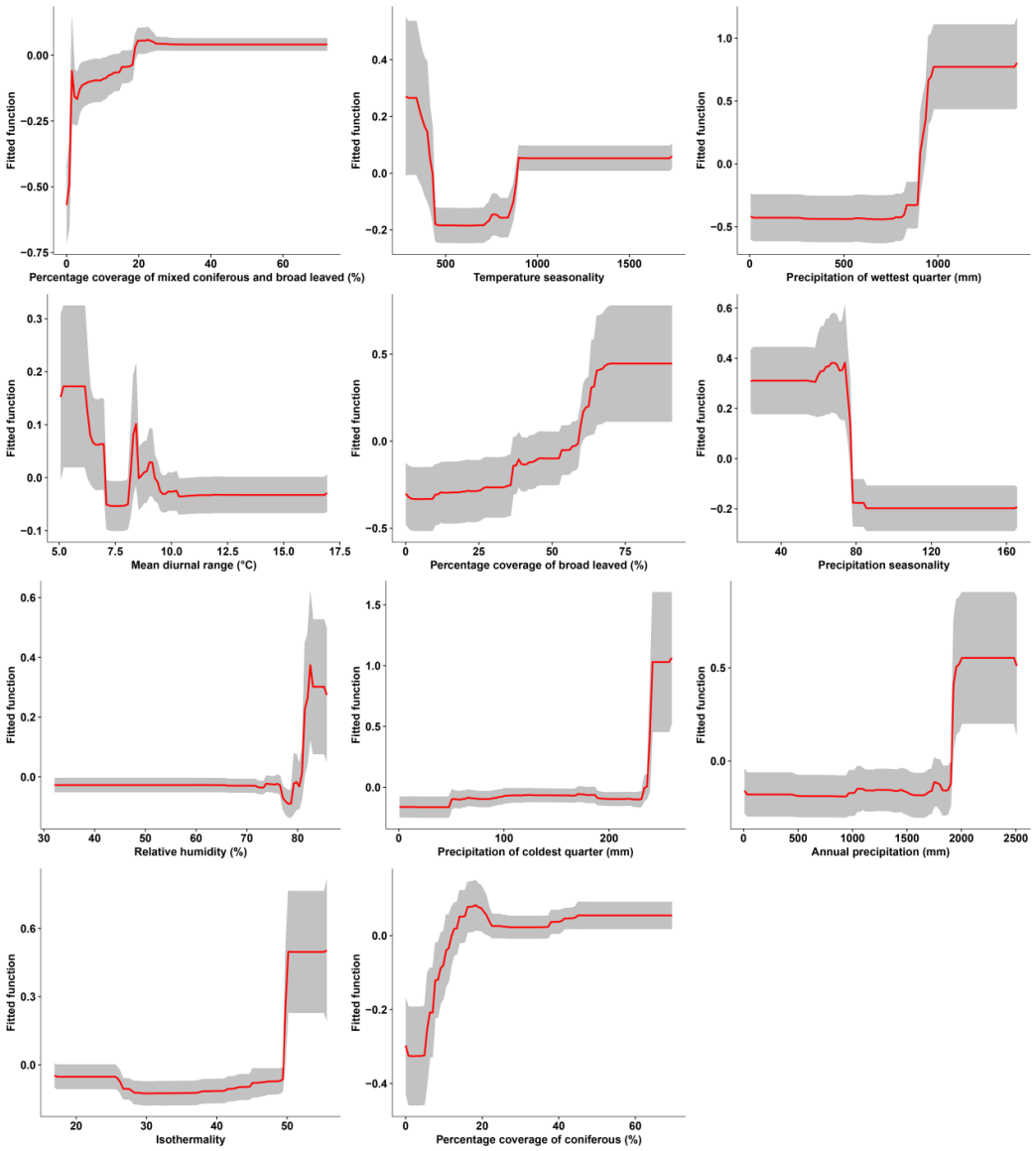
Supplementary Fig. 16 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Ha. longicornis* based on the ensemble of BRT models.



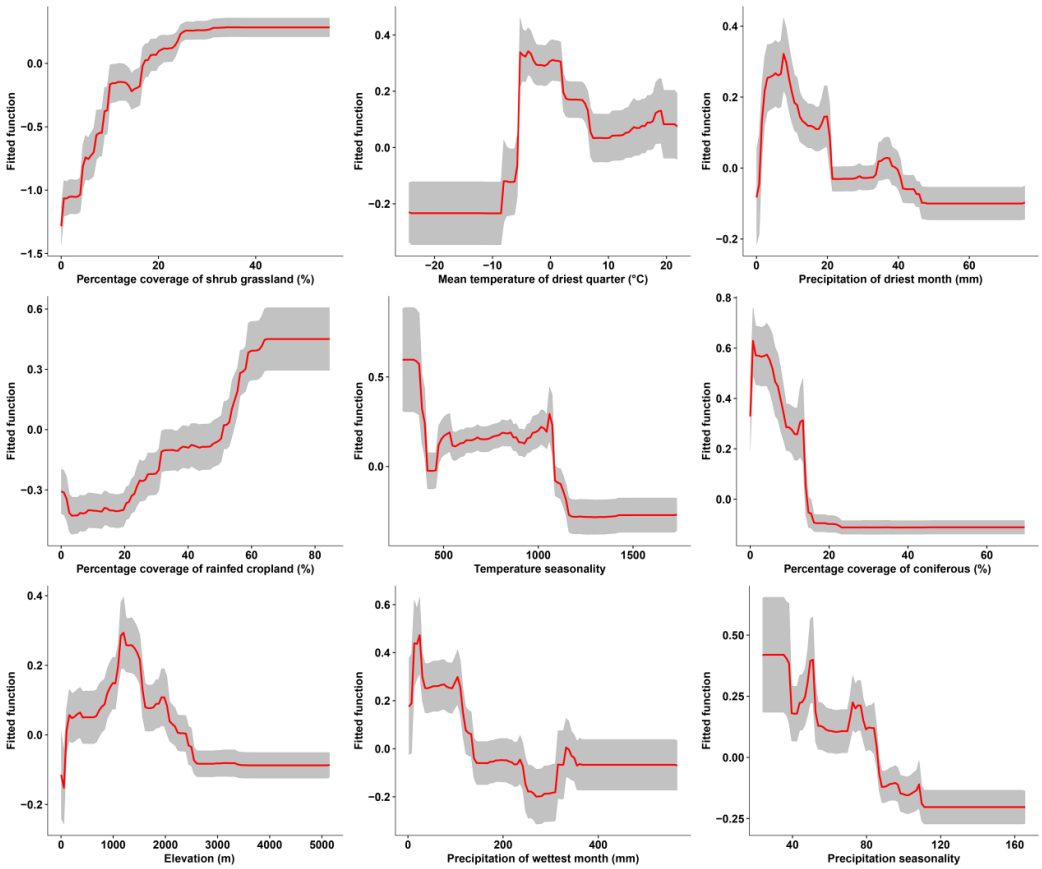
Supplementary Fig. 17 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Ha. concinna* based on the ensemble of BRT models.



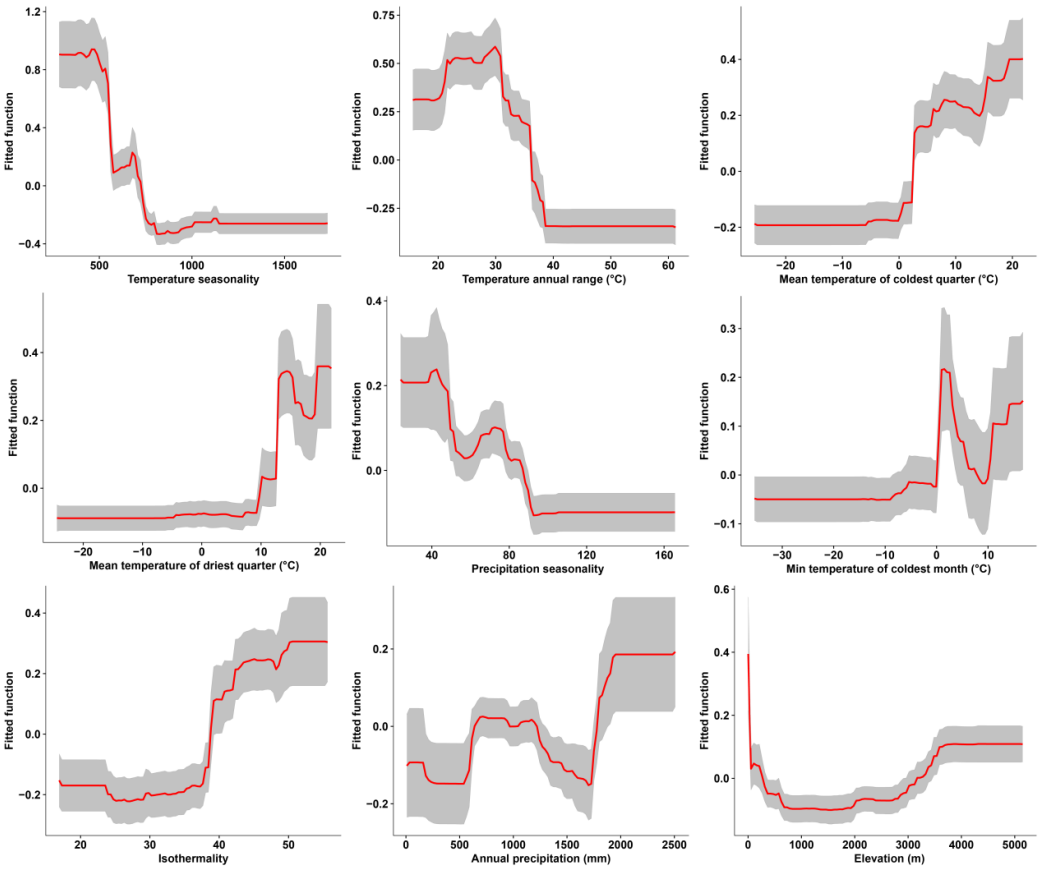
Supplementary Fig. 18 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Ha. japonica* based on the ensemble of BRT models.



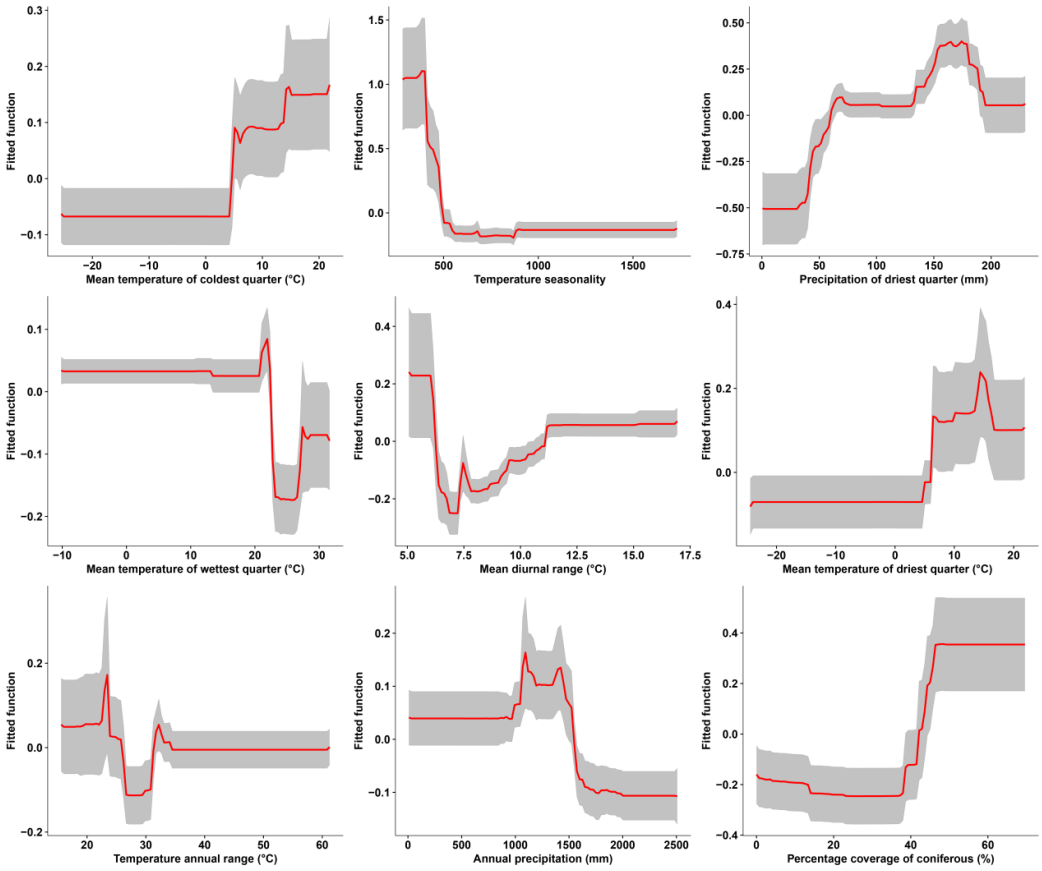
Supplementary Fig. 19 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Ha. hystricis* based on the ensemble of BRT models.



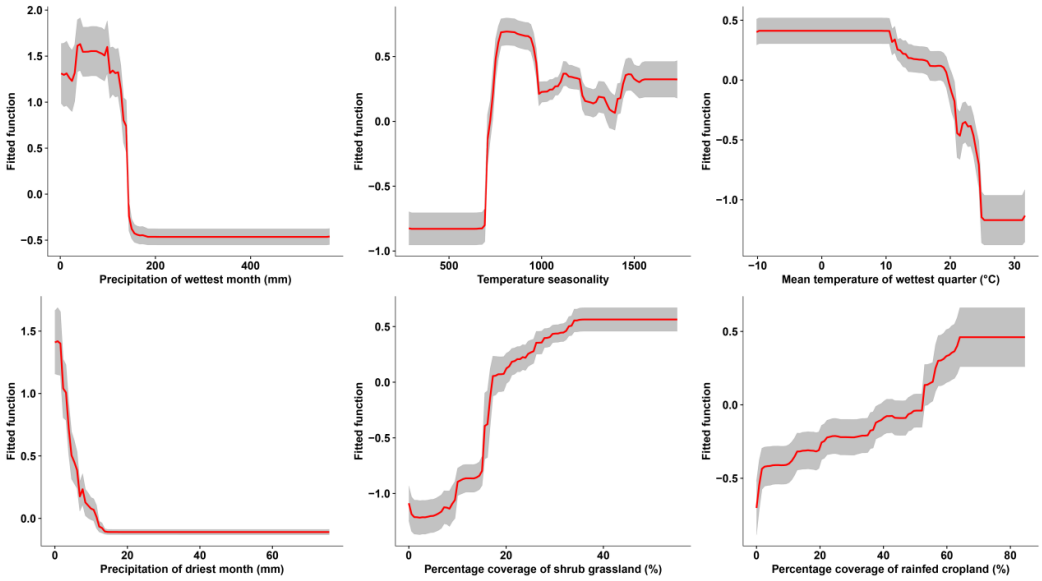
Supplementary Fig. 20 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *R. sanguineus* based on the ensemble of BRT models.



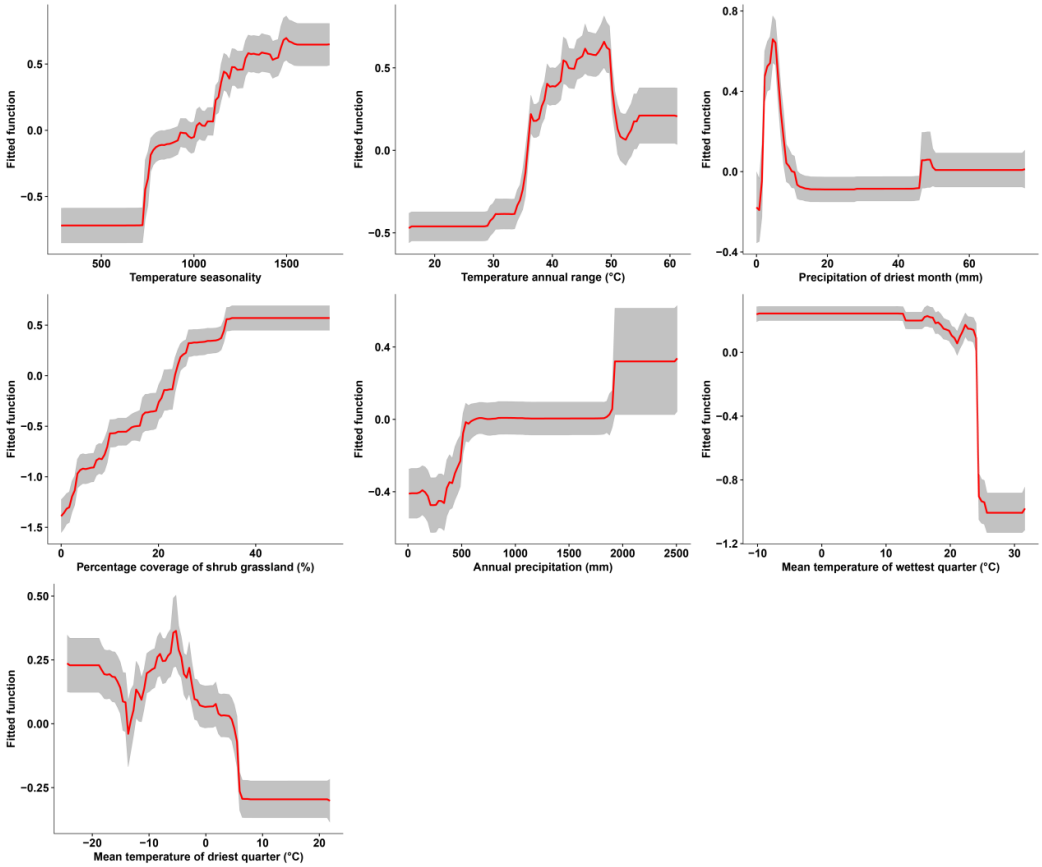
Supplementary Fig. 21 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *R. microplus* based on the ensemble of BRT models.



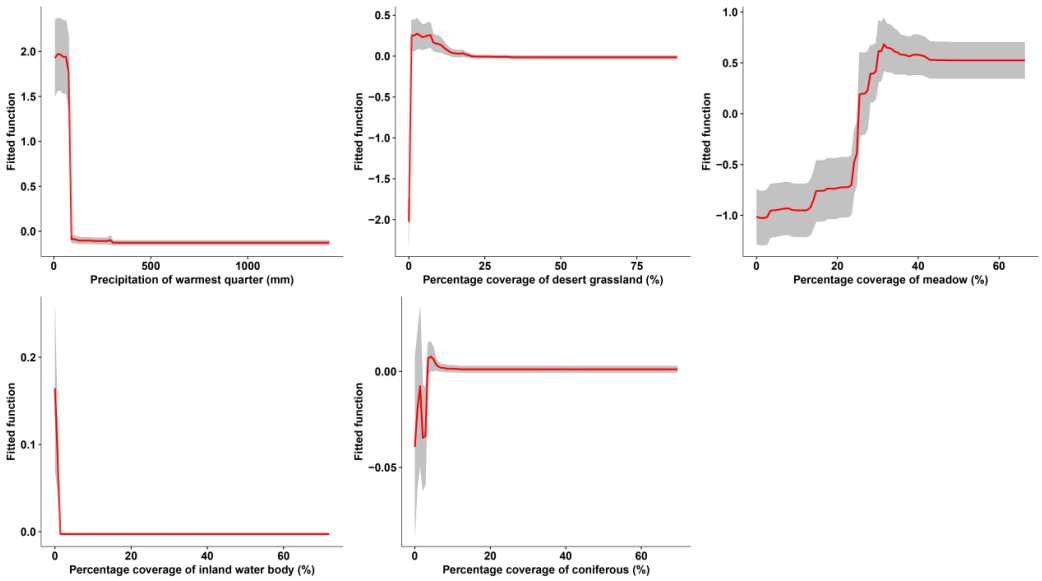
Supplementary Fig. 22 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *R. haemaphysaloides* based on the ensemble of BRT models.



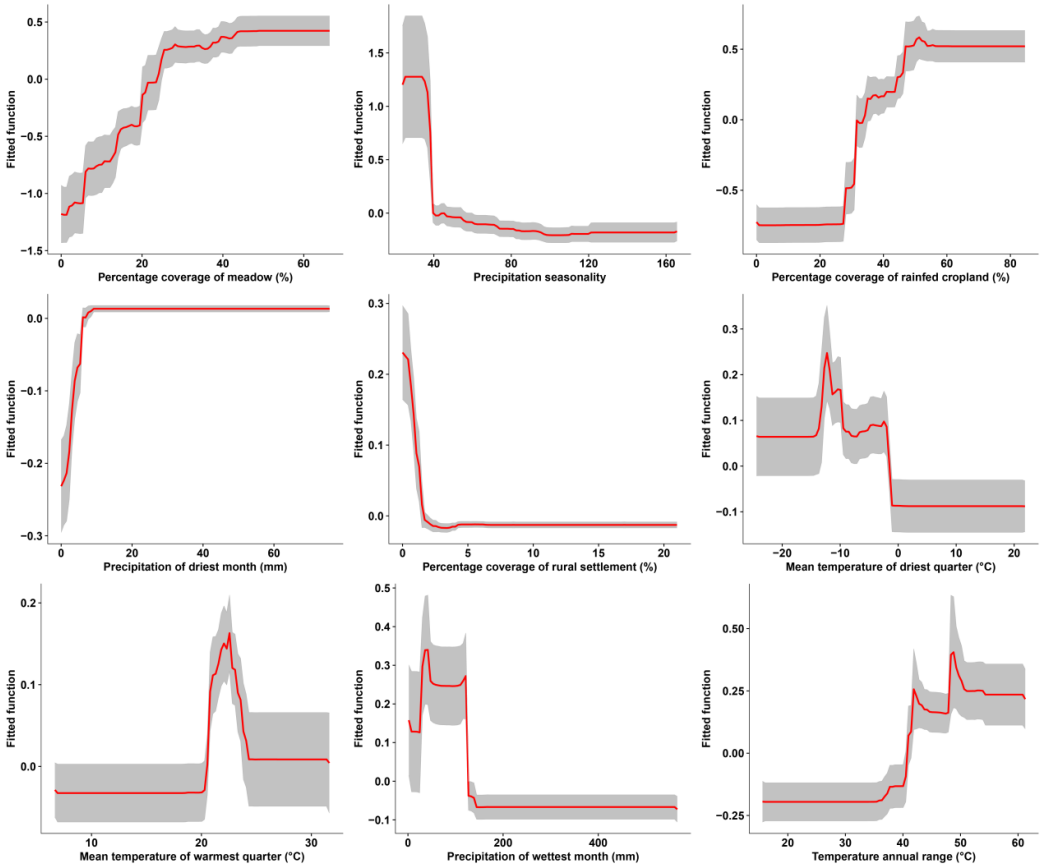
Supplementary Fig. 23 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *D. nuttalli* based on the ensemble of BRT models.



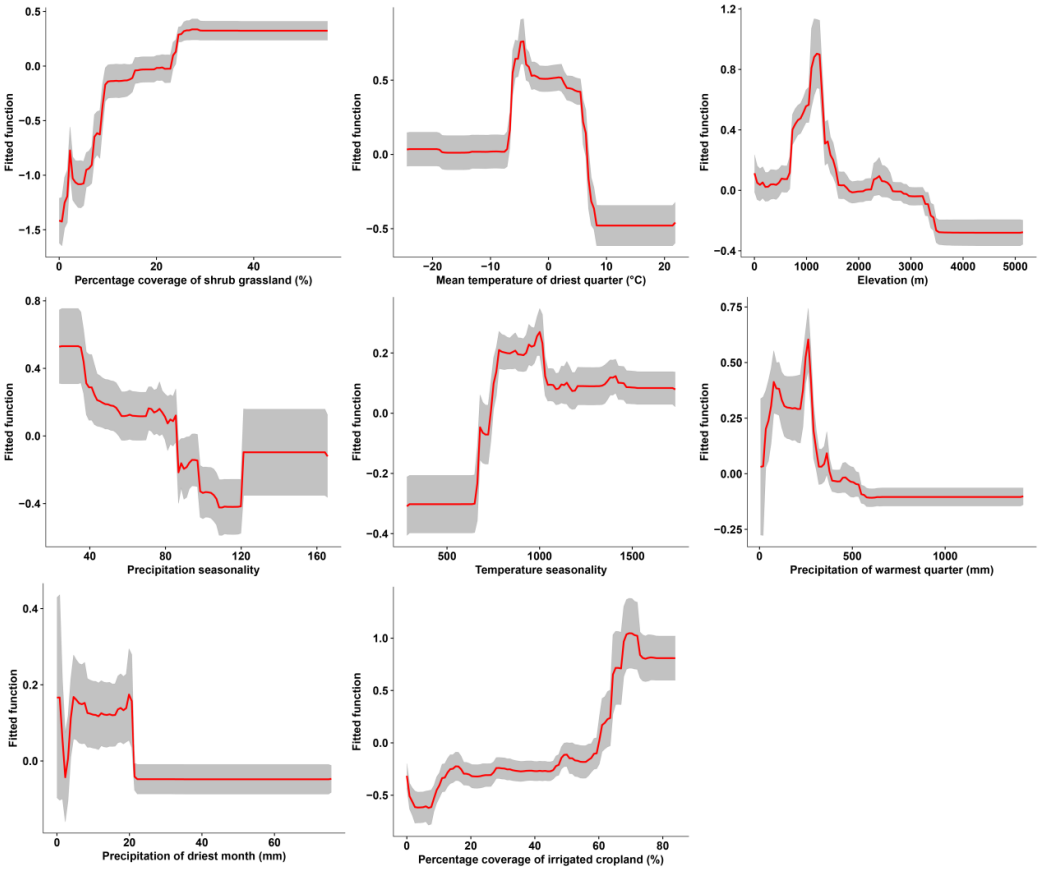
Supplementary Fig. 24 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *D. silvarum* based on the ensemble of BRT models.



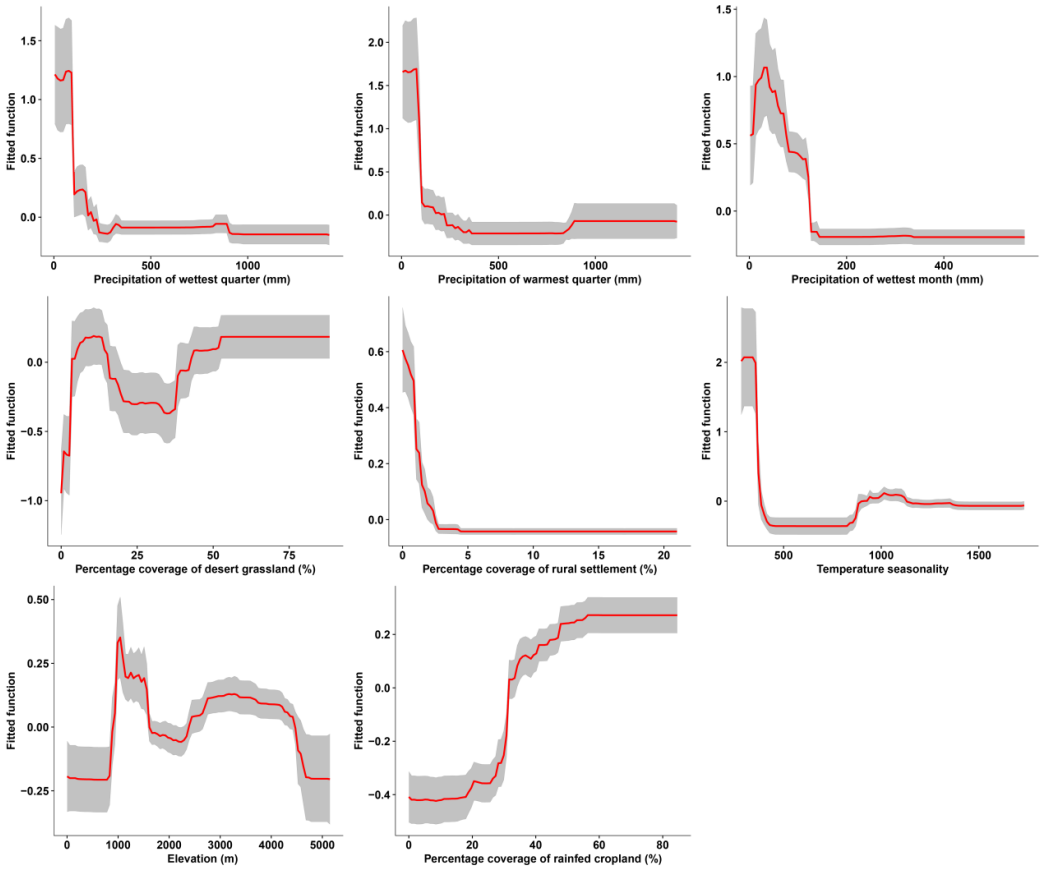
Supplementary Fig. 25 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *D. daghestanicus* based on the ensemble of BRT models.



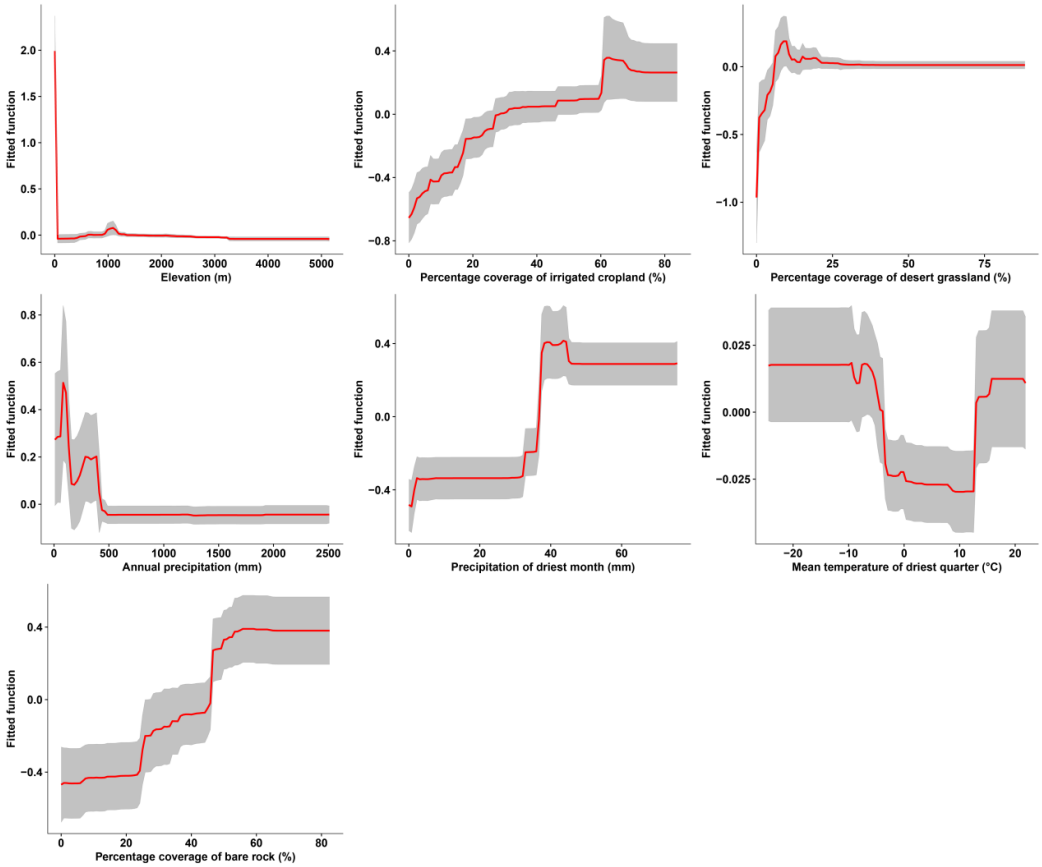
Supplementary Fig. 26 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *D. marginatus* based on the ensemble of BRT models.



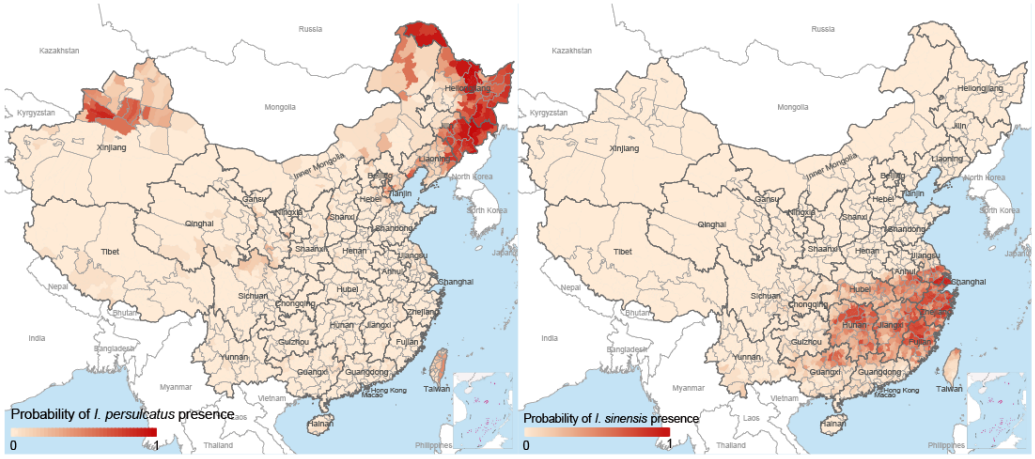
Supplementary Fig. 27 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Hy. scupense* based on the ensemble of BRT models.



Supplementary Fig. 28 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Hy. asiaticum* based on the ensemble of BRT models.

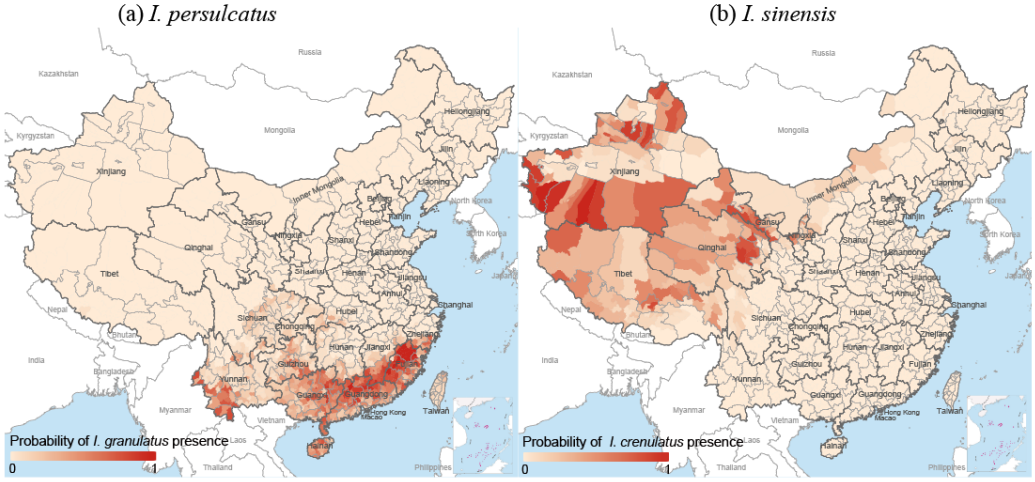


Supplementary Fig. 29 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of *Ar. persicus* based on the ensemble of BRT models.



(a) *I. persulcatus*

(b) *I. sinensis*

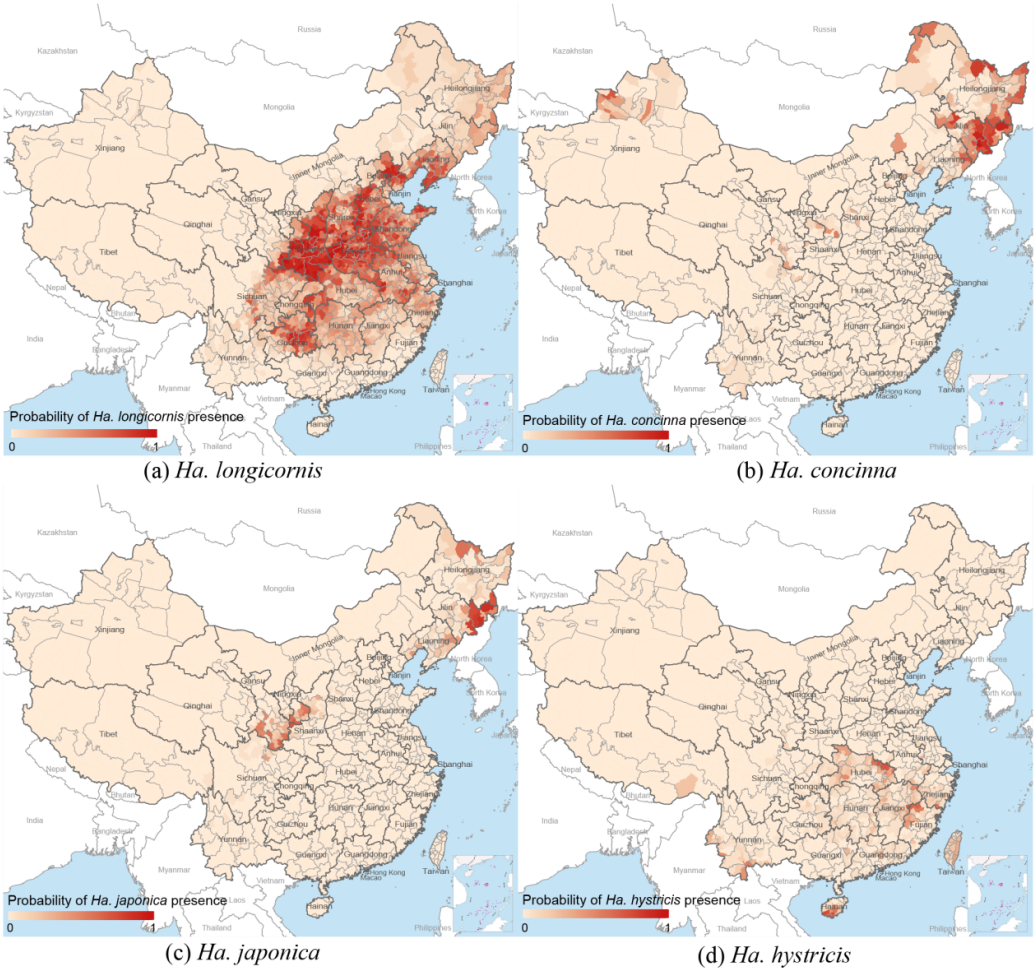


(c) *I. granulatus*

(d) *I. crenulatus*

(e) *I. ovatus*

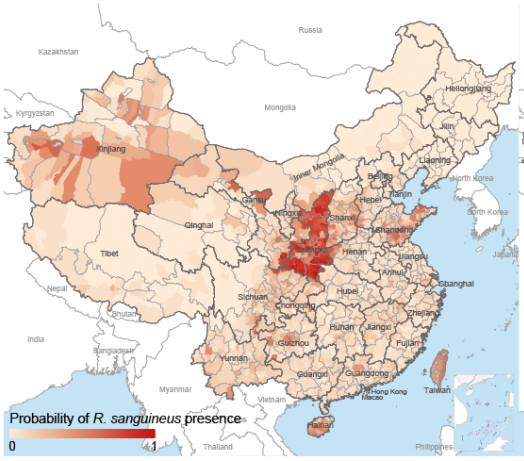
Supplementary Fig. 30 The predicted county-level distributions of the five most prevalent tick species in the *Ixodes* genus, averaged over the ensemble of BRT models (a) *I. persulcatus,* (b) *I. sinensis,* (c) *I. granulatus*, (d) *I. crenulatus*, and (e) *I. ovatus*. Source data are provided as a Source Data file.



(a) *Ha. longicornis* (b) *Ha. concinna*

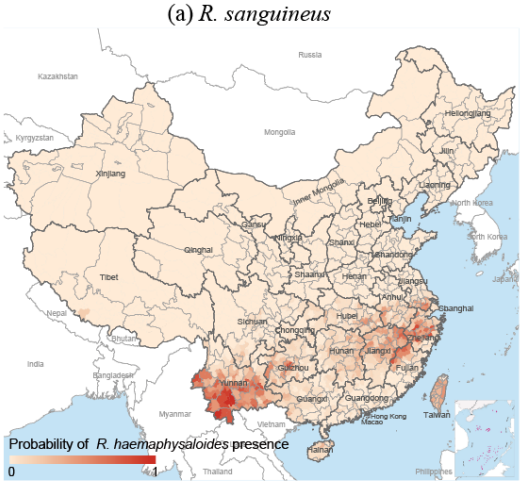
(c) *Ha. japonica* (d) *Ha. hystricis*

Supplementary Fig. 31 The predicted county-level distributions of the four most prevalent tick species in the *Haemaphysalis* genus, averaged over the ensemble of BRT models (a) *Ha. longicornis*, (b) *Ha. concinna*, (c) *Ha. japonica*, and (d) *Ha. hystricis*. Source data are provided as a Source Data file.



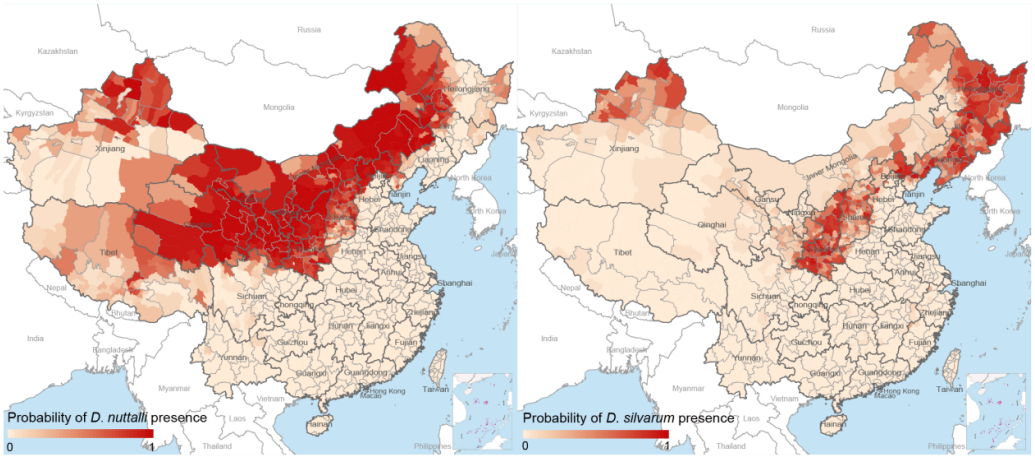
(a) *R. sanguineus*

(b) *R. microplus*



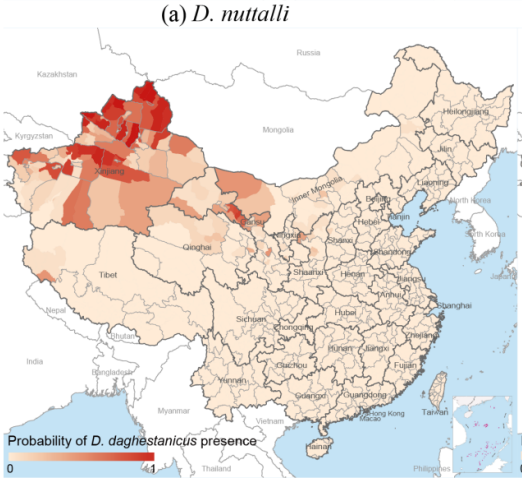
(c) *R. haemaphysaloides*

Supplementary Fig. 32 The predicted county-level distributions of the three most prevalent tick species in the *Rhipicephalus* genus, averaged over the ensemble of BRT models (a) *R. sanguineus*, (b) *R. microplus*, and (c) *R. haemaphysaloides*. Source data are provided as a Source Data file.

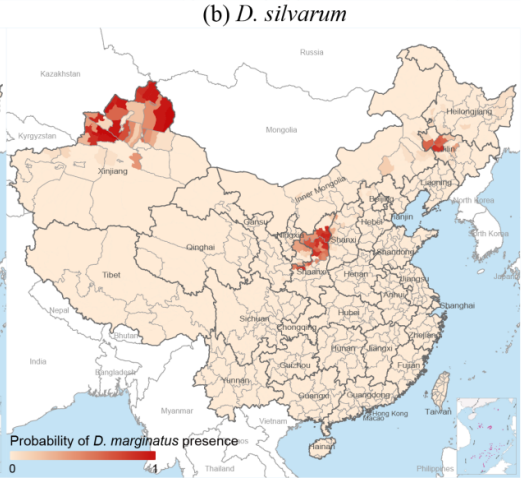


(a) *D. nuttalli*

(b) *D. silvarum*



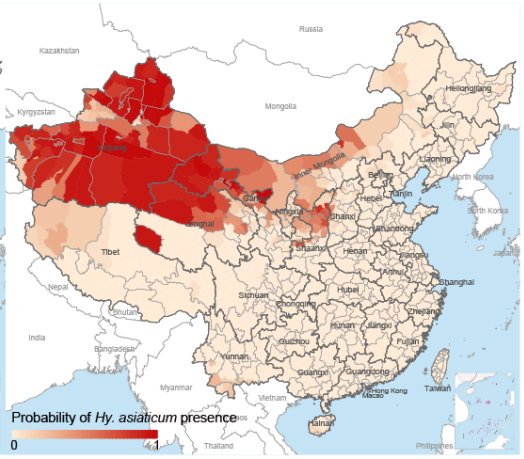
(c) *D. daghestanicus*



(d) *D. marginatus*

Supplementary Fig. 33 The predicted county-level distributions of the four most prevalent tick species in the *Demacentor* genus, averaged over the ensemble of BRT models: (a) *D. nuttalli*, (b) *D. silvarum*, (c) *D. daghestanicus*, and (d) *D. marginatus*. Source data are provided as a Source Data file.

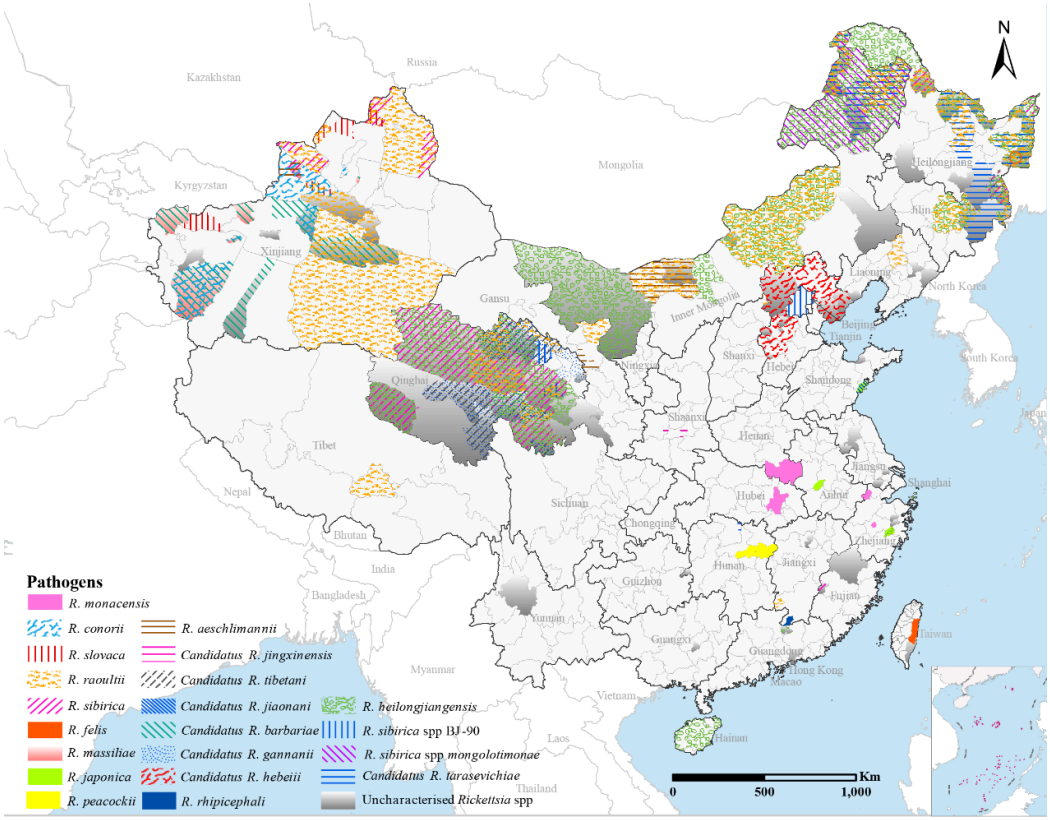
(a) *Hy. scupense*



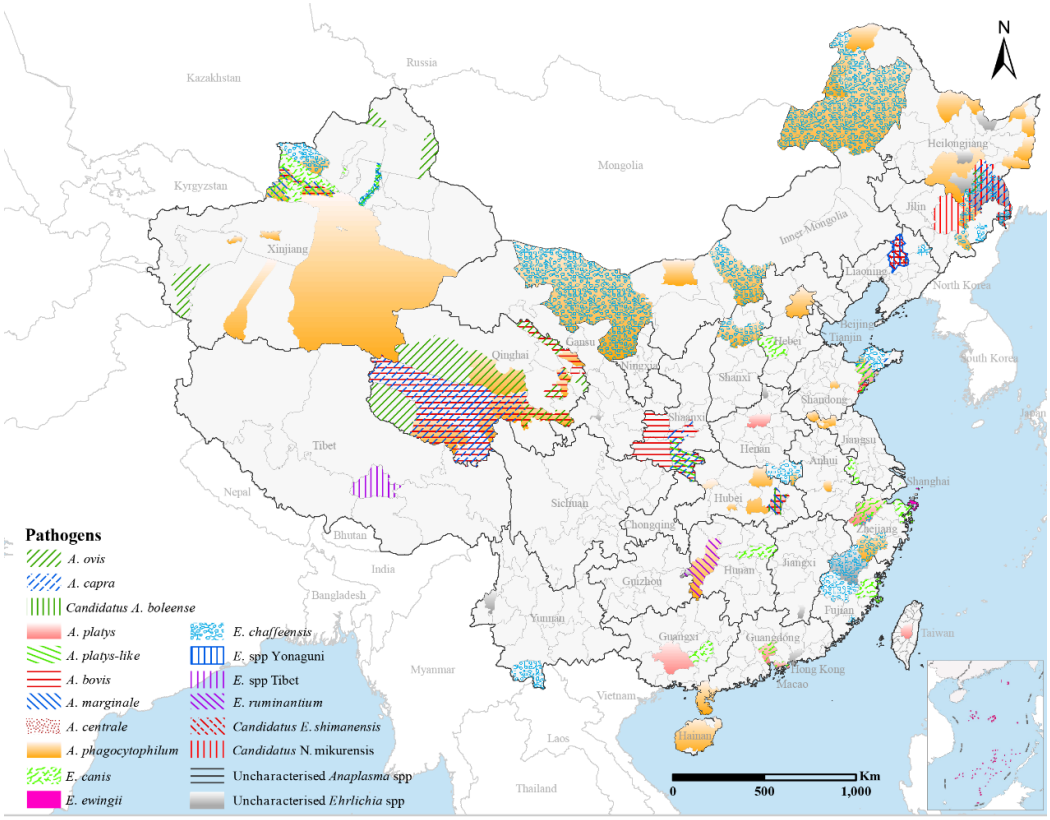
(b) *Hy. asiaticum*

(c) *Ar. persicus*

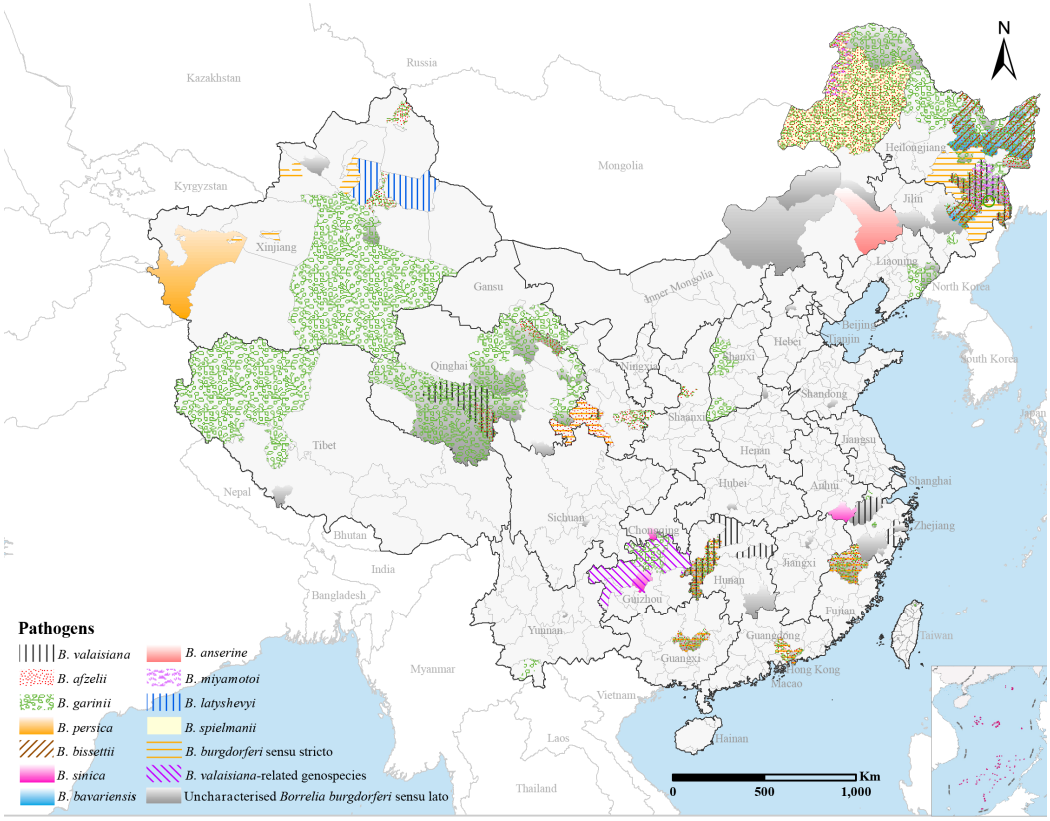
Supplementary Fig. 34 The predicted county-level distributions of the two most prevalent tick species in the *Hyalomma* genus and one in the *Argas* genus, averaged over the ensemble of BRT models (a) *Hy. scupense,* (b) *Hy. asiaticum,* and (c) *Ar. persicus.* Source data are provided as a Source Data file.



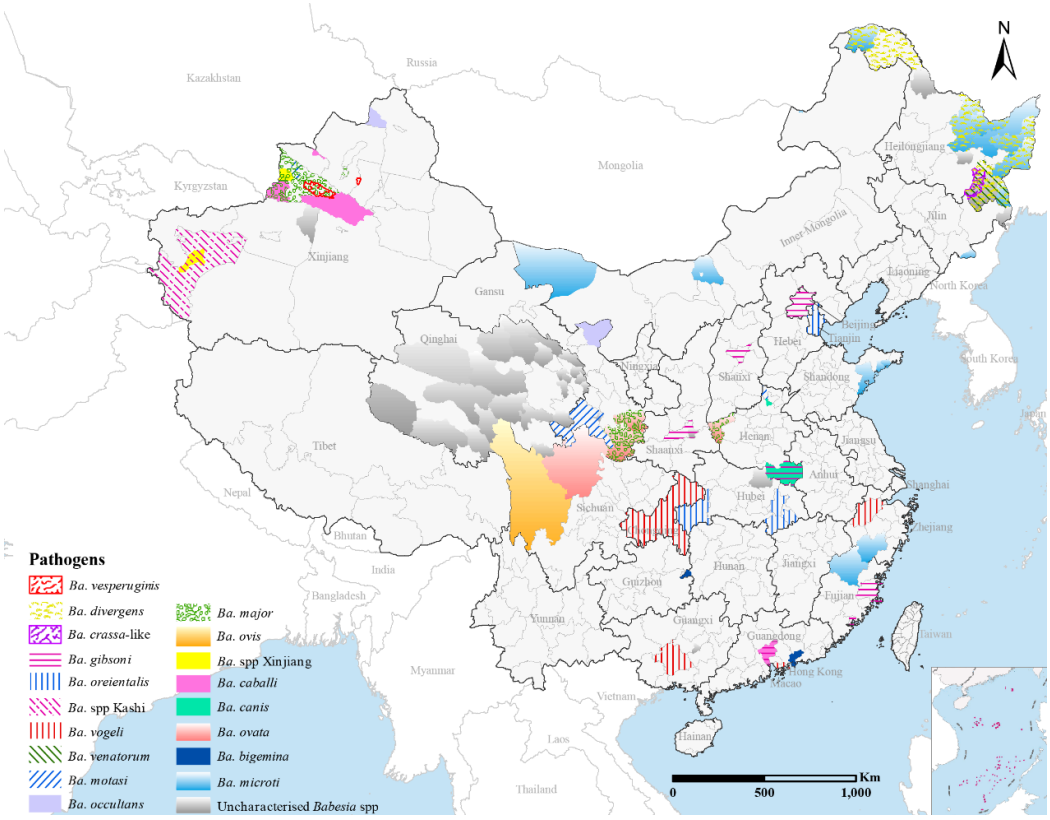
Supplementary Fig. 35 The locations of species or subspecies of spotted fever group rickettsiae detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



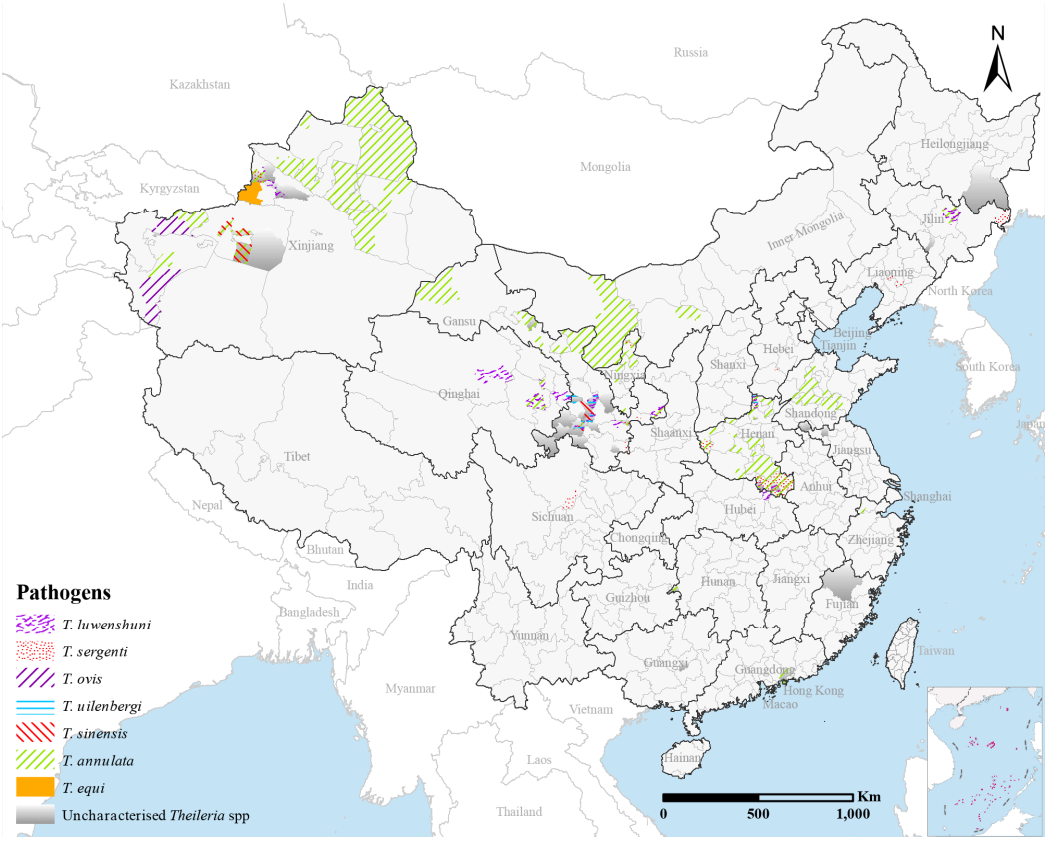
Supplementary Fig. 36 The locations of species or subspecies of *Anaplasmataceae* detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



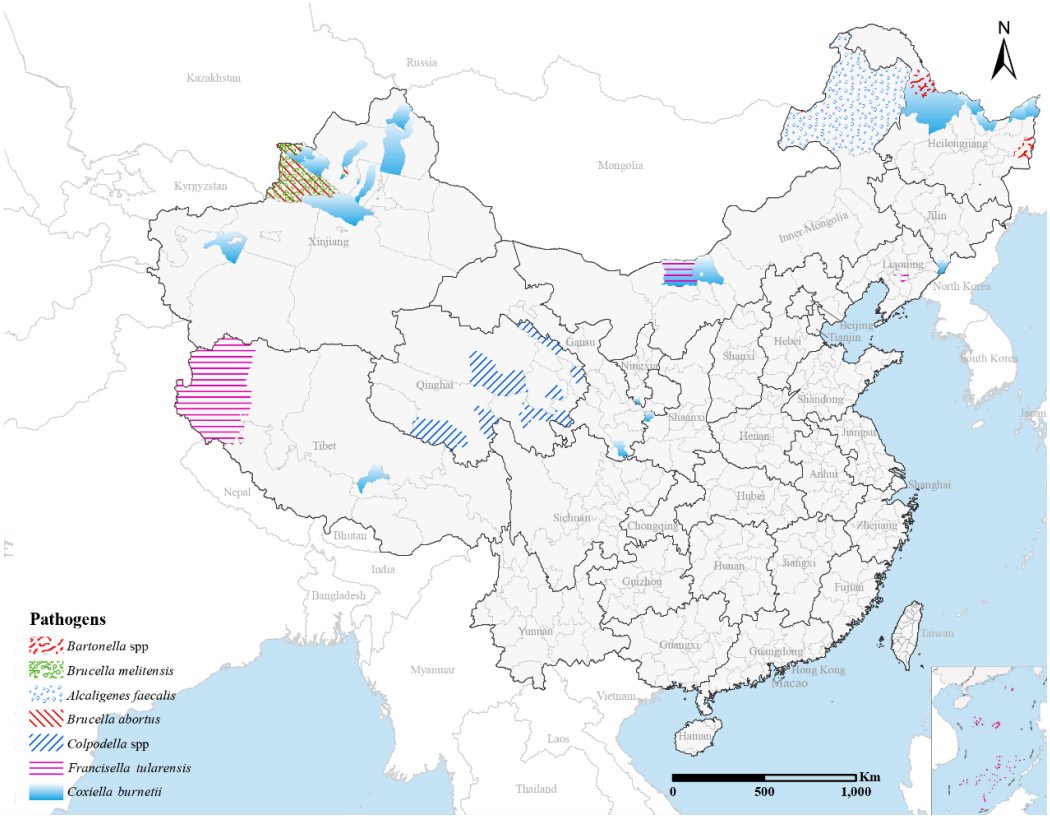
Supplementary Fig. 37 The locations of species or subspecies of *Borrelia* detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



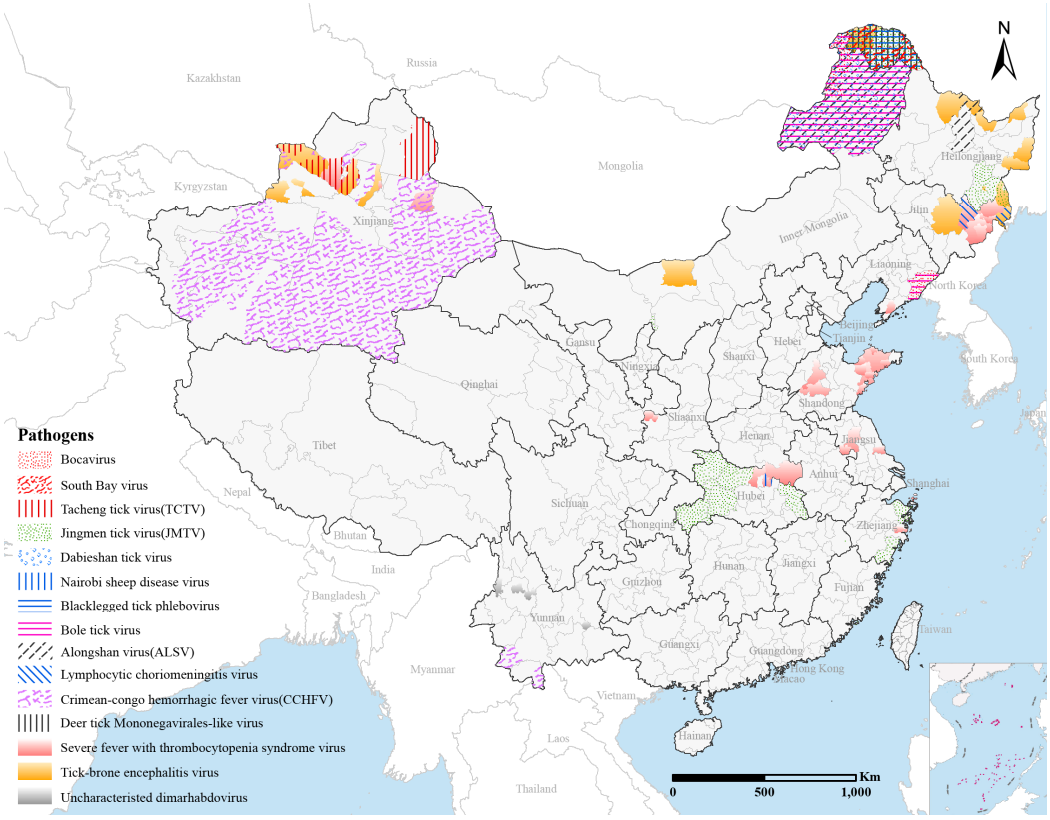
Supplementary Fig. 38 The locations of species or subspecies of *Babesia* spp. detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



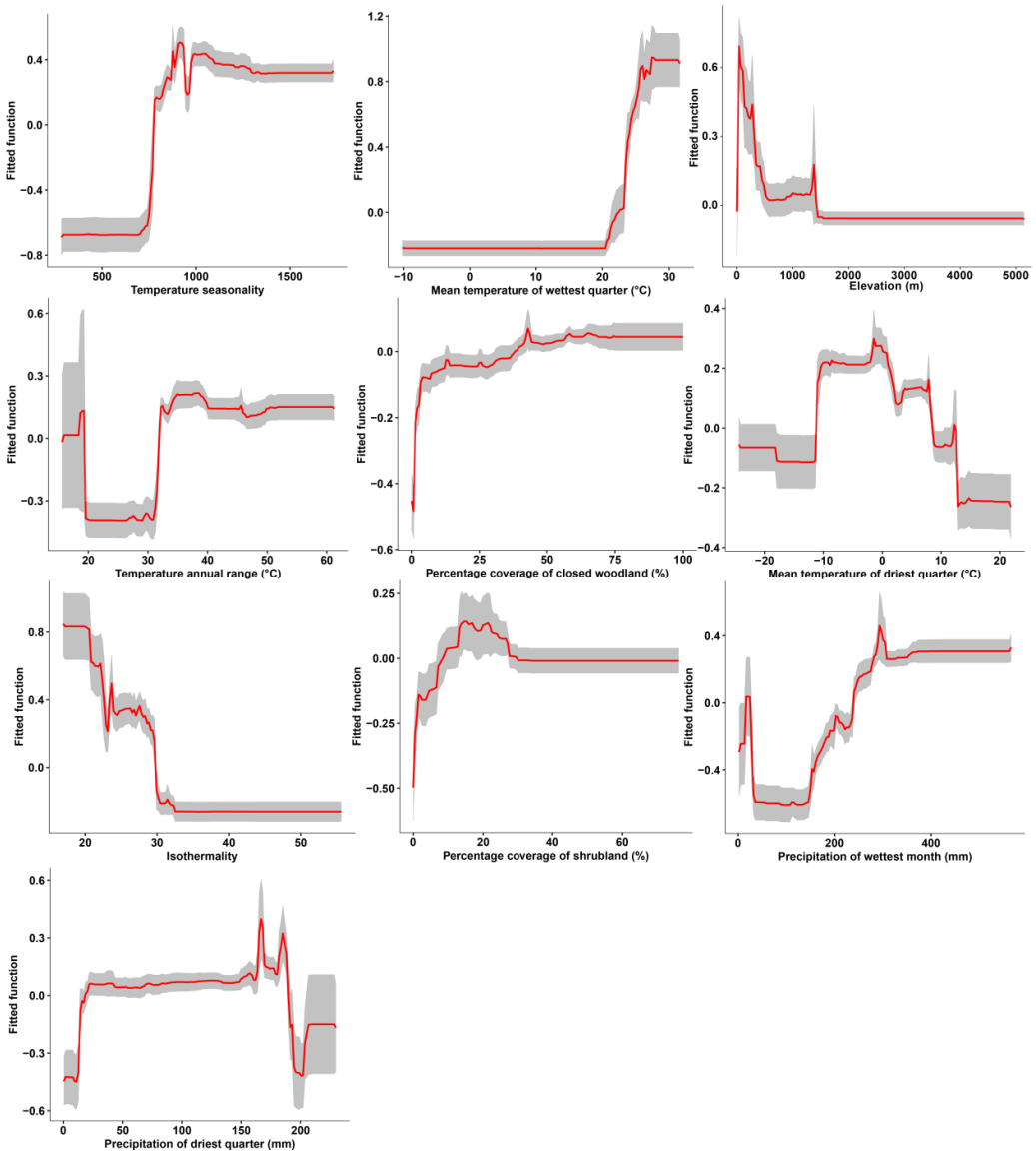
Supplementary Fig. 39 The locations of species or subspecies of *Theileria* detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



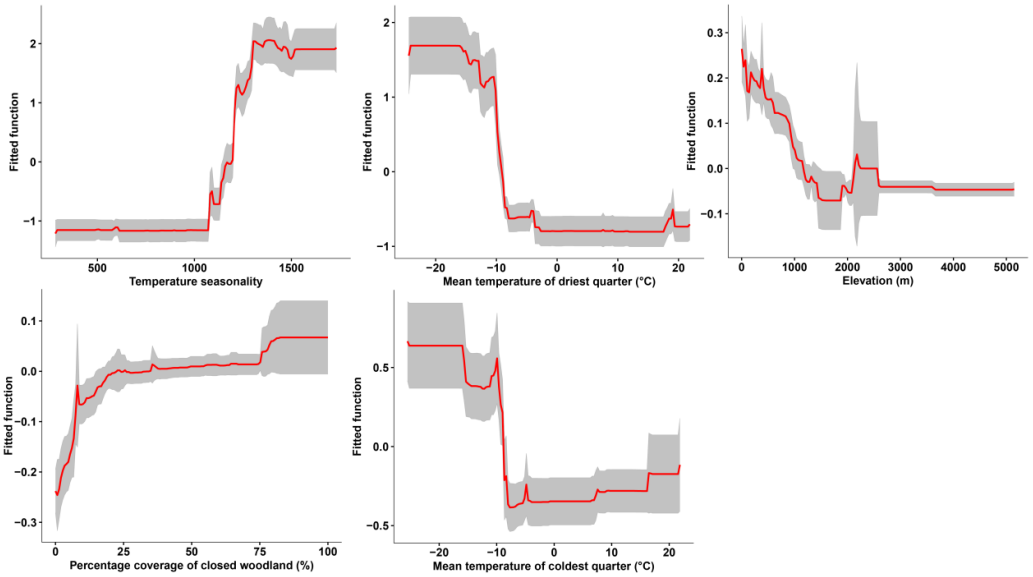
Supplementary Fig. 40 The locations of other tick-borne bacteria detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



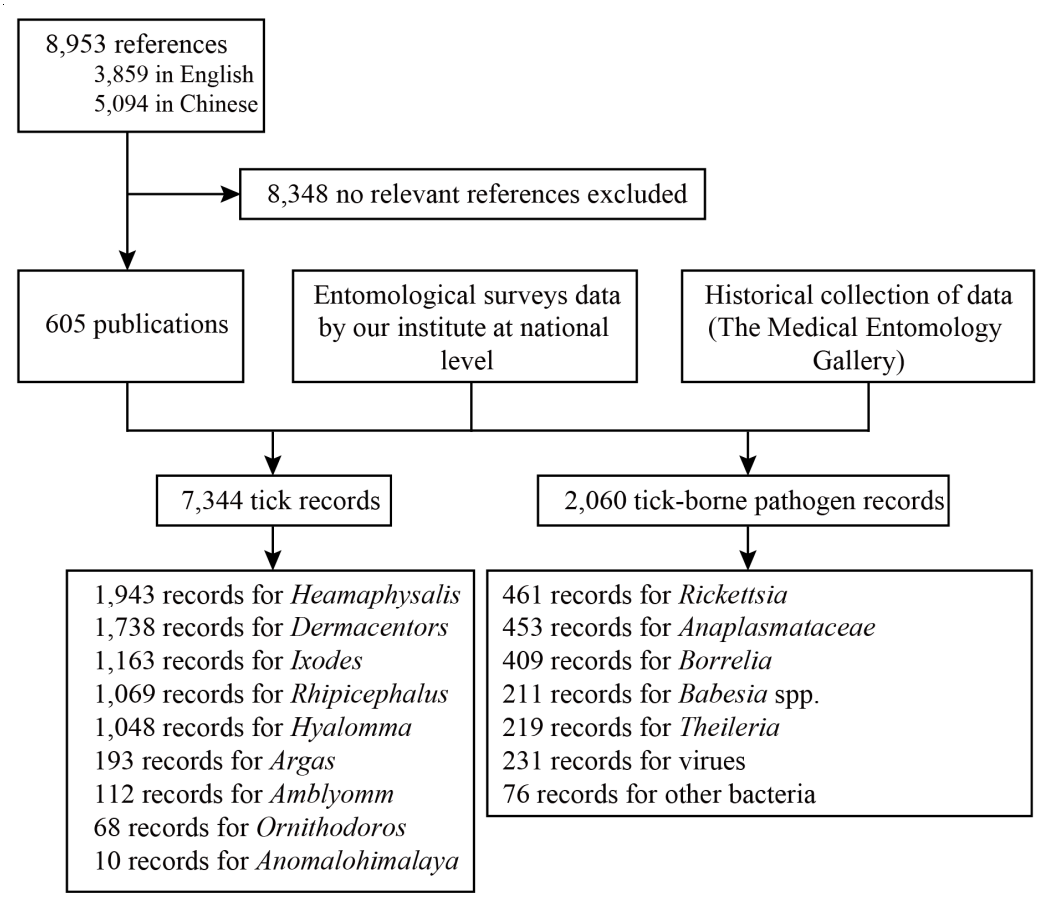
Supplementary Fig. 41 The locations of tick-borne viruses detected in ticks during 1950–2018 in China. Data were plotted at the county or prefecture level, depending on available resolution in the literature. Source data are provided as a Source Data file.



Supplementary Fig. 42 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of SFTSV based on the ensemble of BRT models.



Supplementary Fig. 43 The mean curves (red) and 95% percentiles (gray) for the effects of major predictors (RC≥5%) on the logit-transformed probability of occurrence of TBEV based on the ensemble of BRT models.



Supplementary Fig. 44 The flow diagram of literature review.

Supplementary Table 1 BRT-model-estimated mean (standard deviation) relative contributions of top environmental and ecoclimatic factors (RC≥5%) to the spatial distribution of five most prevalent tick species in the Ixodes genus. Mean AUCs (95% percentiles) and partial area AUC ratio (calculated at tolerance level of 0.2) are given.

Category	Variable	*I. persulcatus*	*I. sinensis*	*I. granulatus*	*I. crenulatus*	*I. ovatus*
Ecoclimatic	Annual mean temp.			18.23 (6.41)		
	Isothermality			6.59 (1.34)		7.23 (2.42)
	Temp. seasonality	16.97 (4.39)	5.34 (1.42)		5.23 (1.17)	9.82 (3.20)
	Max temp. warmest month		6.68 (1.20)		6.69 (1.62)	
	Min temp. coldest month			9.58 (3.40)		
	Annual temp. range		5.75 (1.46)	10.21 (3.02)		5.13 (1.57)
	Mean temp. driest quarter	13.27 (4.79)		15.85 (5.42)	6.42 (1.38)	
	Mean temp. warmest quarter		8.21 (1.73)			5.45 (2.14)
	Mean temp. coldest quarter	8.25 (3.84)		5.08 (2.87)		
	Annual precip.				5.87 (1.80)	
	Precip. Wettest month			5.43 (1.64)	5.43 (2.42)	
	Precip. Driest month	8.79 (2.61)	7.63 (2.24)			
	Precip. Seasonality					5.30 (1.87)
	Precip. Wettest quarter					5.05 (1.62)
	Precip. Driest quarter	6.54 (2.56)	39.74 (6.37)			
	Precip. Coldest quarter		15.35 (4.02)			5.92 (2.44)
Environmental	Mixed coniferous & broad leaved	7.21 (2.32)				5.21 (1.58)
	Shrubland					6.42 (1.73)
	Desert grassland				9.54 (3.47)	
	Alpine meadow steppe				9.83 (2.24)	
	Rainfed cropland			5.25 (1.30)		
	Urban construction land		7.08 (1.45)			
	Bare rock				18.32 (4.03)	
	Elevation				5.60 (1.32)	
	Relative humidity				7.25 (1.71)	

AUC	Train	0.986 (0.977-0.995)	0.987 (0.980-0.993)	0.991 (0.985-0.997)	0.989 (0.981-0.997)	0.979 (0.962-0.995)
	Test	0.892 (0.855-0.929)	0.924 (0.894-0.953)	0.943 (0.920-0.965)	0.918 (0.885-0.951)	0.828 (0.778-0.878)
Partial AUC Ratio	Train	1.79	1.81	1.84	1.87	1.87
	Test	1.54	1.65	1.71	1.68	1.47

Supplementary Table 2 BRT-model-estimated mean (standard deviation) relative contributions of top environmental and ecoclimatic factors (RC≥5%) to the spatial distribution of four most prevalent tick species in the Haemaphysalis genus. Mean AUCs (95% percentiles) and partial area AUC ratio (calculated at tolerance level of 0.2) are given.

Category	Variable	***Ha. longicornis***	***Ha. concinna***	***Ha. japonica***	***Ha. hystricis***
Ecoclimatic	Annual mean temp.	6.98 (1.13)			
	Mean diurnal range				6.82 (2.06)
	Isothermality				5.35 (1.94)
	Temp. seasonality	9.43 (1.72)	7.23 (2.41)		9.38 (2.87)
	Annual temp. range	5.22 (1.15)			
	Mean temp. driest quarter	7.09 (1.83)	6.97 (2.65)		
	Mean temp. coldest quarter	5.64 (1.53)			
	Annual precip.			8.02 (2.36)	5.51 (2.89)
	Precip. seasonality				6.13 (1.82)
	Precip. wettest quarter				7.62 (3.50)
	Precip. coldest quarter				5.97 (2.71)
Environmental	Coniferous		9.61 (2.43)		5.05 (1.31)
	Broad leaved			5.81 (1.61)	6.44 (2.73)
	Mixed coniferous & broad leaved		6.74 (2.00)	17.19 (2.28)	9.85 (2.32)
	Meadow			9.10 (1.83)	
	Shrub grassland	23.25 (2.29)			
	Irrigated cropland	5.66 (1.21)			
	Rainfed cropland	8.01 (0.98)	5.92 (1.43)	13.15 (2.21)	
	Rural settlement	5.83 (1.26)		5.51 (1.80)	
	Inland water body		5.41 (1.74)		
	Elevation	5.24 (0.91)			
	Relative humidity	6.12 (0.93)		5.92 (1.89)	5.99 (2.30)
AUC	Train	0.979 (0.972-0.986)	0.995 (0.988-0.999)	0.994 (0.988-0.999)	0.998 (0.996-0.999)
	Test	0.900 (0.879-0.920)	0.875 (0.827-0.922)	0.888 (0.835-0.941)	0.893 (0.854-0.933)
Partial AUC Ratio	Train	1.59	1.90	1.92	1.93

Test	1.45	1.54	1.59	1.59

Supplementary Table 3 BRT-model-estimated mean (standard deviation) relative contributions of top environmental and ecoclimatic factors (RC≥5%) to the spatial distribution of three most prevalent tick species in the Rhipicephalus genus. Mean AUCs (95% percentiles) and partial area AUC ratio (calculated at tolerance level of 0.2) are given.

Category	Variable	*R. sanguineus*	*R. microplus*	*R. haemaphysaloides*
Ecoclimatic	Mean diurnal range			6.51 (1.34)
	Isothermality		5.27 (1.53)	
	Temp. seasonality	6.41 (1.14)	12.88 (3.52)	8.11 (2.93)
	Min temp. coldest month		5.67 (1.99)	7.98 (1.82)
	Annual temp. range		11.55 (2.74)	5.35 (1.24)
	Mean temp. driest quarter	8.32 (1.28)	5.74 (2.17)	5.56 (2.43)
	Mean temp. warmest quarter			7.08 (1.93)
	Mean temp. coldest quarter		6.79 (1.83)	
	Annual precip.		5.66 (1.28)	5.16 (1.38)
	Precip. wettest month	5.28 (1.23)		
	Precip. driest month	7.72 (1.17)		
	Precip. seasonality	5.25 (1.18)	5.45 (1.22)	
	Precip. driest quarter			7.43 (2.11)
Environmental	Coniferous	6.05 (1.42)		5.04 (1.52)
	Shrub grassland	13.61 (1.38)		
	Rainfed cropland	6.09 (0.96)		
	Elevation	5.80 (1.01)	5.18 (1.02)	
AUC	Train	0.983 (0.975-0.991)	0.970 (0.987-0.998)	0.989 (0.978-0.999)
	Test	0.833 (0.800-0.866)	0.871 (0.844-0.898)	0.901 (0.862-0.940)
Partial AUC Ratio	Train	1.69	1.70	1.87
	Test	1.30	1.47	1.58

Supplementary Table 4 BRT-model-estimated mean (standard deviation) relative contributions of major environmental and ecoclimatic factors (RC≥5%) to the spatial distribution of four most prevalent tick species in the Demacentor genus. Mean AUCs (95% percentiles) and partial area AUC ratio (calculated at tolerance level of 0.2) are given.

Category	Variable	*D. nuttalli*	*D. silvarum*	*D. daghestanicus*	*D. marginatus*
Ecoclimatic	Temp. seasonality	9.38 (1.18)	14.57 (3.50)		
	Annual temp. range		11.39 (2.57)		5.01 (1.84)
	Mean temp. wettest quarter	6.70 (1.27)	5.86 (0.94)		
	Mean temp. driest quarter		5.85 (1.52)		5.68 (1.53)
	Mean temp. warmest quarter				5.21 (1.12)
	Annual Precip.		8.06 (1.22)		
	Precip. wettest month	44.32 (3.31)			5.09 (1.77)
	Precip. driest month	6.67 (1.22)	9.79 (2.47)		6.58 (1.80)
	Precip. seasonality				7.61 (2.23)
	Precip. wettest quarter				
	Precip. driest quarter				
	Precip. warmest quarter			18.69 (4.47)	
Environmental	Coniferous			5.42 (2.29)	
	Meadow			7.24 (2.69)	8.13 (1.94)
	Desert grassland			22.06 (5.41)	
	Shrub grassland	5.92 (0.74)	8.80 (1.01)		
	Rainfed cropland	5.00 (1.10)			7.45 (1.08)
	Rural settlement				6.09 (1.72)
	Inland water body			5.75 (1.22)	
	Elevation				
AUC	Train	0.998 (0.997-0.999)	0.993 (0.987-0.998)	0.994 (0.987-0.999)	0.999(0.998-0.999)
	Test	0.966 (0.956-0.975)	0.926 (0.907-0.944)	0.930 (0.882-0.977)	0.960 (0.942-0.978)
Partial AUC Ratio	Train	1.56	1.66	1.90	1.91
	Test	1.50	1.52	1.72	1.78

Supplementary Table 5 BRT-model-estimated mean (standard deviation) relative contributions of major environmental and ecoclimatic factors (RC≥5%) to the spatial distribution of two most prevalent tick species in the Hyalomma genus and one most prevalent tick specie in the Argas genus. Mean AUCs (95% percentiles) and partial area AUC ratio (calculated at tolerance level of 0.2) are given.

Category	Variable	*Hy. scupense*	*Hy. asiaticum*	*Ar. persicus*
Ecoclimatic	Temp. seasonality	7.18 (1.30)	6.67 (1.64)	
	Mean temp. driest quarter	10.21 (1.35)		5.42 (2.97)
	Annual precip.			7.84 (2.79)
	Precip. wettest month		9.06 (3.86)	
	Precip. driest month	6.52 (1.37)		6.08 (1.49)
	Precip. seasonality	7.45 (1.60)		
	Precip. wettest quarter	6.71 (1.09)	23.08 (6.78)	
	Precip. warmest quarter		20.02 (7.62)	
Environmental	Desert grassland		7.31 (2.20)	7.29 (2.72)
	Shrub grassland	12.79 (1.62)		
	Irrigated cropland	6.08 (0.96)		10.72 (2.17)
	Rainfed cropland		5.32 (0.92)	
	Rural settlement		7.12 (1.23)	
	Bare rock			5.06 (2.14)
	Elevation	9.52 (1.53)	6.03 (1.05)	12.83 (2.89)
AUC	Train	0.993 (0.987-0.998)	0.993 (0.987-0.998)	0.988 (0.976-0.999)
	Test	0.912 (0.893-0.932)	0.948 (0.926-0.969)	0.874 (0.836-0.902)
Partial AUC Ratio	Train	1.70	1.81	1.88
	Test	1.50	1.67	1.49

Supplementary Table 6 The specific references for all 124 tick species in China from 1950 to 2018

Tick species	Reference
Ixodes	1-154
I. persulcatus	2-5,9-14,19,21,23-26,28,29,31-34,36-38,40,42-46,49-51,53,55,57-63,65-71,73-79,81,82,99,104,105,108,110,111,113,115-132,134,136,137,140,142-146,148-154
I. sinensis	5,8,12,15-19,21-23,27,28,39,41,43,49,80,83,85,90,93,94,96,98,106,107,133,139,140
I. granulatus	5,17,20,23,39,43,48,56,86,88,91,92,97,102,107,135,138,140,147
I. crenulatus	5,47,87,89,95,101,103,140,144-146
I. ovatus	5,7,29,35,39,41,48,54,64,87,91,97,102,109,114,135,139,140,147
I. acutitarsus	5,35,48,49,64,84,135,140,144
I. simplex	5,141
I. spinicoxalis	5,109
I. nuttallianus	5,35,64,109,140
I. hyatti	5,49,84,112,126,135
I. pomerantzevi	5,49,84,126,140
I. vespertilionis	5,35,37,112
I. kuntzi	49,84,135
I. moschiferi	87
I. acuminatus	49,84,100,101
I. arboricola	5,47,52,140,145
I. moscharius	5
I. tanuki	5
I. kazakstani	6
I. kaschmiricus	5
I. pavlovskyi	30
I. nipponensis	30,148
I. berlesei	6
I. kangdingensis	1
I. myospalacis	5,72
I. semenovi	5
Haemaphysalis	2-5,15-18,23,25,27-29,35-37,39,41-43,45-49,52,53,55,57-59,62-69,72,74,77,80-82,84-88,90-92,94,96,98-104,106-112,116,121-127,129,131-135,137-140,143-149,151-279
Ha. longicornis	3,5,17,18,23,27,37,42,43,49,53,77,80-82,84,85,92,96,98,102,103,106-108,110,112,124,126,135,140,143,146,148,149,153,155,158-161,164,166,167,173,174,176-182,188,189,192,193,202-204,206,208,210,212,213,216-219,221-223,226,228,230,235,237-240,244,250,255-259,261,262,265,266,271,273,274,278,279
Ha. concinna	2,4,5,15,16,27,28,36,42,43,45,46,49,55,57-59,62,63,65-69,72,74,81,84,99,104,108,112,116,121-123,125,127,129,131,132,134,135,137,140,143,145-148,151,152,154,156,163,168,169,172,185,190-192,205,227,229,247-249,252,256,275-277
Ha. japonica	5,37,46,49,57-59,62,63,65-67,72,74,84,87,99,121,123,125,134,135,140,143,146

	,148,185,227,251
Ha. hystricis	5,17,35,39,49,84,92,94,102,107,135,139,140,175,179,217
Ha. lagrangei	5,39,49,53,84,92,133,135,140,178,215,217,220,272
Ha. punctata	5,101,111,129,140,144,145,148,164,169,195,198,199,201,249,253,277
Ha. verticalis	5,37,49,69,84,135,140,146,211,246,254,268
Ha. qinghaiensis	5,72,144,149,170,171,173,183,184,192,196,202,207,224,227,230-234,236,237, 239-242,245,270
Ha. campanulata	5,37,39,49,84,90,107,135,143,151,154,192,200,246,261,274
Ha. sulcata	5,47,52,101,111,145,197,199,243
Ha. taiwana	5,35,39,90,143,179,214,217,264,269
Ha. doenitzi	5,15,39,86,92,94,106,107,174,217,278
Ha. pospelovashtromae	47,52,101,111,195,267
Ha. flava	5,29,35,48,49,84,106,135,140,147,148,157,190,192,205,278
Ha. yeni	5,17,35,39,41,49,84,90,107,135,138,139,162,209,260,263
Ha. montgomeryi	5,48,91,147,225
Ha. formosensis	107
Ha. aponommoides	5,39,64,217
Ha. moschisuga	5,270
Ha. kitaokai	5,35,102
Ha. spinigera	5,35,39,49,84,135
Ha. tibetensis	5,109
Ha. ornithophila	5,144,147,264
Ha. erinacei	5,100,111,143,194
Ha. warburtoni	5,108,109,112
Ha. wellingtoni	5,39
Ha. birmaniae	5,35,264
Ha. goral	5
Ha. nepalensis	5,49,64,84,135,214
Ha. megaspinosa	5,48,148
Ha. quadriaculeata	186
Ha. asiatica	5,35
Ha. canestrinii	5
Ha. primitiva	5,269
Ha. menglaensis	5
Ha. mageshimaensis	5,147
Ha. aborensis	5
Ha. sinensis	5,84,135
Ha. bandicota	5,25,88
Ha. colasbelcouri	91,147
Ha. heinrichi	165
Ha. megalaimae	187
Amblyomma	5,17,30,35,39,41,80,85,90,92,94,107,143,162,175,217,264,280,281
Am. testudinarium	5,17,35,39,41,80,85,90,92,94,107,143,162
Am. javanense	5,35,92,107,217
Am. crassipes	5,35,264
Am. varanense	5,35,217,280
Am. helvolum	5,175,281

Am. pattoni	107
Am. cordiferum	30
Am. geoemydae	5
Am. breviscutatum	30
Am. pseudolaeve	5
Rhipicephalus	5-7,17,25,35,37,39,43,47,49,52,64,77,80,84,85,87,88,92,96,98,100,102,103,106-109,111,112,129,133,135,140,143-147,149,164,169,173,178-180,182,190,192,194,195,197,199,201,205,207,213,214,237,246,253,255,257,261,263,264,274,276-279,282-313
R. sanguineus	5,7,25,35,37,47,77,80,85,88,92,100,103,111,129,140,143,145,149,164,173,179,182,190,194,205,207,213,237,246,255,257,261,274,278,279,283-285,287,289,292,293,296,297,305,307,310-312
R. microplus	5,17,35,37,39,43,49,64,84,85,87,92,102,106-109,112,129,133,135,140,143,144,146,147,149,164,178-180,182,192,207,214,246,261,263,264,276,279,285,288,290,293-295,297,298,300,303,305,306,308,309
R. haemaphysaloides	5,17,35,39,49,64,84,85,92,96,98,103,107,129,133,179,180,282,285,291,293
R. pumilio	5,47,100,111,140,145,195,197,199,201,264,292,293,301,302,304
R. turanicus	5,52,111,140,143,145,169,253,277,286,292,299,301,302,313
R. schulzei	111,195
R. bursa	5,140,144
R. rossicus	6
Dermacentor	2-5,14,15,17,19,20,27,28,36,37,39,42,43,45-47,52,53,55,57-59,62-69,71,72,74,80,82,85,87,89,92,99,100,102,103,106,107,109,111,113,116-118,121,123,125-129,131,132,134,137,139,140,142-146,148,150-154,163,164,167,169,185,190,192,194,195,197-199,201,205,211,213,217,227,236,237,240,249,252-256,263,274,277,292,302,304,310,313-340
D. nuttalli	5,15,19,27,28,42,43,57,69,72,87,109,111,129,140,144-146,150,151,153,154,167,169,192,195,197-199,201,213,227,236,237,240,255,277,304,310,315,317,324,326,328,330-333,335,336,338,339
D. silvarum	2-5,14,19,20,27,36,37,39,42,43,45,46,53,55,58,59,62,63,65-69,71,72,74,82,99,103,109,111,113,116-118,121,123,125-129,131,132,134,137,139,140,142-146,148,151-154,163,164,185,192,195,198,199,213,227,236,252,254-256,313,316,319,321,326,327,334,337-340
D. daghestanicus	5,47,52,72,100,111,195,197,199,201,211,227,237,292,304,325-327,333,336
D. marginatus	5,111,144,145,150,151,154,164,169,194,195,198,199,201,249,253,255,277,302,320,334
D. reticulatus	5,64,143,195,255
D. abaensis	5,87,109,111,140,144,192,195,199
D. pavlovskyi	5,47,52,111,145,327,339
D. auratus	5,39,80,85,92,140,217,263
D. sinicus	5,72,106,129,140,143,190,192,205,274,318,323
D. everestianus	5,89,329
D. taiwanensis	5,17,102
D. steini	107
D. montanus	5,52,327,336
D. compactus	322
D. raskemensis	314

Hyalomma	5,17,35,37,47,52,53,72,77,80,81,85,88,92,100,103,106,111,129,135,140,143-145,151,154,164,169,179,180,182,190,194,195,197-199,201,202,205,207,211,213,227,233,237,240,246,249,253-255,257,274,277,279,283-285,287,288,292,293,296,297,301,302,304,305,307,310,313,315,318,323,325,326,332,333,336,341-358
Hy. scupense	5,37,47,52,53,72,100,106,111,129,135,140,143-145,151,154,164,169,180,195,197,199,201,202,227,237,240,249,277,279,288,345,353,356-358
Hy. asiaticum	5,17,35,37,47,77,80,81,85,88,92,100,103,111,129,140,143-145,164,169,179,182,190,194,195,197-199,201,205,207,211,213,237,246,249,253-255,257,274,277,283-285,287,292,293,296,297,301,302,304,305,307,310,313,315,318,325,326,332,333,336,341,342,346-348,350-353,355,359
Hy. anatolicum	5,47,111,144,145,164,195,199,240,279,288,292,333,336,343,349,353,354
Hy. marginatum	5,111,195,233,323,333,353,357
Hy. dromedarii	5,47,52,143,197,353
Hy. turanicum	344
Hy. isaaci	5
Anomalohimalaya	5,6,47,360
An. cricetuli	5,47,360
An. lama	5
An. lotozkyi	6
Ornithodoros	30,47,52,140,143,144,196,279,361-364
O. tartakovskyi	143,362
O. papillipes	47,143,196,362
O. lahorensis	47,52,140,143,144,196,279,361,363,364
O. capensis	30
Argas	37,47,135,140,143,144,150,178,365-370
Ar. persicus	37,47,135,140,143,144,178,366-368
Ar. vulgaris	140,178
Ar. vespertilionis	135
Ar. robertsi	369
Ar. beijingensis	369
Ar. japonicus	150,369
Ar. assimilis	370
Ar. pusillus	369
Ar. sinensis	365

Supplementary Table 7 The social, environmental and ecoclimatic variables used for ecological modeling for tick species and tick-borne pathogens at the county level in this study.

Category	Variable	Description
Ecoclimatic	BIO01*	Annual mean temperature (℃)
	BIO02	Mean diurnal range (Mean of monthly (max temp-min temp)) (℃)
	BIO03	Isothermality (BIO02/BIO07)(*100)
	BIO04	Temperature seasonality (standard deviation*100)
	BIO05	Max temperature of warmest month (℃)
	BIO06*	Min temperature of coldest month (℃)
	BIO07	Annual range of temperature (BIO05-BIO06) (℃)
	BIO08*	Mean temperature of wettest quarter (℃)
	BIO09*	Mean temperature of driest quarter (℃)
	BIO10	Mean temperature of warmest quarter (℃)
	BIO11*	Mean temperature of coldest quarter (℃)
	BIO12*	Annual precipitation (mm)
	BIO13*	Precipitation of wettest month (mm)
	BIO14	Precipitation of driest month (mm)
	BIO15*	Precipitation seasonality(Coefficient of variation)
	BIO16	Precipitation of wettest quarter (mm)
	BIO17*	Precipitation of driest quarter (mm)
	BIO18*	Precipitation of warmest quarter (mm)
	BIO19	Precipitation of coldest quarter (mm)
Environmental	Coniferous*	Percentage coverage of coniferous (1%)
	Broad leaved	Percentage coverage of broad leaved (1%)
	Mixed coniferous and broad leaved	Percentage coverage of mixed coniferous and broad leaved (1%)
	Shrubland*	Percentage coverage of shrubland (1%)
	Meadow*	Percentage coverage of meadow (1%)
	Desert grassland*	Percentage coverage of desert grassland (1%)
	Typical grassland	Percentage coverage of typical grassland (1%)
	Alpine meadow steppe*	Percentage coverage of alpine meadow steppe (1%)
	Shrub grassland*	Percentage coverage of shrub grassland (1%)
	Paddy field	Percentage coverage of paddy field (1%)
	Irrigated cropland*	Percentage coverage of irrigated cropland (1%)
	Rainfed cropland*	Percentage coverage of rainfed cropland (1%)
	Urban construction land*	Percentage coverage of urban construction land (1%)
	Rural settlement*	Percentage coverage of rural settlement (1%)
	Swamp	Percentage coverage of swamp (1%)

	Coastal wetlands	Percentage coverage of coastal wetlands (1%)
	Inland water body*	Percentage coverage of inland water body (1%)
	River and lake beach land	Percentage coverage of river and lake beach land (1%)
	Ice and snow	Percentage coverage of ice and snow (1%)
	Bare rock	Percentage coverage of bare rock (1%)
	Bare land	Percentage coverage of bare land (1%)
	Desert	Percentage coverage of desert (1%)
	Elevation*	Average elevation (m)
	Relative humidity	Annually average relative humidity (1%)
Social	Proportion of rural population	# of rural population / # of total population
	Density of rural population	# of rural population / total area

* Used as predictors in the logistic model for selection of counties for tick survey. The output sampling probabilities of counties (after taking reciprocal) were used as weights for the BRT models for the 19 tick species.

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