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Climatic niche defines geographical distribution of *Mesobuthus eupeus mongolicus* (Scorpiones: Buthidae) in Gobi desert

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Abstract Scorpion fauna of Mongolia, which are thus far poorly understood, were investigated country-wide during a China-Mongolia joint field survey from 2009 to 2012. Of the total 134 sites we surveyed, scorpions were found at 10 sites in the southern Gobi regions, Umnugovi and Dornogovi Aimags (Provinces) of Mongolia. All scorpions collected from Mongolia belong to a single species, *Mesobuthus eupeus mongolicus*. Combining with its occurrence records in China, we assembled 98 presence data for *M. eupeus mongolicus* and predicted its geographical distribution using ecological niche modeling approach. This species occurs exclusively in the arid deserts and steppes, ranging from the west extreme of Junggar Basin (Xinjiang) to the Gobi deserts in North China and South Mongolia, with its distributional margins set by the Altai Mountains in the north, the Tian-Shan Mountains and the Qinghai-Tibet Plateau in the south, and the Loess Plateau in the east. We found that ecological niche models could accurately predict (AUC = 0.880 ± 0.016) geographic distribution of *M. eupeus mongolicus*. Our results show that climate is a reliable predictor for the geographic range of *M. eupeus mongolicus*, implying that climate might have exerted a dominant control over the natural occurrence of this species. A brief note on the ecology of *M. eupeus mongolicus* was also provided.

Key words Scorpion fauna, ecological niche modeling, prey, Mongolia, China.

1 Introduction

Scorpions in the genus *Mesobuthus* Vachon, 1950 occur in a variety of arid habitats in the Palearctic Region, with 13 species having been reported so far (Fet & Lowe, 2000; Gantenbein *et al.*, 2000; Lourenço *et al.*, 2005; Kovařík, 2007; Sun & Zhu, 2010; Sun *et al.*, 2010; Teruel & Rein, 2010; Sun & Sun, 2011). In the east range of distribution, Mongolia which covers 1.56 million square kilometers between 41°35'–52°06'N and 87°47'–119°57'E, carries an extreme continental temperate climate and harbors an extensive array of arid ecosystems, including the Gobi deserts. This region thus might

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provide suitable habitats for *Mesobuthus* scorpions. Unfortunately, scorpion fauna of Mongolia is poorly understood and has never been systematically investigated.

The first formal record of scorpion from Mongolia was *Buthus eupeus mongolicus* Birula, 1911 (now known as *Mesobuthus eupeus mongolicus*) from Gobi-Altai in mid 1920s (Birula, 1925). The type specimens of this subspecies were collected from West Gansu, China (Birula, 1911), and it was lately recorded from the nearby region Alxa (Ala-Shan), Inner Mongolia, China (Birula, 1925). This species were collected from 22 sites in the Southwest Mongolia by Dr. Z. Kaszab during zoological expeditions from 1963 to 1968 (Stahnke. 1967, 1970). Since then no record has been reported from Mongolia. Two additional species of the same genus, *M. caucasicus* (Nordmann, 1840) and *M. martensii* (Karsch, 1879), have been recorded or assumed to occur in Mongolia (Kraepelin, 1899; Fet, 1989; Fet & Lowe, 2000), but their exact geographic distributions in Mongolia were unknown. However, *M. martensii*, the Chinese scorpion, is restricted to monsoonal temperate China and has adapted to humid climate (Shi *et al.*, 2007, 2013). Recent field survey revealed that *M. martensii* could not be found to the north of latitude 43°N in China, and ecological niche modeling (ENM) suggested that Mongolia was not suitable for its survival (Shi *et al.*, 2007). In strong contrast, ENM suggests that a major part of the southern Gobi region is suitable for the survival of *M. eupeus* (Shi *et al.*, 2007). These findings urge an effort of systematic field investigation to verify the accuracy of historical documentation on scorpion fauna of Mongolia and to validate the results of ENM prediction, so that the geographical distribution of *M. eupeus* can be defined.

Therefore, a China-Mongolia joint field survey of scorpion fauna in Mongolia had been conducted from 2009 to 2012, organized by the Institute of Zoology of the Chinese Academy of Sciences, the Plant Protection Research Institute of the Mongolian State University of Agriculture, and the Institute of Biology of the Mongolian Academy of Sciences. Here, we report the results from this joint field investigation. By integrating information from field observation in Mongolia and China with ecological niche modeling, we demarcated a detailed geographical distribution for the scorpion *M. eupeus mongolicus*. Our field survey did not support the occurrence of the Chinese scorpion *M. martensii* in Mongolia, an outcome expected from earlier ENM (Shi *et al.*, 2007). With scorpions emerging as a rich source for modern medicine (Cao *et al.*, 2014) and *M. eupeus* has been also used in traditional Chinese medicine (C-M Shi unpublished data), our findings provide up-to-date baseline data on this medically important species, which are fundamental for conservation planning and sustainable resource exploitation.

2 Materials and methods

2.1 Field survey and scorpion collection

Extensive field surveys were conducted from June to September during 2009 to 2012 (a total of 93 field days). Scorpion collection was carried out by stone-rolling in daytime and portable light searching at night. The surveying localities were positioned using a GPS receiver, with their longitude, latitude, and elevation recorded. The specimens obtained were deposited in 95% ethanol and morphologically examined under a Nikon SMZ1500 stereomicroscope. All the materials are deposited at the Laboratory of Molecular Ecology and Evolution, Institute of Zoology, Chinese Academy of Sciences, and will be permanently deposited in the National Zoological Museum, Chinese Academy of Sciences, Beijing, China. Representatives of specimens for each population will also be deposited in the Institute of Plant Protection Research, Mongolian State University of Agriculture, Ulaanbaatar, Mongolia.

2.2 Ecological niche modeling

New occurrence sites in Mongolia were combined with records from Stahnke (1967, 1970) and with records from Shi *et al.* (2007, 2013) and Sun & Sun (2011) in China to perform ecological niche modeling for scorpion (Table 1). We only included the occurrence points of the subspecies *M. eupeus mongolicus* in ENM, and records for the other subspecies were excluded. Thus the ENM reported here only pertained to *M. eupeus mongolicus*. To correct for sampling bias, records < 5 km apart were excluded.

We preferred the modeling method using presence-only data as absence of scorpion at a given locality could not be assured. Nevertheless, localities from which we failed to spot a scorpion were used as a *post hoc* evaluation of model accuracy. We created niche models with a maximum entropy algorithm implemented in MaxEnt version 3.3.3k (Phillips *et* *al.*, 2006; Phillips & Dudík, 2008). MaxEnt is a robust method for estimating distributions when absence data are lacking (Phillips *et al.*, 2006) and generally performs better than other distribution modeling approaches (Elith *et al.*, 2006; Wisz *et al.*, 2008). It avoids over-parameterization by incorporating a method of regularization for selecting environmental variables when building models, besides some variable selection is recommended to reduce collinearity (Elith *et al.*, 2011). The bioclimatic variables in the WorldClim data set (Hijmans *et al.*, 2005) were used to construct ENM models with MaxEnt. These bioclimatic variables represent a set of climatic measurements that summarize temperature and precipitation dimensions of the environment at a 2.5 arc-minute resolution (c. 5×5 km). MaxEnt generates ENMs using presence-only records and pseudo-absence or background data was resampled from the study area. MaxEnt was run with a convergence threshold of 10^{-5} and maximum number of iterations of 1 000 with 25% of localities used for model testing. Model performance was assessed via the area under the ROC (receiver operating characteristic) curve (AUC) statistic and the importance of climatic variables was assessed by jackknife tests. The AUC in MaxEnt is the probability that a random presence location is ranked above a random background sites and ranges from 0 to 1 (Phillips *et al.*, 2006). Models with AUC > 0.75 are considered adequate and > 0.90 are considered excellent (Swets, 1988; Elith, 2002).

Table 1. Occurence sites of *Mesobuthus eupeus mongolicus*.

Code	Longitude	Latitude	Province	Country	Reference
01	103.20	36.80	Gansu	China	Shi *et al.*, 2007
02	104.15	37.15	Gansu	China	Shi *et al.*, 2007
03	104.30	37.20	Gansu	China	Shi *et al.*, 2007
04	104.57	37.34	Gansu	China	Shi *et al.*, 2007
05	103.63	37.52	Gansu	China	Shi *et al.*, 2013
06	102.50	38.60	Gansu	China	Shi *et al.*, 2013
07	102.45	38.64	Gansu	China	Shi *et al.*, 2007
08	100.20	38.70	Gansu	China	Shi *et al.*, 2007
09	100.67	38.97	Gansu	China	Shi *et al.*, 2007
10	101.23	39.02	Gansu	China	Shi *et al.*, 2007
11	100.30	39.10	Gansu	China	Shi *et al.*, 2007
12	99.82	39.41	Gansu	China	Shi *et al.*, 2007
13	98.84	39.91	Gansu	China	Shi *et al.*, 2013
14	100.38	38.93	Gansu	China	Sun & Sun, 2011
15	99.02	39.30	Gansu	China	Sun & Sun, 2011
16	98.87	39.83	Gansu	China	Sun & Sun, 2011
17	105.76	37.78	Inner Mongolia	China	Shi *et al.*, 2007
18	105.70	38.35	Inner Mongolia	China	Shi *et al.*, 2007
19	101.70	39.20	Inner Mongolia	China	Shi *et al.*, 2007
20	106.20	39.25	Inner Mongolia	China	Shi *et al.*, 2007
21	106.86	39.68	Inner Mongolia	China	Shi *et al.*, 2007
22	107.51	40.15	Inner Mongolia	China	Shi *et al.*, 2013
23	104.20	40.20	Inner Mongolia	China	Shi *et al.*, 2007
24	103.00	40.50	Inner Mongolia	China	Shi *et al.*, 2007
25	108.73	40.67	Inner Mongolia	China	Shi *et al.*, 2007
26	103.50	40.70	Inner Mongolia	China	Shi *et al.*, 2007
27	107.10	40.90	Inner Mongolia	China	Shi *et al.*, 2007
28	106.80	40.95	Inner Mongolia	China	Shi *et al.*, 2007
29	108.15	41.27	Inner Mongolia	China	Shi *et al.*, 2007

Table 1 (continued)

Code	Longitude	Latitude	Province	Country	Reference
30	108.58	41.30	Inner Mongolia	China	Shi *et al.*, 2013
31	106.80	39.63	Inner Mongolia	China	Sun & Sun, 2011
32	106.93	39.66	Inner Mongolia	China	Sun & Sun, 2011
33	106.95	40.37	Inner Mongolia	China	Sun & Sun, 2011
34	104.33	40.90	Inner Mongolia	China	Sun & Sun, 2011
35	108.22	41.27	Inner Mongolia	China	Sun & Sun, 2011
36	107.07	41.32	Inner Mongolia	China	Sun & Sun, 2011
37	105.44	37.03	Ningxia	China	Shi *et al.*, 2007
38	105.46	37.30	Ningxia	China	Shi *et al.*, 2013
39	105.97	37.37	Ningxia	China	Shi *et al.*, 2007
40	105.25	37.43	Ningxia	China	Shi *et al.*, 2007
41	104.52	37.45	Ningxia	China	Shi *et al.*, 2007
42	105.50	37.60	Ningxia	China	Shi *et al.*, 2007
43	105.55	37.66	Ningxia	China	Shi *et al.*, 2007
44	106.00	37.70	Ningxia	China	Shi *et al.*, 2007
45	105.90	37.84	Ningxia	China	Shi *et al.*, 2007
46	106.00	37.89	Ningxia	China	Shi *et al.*, 2007
47	106.35	38.08	Ningxia	China	Shi *et al.*, 2007
48	106.30	38.30	Ningxia	China	Shi *et al.*, 2007
49	106.33	39.05	Ningxia	China	Shi *et al.*, 2007
50	87.60	43.80	Xinjiang	China	This study
51	84.73	45.86	Xinjiang	China	This study
52	87.80	47.30	Xinjiang	China	Shi *et al.*, 2013
53	87.05	47.56	Xinjiang	China	This study
54	86.72	47.66	Xinjiang	China	This study
55	86.67	47.84	Xinjiang	China	This study
56	87.55	48.14	Xinjiang	China	This study
57	87.22	43.73	Xinjiang	China	Sun & Sun, 2011
58	85.85	43.92	Xinjiang	China	Sun & Sun, 2011
59	82.03	44.78	Xinjiang	China	Sun & Sun, 2011
60	82.57	45.03	Xinjiang	China	Sun & Sun, 2011
61	82.60	45.15	Xinjiang	China	Sun & Sun, 2011
62	84.85	45.63	Xinjiang	China	Sun & Sun, 2011
63	84.55	46.10	Xinjiang	China	Sun & Sun, 2011
64	90.33	46.67	Xinjiang	China	Sun & Sun, 2011
65	89.52	46.97	Xinjiang	China	Sun & Sun, 2011
66	108.07	43.58	Dornogovi	Mongolia	This study
67	110.60	43.65	Dornogovi	Mongolia	This study
68	104.26	43.70	Dornogovi	Mongolia	Shi *et al.*, 2013
69	110.09	44.78	Dornogovi	Mongolia	Stahnke, 1967[*]

Table 1 (continued)

Code	Longitude	Latitude	Province	Country	Reference
70	104.00	42.50	Umnogovi	Mongolia	Shi *et al.*, 2007
71	102.25	43.17	Umnogovi	Mongolia	This study
72	102.17	43.18	Umnogovi	Mongolia	This study
73	107.20	43.19	Umnogovi	Mongolia	This study
74	101.01	43.22	Umnogovi	Mongolia	This study
75	101.74	43.25	Umnogovi	Mongolia	This study
76	107.64	43.40	Umnogovi	Mongolia	This study
77	102.58	43.86	Umnogovi	Mongolia	This study
78	102.99	43.98	Umnogovi	Mongolia	This study
79	103.12	43.34	Umnogovi	Mongolia	Stahnke, 1970*
80	102.14	43.51	Umnogovi	Mongolia	Stahnke, 1970*
81	101.84	43.21	Umnogovi	Mongolia	Stahnke, 1970*
82	101.86	43.34	Umnogovi	Mongolia	Stahnke, 1970*
83	102.44	42.26	Umnogovi	Mongolia	Stahnke, 1970*
84	105.33	42.40	Umnogovi	Mongolia	Stahnke, 1967*
85	102.16	43.83	Umnogovi	Mongolia	Stahnke, 1967*
86	96.16	46.18	Govi Altai	Mongolia	Stahnke, 1970*
87	96.52	45.86	Govi Altai	Mongolia	Stahnke, 1970*
88	98.27	45.28	Govi Altai	Mongolia	Stahnke, 1970*
89	95.93	45.16	Govi Altai	Mongolia	Stahnke, 1970*
90	95.17	44.66	Govi Altai	Mongolia	Stahnke, 1970*
91	94.54	45.32	Govi Altai	Mongolia	Stahnke, 1970*
92	98.82	42.75	Bayankhongor	Mongolia	Stahnke, 1970*
93	98.79	42.76	Bayankhongor	Mongolia	Stahnke, 1970*
94	98.95	42.79	Bayankhongor	Mongolia	Stahnke, 1970*
95	99.18	43.56	Bayankhongor	Mongolia	Stahnke, 1970*
96	91.95	46.14	Khovd	Mongolia	Stahnke, 1970*
97	91.44	46.03	Khovd	Mongolia	Stahnke, 1970*
98	91.79	46.45	Khovd	Mongolia	Stahnke, 1970*

*Coordinates for sites reported by Stahnke, 1967 and 1970 were georeferenced approximately basing on description of places but not GPS records.

3 Results

3.1 Species identification and distribution

We surveyed all Aimags (Provinces) except Bayan-Ulgii Aimag at the western extreme of Mongolia. The areas we surveyed comprised all major climatic zones and ecosystems. Of a total 134 investigated sites, including 63 stopovers and 71 camping sites where scorpion search was also conducted at night, we only successfully collected scorpions at 10 sites (Table 1), all located in the Southern Gobi (Fig. 1A). All specimens were identified as *M. eupeus mongolicus* basing on morphological description of Shi *et al.* (2007) and Sun & Sun (2011). No other scorpion species was discovered in Mongolia during our field survey. Specimens displayed at the Mongolian Museum of Natural History and a specimen deposited at

Institute of Biology, Mongolian Academy of Sciences collected by Dorjsuren Altanchimeg also belong to this species. Neither *M. martensii* nor *M. caucasicus* was found in Mongolia.

3.2 Ecological niche modeling

We assembled 33 points of occurrence data (including 23 historical record) from Mongolia and additional 65 presence

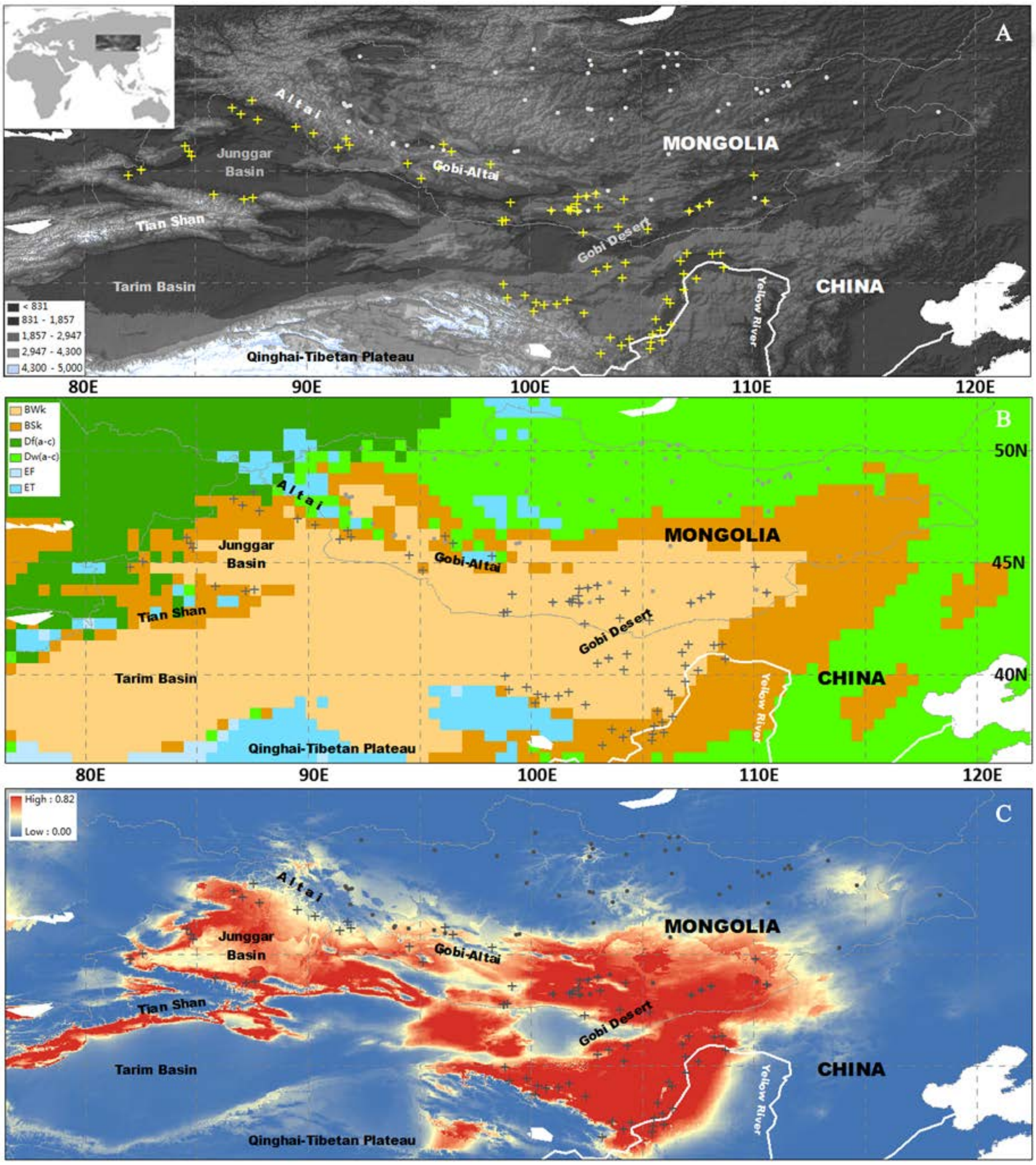

Fig. 1. Geographic and climatic features for the occurrence sites of *Mesobuthus eupeus mongolicus* and its suitable distributional areas predicted by ecological niche modeling. A. Field surveying sites (camping sites and stopovers) in Mongolia (dots) and occurrence points (crosses) of *M. eupeus mongolicus* is projected on the physical map of studied region. B. Scorpion occurring sites is projected on the map of Köppen-Geiger climatic classification. BWk: arid, desert, cold; BSk: arid, steppe, cold; Df(a-c): cold, without dry season; Dw(a-c) cold, dry winter; EF: polar, frost; ET: polar, tundra. C. Suitable distributional areas (red) predicted with MaxEnt basing on 98 presence-only data for *M. eupeus mongolicus.*

GPS points from China for *M. eupeus mongolicus* (Table 1). A visual inspection of these distributional data on the Köppen-Geiger climatic classification map revealed that *M. eupeus mongolicus* was exclusively distributed in cold arid climate no matter it was desert (BWk) or steppe (BSk), except three site fell on Df (cold without dry season) (Fig. 1B). ENMs for distribution of *M. eupeus mongolicus* basing on these 98 presence-only data maintained a high AUC statistic (0.880 ± 0.016), indicating the good performance of these models. The suitable distributional areas for *M. eupeus mongolicus* averaged over 10 replicated models are shown in Fig. 1C. All our presence points fall into the predicted suitable distribution areas, which was a bit larger than the point outline. Of the 19 climate variables used (Table 2), Bio12 (annual precipitation) contributed to the MaxEnt models most with a mean relative contribution of 19.5%, then followed by BIO11 (mean temperature of coldest quarter, 18.6%) and Bio18 (precipitation of warmest quarter, 18.6%). BIO1 (annual mean temperature) contributed 9.8% to the models. The remaining 15 variables collectively have a relative contribution of 33.5%, with BIO5 (max temperature of warmest month) having no contribution to the models at all.

Table 2. Bioclimatic variables used for the ecological niche modeling and their relative contributions to the MaxEnt model.

Codes	Name	Percent contribution
BIO1	Annual Mean Temperature	9.8
BIO2	Mean Diurnal Range (max temp - min temp)	0.1
BIO3	Isothermality ((BIO2/BIO7) * 100)	3.3
BIO4	Temperature Seasonality (standard deviation * 100)	0.1
BIO5	Max Temperature of Warmest Month	0
BIO6	Min Temperature of Coldest Month	0.1
BIO7	Temperature Annual Range (BIO5-BIO6)	0.1
BIO8	Mean Temperature of Wettest Quarter	0.9
BIO9	Mean Temperature of Driest Quarter	7.7
BIO10	Mean Temperature of Warmest Quarter	0.4
BIO11	Mean Temperature of Coldest Quarter	18.6
BIO12	Annual Precipitation	19.5
BIO13	Precipitation of Wettest Month	5.5
BIO14	Precipitation of Driest Month	6.6
BIO15	Precipitation Seasonality (Coefficient of Variation)	0.5
BIO16	Precipitation of Wettest Quarter	5.0
BIO17	Precipitation of Driest Quarter	0.8
BIO18	Precipitation of Warmest Quarter	18.6
BIO19	Precipitation of Coldest Quarter	2.3

4 Discussion

4.1 Scorpion fauna of Mongolia

Of the three *Mesobuthus* species recorded or assumed to occur in Mongolia, we have only collected one species, *M. eupeus*, during four years of country-wide field survey. Like zoological expeditions by Dr. Z. Kaszab (Stahnke, 1967, 1970), this species was only found in the easternmost Gobi-Altai Mts and the southern Gobi desert (Fig. 1 and Table 1). Outside these regions we failed to spot any scorpion, although habitats typical for *Mesobuthus* species were repeatedly encountered in the west and southeast parts of Mongolia. Both *M. martensii* and *M. caucasicus* were not found in Mongolia. The Chinese scorpion, *M. martensii*, the only species of the genus which has adapted to humid climate, occurs widely in the temperate monsoonal regions (Shi *et al.*, 2007, 2013), and even the littoral zone in East China (Remy & Leroy, 1933; Millot & Vachon, 1949; Shi *et al.*, 2007). It was never found to the north of latitude 43°N and to the west of the Helan Mts in China. In addition, our earlier ENM study suggested that no area in Mongolia were suitable for this species (Shi *et al.*, 2007). It was very likely that the citation of *M. martensii* from Mongolia in earlier literatures was due to geographical misinterpretation (e.g. by mistaking Inner Mongolia, China, with Mongolia; this species does occur in Inner Mongolia (*see* Shi *et al.*, 2007)). However, the occurrence of *M. caucasicus* in Mongolia could not be entirely ruled out yet, given its distribution in the nearby regions of Kazakhstan and China (Fet, 1989). Nevertheless, our survey suggests that scorpion diversity in Mongolia is relatively low, a situation paralleling that in the Palearctic China (Shi *et al.*, 2007). This is not unexpected as these regions represent a distributional edge for scorpions.

M. eupeus is the most widely distributed species of the genus, with a dozen or so subspecies being recognized based mainly on coloration and morphometric characteristics (Fet, 1994). Recent molecular phylogenetic analysis revealed that it represented a deeply diverged species complex (Mirshamsi *et al.*, 2010, 2011) and a subspecies from Iran has been promoted to full species (Mirshamsi *et al.*, 2011). Our earlier biogeographic study suggested that *M. eupeus* from China and Mongolia represents a recent diverged lineage which originated from Central Asia some 0.68 million years ago (Shi *et al.*, 2013). As mentioned above, this lineage morphologically corresponds to the subspecies *M. eupeus mongolicus*.

4.2 Geographic distribution of *M. eupeus mongolicus*

Although its distribution in the Tarim Basin still awaits to be explored and a large gap exists in the Northwest China, basing on distributional records available from Mongolia and China, a rough sketch for the range of *M. eupeus mongolicus* now emerges out: it ranges from the southern slope of the Altai Mts in the west to the Gobi deserts of Mongolia and China, and is limited by the northern edge of the Qinghai-Tibet Plateau in the south, and the Loess Plateau in the east (Fig. 1A). This region encompasses Umnugovi, Dornogovi, the southern parts of Govi-Altai and Bayankhongor, the southernmost Khovd of Mongolia, and the northern part of Xinjiang Uygur Autonomous Region (Altay, Changji, Karamay, Tacheng, Urumqi and Yili), the west part of Inner Mongolia Autonomous Region (Alxa Meng, Bayannur Meng and Wuhai), the west part of Gansu Province (Baiyin, Jiayuguan, Jinchang, Wuwei and Zhangye) and the whole Ningxia Hui Autonomous Region of China (Fig. 1A and Table 1). The range of *M. eupeus mongolicus* is dominated by arid deserts (sandy and Gobi deserts) and steppe ecosystems (Fig. 1B) which are characterized by deficiency of precipitation with annual rainfall normally less than 200 mm, but evaporation being more than 1 600 mm (even more than 2 400 mm in the Gobi desert regions).

Ecological niche modeling by MaxEnt performed well (AUC = 0.880 ± 0.016) and no omission (a site where scorpion present but predicted unsuitable) was observed. The intervening region between Xinjiang and Southern Mongolia seemed less suitable for *M. eupeus mongolicus*. However, this pattern does not necessarily indicate the absence of this scorpion there, since it may just reflect a lack of spotting sites there, or suggest that scorpion occurrence in this region is ecologically unfavorable (thus the population density is very low such that it is difficult to encounter the animal). Also, our results revealed that climate was a reliable predictor for the geographic range of *M. eupeus mongolicus*. This implies that climate variables have exerted determinate constraints on the natural distribution of this scorpion, as evidenced from other biota (Pearson & Dawson, 2003).

Note that a few sizeable areas in the southeast Mongolia and north China were predicted suitable for survival of *M. eupeus mongolicus*, but scorpion was not observed there (Fig. 1C). This phenomenon may be due to model commission where absence areas are predicted to be suitable, or reflect the fact that the climatic condition there are suitable but scorpion's presence is limited by some other factors, such as biological interaction, or the scorpion has insufficient time to disperse there yet. We think the latter explanations are more probable. First, because commission is a systematic error, it is expected to affect whole model performance. However, commission was much less at the northwest part of the distributional edges. Second, at the eastern edge by the Loess Plateau, the suitable areas are occupied by *M. martensii*. Interspecific competition for preys and shelters might have prevented *M. eupeus mongolicus* from establishing populations there - its smaller body size would put *M. eupeus mongolicus* at disadvantage (Shi *et al.*, 2007). Third, populations of *M. eupeus mongolicus* in Mongolia and China represent a very young lineage which dispersed from Central Asia very recently, with the age to their most recent common ancestor being just around 0.68 million years (Shi *et al.*, 2013). It's very likely that *M. eupeus mongolicus* is still on its way to eastward dispersal, and has not reached its ecological niche limit yet.

4.3 Notes on ecology of *M. eupeus mongolicus*

The habitats of *M. eupeus mongolicus* are exclusively arid deserts and steppes. In some regions where steppe dominates, the elms (*Ulmus* sp.) struggle along ephemeral river valleys on rare occasions. Scorpions were relatively abundant at the sites where we collected specimens. They were commonly found under rocks of Gobi (gravel) deserts and on recent deposited sandy slopes, and incidentally under rotted logs during daytime. They remained actively hunting at midnight when the temperate was as low as 7°C (Sep. 2, 2012; 43.65°N, 110.60°E; east Gobi). Moderate wind did not prevent their foraging activities. Ground beetles composed a major bulk of scorpion diet in Mongolia. The most often observed preys are *Harpalus amplicollis* Ménétriés, 1848 and *Harpalus froelichii* Sturm, 1818. At some sites where some elm trees survive, scorpion was never found on trunks although leaf beetles were abundant on the trees. On one occasion, we observed a *M. eupeus mongolicus* attacking a gecko (*Alsophylax* sp.), with which it was sharing a shelter rock. Obviously, the ecology, biology and subspecies status of *M. eupeus mongolicus* remain to be systematically examined.

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