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Morphological Variation of *Mesobuthus eupeus mongolicus* (Birula, 1911) (Scorpiones: Buthidae) in Mongolia

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Morphological variation of *Mesobuthus eupeus mongolicus* (Birula, 1911) (Scorpiones: Buthidae) in Mongolia[1]

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Abstract

In the present study, we investigated morphological variation of *Mesobuthus eupeus mongolicus* (Birula, 1911) in Mongolia. Samples were collected in 16 sites located in the provinces Bayankhongor, Khovd, Dundgovi, Dornogovi, Govisümber and Ömnögovi. Statistical analyses (Kruska-Wallis one-way ANOVA, PCA and hierarchical cluster analysis) showed that *(a)* morphologically the *M. e. mongolicus* males sampled in Dundgovi, Dornogovi, Govisümber and Ömnögovi were similar to each other, while the populations of Bayankhongor and Khovd were differentiated, and *(b)* the females from Bayankhongor, Dundgovi, Dornogovi, Govisümber and Ömnögovi had a similar morphology, while the population from Khovd was differentiated.

Key words: Scorpiones, *Mesobuthus eupeus mongolicus*, Mongolia, morphometrics, variation

Introduction

Differences of morphological characteristics among geographically separated populations are considered as starting point of allopatric speciation. Habitat differences can generate a divergent selection in nature, resulting in reproductive isolation of the different populations (MAYR 1942, 1963; SCHLUTER 2000). Data on this diversification process are therefore useful for understanding evolutionary processes (COYNE & ORR 2004).

Two species of scorpions from the genus *Mesobuthus* (Vachon, 1950) have been reported to occur in Mongolia: *Mesobuthus martensii martensii* (Kalasch, 1879) and the subspecies *Mesobuthus eupeus mongolicus* (Birula, 1911) (HEDDERGOTT et al. 2016), of which the latter appears to be more widespread. In his first description of *M. e. mongolicus* (initially referred to as *Buthus eupeus mongolicus*), BIRULA (1911) considers the subspecies to occur in Central-Mongolia (locality: Alashan province). After a careful inspection of old travelogues of the type series P.K. Kozlov, all samples were collected on territories now belonging to China [Autonomous Region Inner Mongolia: Alxa Zuoqi (in chinese: 阿拉善左旗)] (cf. SUN & SUN 2011, HEDDERGOTT et al. 2016). According to current knowledge, the subspecies only occurs in central Asia (Mongolia and China) (cf. ZUH et al. 2004, SHI et al. 2007, SUN & SUN 2011, HEDDERGOTT et al. 2016). In Mongolia, *M. e. mongolicus* is present in the desert or desert-steppe and occurs in all southern areas. There are records of the subspecies from the six Mongolian provinces Bayankhongor, Khovd, Dundgovi, Dornogovi, Govisümber and Ömnögovi (BIRULA 1927, STAHNKE 1967, KOVAŘÍK 1997, HEDDERGOTT et al. 2016). Individuals are found in small, self-burrowed holes, under stones or in gaps of walls and rocks. They are normally observed near ground level (HEDDERGOTT et al. 2016).

Because *M. e. mongolicus* is widespread in Mongolia, we aimed to test this species for morphological variations that may be associated with the geographical origin. HEDDERGOTT et al. (2016) had identified variability in morphology and in colour among the Mongolian population of *M. e. mongolicus*. For the present study, we use specimens from six provinces (Bayankhongor, Khovd, Dundgovi, Dornogovi, Govisümber und Ömnögovi). The sampling scheme included

[1] Results of the Mongolian-German Biological Expeditions since 1962, No. 332.

western, eastern and northern parts of the species Mongolian distribution range. The geographical distance between the western- and the eastern-most populations was about 1500 km, the distance between the southern-most and the northern-most about 450 km. The altitude reached from Galbyn-gobi (Province Ömnögovi) with 925 m a.s.l to Cagaan Bogd (Province Bayankhongor) with 1705 m a.s.l.

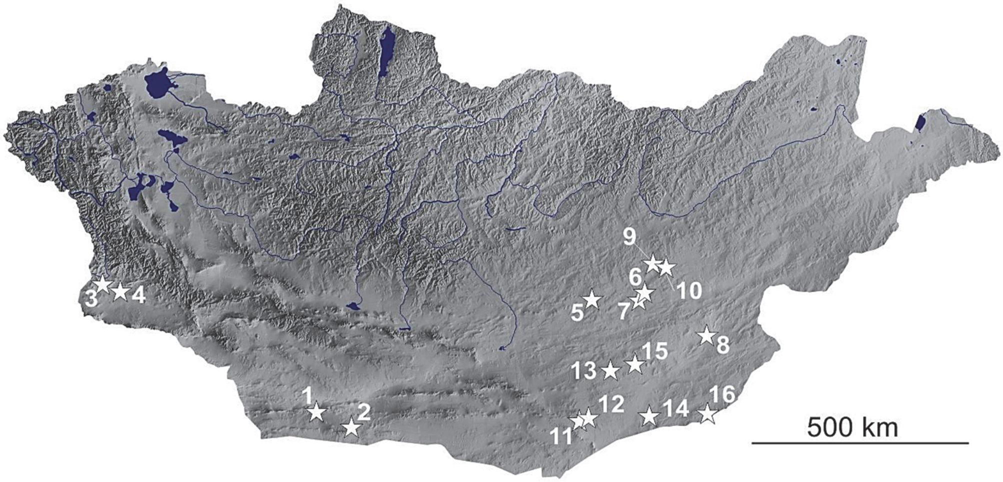

Fig.1: Map of Mongolia showing the sampling localities of *Mesobuthus eupeus mongolicus*. Locality numbers are shown in the list of specimens examined: 1 and 2 province Bayankhongor, 3 and 4 province Khovd; 5, 6 and 7 province Dundgovi; 8 and 16 province Dornogovi; 9 and 10 province Govisümber; 11, 12, 13, 14 and 15 province Ömnögovi.

Material and methods

All scorpions were collected during the Mongolian-German Biological Expeditions of the years 2001 to 2012. All animals were collected during daytime under stones, in crevices, and in gaps of walls as well as at night with the help of black light. All specimens, which were stored in 70 % alcohol, were deposited in the collection of the department of zoology of the Martin-Luther University Halle-Wittenberg (MLUH) and in the first author's private collection (CMH S.). We analyzed specimens from 158 *M. e. mongolicus* (63 males; 95 females) (complete list of materials in Appendix 1) that were selected from different distant populations (fig. 1). For the morphological analysis, 15 different parameters were measured. All measurements were taken with a Stereomicroscope Stemi 2000C (Carl Zeiss Microscopy GmbH; Germany) with > 0.001 mm accurate micro-metric ocular. All measurements were done in mm. The terminology follows HJELLE (1990) and the methods of measurement follow SISSOM et al. (1990).

The statistical analyses included descriptive statistics [means and standard deviations (±SD)] for each variable. Principal component analysis (PCA) was applied to limit over-parametrization by reducing the data set to several principle components, and to determine whether any of the geographic populations were morphologically distinct. A Kruskal-Wallis one-way ANOVA was used to determine statistical significance ($p < 0.05$). Cluster analysis was conducted to investigate the relationship the morphologies of the six provinces. A hierarchical clustering scheme was applied to the mean ratios for each province and dendrograms were obtained as follows: the horizontal scale represents the distance of levels of mergers between clusters. We choose Between-groups linkage and Within-groups linkage to do our cluster analysis (BACKHAUS et al. 2011). All statistical analysis were conducted using SPSS 22.0 for windows.

List of abbreviations of morphometric rations

The following values were used for the study: Ca_L/AW – carapace length to anterior width; Ca_AW/PW – carapace anterior width to posterior width; Fem_L/W – pedipalp femur length to width; Pat_L/W – pedipalp patella length to width; Ch_L/W – pedipalp chela length to width; Met-I_L/W – metasomal segment I length to width; Met-I_L/H – metasomal segment I length to height; Met-II_L/W – metasomal segment II length to width; Met-II_L/H – metasomal segment II length to height; Met-III_L/W – metasomal segment III length to width; Met-III_L/H – metasomal segment III length to height; Met-IV_L/W – metasomal segment IV length to width; Met-IV_L/H – metasomal segment IV length to height; Met-V_L/W – metasomal segment V length to width and Met-V_L/H – metasomal segment V length to height.

Results

Kruskal-Wallis one-way ANOVA

For male populations, a Kruskal-Wallis one-way ANOVA revealed that there were significant differences among the provinces for the measurements Ca_L/AW, CA_AW/PW, Pat_L/W, Met-II_L/W, Met-III_L/W, Met-IV_L/W, Met-IV_L/H and Met-V_L/W while no significant difference was found for Fem_L/W, Ch-L/W, Met-I_L/W, Met-I_L/H, Met-II_L/H, Met-III_L/H and Met-V_L/H (table 1). For female populations, there are significant differences for Ca_L/AW, Fem_L/W, Pat_L/W, Met-I_L/W, Met-I_L/H, Met-II_L/W, Met-II_L/H, Met-III_L/W, Met-III_L/H and Met-V_L/H. No significant difference was found for Ca_AW/PW, Met-IV_L/W, Met-IV_L/H and Met-V_L/H (table 2).

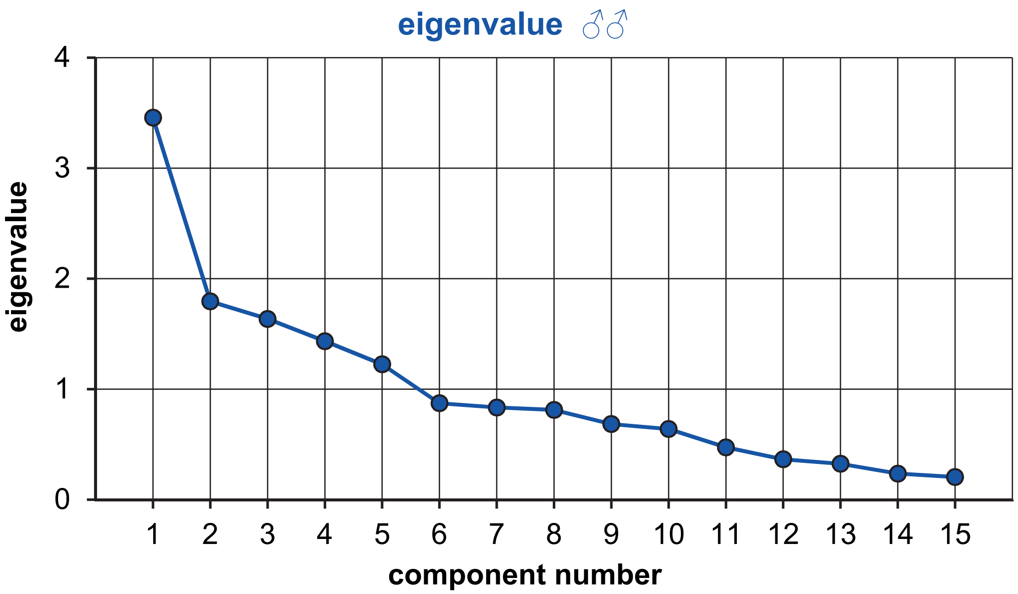

Fig. 2: Screen plot of principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* males.

Principal component analysis (PCA)

For males, five principal components were associated with eigenvalues greater than 1. The total eigenvalue is 9.548. The total of the four components explained 63.659 % of the total variance. The total overview of component loadings is given in table 3 and the screen plot in fig. 2. In the score plots of the first and second principal components PC1 vs. PC2, it was observed that the males were not separated to form independent groups (fig. 3 A). The same was also found in PC1 vs. PC3, PC1 vs. PC4 and PC1 vs. PC5 (fig. 3 B, C and D). These results indicate therefore that

Table 1: Descriptive statistics of *Mesobuthus eupeus mongolicus* males of the investigated provinces in Mongolia (means±SD)

province	**Bayankhongor**	**Khovd**	**Dundgovi**	**Dornogovi**	**Govisümber**	**Ömnögovi**	**Kruskal-Wallis**	
n	**12**	**10**	**10**	**11**	**4**	**16**	***P***	
Ca_L/AW	1.737 ± 0.098	1.820 ± 0.067	1.719 ± 0.068	1.771 ± 0.087	1.670 ± 0.045	1.794 ± 0.083	0.014	*
Ca_AW/PW	0.539 ± 0.020	0.558 ± 0.021	0.551 ± 0.020	0.539 ± 0.025	0.571 ± 0.032	0.533 ± 0.018	0.027	*
Fem_L/W	2.535 ± 0.216	2.557 ± 0.174	2.595 ± 0.276	2.512 ± 0.134	2.907 ± 0.176	2.572 ± 0.252	0.192	ns
Pat_L/W	2.792 ± 0.181	2.874 ± 0.230	2.615 ± 0.174	2.647 ± 0.170	2.496 ± 0.160	2.690 ± 0.109	0.012	*
Ch_L/W	3.362 ± 0.206	3.424 ± 0.218	3.567 ± 0.187	3.585 ± 0.220	3.606 ± 0.100	3.544 ± 0.223	0.149	ns
Met-I_L/W	1.121 ± 0.105	1.078 ± 0.082	1.416 ± 0.090	1.145 ± 0.074	1.082 ± 0.120	1.145 ± 0.047	0.335	ns
Met-I_L/H	1.089 ± 0.106	1.012 ± 0.092	1.118 ± 0.085	1.109 ± 0.083	1.145 ± 0.201	1.104 ± 0.065	0.111	ns
Met-II_L/W	1.210 ± 0.109	1.108 ± 0.078	1.225 ± 0.066	1.226 ± 0.074	1.204 ± 0.088	1.214 ± 0.090	0.035	*
Met-II_L/H	1.230 ± 0.087	1.291 ± 0.111	1.292 ± 0.067	1.278 ± 0.055	1.309 ± 0.080	1.283 ± 0.073	0.389	ns
Met-III_L/W	1.163 ± 0.082	1.108 ± 0.063	1.211 ± 0.056	1.202 ± 0.042	1.200 ± 0.062	1.185 ± 0.071	0.040	*
Met-III_L/H	1.231 ± 0.083	1.234 ± 0.085	1.320 ± 0.078	1.311 ± 0.083	1.311 ± 0.068	1.295 ± 0.067	0.082	ns
Met-IV_L/W	1.395 ± 0.107	1.409 ± 0.082	1.547 ± 0.070	1.562 ± 0.048	1.500 ± 0.139	1.595 ± 0.058	0.000	*
Met-IV_L/H	1.746 ± 0.128	1.729 ± 0.120	1.964 ± 0.100	1.970 ± 0.090	1.977 ± 0.214	1.942 ± 0.094	0.000	*
Met-V_L/W	1.861 ± 0.107	1.823 ± 0.076	2.044 ± 0.280	1.983 ± 0.131	1.930 ± 0.103	2.016 ± 0.076	0.001	*
Met-V_L/H	2.541 ± 0.119	2.564 ± 0.084	2.632 ± 0.341	2.604 ± 0.202	2.526 ± 0.109	2.583 ± 0.143	0.862	ns

n = sample size; * = *P* < 0.05; ns = no significant difference the variation for males was below the species level. In females, an eigenvalue greater than 1 is found in six principal components. The total eigenvalue was 10.481 and six components explained 69.877 % of total variance. The total overview of component loadings is given in table 4 and the screen plot in fig. 3. In the score plots of the first and second principal components PC1 vs. PC2, it was observed that the values of females were also not separated enough to form independent groups (fig. 4 A). The same was also found in PC1 vs. PC3, PC1 vs. PC4, PC1 vs. PC5 and PC1 vs. PC6 (fig. 4 B, C, D and E). Similarly to the males, all results indicate that the variation was below the species level.

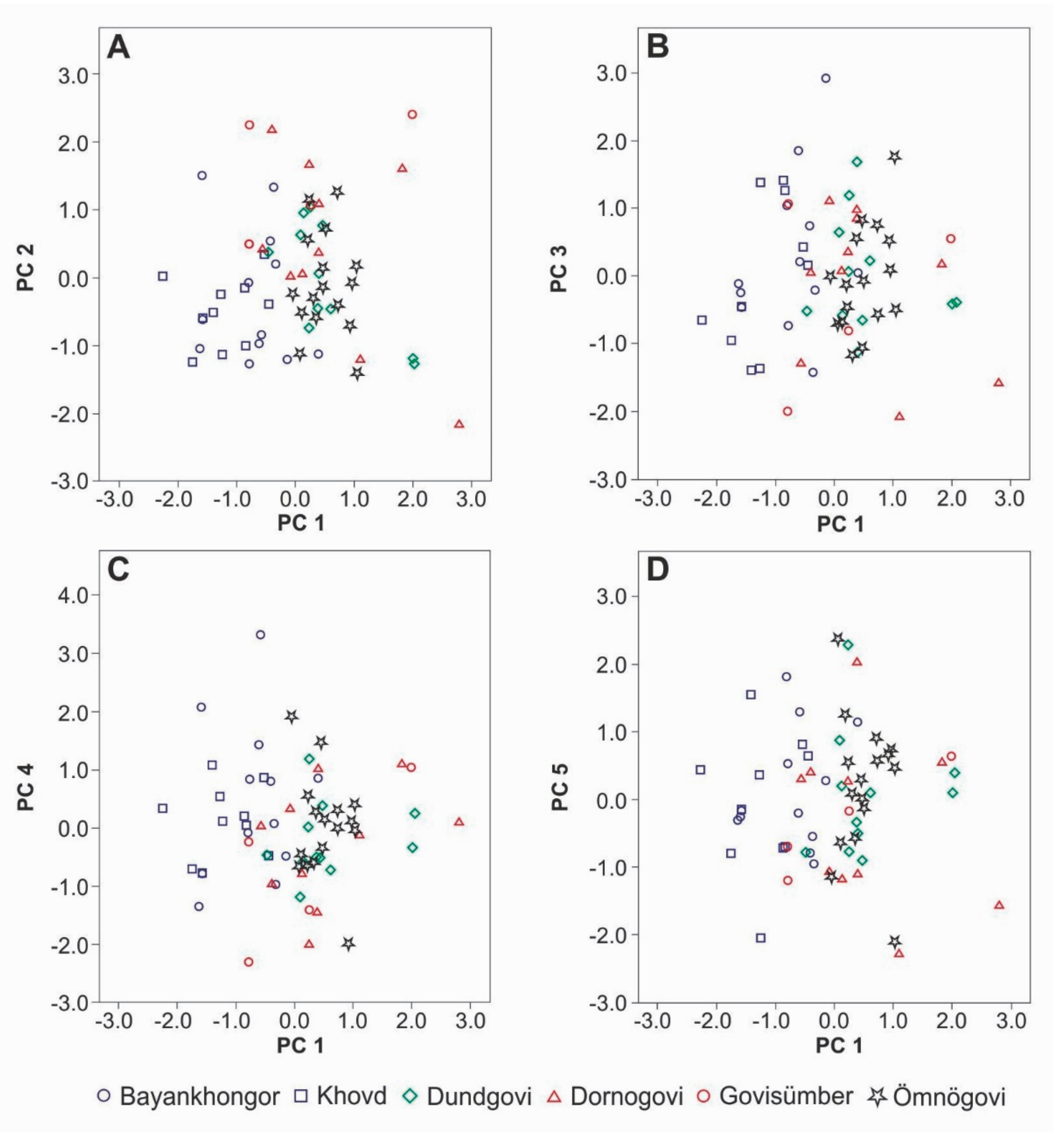

Fig. 3: Score plots of principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* males. Score plots: **A** – PC1 and PC2. **B** – PC1 and PC3. **C** – PC1 and PC4. **D** – PC1 and PC5.

Table 2: Descriptive statistics of *Mesobuthus eupeus mongolicus* females of the Provinces in Mongolia (means±SD)

Province	Bayankhongor	Khovd	Dundgovi	Dornogovi	Govisümber	Ömnögovi	Kruskal-Wallis	
n	20	15	14	16	5	25	*P*	
Ca_L/AW	1.728 ± 0.085	1.866 ± 0.166	1.770 ± 0.077	1.779 ± 0.089	1.741 ± 0.117	1.849 ± 0.121	0.010	*
Ca_AW/PW	0.544 ± 0.004	0.541 ± 0.040	0.516 ± 0.025	0.525 ± 0.023	0.518 ± 0.024	0.515 ± 0.030	0.050	ns
Fem_L/W	2.595 ± 0.270	2.332 ± 0.312	2.830 ± 0.156	2.863 ± 0.129	2.842 ± 0.208	2.868 ± 0.191	0.000	*
Pat_L/W	2.707 ± 0.212	2.798 ± 0.240	2.620 ± 0.155	2.675 ± 0.187	2.594 ± 0.212	2.830 ± 0.226	0.043	*
Ch_L/W	3.344 ± 0.301	3.504 ± 0.224	3.435 ± 0.190	3.350 ± 0.187	3.607 ± 0.131	3.282 ± 0.169	0.012	*
Met-I_L/W	1.141 ± 0.078	1.089 ± 0.067	1.150 ± 0.072	1.140 ± 0.060	1.131 ± 0.119	1.180 ± 0.081	0.045	*
Met-I_L/H	1.071 ± 0.112	1.031 ± 0.063	1.133 ± 0.117	1.159 ± 0.095	1.172 ± 0.084	1.186 ± 0.080	0.000	*
Met-II_L/W	1.222 ± 0.149	1.068 ± 0.100	1.242 ± 0.098	1.240 ± 0.073	1.248 ± 0.135	1.258 ± 0.068	0.000	*
Met-II_L/H	1.271 ± 0.130	1.247 ± 0.077	1.119 ± 0.142	1.368 ± 0.139	1.370 ± 0.149	1.381 ± 0.143	0.015	*
Met-III_L/W	1.152 ± 0.069	1.283 ± 0.083	1.185 ± 0.050	1.161 ± 0.056	1.190 ± 0.028	1.192 ± 0.056	0.049	*
Met-III_L/H	1.241 ± 0.089	1.258 ± 0.084	1.330 ± 0.050	1.328 ± 0.090	1.369 ± 0.119	1.305 ± 0.100	0.002	*
Met-IV_L/W	1.401 ± 0.082	1.496 ± 0.110	1.431 ± 0.076	1.441 ± 0.090	1.437 ± 0.084	1.413 ± 0.129	0.178	ns
Met-IV_L/H	1.651 ± 0.136	1.804 ± 0.139	1.681 ± 0.148	1.631 ± 0.182	1.720 ± 0.185	1.651 ± 0.189	0.100	ns
Met-V_L/W	1.842 ± 0.132	1.835 ± 0.071	1.866 ± 0.083	1.890 ± 0.075	1.837 ± 0.108	1.887 ± 0.086	0.205	ns
Met-V_L/H	2.579 ± 0.241	2.653 ± 0.191	2.384 ± 0.096	2.439 ± 0.158	2.466 ± 0.167	2.418 ± 0.151	0.000	*

n = sample size; *= P<0.05; ns = no significant difference

Table 3: Principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* males

		components				
		1	**2**	**3**	**4**	**5**
initial eigenvalues	**total**	3.457	1.795	1.636	1.435	1.225
	% of variance	23.048	11.968	10.909	9.564	8.170
Ca_L/AW		0.157	-0.719	0.173	-0.008	0.328
Ca_AW/PW		-0.458	0.455	-0.216	-0.044	-0.325
Fem_L/W		-0.105	0.705	-0.148	0.026	0.222
Pat_L/W		-0.576	-0.083	0.048	0.218	0.296
Ch_L/W		0.292	-0.116	-0.353	-0.565	0.287
Met-I_L/W		0.548	0.049	0.201	0.608	0.294
Met-I_L/H		0.606	0.252	-0.117	0.399	0.295
Met-II_L/W		0.362	0.003	0.639	0.150	-0.272
Met-II_L/H		0.230	0.230	0.640	-0.057	-0.320
Met-III_L/W		0.462	0.019	0.310	-0.419	0.326
Met-III_L/H		0.488	0.177	0.250	-0.534	-0.079
Met-IV_L/W		0.613	0.335	-0.236	0.106	0.025
Met-IV_L/H		0.736	0.261	-0.195	-0.092	0.020
Met-V_L/W		0.593	-0.287	-0.436	0.066	-0.269
Met-V_L/H		0.472	-0.371	-0.312	0.161	-0.507

Table 4: Principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* females

		component					
		1	**2**	**3**	**4**	**5**	**6**
initial eigenvalues	**total**	3.371	1.932	1.708	1.215	1.166	1.089
	% of variance	22.473	12.881	11.388	8.101	7.773	7.261
Ca_L/AW		0.430	-0.632	0.109	0.332	-0.016	0.215
Ca_AW/PW		-0.609	0.363	-0.316	-0.185	0.335	-0.089
Fem_L/W		0.417	0.724	0.146	-0.098	-0.140	0.103
Pat_L/W		0.203	-0.163	0.233	0-487	0.519	0.336
Ch_L/W		-0.358	0.149	0.617	0.265	0.093	-0.242
Met-I_L/W		0.603	-0.026	-0.109	0.335	0.355	0.219
Met-I_L/H		0.780	-0.084	0.090	0.180	0.130	0.149
Met-II_L/W		0.585	0.057	-0.164	-0.482	-0.361	-0.005
Met-II_L/H		0.306	0.296	-0.493	0.264	-0.366	0.039
Met-III_L/W		0.269	0.428	0.351	-0.163	0.276	0.018
Met-III_L/H		0.400	0.493	0.373	0.317	0.021	-0.279
Met-IV_L/W		-0.459	-0.071	0.356	-0.130	-0.388	0.461
Met-IV_L/H		-0.544	0.071	0.441	0.225	-0.198	0.346
Met-V_L/W		-0.077	0.540	-0.243	0.139	0.060	0.602
Met-V_L/H		-0.565	0.052	-0.455	0.305	0.281	0.086

Cluster analysis

Using a “between-groups” linkage method to the six geographic clusters of males (fig. 6 A), the last merger was between Bayankhongor and Khovd and the others at a relative distance of 25. Next, Govisümber and the others were divided at the distance of around 18. The first merger was between Dornogovi, Ömnögovi and Dundgovi at a distance of 1. Using a “within-groups” linkage method to the six geographic clusters of males (fig. 6 B), the last merger was between Bayankhongor and Khovd and the others at a relative distance of 25. Next, Govisümber and the others were divided at a distance of around 14. The first merger was between Dornogovi, Ömnögovi and Dundgovi at a distance of 1. Applying a “between-groups” linkage method to the six geographic clusters of females (fig. 6 C), the last merger was between Khovd and the others at a distance of 25. Next, Bayankhongor and the others were divided at a distance of about 9. The first merger was between Dornogovi and Dundgovi at a distance of 1. The second merger was between Dornogovi, Dundgovi and Ömnögovi at a distance of about 6. Using a “within-groups” linkage method to the six geographic clusters of females (fig. 6 D), the last merger was between Khovd and the others at a distance of 25. Next, Bayankhongor and the others were divided at a distance of about 12.5. The first merger was between Dornogovi and Dundgovi at a distance of 1. The second merger was between Dornogovi, Dundgovi and Ömnögovi at a distance of about 8. The results of cluster analysis suggest that the morphology of male Khovd and Bayankhongor population differs substantially from the male populations of other provinces. For female populations the cluster analysis suggested that the morphology of Khovd populations differs substantially from the (female) populations of the other regions.

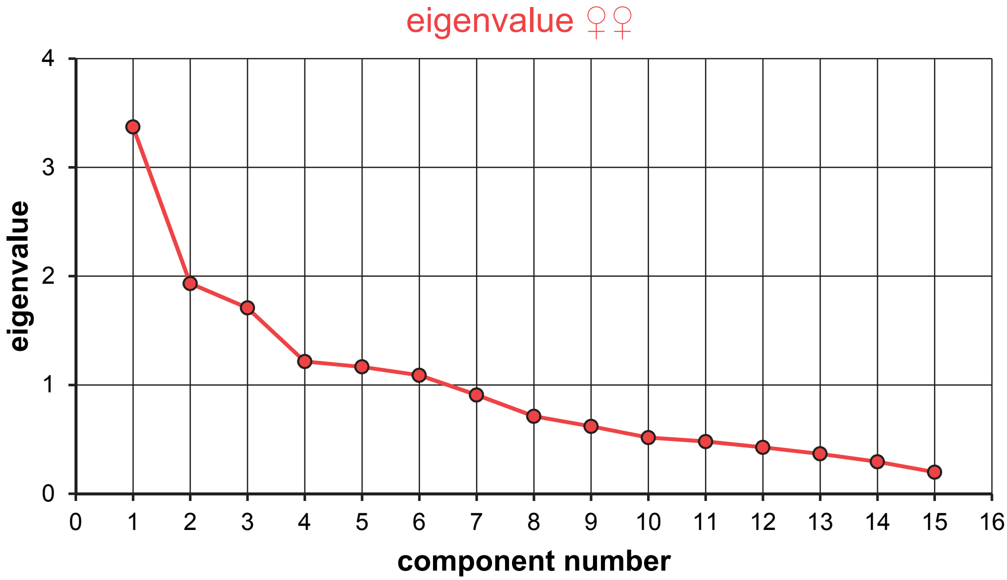

Fig. 4: Screen plot of principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* females.

Discussion

HEDDERGOTT et al. (2016) identified morphological and colour differences between the Mongolian population of *M. e. mongolicus.* For males and females, the average total length of specimens from the province Khovd was smaller compared to the other provinces (Bayankhongor, Dundgovi, Dornogovi, Govisümber and Ömnögovi).

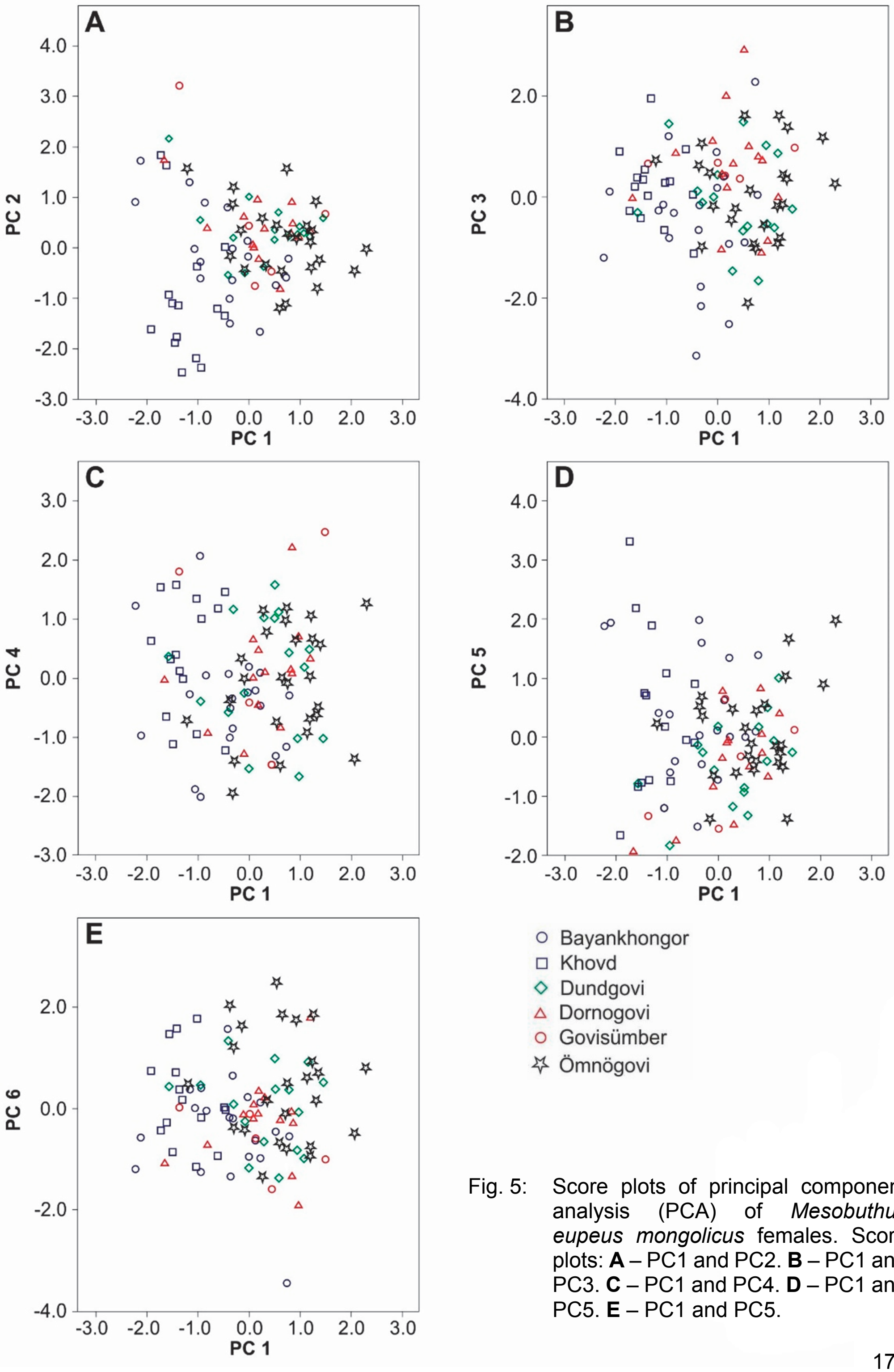

Fig. 5: Score plots of principal component analysis (PCA) of *Mesobuthus eupeus mongolicus* females. Score plots: **A** – PC1 and PC2. **B** – PC1 and PC3. **C** – PC1 and PC4. **D** – PC1 and PC5. **E** – PC1 and PC5.

The results of our analysis showed the existence of intra-specific geographical variations of morphological characteristics for the Mongolian population of *M. e. mongolicus*. Although *M. e. mongolicus* is widespread in southern Mongolia, no substantial morphological differences were found. In comparison to the specimens collected from other provinces, the ratios of Ca_L/AW and Pat_L/W for Khovd male populations seemed to be larger while the ratios of Met-II_L/W, Met-III_L/W, Met-IV_L/W, Met-IV_L/H and Met-_L/W were smaller (cf. table 1), which indicates that *M. e. mongolicus* males in Khovd have a narrower prosoma and a broader metasoma. For the female population in Khovd, we found that the ratios of Ca_L/AW, Pat_L/W, Met-III_L/W, Met-IV_L/H and Met-V_L/H were larger while the ratios of Fem_L/W, Met-I_L/W, Met-I_L/H, Met-II_L/W were smaller in comparison to the specimens collected from the other provinces (cf. table 2). This indicates that *M. e. mongolicus* females in Khovd have a narrower prosoma and the third, fourth and fifth metasomal segments are narrower while the first and second metasomal segments are broader.

In a comparable study ZHANG & ZHU (2009) analyzed the morphological variation of the related species *Mesobuthus martensii* (Karsch, 1879) in northern China. The study was performed using 161 (68 male and 93 female) specimens from five provinces (Hebei, Ningxia, Inner Mongolia, Liaoning and Qinghai). The authors did not find a substantial variation, but emphasized a larger variation for females than for males. The populations from Hebei, Ningxia, Inner Mongolia, and Liaoning Provinces were similar to each other while the populations from Qinghai were distinct. With the exception of Met-I_L/W and Met-V_L/W, each ratio of metasoma in both females and males of Qinghai populations was smaller and the ratio of Ca_L/AW was larger than those from other provinces. All morphological variations were found to be below the species level. The differences between specimens from the province Qinghai and the other provinces was explained with the rise of the Qinghai-Tibetan Plateau and the associated geographical isolation. For the Mongolian *M. e. mongolicus*, the morphological difference of the Khovd population can be explained by geographical isolation. Toward the end of the Pliocene and in the Pleistocene the creation of the Mongolian Altai and Gobi Altai induced a separation between the Khovd population, the population of Dundgovi, Dornogovi, Govisümber and Ömnögovi in the eastern Gobi and the Bayankhongor population in Trans-Altai Gobi.

ABDEL-NABI et al. (2004) analyzed *Scorpio maurus palmatus* (Ehrenberg, 1828) from four different locations in Egypt. Most of the morphological measurements (total body length, pedipalp length, pedipalp hand width, number of setae on legs and number of pectinal teeth) showed highly significant differences within and between the populations. OLIVERO et al. (2012) found a significant variation in the total body length and other morphological characteristics (e.g. prosoma length, hand height, hand width, and telson height) between six populations of *Bothriurus bonariensis* (Koch 1842) in Argentinia and Uruguay. The populations of the four Argentinian regions showed no significant difference. However, differences to the populations from the two regions in Uruguay were found.

In scorpions, altitude appears to be inversely correlated with body size. The *M. martensii* examined by ZHANG & ZHU (2009) in northern China were collected from sites varying between 10 m a.s.l. (province Hebei) to 2300 m a.s.l. (province Qinghai). The smallest specimens of *M. martensii* were found in the province Quinghai (i.e. at the highest altitudes). ABDEL-NABI et al. (2004) have found a similar result for *S. m. palmatus* in Egypt. In both sexes, the largest specimens were found at 10 m a.s.l. The smallest female specimens were found at an altitude of 1676 m a.s.l. and the smallest male specimen at an altitude of 1225 m a.s.l. Our study complements this hypothesis. The provinces with the largest morphological variations are located on the same altitude. On the other hand the *M. e. mongolicus* population in the province Bayankhongor (altitude: 1705 m a.s.l.) did not appear to differ from populations in Khovd, Dundgovi, Dornogovi, Govisümber and Ömnögovi whose altitudes vary between 925 m and 1360 m a.s.l.

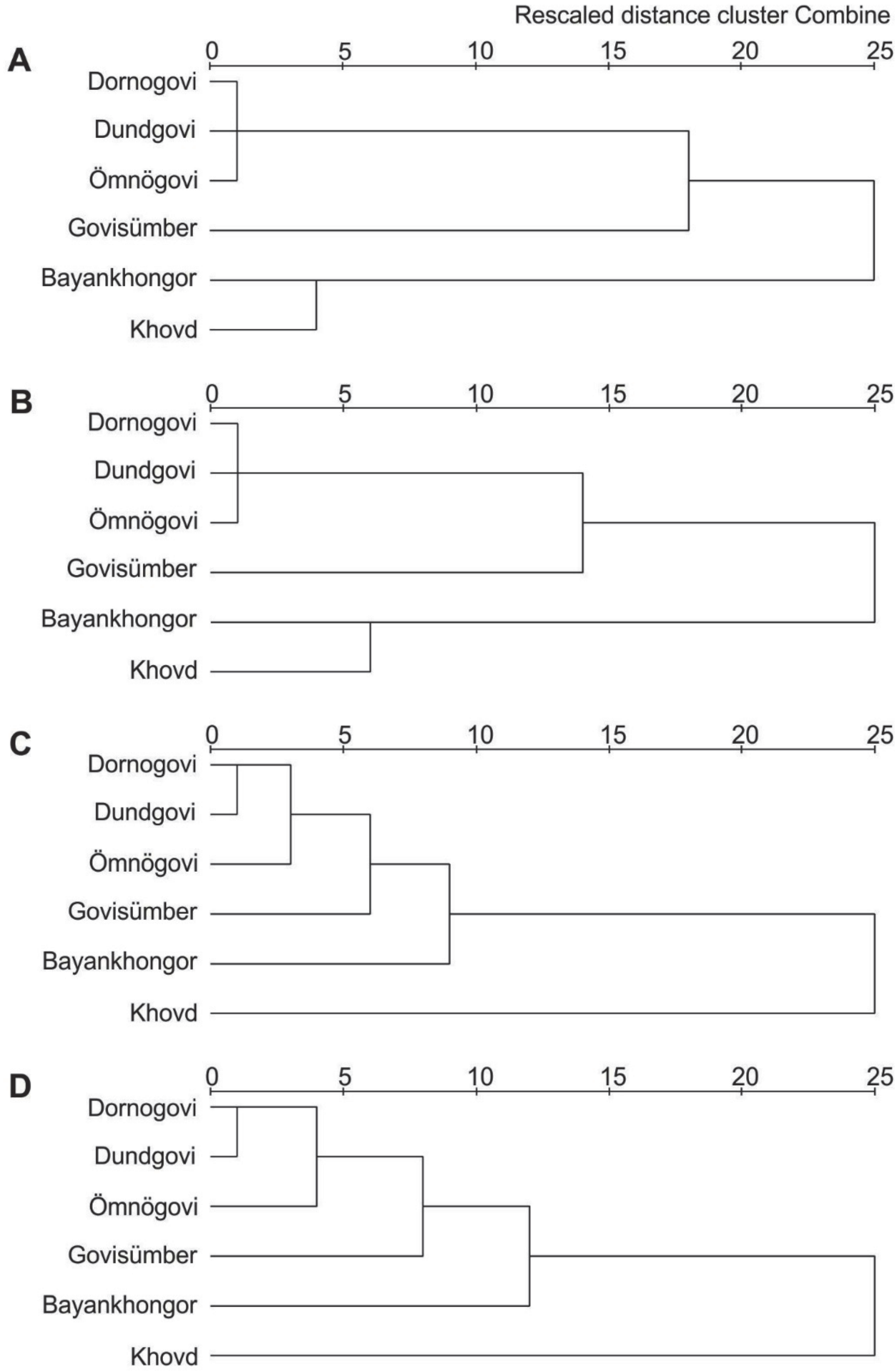

Fig. 6: Cluster analysis dendrogams of *Mesobuthus eupeus mongolicus* of the provinces in Mongolia. **A** – Between-groups linkage of male. **B** – Within-groups linkage of male. **C** – Between-groups linkage of female. **D** – Within-groups linkage of female.

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Fig. 7: Expedition camp in the canyon of Šutegijn Bajan-gol rife with *Mesobuthus eupeus mongolicus*; photo: A. STUBBE.

Appendix 1

Material of *Mesobuthus eupeus mongolicus* examined:

Province Bayankhongor: Cagaan Bogd (42°52’49.8’’N, 98°51’40.5’’E) [fig. 1; no. 1], 1705 m a.s.l, 29-30 June 2011, 2♂♂ and 2♀♀ [MLUH], detection UV-light, leg. A. Stubbe, M. Stubbe. – Cagaan Bogd (42°52’49.8’’N, 98°51’40.5’’E) [fig. 1; no. 1], 1705 m a.s.l, 29-30 June 2011, 11♂♂ and 18♀♀ [CMH S-20114589-20114618], detection UV-light, leg. A. Stubbe, M. Stubbe. – Šar-chulst-bulag (43°18’29.0’’N, 97°47’08.1’’E) [fig. 1; no. 2], 1215 m a.s.l, 1 July 2011, 1♂ [CMH S-20114619], detection UV-light, leg. A. Stubbe, M. Stubbe.

Province Khovd: Bulgan-gol, 5 km N Somon Bulgan (46°08’43.9’’N, 91°29’54.9’’E) [fig. 1; no. 3], 1160 m a.s.l, 7 August 2010, 1♂ and 1♀ [MLUH], detection UV-light, leg. A. Stubbe, M. Stubbe, W. Stubbe. - Bulgan-gol, 5 km N Somon Bulgan (46°08’43.9’’N, 91°29’54.9’’E) [fig. 1; no. 3], 1160 m a.s.l, 7 August 2010, 9♂♂ and 14♀♀ [CMH S-201058898-201058921], detection UV-light, leg. A. Stubbe, M. Stubbe, W. Stubbe. - Uenč-gol 10 km S Somon Uenč (45°59’01.3’’N, 91°57’46.4’’E) [fig. 1; no. 4], 1300 m a.s.l, 8 August 2010, 1♂ [CMH S-201058924], detection UV-light, leg. A. Stubbe, M. Stubbe, W. Stubbe.

Province Dundgovi: river valley 1 km south Mandalgovi (45°34’47.4’’N, 106°16’48.4’’E) [fig.1; no. 5], 1360 m a.s.l., 8 August 2003, 5♀♀ [CMH S-2003180-2003182], under stones, leg. M. Heddergott, R. Sommer. - river valley 1 km south Mandalgovi (45°34’47.4’’N, 106°16’48.4’’E) [fig.1; no. 5], 1360 m a.s.l., 10 August 2003, 1♂ and 2♀♀ [CMH S-2003190-2003192], detection UV-light, leg. M. Heddergott, R. Sommer. – 7 km northeast Bayanjargalan (45°47’15.5’’N, 108°02’38.2’’E) [fig.1; no. 6], 1230 m a.s.l., 9 August 2003, 1♂ and 2♀♀ [CMH S-2003195-2003197], detection UV-light, leg. M. Heddergott, R. Sommer. – 2 km south Bayanjargalan (45°43’51.6’’N, 107°59’27.6’’E) [fig.1; no. 7], 1210 m a.s.l., 12 August 2003, 8♂♂ and 6♀♀ [CMH S-2003199-2003213], detection UV-light, leg. M. Heddergott, R. Sommer.

Province Dornogovi: 2 km east of Sainshand (44°54’01.5’’N, 110°11’01.5’’E) [Fig.1; No 8], 980 m a.s.l., 13 August 2003, 4♂♂ and 11♀♀ [CMH S-200356-200370], detection UV-light, leg. M. Heddergott, R. Sommer. - Galbyn-gobi (42°38’28.6’’N, 108°01’35.5’’E) [fig.1; no. 9], 925 m a.s.l, 10 July 2010, 7♂♂ and 5♀♀ [CMH S-20102398-20102410], detection UV-light, leg. A. Stubbe, M. Stubbe, W. Stubbe. - Undagijn-gol (42°37’23.8’’N, 109°48’53.6’’E) [fig.1; no. 16], 955 m a.s.l, 25-26 July 2011, 1♀ [CMH S-20111331], detection UV-light, leg. A. Stubbe, M. Stubbe.

Province Govisümber: northeast of Choir (46°22’17.3’’N, 108°20’32.7’’E) [fig.1; no. 9], 1260 m a.s.l., 14 August 2003, 3♂♂ and 3♀♀ [CMH S-20033145-20033151], detection UV-light, leg. M. Heddergott, R. Sommer. – 5 km southeast of Choir (46°18’31.9’’N, 108°26’30.1’’E) [fig.1; no. 10], 1200 m a.s.l., 14 August 2003, 1♂ and 2♀♀ (CMH S-20033159-20033160, CMH S-20033165), detection UV-light, leg. M. Heddergott, R. Sommer.

Province Ömnögovi: Galbyn-Gobi (42°35’09.4’’N, 105°45’44.8’’E) [fig.1; no. 11], 1200 m a.s.l, 1 July 2009, 4♂♂ and 1♀ [MLUH], detection UV-light, leg. A. Stubbe, M. Stubbe. – Dumdajn-gol (42°36’06.6’’N, 105°55’39.7’’E) [fig.1; no. 12], 1000 m a.s.l, 3 July 2009, 3♂♂ and 2♀♀ [MLUH], detection UV-light, leg. A. Stubbe, M. Stubbe. - Somon Manlaj, Bajan-gol (43°35’29.5’’N, 107°03’40.1’’E) [fig.1; no. 13], 1195 m a.s.l, 1 August 2009, 2♂♂ [CMH S-2009268], detection UV-light, leg. A. Stubbe, M.Stubbe. - Somon Manlaj Bajan-gol (43°35’29.5’’N, 107°03’40.1’’E) [fig.1; no. 13], 1195 m a.s.l, 2-4 August 2009, 2♂♂ and 4♀♀ [CMH S-20091685-20091691], detection UV-light, leg. A. Stubbe, M. Stubbe. – Šutegijn Bajan-gol (43°54’19.3’’N, 107°43’45.5’’E) [fig.1; no. 15], 1040 m a.s.l, 14 July 2010, 4♂♂ and 13♀♀ [CMH S-20104212-20104229], detection UV-light, leg. A. Stubbe, M. Stubbe, W. Stubbe. - Šutegijn Bajan-gol (43°54’19.3’’N, 107°43’45.5’’E) [fig.1; no. 15], 1040 m a.s.l, 24-28 July 2011, 5♂♂ and 4♀♀ [CMH S-20111321-20111330], detection UV-light, leg. A. Stubbe.