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A taxonomic revision of the Eurasian *Myrmica salina* species complex (Hymenoptera: Formicidae)

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Abstract

The *Myrmica salina* species complex (MSS complex) is distributed in steppes and other xerothermous open habitats of the Mediterranean and south Temperate zone from Iberia to E Kazakhstan, in latitudes between 37° in Central Asia and 56°N in S Sweden. The taxonomic status of twelve taxa belonging to the MSS complex s. str. was assessed. 16 numerically described phenotypic characters of workers and one distributional character were evaluated in explorative (principal component analysis, PCA) and hypothesis-driven (discriminant analysis, DA) approaches on the basis of 157 nest samples with 435 worker specimens from the whole geographic range. The PCA indicated two main clusters which were confirmed by a cross-validated DA in 98.1% of the samples. The two clusters are recognised as the species *M. salina* Ruzsky, 1905 and *M. specioides* Bondroit, 1918 which are sympatric over 4000 km of east-west extension of their range. It was not possible to credibly demonstrate a third or fourth entity by PCA, k-means clustering or running different type-series-centered hypotheses in a DA. The taxa *M. scabrinodis* var. *ahngeri* Karavajev, 1926 ($p = 0.999$), *M. georgica* Seifert, 1987 ($p = 0.998$) and *M. tobiasi* Radchenko & Elmes, 2004 ($p = 1.000$) are synonymised with *M. salina* ($p = 1.000$) and *M. scabrinodis* var. *sancta* Karavajev, 1926 ($p = 0.997$), *M. scabrinodis* var. *turcica* Santschi, 1931 ($p = 0.983$) and *M. kozakorum* Radchenko & Elmes, 2010 ($p = 0.972$) with *M. specioides* ($p = 1.000$) [in brackets: posterior probability of cluster allocation of the type series in a DA]. *M. puerilis* Stärcke, 1942, *M. puerilis* ab. *dolens* Stärcke, 1942, *M. balcanica* Sadil, 1952 and *M. balcanica* var. *scrabrinodoides* Sadil, 1952, of which type series were not available, are synonymised with *M. specioides* based upon original description and terrae typicae. High-resolution z-stack photographs of the lectotypes of *M. salina* and *M. specioides* are provided. The species identity of a suggested cluster found in Great Caucasus, Armenia and E Turkey cannot be credibly shown by phenotypic and geographic information and should be checked by means of integrative taxonomy.

Key words: ant taxonomy, Palaearctic region, cluster analysis, sibling species.

1. Introduction

The recent discovery of type specimens of *Myrmica salina* Ruzsky, 1905 in the collection of MCSN Genoa (Radchenko & Elmes 2009) caused several alterations in the complicated taxonomy of the Genus *Myrmica*. Radchenko & Elmes concluded that the name *Myrmica salina* Ruzsky has been referred to a wrong species based on the interpretation of Ruzsky's misleading original description by Seifert (1988, 2002), Radchenko & Elmes (2004) and

Seifert (2007). Instead, *Myrmica curvithorax* Bondroit, 1920 is the first available name for this morphologically and ecologically well-characterised, facultatively halophilic ant. According to my own investigation of the type specimen of *M. curvithorax* in the IRSNB Bruxelles and comparison with syntypes of *Myrmica slovaca* Sadil, 1952, *M. curvithorax* is clearly a senior synonym of *M. slovaca*. This confirms the view of Radchenko & Elmes (2010). Investigation of the *M. salina* lectotype worker and paralectotype gynes, in contrast, showed that *M. salina* truly belongs to the species complex around *Myrmica specioides* Bondroit, 1918 as already suggested by Radchenko & Elmes (2009). Since *M. salina* is the oldest available name for an ant belonging to this group, I name it in the following *Myrmica salina* species complex (MSS complex). The MSS complex includes twelve described taxa distributed in steppes and other xerothermous open habitats of the Mediterranean and south Temperate zone from Iberia to W Siberia, in latitudes between 37° in Central Asia and 56°N in S Sweden. The species are highly competitive and one of them, apparently the true *M. specioides*, has been introduced to the USA (Jansen & Radchenko 2009). Among other characters, the MSS complex can be distinguished from the species of the *M. scabrinodis* complex by the following character combination:

(a) worker: petiole profile without clear angularities, its slightly concave frontal face forms a rounded transition or rounded corner with the convex dorsal face that slopes continuously caudad (i.e., without any distinct step),

(b) worker: caudal slope of basal scape lobe flat, ranging between 8–45° (for definition of this slope see Seifert 1988, 2007),

(c) males: short suberect hairs on flexor part of hind metatarsus as opposed to the longer ones on extensor profile (in members of the *M. scabrinodis* complex these are much longer, more erect and almost equally long on both flexor and extensor profile); scape short (scape length/cephalic length <0.48).

Twelve taxa belonging to the MSS complex in a restricted sense have been validly described and these are the issue of this study: *Myrmica salina* Ruzsky, 1905, *M. specioides* Bondroit, 1918, *M. scabrinodis* var. *ahngeri* Karavajev, 1926, *M. scabrinodis* var. *sancta* Karavajev, 1926, *M. scabrinodis* var. *turcica* Santschi, 1931, *M. puerilis* Stärcke, 1942, *M. puerilis* ab. *dolens* Stärcke, 1942, *M. balcanica* Sadil, 1952, *M. balcanica* var. *scabrinodoides* Sadil, 1952, *M. georgica* Seifert, 1987, *M. tobiasi* Radchenko & Elmes, 2004, *M. kozakorum* Radchenko & Elmes, 2010. Such a plenty of names for ants hardly separable by morphology and apparently being most similar in ecology raises the question which of them could have taxonomic significance. This problem became obvious in a recent addition to the taxonomical

Fig. 1 typical petiole shape of the members of the *Myrmica salina* species complex.

literature: the big monograph on the *Myrmica* species of the Old World written by Radchenko & Elmes (2010). The authors believed to distinguish five good species within the MSS complex and proposed two, very simple characters for species delimitation. My own tests of this determination system on the basis of the type series of these five taxa resulted in a dramatic ratio of misidentification in each of these entities. Details of this issue, which came up after the first manuscript of this revision had been completed, are reported in the Discussion section of this paper.

The MSS complex seems to be a taxonomic nightmare. Obviously, the strong orographic structuring of some areas in the range of the MSS complex in combination with glacial and postglacial isolation induced a rapid development of local variants which, however, did not completely lose contact to neighbouring populations. Most problematic in this respect is the region of Anatolia, Armenia, the Great Caucasus and Tian Shan, while morphological variation in the lowland steppe region from Slovakia to E Kazakhstan is less strong. I present here an analysis of morphological data combined with geographic information suggesting that ten out of the twelve described taxa are younger synonyms.

2. Material

2.1. Type specimens investigated

Myrmica scabrinodis var. ***salina*** Ruzsky, 1905:

Lectotype worker des. Radchenko & Elmes 2009 [together with a paralectotype gyne on the same pin] labelled by Ruzsky 'Myrm. scabrinodis v. salina ☿, ♀ R. Gouv. Orenburg, Sary-Kul See. Salzboden'; MCSN Genova. 1 paralectotype gyne and 1 paralectotype male on the same pin labelled 'Myrm. scabrinodis v. salina R. ♂ Gouv. Orenburg, Sary-Kul See'; deposited in Museo Civico di Storia Naturale Genoa.

Myrmica ***specioides*** Bondroit, 1918:

Lectotype worker labelled 'Myrmica specioides Type Bondr.', 'St.Affrique', 'R.I.Sc.N.B.I.G. 21.400', 'Lectotype des. B. Pisarski'; somebody damaged it strongly and covered many body parts with glue since my last loan in 1986. Two paralectotype workers on another pin labelled 'Myrmica specioides Bondr. Type', 'St. Affrique', 'Paralectotype des. B. Pisarski'. All these deposited in Institut Royal des Sciences Naturelles Belgique Bruxelles and considered as one sample.

Myrmica scabrinodis var. ***ahngeri*** Karavajev, 1926:

Lectotype worker labelled 'Taganrog 31.V.1926 C. Ahnger' ('Taganrog' in Cyrillic, 'C. Ahnger' in Latin letters, both printed), 'Myrmica scabrinodis ahngeri Karav K. Arnoldi det. lectotyp.', 'Myrmica scabrinodis var. ahngeri nova typus Karavaiev', deposited in Schmalhausen Institute of Zoology Kiev. Paralectotype worker labelled 'Taganrog 8.VI.1926 C. Ahnger, No 4013 coll Karavajev'; this specimen only investigated for a reduced character set in 1986, at that time in Zoological Museum of Lomonossov State University Moscow, now missing.

Myrmica scabrinodis var. ***sancta*** Karavajev, 1926:

Six worker syntypes labelled '2854.Coll. Karavaievi', 'Syntypus Myrmica scabrinodis var. sancta Karaw.', deposited in Schmalhausen Institute of Zoology Kiev. Type identity clear from original description stating as type locality: 'Umgegend von Karadagh, nicht weit von Theodosia, Krym, 10.v.1920, Nr. 2854, leg. Karawajew, ☿☿'.

Myrmica scabrinodis var. ***turcica*** Santschi, 1931:

Lectotype and one paralectotype worker on the same pin labelled 'Type', 'Angora (Kerville)', 'M. scabrinodis v. turcica Sant Type','17', '223' and 'LECTOTYPE (upper specimen) desig. Radchenko & Elmes 2000'; the lectotype with CS = 1.167 mm, FR/CS 0.314 (for explanation of these acronyms see character description in the Methods section). Two paralectotype workers on the same pin labelled 'Type', 'Angora Asie.Min (Kerville)', 'M. scabrinodis v. turcica Sant Type', and 'PARALECTOTYPE desig. Radchenko & Elmes 2000'. One paralectotype gyne and one paralectotype worker on the same pin labelled 'Type', 'Angora Asie.Min (Kerville)', '223', 'M. scabrinodis v. turcica Sant ♀ ☿ Type', and 'PARALECTOTYPE desig. Radchenko & Elmes 2000'. All this material deposited in Naturhistorisches Museum Basel.

Myrmica ***georgica*** Seifert 1987:

Holotype labelled 'Holotyp', 'Myrmica georgica SEIFERT', 'Georgien 21.7.85 44°51´E, 41° 53 ´N 500 m NN, leg. Seifert' and 'N9'(underside of label); 7 worker paratypes labelled 'Myrmica georgica SEIFERT Paratyp', 'Georgien 21.7.85 44° 51 ´E, 41° 53 ´N 500 m NN, leg. Seifert' and 'N9'(underside of label); all this material deposited in Senckenberg Museum für Naturkunde Görlitz.

Myrmica ***tobiasi*** Radchenko & Elmes, 2004:

Two paratype workers from the holotype nest; one labelled 'Alma-Atinsk. Zapovednik Talgar No 749 VIII 68 Antsyferov', 'Paratypus Myrmica tobiasi Rad. et Elmes' [handwriting of Radchenko], the other one labelled 'Alma-Atinsky Z-k Antsyferov' and 'Paratypus Myrmica tobiasi Rad. et Elmes' [handwriting of Radchenko], both deposited in Zoological Museum of Lomonossov State University Moscow.

Myrmica ***kozakorum*** Radchenko & Elmes, 2010

Holotype nest series: one pin with a male, the holotype and a paratype worker labelled 'Ukraine, Kherson Reg. Black Sea Res., Ivano-Ryb. distr. 54-04 A. Radchenko 1.ix.2004', '1', 'Holotype up. w'; another pin with a male and two paratype workers labelled 'Ukraine, Kherson Reg. Black Sea Res., Ivano-Ryb. distr. 54-04 A. Radchenko 1.ix.2004', '2'; all deposited in Schmalhausen Institute of Zoology Kiev. Holotype CW 0.9879 mm, FL 0.4714 mm, FR 0.3283 mm (for explanation of these acronyms see character description in the Methods section).

2.2. Material investigated by numeric character analysis

A detailed account of samples and sampling localities is given in the results section. Summing up, a total of 157 samples with an average of 2.77 worker individuals per sample were analysed by numeric character analysis. The material originated from the following regions:

Spain and France (8 samples), Central Europe and Denmark (46), Italy (1), Romania, Moldavia, Bulgaria and European part of Turkey (8), the Asian part of Turkey, Armenia, and NE Iran (25), Great Caucasus (17), Ukraine (32), the steppe zone of European Russia (3), Kazahkstan (9) and Kyrghyztan (9). The higher investigation density in Ukraine is explained by the fact that it is a main region with sympatric occurrence of western *M. specioides* and eastern *M. salina*.

3. Methods

3.1. Recording of morphological data

Optical equipment, details of morphological character definitions, of their recording methods and estimation of measuring errors are as given for the ‘higher quality system’ in Seifert et al. (2009). The strongly shortened version of these definitions presented below does not allow to precisely reproduce data recording but gives the reader an idea what the morphometric characters are:

CL - Maximum cephalic length in median line.

CS - Cephalic size; the arithmetic mean of CL and CW.

CW - Maximum cephalic width; in *Myrmica* this is always across the eyes.

EYE - Eye-size index: the arithmetic mean of the large (EL) and small diameter (EW) of the elliptic compound eye is divided by CS, i.e. EYE = (EL+EW)/(CL+CW).

FL - Maximum anterior divergence of frontal carinae

FR - Minimum distance between frontal carinae.

MetL - The height of metapleuron including the propodeal lobe measured in lateral view perpendicular to the straight section of metapleuro-coxal border.

MetSp - The height of subspinal excavation from upper margin of propodeal lobe to lower spine margin measured along the dorsal continuation of the measuring line for MetL.

PEH - Maximum petiole height measured perpendicular to a reference line stretching from the centre of the petiole-propodeal junction to the centre of petiole-postpetiolar junction.

PEL - Maximum measurable diagonal petiole length from the tip of subpetiolar process to the dorsocaudal corner of the caudal cylinder.

PEW - Maximum width of petiole.

PoOc - Postocular distance - distance from the transversal level of posterior eye margin to hind margin of head measured in median line.

PPHL - Length of longest hair on dorsal postpetiole.

PPW - Maximum width of postpetiole.

SL - Maximum measurable straight line scape length excluding articulary condyle.

SP - Maximum length of propodeal spines as bilateral arithmetic mean, measured in dorsofrontal view from spine tip to a point at the bottom of the interspinal meniscus.

SW - Maximum width of scape at the level of basal scape lobe measured perpendicular to the longitudinal axis of scape.

3.2. Removal of allometric variance

In order to make body ratios such as CL/CW, SL/CS or SP/CS directly comparable in synoptic tables, a removal of allometric variance (RAV) was performed with the procedure described by Seifert (2008). RAV was calculated for the assumption of all individuals having an identical cephalic size of 1.15 mm. Overall genus specific RAV functions were applied the parameters of which were calculated as the arithmetic mean of the species-specific functions of 33 W Palaearctic *Myrmica* species with sufficient sample size. It can be seen from the functions below that allometries are rather weak and usually less than 5% per 400 µm CS change (this is the average intraspecific size difference between the smallest and largest worker). However SP/CS grows by 12.5% from smallest to largest workers.

$CL/CW_{1.15}$ = CL/CW / (-0.0592*CS+1.1020)*1.0339
$SL/CS_{1.15}$ = SL/CS / (-0.0814*CS+0.9010)*0.8074
$EYE/CS_{1.15}$ = EYE/CS / (0.0166*CS+0.1778)*0.1969
$FL/CS_{1.15}$ = FL/CS / (0.0200*CS+0.4060)*0.4290
$FR/CS_{1.15}$ = FR/CS / (0.0080*CS+0.3186)*0.3278
$PEW/CS_{1.15}$ = PEW/CS / (-0.0229*CS+0.2835)*0.2572
$PPW/CS_{1.15}$ = PPW/CS / (0.0596*CS+0.3306)*0.3991
$PEH/CS_{1.15}$ = PEH/CS / (-0.0149*CS+0.3451)*0.3280
$PEL/CS_{1.15}$ = PEL/CS / (-0.0291*CS+0.4985)*0.4650
$PPHL/CS_{1.15}$ = PPHL/CS / (-0.0596*CS+0.2422)*0.1737
$SP/CS_{1.15}$ = SP/CS / (0.1038*CS+0.2129)*0.3323
$MetL/CS_{1.15}$ = MetL/CS / (0.0028*CS+0.1986)*0.2018
$MetSp/CS_{1.15}$ = MetSp/CS / (0.0082*CS+0.1731)*0.1825
$PoOc/CL_{1.15}$ = PoOc/CL / (0.0107*CS+0.4125)*0.4248
$SW/SL_{1.15}$ = SW/SL / (0.0134*CS+0.1856)*0.2010

3.3. Data analysis

All analyses were performed with the SPSS 15.0 statistical package on the basis of sample means which, as a rule, can be interpreted as nest sample means. Sixteen morphological characters (CS plus those 15 RAV-corrected characters given above) and geographical longitude LON were computed in a principal component analysis (PCA), a canonical discriminant analysis (DA). All characters passed the tolerance test in a DA to the level of 0.01 as implemented in SPSS. A parallel run of an ordinary DA and of a 'Leave-One-Out Cross-Validation' DA (LOOCV-DA, Lachenbruch & Mickey 1968, Lesaffre et al. 1989) was performed to realistically estimate the error rate. The data presented by Seifert & Schultz (2009) show that the means of the pessimistic error indication by the LOOCV-DA and of the optimistic error indication by the ordinary DA are close to the true error rate. The significance of the final grouping was checked by a MANOVA.

The basic rationale of the survey was forming initial hypotheses by PCA plots, running these hypotheses iteratively in a DA until the error rate of classification was at minimum, testing the correllation of the primary PCA grouping with the new DA grouping, checking the error rate by a LOOCV-DA and finally testing the significance in a MANOVA. In order to test maximum-taxon-splitting hypotheses, in particular to check if *M. georgica*, *M. tobiasi*, *M. salina, M. turcica, M. kozakorum* and *M. specioides* each could form separate clusters, two alternative methods were run. The first one was K-means clustering with K = 3,4, 5 and 6 and subsequent testing if these clusters formed a reasonable structure. The second one was type-series-centred hypothesis formation with subsequent iterative running of a DA until error rate was at minimum.

4. Results

4.1. Species related to the MSS complex

For completeness, I shortly discuss six species not belonging to the MSS complex s.str. but being closely related to it. They are not analysed in this paper. *M. constricta* Karavajev, 1934 and *M. curvithorax* Bondroit, 1920 indicate their affinities to the MSS complex by very similar males but *M. constricta* differs in the worker by a wider frons (FR/CS>0.36), smaller size and the absence of a caudal lobe at scape base while *M. curvithorax* differs by an extremely narrow frons (FR/CS<0.280), a shorter head and deviating petiole shape. *M. stangeana* Ruzsky, 1902 is very close to the MSS complex but differs from all its members by the characteristic spatial structure of scape base, by the mesosomal and waist sculpture having a very distinct longitudinal and almost no transverse or wrinkled component and thin spines, erected by ± 42° relative to longitudinal axis of mesosoma. Another species related to the MSS complex is *M. hellenica* Finzi, 1926 which differs in the worker by a wider frons (FR/CS>0.36) and the much steeper slope (>45°) of the plane between dorsal and caudal carina at scape base and in the male by much more hirsute tibiae and a longer scape. *M. sancta* ssp. *tshuliensis* Arnoldi, 1976, an endemic of the Kopet Dagh mountains and only known from the type series, shows in the worker a lot of similarities to *M. specioides* but the long setae on male scape and metatarsae indicate stronger affinities to the *M. hellenica* branch. Near to the MSS complex is also *M. bakurianica* Arnoldi, 1970, a poorly known endemic of SW Georgia. Its workers differ from members of the MSS complex by a more profuse pilosity on all body surfaces, very dark pigmentation, distinctly wider waist segments and longer spines and its males by distinctly longer setae on flexor part of hind metatarsus (Seifert 1988, Radchenko & Elmes 2010).

4.2. The cluster analyses

Little structuring was visible in a PCA computing the 17 characters described above. However, the plotting of the 1st and 3rd factor showed a clustering which was in agreement with the author's subjective prejudice that there should exist two main groups separable by width of basal scape lobe ($SW/SL_{1.15}$), frontal lobe width ($FL/CS_{1.15}$), head size (CS), spine length ($SP/CS_{1.15}$), petiole ($PEW/CS_{1.15}$) and postpetiole width ($PPW/CS_{1.15}$) and by differing distribution relative to geographical longitude. These PCA-derived clusters (Fig. 2A) can be fully separated by the function PCA(1,3) = fac1 -0.2707 fac3 +0.5 with PCA(1,3) -0.588 ± 0.416 [-2.062, -0.040] n = 59 for group 1 and 1.155 ± 0.684 [0.047,2.846] n = 98 for group 2. This PCA grouping was confirmed in the first run of a DA and LOOCV-DA with an error rate of 3.2 and 5.1%. A single iteration was necessary to achieve at error rates of 0 and 1.9% respectively. This new hypothesis changed only 2.5% of the initial classifications having 62 samples in group 1 and 95 samples in group 2.

The discriminant values D(17) of the new hypothesis showed a linear correlation of 0.9362 ($p<0.0001$, n = 157) with the values of the PCA-derived grouping function (Fig. 2B). As a Levene test found unequality of variances between the groups for the characters $FR/CS_{1.15}$, $PEW/CS_{1.15}$, $PPW/CS_{1.15}$, a MANOVA was run with the 14 remaining characters. It resulted in $p<0.0005$ for each of the applied test systems (Pilai-Bartlett trace, Wilk's lambda, Hotelling trace, Roy's largest root).

The type samples of the following taxa were allocated in a DA to group 1: *M. salina* (p = 1.000), *M. ahngeri* (p = 0.999), *M. georgica* (p = 0.998), *M. tobiasi* (p = 1.000). Group 2 contained

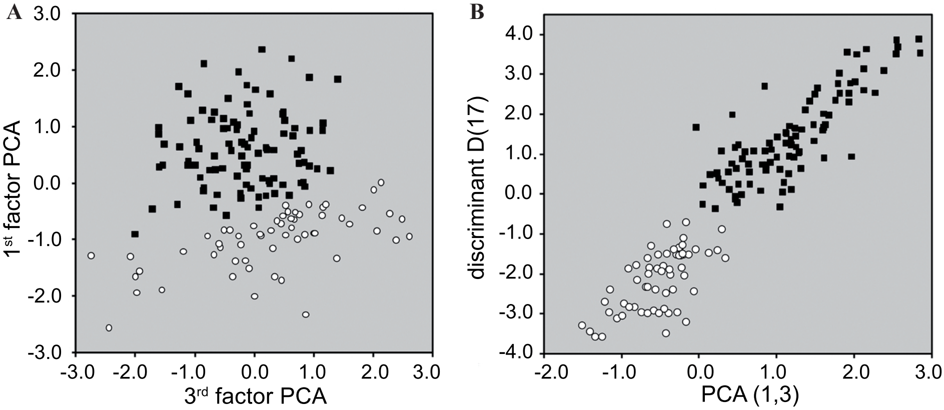

Fig. 2 **A**: 1st and 3rd factor of a principal component analysis of RAV-corrected worker nest sample means considering 16 morphometric and one geographic character. Dark squares: 95 samples of *Myrmica specioides* Bondroit, white circles: 65 samples of *M. salina* Ruzsky. **B**: Plotting of the values of a discriminant analysis D(17) and of a principal component analysis PCA(1,3) of RAV-corrected worker nest sample means considering 16 morphometric and one geographic character. PCA(1,3) is a vector considering the 1st and 3rd factor of a principal component analysis shown in Fig. 2 with PCA(1,3) = fac1 -0.2707 fac3. Dark squares: 95 samples of *Myrmica specioides* Bondroit; white circles: 65 samples of *M. salina* Ruzsky.

the type samples of *M. specioides* ($p = 1.000$), *M. sancta* ($p = 0.997$), *M. turcica* ($p = 0.983$), *M. kozakorum* ($p = 0.972$). Exclusion of the variable geographical longitude from the PCA and DA did not change the allocation of the type samples but moved two of the samples from Spain to group 1 (data not shown). These data indicate that the taxonomic naming of group 1 and 2 must be *M. salina* and *M. specioides* and provide the basis for the synonymic lists presented below. Morphometric data of the two recognised species of the MSS complex are shown in Tab. 1. The z-stack photos of the lectotypes of *M. salina* and *M. specioides* depict typical scape and head characters (Figs 3A–D). The distributional data given in Tab. 2 show a huge overlap of the geographic ranges of both species between 22° E (Romania) and 75° E (Kyrghyztan) – i.e., within 6600 kilometres of east-west range extension of both species, there are 4000 km with sympatric or potentially sympatric occurrence. This is a further argument for heterospecificity of *M. salina* and *M. specioides*.

Attempts to show the presence of more than two groups were not convincing. A quite reasonable clustering was derived from the PCA plot in Fig. 1: eight samples of group 1 possibly forming an own cluster in the lower left part of the plot were introduced as group 3 in a DA. These eight samples originate from a rather small region in Georgia near to the localities Kazbegi, Passanauri and Shatili. The first run of a DA and LOOCV DA resulted in error rates of 4.5 and 9.1% respectively. After four iterations, the DA was stopped at error rates of 0.6 and 8.4% respectively. 15 samples from Great Caucasus, Armenia and E Anatolia now formed group 3. The allocation of type samples to the groups 1 and 2 remained as shown above and each of them was positioned widely distant from group 3 ($p<0.001$). Other attempts to demonstrate more than two entities by type-series-centred DA or SPSS k-means-clustering resulted in classifications not fitting to any PCA clustering. These clusterings of three or four classes indicated a frequent syntopic occurrence of more than two entities over a wide geographic range. This is a pattern not credible for highly competitive sibling species (data not shown and not discussed below).

Tab. 1 Nest sample means of RAV-corrected and primary morphometric data of *Myrmica specioides* and *M. salina* ordered according to falling discriminative value after RAV correction. ANOVA columns show F values and significance levels.

RAV-corrected indices				**primary indices**			
	M. specioides (n = 95)	ANOVA	***M. salina*** (n = 62)		***M. specioides*** (n = 95)	ANOVA	***M. salina*** (n = 62)
SW/SL	0.158 ± 0.020	96.81	0.192 ± 0.022	SW/SL	0.157 ± 0.020	99.77	0.191 ± 0.021
(1150)	[0.125,0.223]	0.000	[0.146,0.230]		[0.125,0.220]	0.000	[0.146,0.229]
FL/CS	0.454 ± 0.015	86.29	0.476 ± 0.015	FL/CS	0.452 ± 0.015	91.61	0.475 ± 0.015
(1150)	[0.431,0.500]	0.000	[0.444,0.518]		[0.429,0.500]	0.000	[0.443,0.518]
SP/CS	0.347 ± 0.019	49.83	0.323 ± 0.024	SP/CS	0.337 ± 0.018	30.21	0.318 ± 0.024
(1150)	[0.294,0.382]	0.000	[0.246,0.374]		[0.286,0.373]	0.000	[0.240,0.371]
PEW/CS	0.248 ± 0.009	49.61	0.238 ± 0.008	PEW/CS	0.250 ± 0.009	59.07	0.239 ± 0.008
(1150)	[0.228,0.272]	0.000	[0.218,0.254]		[0.228,0.275]	0.000	[0.217,0.255]
CS	1055 ± 45	43.14	1104 ± 46	CS	1055 ± 45	43.14	1104 ± 46
	[956,1163]	0.000	[1016,1213]		[956,1163]	0.000	[1016,1213]
PPW/CS	0.403 ± 0.013	40.46	0.390 ± 0.011	PPW/CS	0.397 ± 0.013	25.01	0.387 ± 0.011
(1150)	[0.376,0.434]	0.000	[0.356,0.419]		[0.368,0.426]	0.000	[0.359,0.416]
PEH/CS	0.324 ± 0.009	33.38	0.316 ± 0.008	PEH/CS	0.325 ± 0.009	40.02	0.316 ± 0.008
(1150)	[0.304,0.348]	0.000	[0.300,0.343]		[0.306,0.349]	0.000	[0.300,0.344]
PPHL/CS	0.174 ± 0.010	14.69	0.168 ± 0.011	PPHL/CS	0.180 ± 0.010	28.90	0.171 ± 0.011
(1150)	[0.135,0.205]	0.000	[0.141,0.196]		[0.144,0.206]	0.000	[0.142,0.194]
MetL/CS	0.233 ± 0.009	14.68	0.227 ± 0.008	MetL/CS	0.232 ± 0.009	14.15	0.227 ± 0.008
(1150)	[0.206,0.252]	0.000	[0.204,0.244]		[0.206,0.251]	0.000	[0.204,0.244]
PEL/CS	0.464 ± 0.011	3.61	0.461 ± 0.012	PEL/CS	0.464 ± 0.011	6.82	0.462 ± 0.012
(1150)	[0.435,0.489]	n.s.	[0.432,0.485]		[0.435,0.489]	0.010	[0.433,0.487]
FR/CS	0.339 ± 0.011	3.41	0.336 ± 0.016	FR/CS	0.339 ± 0.011	2.69	0.335 ± 0.016
(1150)	[0.314,0.375]	n.s.	[0.304,0.363]		[0.314,0.374]	n.s.	[0.304,0.362]
CL/CW	1.042 ± 0.014	2.56	1.045 ± 0.013	CL/CW	1.047 ± 0.014	0.11	1.048 ± 0.014
(1150)	[0.993,1.081]	n.s.	[1.007,1.076]		[1.000,1.086]	n.s.	[1.010,1.079]
MetSP/CS	0.161 ± 0.013	2.34	0.158 ± 0.013	MetSP/CS	0.161 ± 0.013	1.89	0.158 ± 0.013
(1150)	[0.136,0.214]	n.s.	[0.136,0.223]		[0.136,0.213]	n.s.	[0.136,0.223]
SL/CS	0.804 ± 0.014	0.37	0.802 ± 0.016	SL/CS	0.811 ± 0.015	4.66	0.806 ± 0.016
(1150)	[0.774,0.840]	n.s.	[0.777,0.844]		[0.779,0.846]	0.032	[0.778,0.843]
EYE	0.208 ± 0.005	0.09	0.208 ± 0.005	EYE	0.206 ± 0.005	0.34	0.207 ± 0.006
(1150)	[0.193,0.221]	n.s.	[0.195,0.214]		[0.192,0.222]	n.s.	[0.193,0.217]
PoOc/CL	0.420 ± 0.007	0.01	0.420 ± 0.008	PoOc/CL	0.419 ± 0.007	0.10	0.420 ± 0.007
(1150)	[0.405,0.439]	n.s.	[0.401,0.439]		[0.404,0.438]	n.s.	[0.401,0.439]

Abbreviations: **CL** - maximum cephalic length. **CS** - cephalic size: (CL+CW)/2. **CW** - maximum cephalic width across eyes. **EYE** - mean of the largest and smallest eye diameter. **FL** - maximum anterior divergence of frontal carinae. **FR** - minimum distance between frontal carinae. **MetL** - Metapleural height. **MetSp** - height of subspinal excavation. **PEH** - Petiole height. **PEL** - diagonal petiole length in lateral view. **PEW** - petiole width. **PoOc** - distance of posterior eye margin to hind margin of head. **PPHL** - Length of longest dorsal postpetiole hair. **PPW** - postpetiole width. **SL** - scape length excluding articulary condyle. **SP** - length of propodeal spines. **SW** - Maximum width of scape at the level of basal scape lobe. For details see section Recording of morphological data and Seifert et al. (2009).

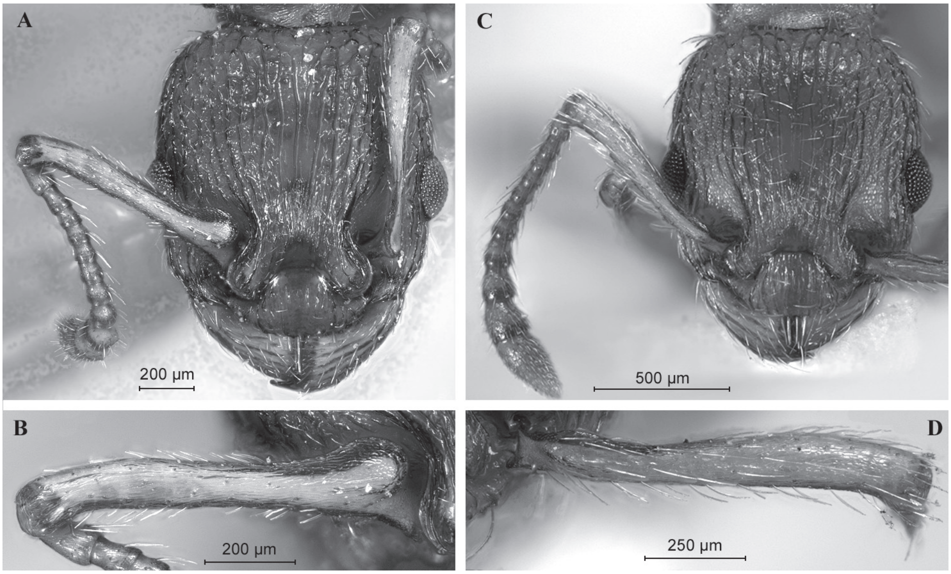

Fig. 3 *Myrmica salina* Ruzsky, 1905. **A:** Head of the lectotype, **B**: Scape of the lectotype. *Myrmica specioides* Bondroit, 1918. **C**: Head of the lectotype, **D**: Scape of the lectotype.

Tab. 2 List of samples investigated by numeric character analysis. Sampling date is given in alphanumeric format followed after a hyphen by the field sample number (e.g. 19980623-093). Geographic coordinates LAT and LON are given in decimal format. Negative signs mean western longitude. ALT = altitude in metres a.s.l.

SITE	SPECIES	LAT	LON	ALT
ARM: Megri: Legvas, 19860623-403	salina	38.939	46.215	900
ARM: Megri: ushch. Agedzor, 19860619-317	salina	38.930	46.240	900
ARM: vic.Megri, 19860621-363	salina	38.900	46.240	900
GEO: Araqui gorge, 20040814	salina	42.495	44.923	1390
GEO: Kazbegi, 19850729-N8	salina	42.618	44.602	1800
GEO: Kazbegi, 19850810-N6	salina	42.618	44.602	1800
GEO: Kazbegi, 19850810-N7	salina	42.618	44.602	1800
GEO: Kazbegi, 19850810-x	salina	42.618	44.602	1800
GEO: Mzcheta, 19840729	salina	41.842	44.709	510
GEO: Passanauri, 19750918	salina	42.349	44.691	1150
GEO: Passanauri, 1984	salina	42.380	44.710	2000
GEO: Shatili, 19850813-N4	salina	42.658	45.159	1430
GEO: Shatili-2E, 19850813-N1	salina	42.672	45.181	1415
GEO: Tbilissi-E, 19850721-N9, **holotype *georgica***	salina	41.770	44.825	530
GEO: Tbilissi-E, 19850721-div N	salina	41.770	44.825	530
KAZ: Alma-Ata NP, Talgar,1968, **holotype *tobiasi***	salina	43.200	77.300	1500

SITE	SPECIES	LAT	LON	ALT
KAZ: Almaty, Hotel Raketa,20010716-193	salina	43.267	76.917	760
KAZ: Almaty, Hotel Raketa,20010716-A23	salina	43.267	76.917	760
KAZ: Almaty, Hotel Raketa,20010716-B	salina	43.267	76.917	760
KAZ: Borovoje, 19670828	salina	53.076	70.304	316
KAZ: Kokchetav: Shchuchinsk, 19660818-40	salina	52.935	70.194	390
KAZ: Kokterek, 20010804-180	salina	47.055	82.295	1068
KAZ: Tarbagatai Mts.E, 20010803-291	salina	47.053	82.302	1149
KAZ: Tarbagatai Mts.W, 20010720-87	salina	47.269	80.810	615
KYR: Fortress Kudarja Khan, 20040723-126	salina	39.769	71.035	1599
KYR: Issyk-Kul-W, 20000722-184	salina	42.317	76.313	1700
KYR: Issyk-Kul-W, 20000722-237	salina	42.371	76.198	1700
KYR: Karakol, 20000720-145	salina	42.573	78.320	1630
KYR: river Kalay-Machmyd, 20040722-092b	salina	39.694	70.882	1851
KYR: river Kalay-Machmyd, 20040722-093	salina	39.694	70.882	1835
KYR: river Kalay-Machmyd, 20040722-097	salina	39.694	70.882	1866
ROM: Brebu Nou Semenic, 19880704-1824	salina	45.230	22.130	880
RUS: Kalmykia: Kotluban, 20010509	salina	49.015	44.234	68
RUS: Rostov: Proletarsk, 19831004-191	salina	48.701	41.715	15
RUS: Sary-Kul-See, **lectotype *salina***	salina	51.000	56.000	200
TUR: Aydogdu-5SW, 19950626-1151	salina	40.689	42.424	1500
TUR: Bilaloglu-5W, 19890628	salina	38.932	40.339	1430
TUR: Bucak-5W, 1988-2568a	salina	37.460	30.500	790
TUR: Bucak-5W, 19880428-2568	salina	37.460	30.520	1000
TUR: Bünyan,19890627-2945	salina	38.850	35.860	1800
TUR: Kars:Sarikamish, 19980524	salina	40.340	42.570	2070
TUR: Köprübasi-10SE, 19930627-1159	salina	40.720	42.190	1050
TUR: Taurus Mts: Emirlar, 20010628-50	salina	37.470	34.512	1200
TUR: Taurus Mts: Fat Malik, 20010627-35	salina	37.200	34.200	1600
TUR: Taurus Mts: Fat Malik, 20010627-36	salina	37.200	34.200	1600
UKR: Donets: Krivaja Luka, 19820722-233	salina	48.873	37.885	118
UKR: Ivano-Rybalch. Uch., 19850617-22	salina	46.470	32.220	3
UKR: Ivano-Rybalch. Uch., 19810617-21	salina	46.470	32.220	3
UKR: Ivano-Rybalch. Uch., 19820511-44a	salina	46.470	32.220	3
UKR: Ivano-Rybalch. Uch., 19830425-33	salina	46.470	32.220	3
UKR: Kamenny Mogily, 19830615-234	salina	47.100	37.600	25
UKR: Melitopol: Staroberd. Les, 19830612	salina	46.840	35.370	33

Tab. 2 (Continued previous page.) List of samples investigated by numeric character analysis.

SITE	SPECIES	LAT	LON	ALT
UKR: Odessa, 19830803	salina	46.460	30.710	47
UKR: Provalsk. Step, 19830630-390	salina	48.170	39.850	146
UKR: Radensky Les, 19810824-312	salina	46.560	32.870	19
UKR: Rybalche, 19820518-44	salina	46.474	32.235	1
UKR: Streltsovskaya Step, 19830627-362	salina	49.297	39.847	108
UKR: Streltsovskaya Step, 19830627-363	salina	49.297	39.847	108
UKR: Streltsovskaya Step, 19830629-374	salina	49.297	39.847	108
UKR: Taganrog, 19260531, **lectotype *ahngeri***	salina	47.220	38.890	17
UKR: Telmanovo gran., 19830617-258/259	salina	47.410	38.020	118
UKR: Zaporosh.: Altagir, 19830613-201	salina	47.300	35.900	100
ARM: Megri: Legvas, 19860620-345	specioides	38.939	46.215	900
BUL: Sozopol, 19820916	specioides	42.420	27.690	5
BUL: Srebarna, 19880714-1860	specioides	43.196	27.893	50
BUL: Srebarna, 19880714-2099	specioides	43.196	27.893	50
CZE: Praha-Prokop, 19710702-125	specioides	50.032	14.364	260
CZE: Praha-Prokop, 19720409	specioides	50.032	14.364	260
CZE: Usti nad Labem, 19881011	specioides	50.660	14.040	150
DAN: Begstrup-2S, 19930813-31	specioides	56.200	10.530	65
DAN: Begstrup-2SE, 19930813-g19	specioides	56.200	10.530	65
DAN: Fjellerup beach, 19930814-12	specioides	56.523	10.622	2
DAN: Orsted-6NNE, 19930815-g4	specioides	56.551	10.384	2
FRA: St.Affrique, **lectotype *specioides***	specioides	43.958	2.886	328
GEO: Passanauri, 19840729	specioides	42.380	44.690	1200
GEO: Shatili, 19850813-N3	specioides	42.658	45.159	1430
GEO: Shatili-2E, 19850813-N2	specioides	42.672	45.181	1415
GEO: Shenako, 19850802	specioides	42.402	45.685	2000
GEO: Shenako, 19850802-N1	specioides	42.402	45.685	2000
GER: Balgstädt, 19810830	specioides	51.210	11.725	130
GER: Balgstädt, 19810830-N2	specioides	51.210	11.725	130
GER: Bilzingsleben, Steinrinne, 19810910	specioides	51.271	11.061	170
GER: Burkheim/Emmendingen, 19930501-g3	specioides	48.100	7.590	180
GER: Darmstadt-5SW, 19910601-026	specioides	49.845	8.590	105
GER: Ditfurt, 19790415	specioides	51.839	11.219	109
GER: Ditfurt, 19790512/13	specioides	51.839	11.219	109
GER: Ditfurt, 19790519	specioides	51.839	11.219	109

SITE	SPECIES	LAT	LON	ALT
GER: Eberswalde-SW, 19860602	specioides	51.830	13.780	40
GER: Erfurt, Ringelberg, 19871002-BF3	specioides	51.031	10.956	210
GER: Eutrich, 19830928	specioides	51.300	14.290	140
GER: Fränkisch-Crumbach, 19910602	specioides	49.750	8.860	200
GER: Gabow-0.3SW, 19970821	specioides	52.816	14.071	20
GER: Geesow-1S, 19870803/05	specioides	52.240	14.389	24
GER: Halbendorf-1.5W, 19920516-212	specioides	51.292	14.539	140
GER: Halbendorf-1.5W, 19920516-234	specioides	51.292	14.539	140
GER: Hanau, 19770506	specioides	50.140	8.910	100
GER: Hecklingen, 19870529	specioides	51.849	11.552	64
GER: Iphofen-2N, 19910529-232	specioides	49.720	10.263	364
GER: Klotzsche-1.8S, 19920818	specioides	51.099	13.766	173
GER: Klotzsche-1S, 19920818-65	specioides	51.109	13.787	200
GER: Koblenz-1.5NW, 19860817	specioides	51.379	14.323	128
GER: Kostebrau: Wischgrund, 1981	specioides	51.529	13.804	120
GER: Kostebrau: Wischgrund, 19860808-4	specioides	51.529	13.804	120
GER: Mallnow-1NW, 19870811	specioides	52.464	14.480	51
GER: Niesendorf, 19820808	specioides	51.297	14.308	145
GER: Oderberg-1.6W, 20020509-127	specioides	52.863	14.023	27
GER: Premnitz, 19820722	specioides	52.550	12.350	66
GER: Premnitz, 198304/04	specioides	52.550	12.350	66
GER: Premnitz, 198305/06	specioides	52.550	12.350	66
GER: Reinstädt-1NW, 19930720-g13	specioides	50.816	11.471	390
GER: Saarmund, 19850505	specioides	52.319	13.128	34
GER: Torfwiesen/Wölpern, 19840828	specioides	51.443	12.601	114
GER: Wartha-1E, 19860816	specioides	51.274	14.599	143
GER: Zscheiplitz, 19810904	specioides	51.210	11.730	158
HUN: Balatonakali, 198706	specioides	46.882	17.747	111
IRA: Caspian Sea coast, Sahba, 1978	specioides	36.700	51.200	-15
ITA: Volterra, 19970817	specioides	43.401	10.859	530
KYR: Bishkek, 20000712	specioides	42.880	74.600	775
KYR: river Kalay-Machmyd, 20040722-106	specioides	39.697	70.882	1939
MOL: Kishinyev, 19830602-100	specioides	47.030	28.840	52
MOL: Kishinyev, 19830603-124	specioides	47.027	28.841	52
ROM: Brebu Nou, 19880704-1875	specioides	45.230	22.130	880
SLA: Zemplinska Sirava, 19830830-1	specioides	48.800	22.000	128

Tab. 2 (Continued previous page.) List of samples investigated by numeric character analysis.

SITE	SPECIES	LAT	LON	ALT
SLA: Zemplinska Sirava, 19830830-2	specioides	48.800	22.000	128
SPA: Dulce, Madrid→Zaragossa, 198906	specioides	41.100	-2.200	1000
SPA: Huesca: Nocito, 19800729	specioides	42.320	-0.250	1200
SPA: Llerida/St.Lorenz de Montgai, 1980	specioides	41.867	0.841	260
SPA: Ona, pre 1986 (Collingwood)	specioides	42.730	-3.400	750
SPA: Sierra Nevada: Mulhacen, 19910510-156	specioides	36.970	-3.310	2000
SPA: Seo de Urgell-17W, 19910515-2	specioides	43.366	1.262	1600
SPA: Seo de Urgell-17W, 19910515-76	specioides	42.366	1.262	1600
SWI: Merishausen, 198208	specioides	47.750	8.600	620
TUR: Angora (Kerville), **lectotype *turcica***	specioides	39.920	32.850	890
TUR: Antalya: Kizikadag, 19930521-893	specioides	36.900	30.000	1400
TUR: Aydogdu-2NE, 19930626-1155	specioides	40.710	42.491	1500
TUR: Aydogdu-5SW, 19930626-1150	specioides	40.689	42.424	1500
TUR: Aydogdu-5SW, 19930626-1149	specioides	40.689	42.424	1500
TUR: Edirne: Kustepe, 20000527-TK-9	specioides	41.370	26.960	76
TUR: Köprübasi-10SE,19930627-1160	specioides	40.720	42.190	1050
TUR: Seydiler, 19890708	specioides	41.630	33.700	1200
TUR: Sivas: Hafik, 19980516	specioides	39.860	37.390	1300
TUR: Tuzluka-10E,19930623-1117	specioides	40.050	43.780	1000
UKR: Askania Nova, park, 19810712-155	specioides	46.460	33.879	26
UKR: Askania Nova, park, 19820521-76	specioides	46.460	33.879	26
UKR: Crimea: Aj-Petri, 19950816	specioides	44.451	34.053	1100
UKR: Crimea: Babugan-Jaila, 19990828-72	specioides	44.500	34.000	1200
UKR: Crimea: Babugan-Jaila, 19990828-73	specioides	44.500	34.000	1200
UKR: Crimea: Theodosia,1920-2854, **syntypes *sancta***	specioides	45.050	35.380	15
UKR: Ivano-Rybalch. Uch., 19830413-17	specioides	46.470	32.220	3
UKR: Ivano-Rybalch. Uch., 19830415-21	specioides	46.470	32.220	3
UKR: Ivano-Rybalch. Uch., 2004-54, **holotype *kozakorum***	specioides	46.470	32.220	3
UKR: Kamenny Mogily, 19830614-216	specioides	47.100	37.600	25
UKR: Kamenny Mogily, 19830615-236	specioides	47.100	37.600	25
UKR: Khomutovskaya Step, 19760504-5.3	specioides	47.273	38.254	78
UKR: Khomutovskaya Step, 19830618-237	specioides	47.273	38.254	78
UKR: Khomutovskaya Step, 19830619-267	specioides	47.273	38.254	78
UKR: Zakotnoye (Zakitne), 19830621-277	specioides	48.896	37.966	100

4.3. Synonymic lists

Within the 12 taxa considered in the synonymic lists below, type material could not be studied in *Myrmica puerilis* Stärcke, 1942 *Myrmica puerilis* ab. *dolens* Stärcke, 1942, *Myrmica balcanica* Sadil, 1952, and *Myrmica balcanica* var. *scabrinodoides* Sadil, 1952. The original descriptions of *M. puerilis* and *M. p.* ab. *dolens* clearly indicate them to be members of MSS complex. *M. salina* can be safely excluded by geographic data and the scape base of female castes described to be without lobe but only with 'zeer kleine oortjes' (= with 'very small auricles'). *M. constricta* seems possible from this morphological description of the worker but zoogeography and the more massive petiole of the male indicate a junior synonymy with *M. specioides*. *M. balcanica* is most likely a synonym of *M. specioides* because the series of drawings depicting the variability of scape lobe show a lobe size much smaller than the *M. salina* average observed in this study, because of its large mean index FR/FL of 0.783 (means found in this study: *M. specioides* 0.750, *M. salina* 0.705) and because 85% of the *M. balcanica* sites reported by Sadil, who did not explicitly mention a locus typicus or a type series, were outside the known range of *M. salina. M. b.* var. *scabrinodoides* is most likely no synonym of *M. salina* because any site reported by Sadil was outside the known range of *M. salina* and because the variability of scape lobe size corresponds to the *M. specioides* average found in this study. The sum of data also exclude synonymies of Sadil's two taxa with *M. sabuleti* Meinert, 1861 or *M. constricta*.

Myrmica salina Ruszky, 1905

nec *Myrmica salina* sensu Seifert 1988, 2002, Radchenko & Elmes 2004, Seifert 2007 [misidentification]
Myrmica scabrinodis var. *salina* Ruzsky, 1905 [type investigation]
Myrmica scabrinodis var. *ahngeri* Karavajev, 1926; new synonymy [type investigation]
Myrmica georgica Seifert, 1987; new synonymy [type investigation]
Myrmica tobiasi Radchenko & Elmes, 2004; new synonymy [type investigation]

***Myrmica specioides* Bondroit, 1918**

Myrmica specioides Bondroit, 1918; [type investigation]
Myrmica scabrinodis var. *sancta* Karavajev, 1926; [type investigation]
Myrmica scabrinodis var. *turcica* Santschi, 1931; new synonymy [type investigation]
Myrmica puerilis Stärcke, 1942 [description and terra typica]
Myrmica puerilis ab. *dolens* Stärcke, 1942 [description and terra typica]
Myrmica balcanica Sadil, 1952 [description and terra typica]
Myrmica balcanica var. *scabrinodoides* Sadil, 1952 [description and terra typica]
Myrmica kozakorum Radchenko & Elmes, 2010; new synonymy [type investigation]

Note: Radchenko & Elmes (2010) have synonymised *M. scabrinodis* var. *ahngeri* Karavajev, 1926 with *M. scabrinodis* Nylander, 1846. My own investigation of the lectotype showed that both the 3-dimensional structure of scape base as well as petiole shape and overall sculpture were in agreement with the characters of the MSS complex as this was the case with the characters of the associated paralectotype male. Furthermore, using the 16 morphometric characters of this study, I got an ideal clustering of 159 *M. salina* and 196 *M. scabrinodis* workers individuals from the whole Palaearctic range in a PCA and DA with the lectotype of *M. s. ahngeri* being allocated to the *M. salina* cluster with p = 0.999.

4. 4. A simpler method of identifying workers

As non-taxonomist practitioners would usually flinch from applying the complex identification methods presented above, I have tried to find a simpler procedure by using absolute measurements, omitting RAV corrections and reducing the number of characters. Based upon nest sample means and with geographic longitude LON in decimal format, the discriminant

$D(6) = 19.38\,FL - 34.05\,PEW - 26.04\,PPHL - 54.25\,PEH + 31.73\,SW + 0.017\,LON + 16.48$

separates the 157 nest samples with an error rate of 4.5%:

M. specioides -1.197 ± 1.075 [-3.77, 0.65] n = 95

M. salina 1.833 ± 0.872 [-0.01, 4.19] n = 62.

I regret that there is no simpler method with lower error rate available but this example nicely illustrates that we cannot give simple answers to complicated questions.

5. Discussion

Morphological differences demonstrable within a big range of sympatric occurrence can be accepted as an argument for heterospecificity of *M. salina* and *M. specioides*. The good agreement between PCA, DA and a priori subjective assessment, the low error estimates and the high significance in the MANOVA suggest the two-species hypothesis to be the most credible interpretation of the data available at the moment. The sufficiently clear allocation of the type samples to either group 1 or group 2 provides a further good argument to accept this grouping as the current state of art. The synonymic list presented above follows this concept. However, cryptic species are not necessarily detectable by the applied morphological methods and it is difficult to distinguish these from regional conspecific variants. The suggested cluster formed by 15 samples from Great Caucasus, Armenia and E Anatolia (with an error estimate of 4.5%) presents such a problem. This cluster is a possible candidate for a new species as no type series of a taxon of the MSS complex is positioned near to this cluster. However, because the geographic structuring and biological identity of this cluster is poorly understood, I refrain from taxonomically naming this entity. Future investigators should check this entity by integrative multi-source approaches including molecular-genetic data (cf. Moreau 2009, Seifert 2009, Schlick-Steiner et al. 2010, Bernasconi et al. 2011).

The same applies for possible attempts to reestablish taxa such as *M. turcica, M. georgica*, *M. tobiasi* and *M. kozakorum* which were considered by Radchenko and Elmes (2010) as good species in addition to *M. salina* and *M. specioides.* Radchenko and Elmes probably distinguished most of their proposed species by assuming a separate geographic distribution. They considered the following four species allopatric: *M. turcica* was restricted to Asia Minor and Armenia, *M. georgica* to Georgia, *M. tobiasi* to Middle Asia and *M. salina* to the steppes southeast of the Urals. *M. specioides* was considered to have sympatric ranges with all the other species except for *M. tobiasi* while *M. kozakorum* was considered to have sympatric ranges with *M. specioides* and *M. salina*. As testable data on morphological or biological species delimitation are missing in the main text, it remains obscure how Radchenko & Elmes constructed this distributional picture and how they distinguished their species within the sympatric ranges. We can only try to extract some information from the key - explicitly from section 5.2 couplets 25 to 33. In couplet 25, *M. kozakorum* and *M. georgica* are said to differ from *salina*, *specioides* and *turcica* by ‘Frons relatively narrow, species means FI <0.35. Scape at the base with a relatively large lobe that is more extended posteriorly than anteriorly’ against ‘Frons relatively wide, species means FI >0.36. Scape at the base with smaller lobe that is more extended anteriorly than posteriorly, sometimes with a narrow carina only’. The verbal character is unitelligible as there is nowhere explained in the monograph what the authors understand as ‘anterior’ or ‘posterior’ regarding an appendage which has freely variable positions relative to the fixed main body axes. From some of the figure captions in the book one might suppose that they term ‘anterior’ what is proximal according to the standard anatomical terms of location employed in science. If so, the verbal character is not useable as one cannot decide which part of the scape lobe extends more proximad and which more distad because we look at a continous structure without a demarcation line between ‘more proximad’ and ‘more distad’. Remain the testable statements on frontal width index FI which is FR divided by cephalic width posterior of the eyes. According to my own measurements in the specimens available for this study, FI varies 0.370 ± 0.013 [0.338,0.386] (n = 17) in the *M. kozakorum* type population from Ivano-Rybalchansky Uchastok, 0.354 ± 0.014 [0.334,0.384] (n = 17) in the *M. georgica* type population from near Tbilissi, 0.364 ± 0.012 [0.353,0.381] (n = 4) in the type series of *M. turcica* and is 0.356 in the lectotype worker of *M. salina*. The misidentification frequency using this index is 47% in *M. georgica*, 94% in *M. kozakorum*, 50% in *M. turcica* and the lectotype worker of *M. salina* is misidentified. Within the total of 39 specimens, there is a misidentification frequency of 69% already in the first couplet. It is predictable that this error will grow further if we run through the whole procedure.

Finally, I want to emphasise that no contemporary taxonomist including me can exclude that taxa such as *M. turcica, M. georgica*, *M. tobiasi* or *M. kozakorum* might possibly be reestablished as good, cryptic species once the appropriate multi-source tools of recognition will have been developed. Scientists are invited to work in this field but they must feel strict responsibility to do this business on the basis of testable data sets.

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