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New molecular and morphological data on the "*Euscorpius carpathicus*" species complex (Scorpiones: Euscorpiidae) from Italy, Malta, and Greece justify the elevation of *E. c. sicanus* (C. L. Koch, 1837) to the species level

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New molecular and morphological data on the "*Euscorpius carpathicus*" species complex (Scorpiones: Euscorpiidae) from Italy, Malta, and Greece justify the elevation of *E. c. sicanus* (C. L. Koch, 1837) to the species level. - The first mitochondrial DNA phylogeny (based on 17 unique haplotypes) is presented for a number of scorpion populations from Italy, Malta, and Greece, previously classified under the "catch-all" name *Euscorpius carpathicus* (Linnaeus, 1767). A comparative analysis of the mitochondrial gene for 16S (large subunit) ribosomal RNA suggests that at least two clearly separated lineages are present. However, neither of these belongs to *E. carpathicus* (L.) in a strict sense, which was limited to Romania in a recent morphological study. The first, "western" lineage, found in northern and central Italy (also present in southern France, Slovenia, Croatia, and Austria) corresponds to *E. tergestinus* (C. L. Koch, 1837) as recently defined by Fet & Soleglad. Another monophyletic, "southern" lineage is elevated here to the species rank as *E. sicanus* (C. L. Koch, 1837). Originally described from Sicily, *E. sicanus* includes as new synonyms *E. carpathicus canestrinii* (Fanzago, 1872) and six subspecies described by Caporiacco: *E. c. calabriae*, *E. c. ilvanus*, *E. c. garganicus*, *E. c. argentarii*, *E. c. palmarolae*, and *E. c. linosae*. Morphology confirms the

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existence of two lineages: *E. sicanus* is characterized by a unique trichobothrial pattern and number where series *eb*, and in some populations also series eb_a, have 5 trichobothria (all *E. tergestinus* possess only four of them). *E. sicanus* is found in southern Italy (including Sicily and Sardinia), northern Africa, Malta, and Greece. The enigmatic "*E. mesotrichus* Hadži" from Greece also belongs to *E. sicanus*.

Key-words: Scorpions - trichobothria - 16S mtDNA - biogeography - phylogeny - Southern Mediterranean - Italy - Malta - Greece.

INTRODUCTION

Scorpions of the genus *Euscorpius* Thorell, 1876 (Scorpiones: Euscorpiidae) are very common in southern Europe. they are ecologically diverse and they occupy a variety of habitats from xeric to mesic, from the Mediterranean shoreline to the high altitudes of the Alps and of the Balkan.

Linnaeus (1767: 1038) described *Scorpio carpathicus* from the Transylvanian Alps (Romania) (now *Euscorpius carpathicus*, the type species of the genus). Thorell (1876) introduced the new generic name *Euscorpius*. Numerous species have been described in *Euscorpius*; the traditional taxonomy of this genus, based mainly on morphosculpture and coloration characters, is complicated and confusing (Fet & Sissom, 2000).

C. L. Koch (1850: 86-87) reviewed all the *Euscorpius* species in his series "Die Arachniden", and clearly divided these species into three groups according to the number of trichobothria ("Grübchen") on the ventral aspect of the pedipalp patella (called tibia by many earlier authors). The large and conspicuous trichobothria (sensory bristles) of *Euscorpius* were then also used as taxonomic characters by Hadži (1929, 1930, 1931) and by Caporiacco (1950) who utilised total trichobothrial counts on different aspects of the pedipalp chela and patella. In the 50 years since Caporiacco's revision (which was mostly confined to the Italian forms, and only touched upon material from other countries), many authors paid attention to the intricate and intriguing taxonomy of this most common European scorpion genus (Bonacina, 1980; Ćurčić, 1972; Fet, 1986, 1993, 1997a, 1997b; Fet & Braunwalder, 2000; Kinzelbach, 1975; Lacroix, 1991a, 1991b; Scherabon, 1987; Vachon, 1963, 1975, 1978, 1981; Vachon & Jaques, 1977; Valle, 1975).

For almost a century, only four species were listed in *Euscorpius*: *E. carpathicus*, *E. germanus*, *E. flavicaudis* and *E. italicus* (see e.g., Birula, 1900, 1917; Caporiacco, 1950; Kraepelin, 1899; Vachon, 1963, 1981; Vachon & Jaques, 1977). Bonacina (1980) reestablished *E. mingrelicus* (Kessler, 1874). Further revisional work resulted in 12 formally recognized species: *E. alpha* Caporiacco, 1950, *E. balearicus* Caporiacco, 1950, *E. beroni* Fet, 2000, *E. carpathicus* (Linnaeus, 1767), *E. gamma* Caporiacco, 1950, *E. germanus* (C. L. Koch, 1837), *E. hadzii* Caporiacco, 1950, *E. flavicaudis* (DeGeer, 1778), *E. italicus* (Herbst, 1800), *E. koschewnikowi* Birula, 1900, *E. mingrelicus* (Kessler, 1874), and *E. tergestinus* (C.L. Koch, 1837) (Fet, 2000; Fet & Sissom, 2000; Gantenbein *et al.*, 2000a, 2001; Scherabon *et al.*, 2000; Fet & Soleglad, 2002).

One of the most recent developments in *Euscorpius* taxonomy was the introduction of molecular techniques which started with the pioneering paper of Gantenbein *et al.* (1999) on application of allozyme and 16S ribosomal RNA gene sequence analyses to assess the phylogeny of this genus. This study provided the first ever published DNA-based phylogeny for scorpions. These data revealed a phylogenetic relationship between four species (*E. flavicaudis*, *E. carpathicus*, *E. italicus*, and *E. germanus*) which differed from the former, morphology-based views on evolution of this genus (Hadži, 1931; Kinzelbach, 1975). Further work included more detailed genetic and morphological analysis of *E. germanus*, *E. alpha*, and *E. gamma* (Gantenbein *et al.*, 2000a; Scherabon *et al.*, 2000) as well as *E. carpathicus* (Gantenbein *et al.*, 2001; Huber *et al.*, 2001).

Gantenbein *et al.* (2001) elevated *E. c. balearicus*, an isolated *E. carpathicus* population from the Balearic Islands from subspecific to species status. Most recently, Fet & Soleglad (2002) conducted a morphological analysis of the "*E. carpathicus*" complex by including a number of new characters (foremost of which are individually mapped patellar trichobothria). They restricted the species *E. carpathicus* to populations from Romania, elevated one Balkan subspecies to species status (*E. hadzii*), confirmed species status for *E. koschewnikowi* from Greece, and assigned a number of Italian subspecies to the species *E. tergestinus*. However, the five species established by Gantenbein *et al.* (2001) and Fet & Soleglad (2002) did not yet embrace all diversity of populations traditionally placed under *E. carpathicus*.

The goal of this paper is to continue the study of the polymorphic and poorly studied "*E. carpathicus*" complex in Italy, with additional comparative material now available from Malta and Greece.

MATERIAL AND METHODS

MATERIAL

For this study, we used DNA sequences from 18 specimens belonging to the "*E. carpathicus*" complex, represented by 14 unique haplotypes. Two additional sequences, belonging to *E. tergestinus*, have been taken from the GenBank database (Gantenbein *et al.* 1999, 2001; Huber *et al.*, 2001): *Ec*LM1, AJ389377; *Ec*PR2= *Ec*PR1, AJ309211. GenBank also provided the outgroup sequence of *E. italicus*, *Ei*TO1 = AJ298067. All 14 new sequences have been deposited in GenBank under accession numbers AY090076 to AY090089 (see below).

Specimens used for DNA analysis: *E. sicanus* (=*E. c. ilvanus* Caporiacco, 1950; = *E. c. argentarii* Caporiacco, 1950; =*E. c. canestrinii* (Fanzago, 1872); =*E. c. garganicus* Caporiacco, 1950): *Ec*NE1 (AY090078), *Ec*NE2 (AY090076), Italy, Nebrodi Mts., beech forest (1500 m), northeastern Sicily, Italy, 30 September 1999 (V. Vignoli); *Ec*TR1 (AY090084), San Domino Island, Tremiti Islands (Adriatic Sea), Foggia, Apulia, Italy, 30 August 2001 (V. Vignoli); *Ec*GA1 (AY090085), Vico del Gargano, Foggia, Apulia, Italy, 29 August 2001 (V. Vignoli); *Ec*PU1 (AY090077), Punta Ala, Tuscany, Italy, 10 August 2000 (M. Stiegler & P. Weiner) (identical to haplotypes from Follonica and Siena, Tuscany, Italy); *Ec*AR1 (AY090079), Le Piane, Mt. Argentario, Grosseto, Tuscany, Italy, 22 January 2000 (V. Vignoli) (identical to another haplotype from Siena and a haplotype from Orbetello); *Ec*GG1 (AY090081), Campese, Giglio Island, Tuscany, Italy, 30 May 2000 (V. Vignoli) *Ec*GI1 (AY090082), Cala Maestra, Giannutri Island, Tuscany, Italy, 30 May 2000 (V. Vignoli) (identical to another haplotype from Giglio Island); *Ec*SD1 (AY090083), Lu Fraili, northeastern Sardinia, Italy, 16 August 2001 (V. Vignoli); *Ec*MT1 (AY090086), *Ec*MT2 (AY090087), Buskett, Malta, 17 September 2001 (P. J. Schembri); *Ec*OL2 (AY090088), Mt. Olympus, Thessaly, Greece, 15 May 2001 (V. Fet); *Ec*KB1 (AY090089), Kalambaka, Thessaly, Greece, 14 May 2001 (V. Fet). *E. tergestinus*: *Ec*LM1 (AJ389377), La Morra, Piedmont, Italy, 20 September 1996 (I. & B. Gantenbein); *Ec*PR2 (AJ309211), Procchio, Elba, Italy, 4 October 1996 (I. & B. Gantenbein); *Ec*SZ1 (AY090080), Le Grazie, Porto Venere, La Spezia, Liguria, Italy, June 2001 (D. Facheris). Outgroup *E. italicus*: *Ei*TO1 (AJ298067), Tortoreto, Abruzzo, Italy (M. Bellini).

For our morphological analysis we used additional extensive material deposited in zoological museums (see below, under "Material studied").

Methods

DNA techniques: We used a standard protocol as described in Gantenbein *et al.* (1999, 2000a). For DNA analyses, genomic DNA was extracted from fresh or preserved (in ethanol 94-98%) muscle tissue (usually pedipalp or metasoma) by using a standard phenol/chloroform precipitation method (Sambrook *et al.*, 1989) or the Qiagen™ DNeasy extraction kit. Extracted DNA was amplified by the polymerase chain reaction (PCR) in the Perkin Elmer 2400 PCR Thermocycler by using conditions and primers as described in Gantenbein *et al.* (1999). The mitochondrial LSU (large ribosomal subunit) 16S rRNA PCR primers corresponded to the positions 12,867-12,884 and 13,328-13,308 in the *Drosophila yakuba* mitochondrial genome, or to the positions 11,173-11,190 and 11,625-11,606 in the *Limulus polyphemus* mitochondrial genome (Lavrov *et al.*, 2000). The forward primer is a scorpion-specific version of the "universal" primer 16Sbr, or LR-J-12887, while the reverse primer has a scorpion-specific sequence designed by one of the authors (V.F.). The resulting PCR product was verified on 1% agarose electrophoretic gel and purified by Ultrafree MC 30000 cellulose filters (Millipore Inc.) or using "Rapid Gel Extraction Systems" columns (Concert™). Automated Sanger dideoxy sequencing of the double-stranded PCR product was performed at the Molecular Genetics Instrumentation Facility, University of Georgia (Athens, GA), on the ABI 9600 Sequencer (US team) or at the MWG-Biotech automated DNA sequencing service, Esersberg, Germany (Italian team).

Phylogenetic analyses: 17 mtDNA sequences representing different haplotypes were aligned using Clustal X 1.81 (Thompson *et al.*, 1997). DNA sequences used in earlier studies were downloaded from the GenBank nucleotide sequence database. Identical haplotypes were not considered in further analyses.

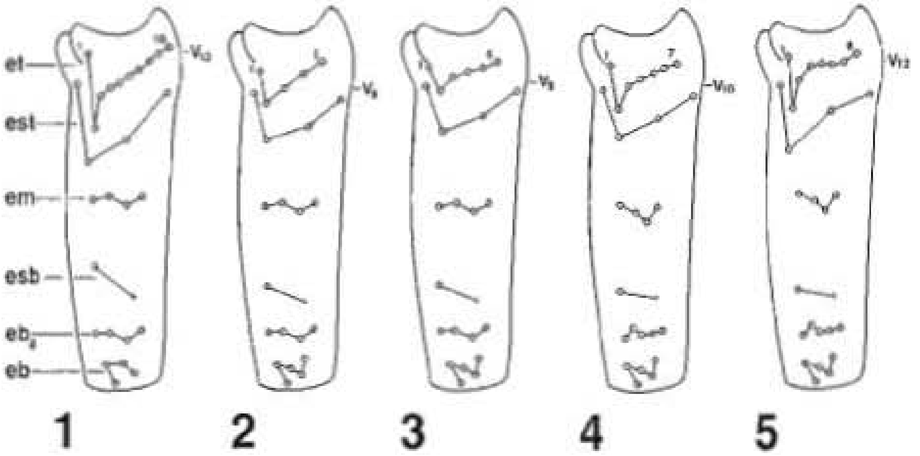
The software package PAUP* Version 4.0b10 (Swofford, 1998) was used for sequence analysis to perform phenetic (Felsenstein, 1984) and cladistic phylogenetic analyses. We are aware that these methods are based on different assumptions, but all of these are expected to estimate the "true" phylogeny in the absence of long-branch-attraction (Page & Holmes, 1998): genetic distance calculation, Maximum Parsimony (MP), and Neighbour-Joining (NJ) analysis (Saitou & Nei, 1987). However, it appears that especially for the choice of "correct" tree topology MP is superior to Maximum Likelihood (ML) in the "inverse Felsenstein zone" (Swofford *et al*., 2001). For choosing the most appropriate DNA substitution model for pairwise distances, we initially estimated a NJ tree using JC69 distance (Jukes & Cantor, 1969). This tree was then used for estimating the ML parameters from 56 different substitution models. Maximum likelihood ratio tests were then performed in a nested design by using the program MODELTEST 3.06 (Posada & Crandall, 1998), which is implemented in PAUP*. Details about likelihood ratio tests are given in Huelsenbeck & Crandall (1997) and Huelsenbeck & Rannala (1997). The rate heterogeneity among sites was assumed to follow a gamma distribution (shape parameter α was ML-estimated) with four categories, each represented by its mean (Yang, 1996). In a further step, the molecular clock hypothesis (i.e., equal rates across all sequences) was tested by using the c^2 approximated likelihood ratio test statistics. The hierarchical LRT statistics suggested the HKY85 + Γ model (Hasegawa *et al*., 1985) for the 16S gene, as it was found also by Gantenbein *et al*. (2001). The test for the molecular clock hypothesis was rejected at the 5% level ($2d = 2(l_0 - l_1) = 840.27 - 823.90 = 32.74$, $P_{\chi}{}^{2} = 0.005$). Therefore, the NJ clustering algorithm was chosen, which allows for unequal branch lengths (Page & Holmes, 1998). For weighted MP analysis the tree space was explored by 100 heuristic tree searches and by randomizing the order of the sequence input in PAUP*. The transition/transversion (Ti/Tv) ratio was ML-estimated to 2.73; therefore we weighted Tv three times over Ti. The four gaps in the data set were treated as the fifth base (McGuire *et al*., 2001). Confidence limits of individual nodes were assessed by using non parametric bootstrapping (Felsenstein, 1985; Swofford *et al*., 1996).

ABBREVIATIONS

MZUF, Museo Zoologico "La Specola" dell'Università di Firenze, Florence, Italy; NMW, Naturhistorisches Museum Wien, Vienna, Austria; ZMH, Zoologisches Museum Universität Hamburg, Hamburg, Germany; NMM, Naturhistorisches Museum, Mainz, Germany; HNHM, Hungarian Natural History Museum, Budapest, Hungary; NMNHS, National Museum of Natural History, Sofia, Bulgaria; VF, private collection of Victor Fet. Specimen numbers from MZUF are given as AAA/BBBB, where AAA is the "collection number" and BBBB is the "catalog number".

RESULTS

The resulting 16S rDNA phylogeny in our study reveals two well-separated monophyletic lineages among the material traditionally placed under *E. carpathicus* (Fig. 8). One of these lineages, recovered by all analyses, is readily identified as *E. tergestinus* (C. L. Koch, 1837) as defined by Fet & Soleglad (2002). All of its specimens possess a "standard" trichobothrial formula (eb_a=4, eb=4). In the molecular phylogeny of Gantenbein *et al*. (2001, Tab. 1, Figs 2, 3), *E. tergestinus* was represented (as *E. carpathicus*) by populations from Mathis (Alpes-Maritimes, France), La Morra (Piedmont, Italy), Procchio (Elba, Tuscany, Italy), Vernazza (Liguria, Italy), Hochosterwitz (Austria), and Mala Duba (Croatia), spanning the entire geographic range of this species as currently accepted by Fet & Soleglad (2002). The same species



FIGS 1-5

Idealized trichobothrial patterns of the external aspect of the pedipalp patella in two *Euscorpius* species exhibiting *eb* series = 4 (with *E. sicanus* populations exhibiting) *eb* = 5. **1.** *Euscorpius balearicus*, Balearic Islands, Spain; **2.** *E. sicanus*, Sicily, Italy; **3.** *E. sicanus*, Mt. Argentario, Italy; **4.** *E. sicanus*, Mt. Olympus, Greece; **5.** *E. sicanus*, Sardinia, Italy. Series *et* = external terminal, *est* = external subterminal, *em* = external median, *esb* = external suprabasal, eb_a = external basal-a, and *eb* = external basal; *v* = ventral.

was characterized (as *E. carpathicus*) by Huber *et al.* (2001) who studied more populations from Austria and Slovenia. In our data, a new haplotype of *E. tergestinus* from La Spezia (Liguria) groups together with previously known haplotypes from Piedmont and Elba.

Another 16S rDNA clade, also recovered in our study by all analyses (Fig. 8), includes a diverse array of populations, located mainly in Italy (Tuscany, Sicily, Sardinia, Gargano, and Tremiti Islands) but also in Malta and Greece (Thessaly). This clade is treated below as a separate species. The senior synonym available for it is *Scorpius sicanus* C. L. Koch, 1837 according to Article 23 of the International Code of Zoological Nomenclature (ICZN, 1999).

Separation of this second monophyletic clade (phylogenetic species), distinct in the DNA phylogeny, is also supported by our morphological analysis (Figs 1-5). The most important feature separating *E. sicanus* from *E. tergestinus* (and from another related species, e.g., *E. balearicus*), is its unique trichobothrial pattern and number where the external patellar series *eb* (and in some populations, also series eb_a) has 5 trichobothria. All specimens examined of *E. tergestinus* and *E. balearicus* possess only 4 trichobothria in these series; Fig. 1. A number of Italian subspecies (*E. c. canestrinii*, *E. c. calabriae*, *E. c. ilvanus*, *E. c. garganicus*, *E. c. argentarii*, *E. c. palmarolae*, and *E. c. linosae*) (Caporiacco, 1950) also belong to this new lineage, and are therefore formally synonymized here with *E. sicanus*. The closest relative of *E. sicanus* is *E. hadzii*, which also has 5 trichobothria in series *eb* but is distinguished by 6 to 7 trichobothria in series eb_a (Fet & Soleglad, 2002).

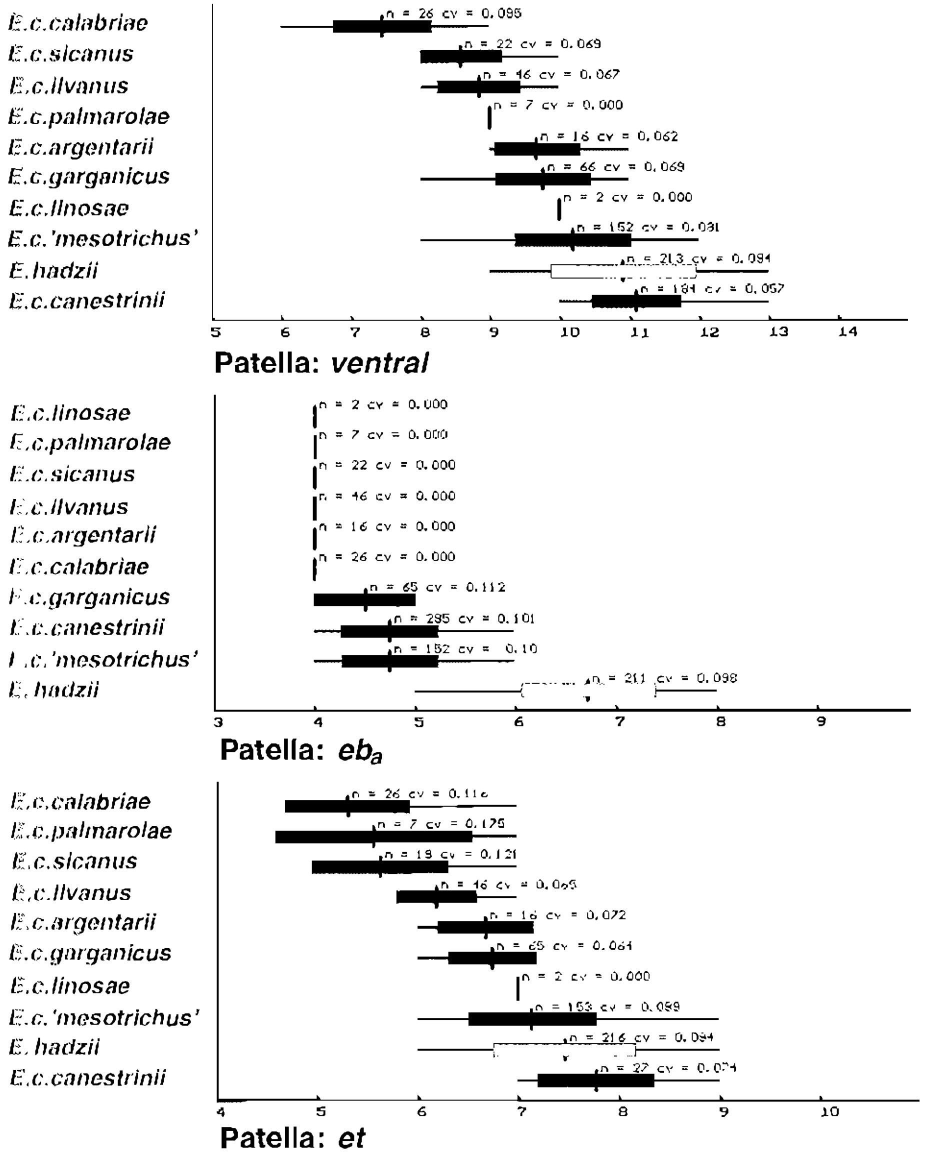
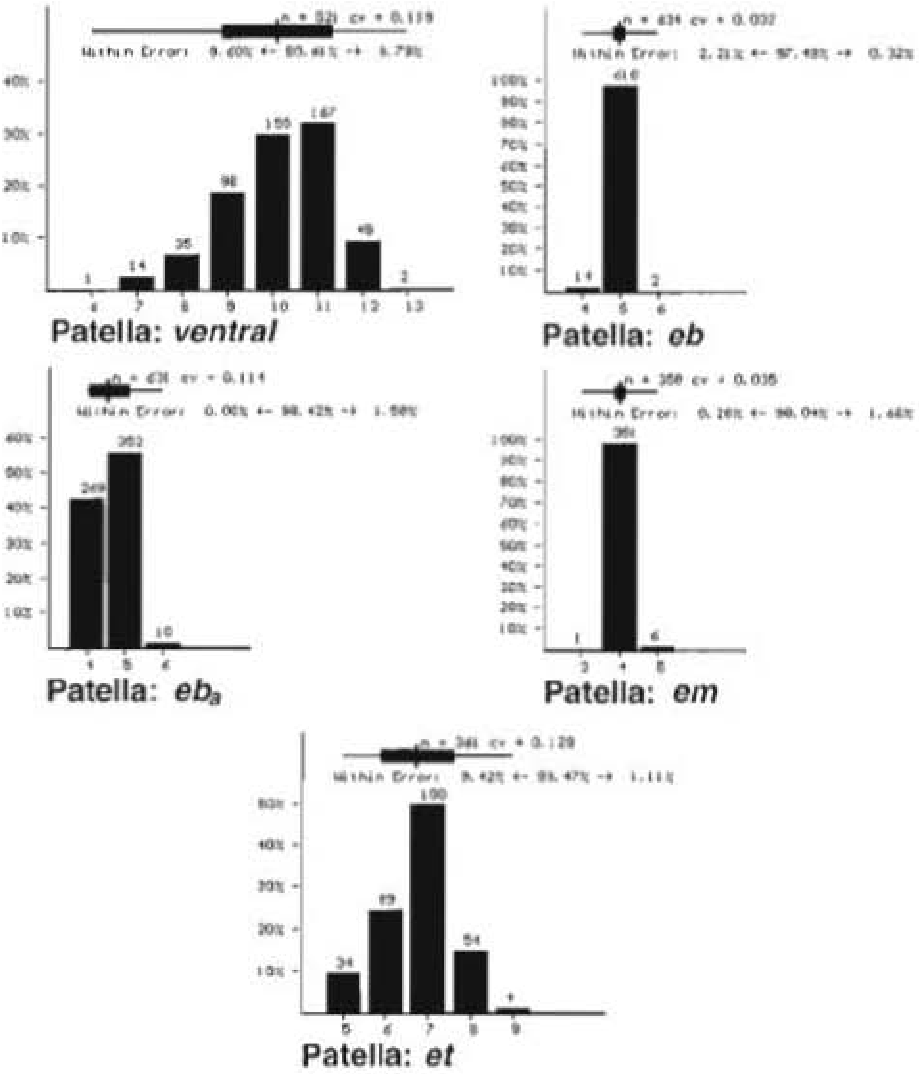


FIG. 6

Trichobothria statistics of *Euscorpius carpathicus* subspecies now placed in the synonymy of *E. sicanus*. *E. hadzii* Caporiacco, 1950 is used as a reference taxon. Series *et* = external terminal, eb_a = external basal-a, *eb* = external basal; *cv* = coefficient of variation.

Figs 2-5 show schematized trichobothrial patterns illustrating the five trichobothria of the patellar *eb* external series diagnostic of *Euscorpius sicanus*. In contrast *E. balearicus* exhibits the typical four trichobothria in the same series (Fig. 1). Also of


Patella: ***ventral***

Patella: ***eb***

Patella: eb_a

Patella: ***em***

Patella: ***et***

FIG. 7

Complete statistics of patellar trichobothria count in all *Euscorpius sicanus* specimens examined. Series *et* = external terminal, *em* = external median, eb_a = external basal-a, *eb* = external basal; *cv* = coefficient of variation.

interest is that *E. sicanus* populations from Greece and Sardinia (Figs 4-5) exhibit a tendency for five trichobothria in the eb_a series, in contrast to some other populations around Italy, including Sicily and Malta, which usually have eb_a=4.

Also apparent from Figs 1-5 is the larger number of trichobothria in the *et* and ventral patellar series for Greek and Sardinian populations. Further statistical data for several subspecies defined by Caporiacco (1950) and herein synonymized with *E. sicanus* are shown in the histograms in Figs. 6-7.

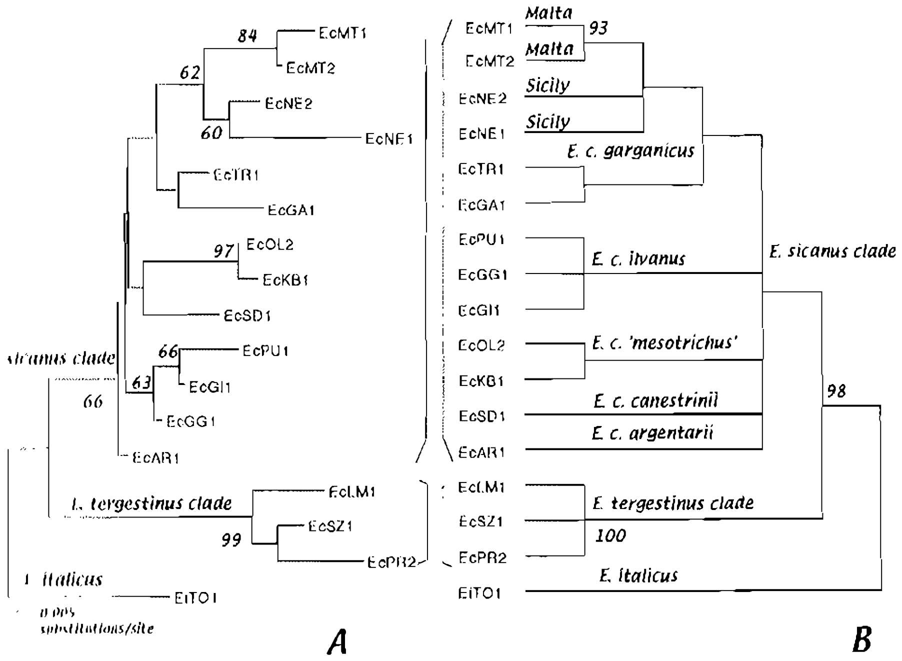


FIG. 8

DNA phylogeny of *E. tergestinus* and *E. sicanus* (branch labels refer to previously recognized subspecies). **A**, Neighbour-joining (NJ) tree using Maximum Likelihood (ML) distances as an input matrix. HKY85 + Γ-ML distances (Hasegawa *et al.*, 1985) were calculated with the following parameters (base frequencies: $p_A = 0.36$, $p_T = 0.41$, $p_C = 0.10$, Ti/Tv ratio = 2.73 ($\kappa = 7.87$), gamma shape parameter $\alpha = 0.098$, respectively. **B**, Strict consensus tree of Maximum Parsimony (MP) analysis (55 equally parsimonious trees of 79 steps). CI and RI were 0.72, respectively. Numbers at nodes are bootstrap values. Outgroup, *E. italicus*.

Euscorpius sicanus (C. L. Koch) can be diagnosed as a small to medium sized species with a somewhat thin metasoma; trichobothrial counts: patella ventral = 6-13 (9-11); external, $eb = 5$, $eb_a = 4$-5, $esb = 2$, $em = 4$, $est = 4$, $et = 5$-9 (7); pectinal tooth counts, 8-10 (9) in males; 6+-8??+ (7+) in females.

Number of trichobothria in series *eb* (=5) and eb_a = (4-5) are key diagnostic characters for this species. *E. sicanus* is contrasted here with its closest relative *E. hadzii*, which also has $eb = 5$ as follows: $eb_a = 4$-5, as opposed to 6-8 (7) in *E. hadzii*; $em = 4$, as opposed to 4-5 in *E. hadzii*. Position of eb_3 in *E. sicanus* is in straight line with eb_2 - eb_3 - eb_4, eb_3 usually situated below eb_2; in *E. hadzii*, eb_2 - eb_3 - eb_4 is not in straight line, eb_3 usually situated above eb_2. Number of trichobothria in series *eb* (=5) and *em* (= 4) distinguishes *E. sicanus* from *E. carpathicus*, and *eb* (=5) distinguishes *E. sicanus* from *E. balearicus*, *E. tergestinus*, and *E. koschewnikowi*.

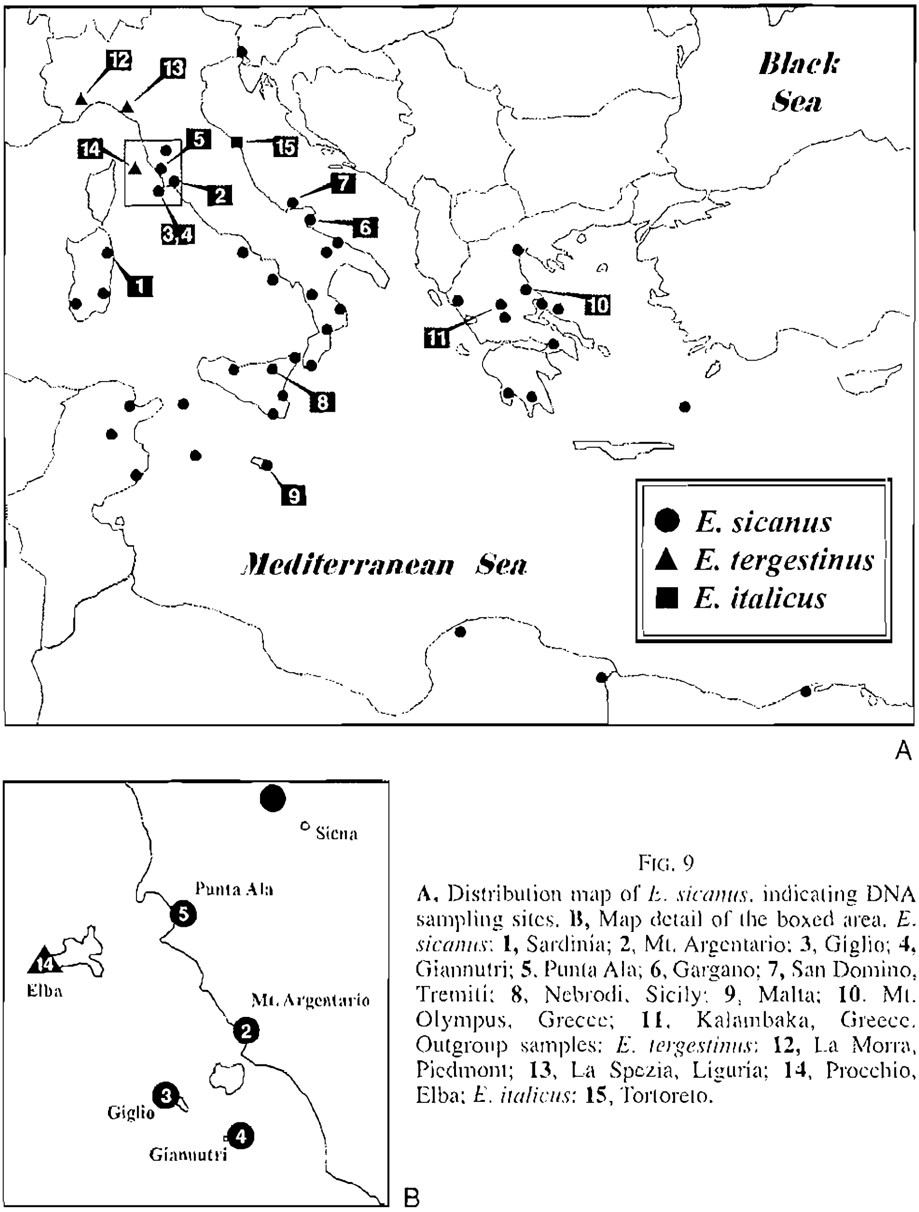


FIG. 9

A, Distribution map of *E. sicanus*, indicating DNA sampling sites. **B**, Map detail of the boxed area. *E. sicanus*: **1**, Sardinia; **2**, Mt. Argentario; **3**, Giglio; **4**, Giannutri; **5**, Punta Ala; **6**, Gargano; **7**, San Domino, Tremiti; **8**, Nebrodi, Sicily; **9**, Malta; **10**, Mt. Olympus, Greece; **11**, Kalambaka, Greece. Outgroup samples: *E. tergestinus*: **12**, La Morra, Piedmont; **13**, La Spezia, Liguria; **14**, Procchio, Elba; *E. italicus*: **15**, Tortoreto.

DISCUSSION

The phylogenies from the 16S data presented here support our morphological data. One should keep in mind that the partial sequence of this gene represents only a small fraction of the mitochondrial genome. It is also known that different genes may underlie different genealogies and that gene trees may not reflect species phylogenies

(Pamilo & Nei, 1988). Incomplete lineage sorting processes and introgression of mtDNA between two species/subspecies might be responsible for such inconsistencies (Page & Charleston, 1998; Avise, 2000). Recently, evidence for asymmetric introgression of mtDNA in a buthid subspecies in the nuclear background of another subspecies and its subsequent complete fixation have been reported (Gantenbein & Largiadèr, 2002). However, in euscorpiids, so far, the phylogenetic information of the mitochondrial 16S fragment has always been in concordance with independent nuclear genetic markers (allozyme data) (Gantenbein *et al.*, 1999, 2000a, 2001; Scherabon *et al.*, 2000). Therefore, the phylogenetic pattern of the 16S gene is very likely to represent the "species tree" for the genus *Euscorpius*. For the taxonomic consequences we strongly rely here on the phylogenetic species concept (PSC) (Cracraft, 1989) as we elevate *E. carpathicus sicanus* to the species level. Therefore, it seems reasonable to use morphological differentiation, *i.e.* trichobothrial patterns of the external aspect of patella, as a further support for the identified phylogenetic lineages. However, we are also aware that "deep" genetic divergences within morphologically conservative phylogenetic groups such as scorpions or other arachnids in general have been reported in the absence of obvious morphological differences (Gantenbein *et al.*, 2000a, 2000b; Bond *et al.*, 2001).

Scorpius sicanus C. L. Koch, 1837 was described from Sicily, and later synonymized with *Euscorpius carpathicus* (L.). Caporiacco (1950) has also mentioned this form, as a subspecies *E. carpathicus sicanus*, for the south of peninsular Italy (Apulia, western Calabria), Malta, and the northern African coast. *Scorpius canestrinii* Fanzago, 1872 was described from Sardinia, and later was synonymized with *E. carpathicus*. Caporiacco (1950) treated these two forms as valid subspecies; our data show that they belong to the same species.

Caporiacco (1950) also established a number of new subspecies for *E. carpathicus*, mainly from Italy. Our morphological investigation of type material for all of these subspecies, and DNA sequences corresponding to some of them, demonstrate that six of Caporiacco's subspecies (*E. c. linosae*, *E. c. garganicus*, *E. c. ilvanus*, *E. c. argentarii*, *E. c. palmarolae*, and *E. c. calabriae*) belong to *E. sicanus* (see below). Several other subspecies accepted or described by Caporiacco (1950) (*E. c. apuanus*, *E. c. concinnus*, *E. c. niciensis*, *E. c. aquilejensis*, *E. c. picenus*, *E. c. oglasae*, and *E. c. corsicanus*) were recently synonymized with *E. tergestinus* by Fet & Soleglad (2002).

Kinzelbach (1975) studied Greek populations of *E. carpathicus*, but did not discuss external patellar trichobothria at all; as we know now, this character set is crucial for the understanding of the genus *Euscorpius* (Vachon, 1974, 1975; Soleglad & Sissom, 2001; Fet & Soleglad, 2002). Vachon (1975) applied the patellar trichobothria analysis to all known *Euscorpius* species. At the same time, the important work of Valle (1975) on *E. carpathicus* appeared independently; Vachon (1975) in a footnote (p. 645) informed that his paper was already in print when he received Valle's publication.

Valle (1975) attempted to analyse some of Caporiacco's subspecies described from Italy by using external patellar trichobothria. Probably because Valle used the old system of designations established by Vachon (1963), his data were ignored by subsequent researchers (e.g. Fet, 1986, 1997a, 2000; Scherabon, 1987; Lacroix, 1991a, 1991b), who adhered to the new system by Vachon (1974, 1975, 1978, 1981). Note that Valle scored external patellar trichobothria summarily for both pedipalps, while Vachon's numbers refer to a single pedipalp. The two systems differ in assignments of individual trichobothria into several groups ("series"). However, comparing *Euscorpius* trichobothrial schemes in Fig. 1 in Valle (1975), Fig. 3 in Vachon (1963; "old system"), and Fig. 17 in Vachon (1975; "new system"), we can adjust Valle's system to Vachon's conventions used today (Table 1). This rather elaborate adjustment allows one to use Valle's valuable statistical data, which are based on the analysis of large series from various localities, and which can be interpreted in much more detail than the data of Caporiacco (1950) who used only total counts for patellar external trichobothria. Valle (1975) was the first to identify the most important trend in *E. carpathicus* trichobothriotaxy: variation,of the B2 series (i.e. *eb*). Valle averaged the summary numbers for both pedipalps together (Valle, 1975: Tables 1-4, Figs. 4, 6, 8-10), and his numbers can be established in terms of Vachon (1975) as given in the Table 2. Recently, Fet & Soleglad (2002) restricted the name *E. carpathicus* to populations from Romania and established the species *E. tergestinus* (C. L. Koch, 1837) for populations from northern Italy. Valle (1975) specifically noted that all specimens from Piedmont and Liguria have B2=6 (*eb*=4); this refers to *E. tergestinus*. In our DNA phylogeny (Fig. 8), one of the monophyletic lineages is referable to *E. tergestinus*; the other Italian lineage (*Euscorpius sicanus*) is unexpectedly diverse geographically, and includes a number of populations, which are discussed below.

Sicily (type locality of *E. c. sicanus*). For specimens from Sicily, Vachon (1975, Fig. 31) illustrated the character *eb*=5, and suggested that this could be a good character, sufficient to elevate this taxon to the species rank. Valle (1975) reported that in specimens from around the island B2 varies from 6 to 8 (*eb* from 4-4 to 5-5). From his Fig. 6 it is evident that *eb*=5 specimens are concentrated in the north (corresponding to our DNA samples from Nebrodi Mts.). It remains to be seen if only *E. sicanus* is present in Sicily, or if in fact there are two sympatric species of *Euscorpius* as is the case on mainland Italy. Since Koch's type of *E. sicanus* originated from Messina (the very northeastern point of Sicily), this name can be associated with Sicilian specimens having *eb*=5.

Apennine Peninsula. *E. sicanus* is found in central and southern parts of the Apennine peninsula, from Tuscany to Calabria. Our data show that this species is found in Tuscany inland (Siena) as well as on the Tyrrhenian coast (Mt. Argentario, Follonica, Punta Ala), and on the nearby islands of the Tuscany Archipelago: Giannutri, Giglio, Capraia, Gorgona (MZUF, Caporiacco, 1950; our data). Further south we find this species on Palmarola (MZUF) and on the Capri (ZMH) Islands in the Tyrrhenian sea.

Caporiacco (1950) listed *E. c. sicanus* not only for Sicily (type locality) but also for the mainland Italy, from Apulia (Bari area) and western Calabria. In addition, Caporiacco (1950) described several new subspecies, the differences between which, according to our study of his type material, are insignificant and usually amount to minor variations in morphosculpture or coloration. *E. carpathicus calabriae* was described from Calabria; *E. c. argentarii*, from an isolated massif (ecological refugium) of Mt. Argentario in Tuscany; and *E. c. garganicus* from Apulia (Gargano Peninsula and Tremiti Islands in the Adriatic Sea). Marcuzzi *et al.* (1963: 81-88) conducted a statistical study on a number of populations from Apulia (using total trichobothrial counts), and could not find characters separating *E. c. garganicus* from other Apulian populations. Valle (1975, Fig. 8, Table 3) demonstrated B2=8 (*eb*=5) for most of southern Italy; he specifically noted (p. 228) that this character is not found north of Tuscany and Marches. However, we discovered a population with *eb*=5 also in Trieste (ZMH); two independent museum records (F. Werner in 1891 and C. Attems in 1901) exclude the possibility of erroneous labeling. It remains to be seen if *E. sicanus* occurs naturally in the northern Adriatic region or if the Trieste record represents an introduced population.

Two other island populations near Italy have been given subspecific names: *E. c. palmarolae* from the Palmarola Island in the southern Tyrrhenian sea (off the Latium coast) and *E. c. ilvanus* from the Tuscany Archipelago. Both also exhibit *eb*=5. Our DNA data shows that all Tuscany populations (mainland and island alike) exhibit very close haplotypes (genetic distance less than 1%), and belong to the same monophyletic clade as *E. sicanus* (Fig. 8, A).

The syntype series of *E. c. ilvanus* originates from several islands of the Tuscany Archipelago (including Elba), and also from Capri. However, our analysis of this material shows that all of Caporiacco's specimens from Elba and Capri have *eb*=4, i.e., they belong to *E. tergestinus*. This is confirmed by our DNA data (see above). Valle (1975, Fig. 4) also noted Elba populations as having B2=6 (*eb*=4); Capri may have two sympatric species (which is also possible for Sicily; see above).

According to Caporiacco, the rest of the syntype series of *E. c. ilvanus* originates from Giannutri, Cerboli, Capraia, Giglio, and Gorgona islands. Only syntypes from Giannutri, Cerboli and Capraia are in MZUF, all with *eb*=5 and eb_a=4; among these, we selected a lectotype from Giannutri. Valle (1975) provides statistics for 145 specimens from Giglio and 74 from Giannutri, most of which have B2=8 (*eb*=5); he also shows this character for specimens from Cerboli, Gorgona, Mt. Argentario, the coast of Tuscany, and Capri (Valle, 1975, Fig. 4).

DNA haplotypes from Giannutri (EcGI1) and Giglio (EcGG1) islands are very close to each other and to a haplotype from the mainland (EcPU1) (Punta Ala, identical with Follonica and Siena haplotypes) (Fig. 8). Another haplotype from Tuscany, which also falls in the *E. sicanus* clade, is found on Mt. Argentario (EcAR1); it is identical to a second haplotype from Siena and to one from Orbetello.

The morphological character combination *eb*=5 and eb_a=4, which is typical for Sicily, persists through some Italian populations of *E. sicanus*, such as those in Tuscany, including the islands of Tuscany Archipelago (type series of *E. c. ilvanus*), Mt. Argentario (type series of *E. c. argentarii*); Gargano Peninsula and Tremiti Islands (type series of *E. c. garganicus*; additional material studied); and Calabria (type series of *E. c. calabriae*).

Sardinia. Our DNA phylogeny (Fig. 8) demonstrates that the Sardinian population (*Ec*SD1), described originally as a separate species (*Scorpius canestrinii*), falls within the monophyletic clade of *E. sicanus*. Caporiacco (1950) studied 75 specimens from this population and treated it as a separate subspecies, *E. c. canestrinii.*. For the Sardinian population, Vachon (1975) mentioned *eb*=5. Valle (1975, Table 4) reported B2=8 (*eb*=5-5), but he also noted that B3 is normally 10 (eb_a=5-5). This was confirmed in a detailed analysis and redescription by Vachon (1978) who studied 142 specimens from Sardinia. These specimens consistently possessed *eb*=5 (94.7% of 284 pedipalps scored), as illustrated in Vachon (1978, Fig. 6; 1981, Fig. 11). Some variation in eb_a was observed; while it was predominantly 5 (in Vachon's series, 71.8% of pedipalps), others (e.g. in a population from Sordogno that we studied) have eb_a =4 (25.7%) and even 6 (2.5%). Vachon (1978: 329) noticed that the feature *eb*=5 was shared with the Sicilian subspecies (*E. c. sicanus*).

Pelagie Islands and Pantelleria. These small islands (belonging to Italy) in the southern Mediterranean Sea between Sicily and Africa are known to have populations of "*E. carpathicus*". Caporiacco (1950) described a new subspecies from Linosa Island, *E. c. linosae*, but our analysis of the type specimen from MZUF clearly indicates that it belongs to the *E. sicanus* clade (*eb*=5, eb_a=4). Valle (1975, Table 2) analysed 13 specimens from Linosa, all with B2=8 (*eb*=5); he also mentioned a population from Lampedusa Island but did not characterize it. Crucitti (1993: Fig. II) reported "*E. carpathicus*" from Pantelleria Island. No DNA data are as yet available from scorpions from the Pelagie Islands or Pantelleria.

Malta. Caporiacco (1950) was the first to report *E. c. sicanus* for Malta. Vachon (1975: 643) mentioned that specimens from Malta have *eb*=5. At the same time, Kinzelbach (1975), who expanded an alleged "hybrid between *E. carpathicus* and *E. mesotrichus*" to many Mediterranean populations, listed it also for Malta. Schembri & Schembri (1990) reported specimens from all of the Maltese islands (Malta, Gozo, Comino, and St. Paul's Islands) as belonging to *E. c. candiota* Birula, 1903, following Kinzelbach (1975). This identification was also given by Kritscher (1992) and Schembri (1992). Our analysis of Kritscher's original specimens deposited at NMW and of new Maltese material clearly indicates that it belongs to the *E. sicanus* clade (*eb*=5, eb_a=4), as stated by Caporiacco (1950). Trichobothria counts also show similarity between populations on Malta and Sicily, with series *et* and *v* about 20% lower on Sicily and Malta as compared to Sardinia. Our DNA phylogeny further demonstrates that the Maltese population is closest to the Sicilian *E. sicanus* (Fig. 8, A). This is to be expected, given the geological history and biogeographic affinities of the Maltese fauna: the Maltese Islands were connected to Sicily, and possibly to North Africa, in Late Miocene (Messinian) times, and may have been connected again during Pleistocene sea-level lows (Thake, 1985; Schembri, 1992; Hunt & Schembri, 1999). As for *E. c. candiota* Birula, this taxon was originally described from Crete (Birula, 1903), and Kinzelbach's (1975, 1982) interpretation that this species ranges beyond the Aegean Sea is not justified by either morphology or DNA analysis (Fet *et al.*, in preparation).

North Africa. "*E. carpathicus*" has been reported many times from isolated localities along the north African Mediterranean coast (Tunisia, Libya, Egypt) (Simon, 1885; Birula, 1909; Caporiacco, 1950; Valle, 1975; Vachon, 1952, 1975, 1978; Fet & Sissom, 2000; Stathi & Mylonas, 2001). Specimens from North Africa were listed under *E. c. sicanus* by Caporiacco (1950) and by Vachon (1975, 1978). Our analysis of museum material shows that these populations conform to the "*sicanus*" trichobothrial formula. Valle (1975, Table. 4) analysed 15 specimens from Tunisia and one from Libya (Cyrenaica), but his data are unclear since he quoted B2 as mostly 9 or even 10. In this case, Valle might have added up the eb_a and eb series, thus $eb=eb_a=5$. Vachon (1978: 328) mentioned specimens from Tunisia (Carthage and Tunis) with $eb=eb_a=5$, and from Tunisia (Sfax) and Libya (Cyrenaica) with $eb=5$ and $eb_a=4$. We analysed four specimens from Tunisia (Tunis and Djebel bou Kournine), all with $eb=5$ and $eb_a=4$. However, a single specimen from Tripoli, Libya (Birula, 1909) that we have seen in NMW has $eb=eb_a=4$. Recently, Stathi & Mylonas (2001) reported a new locality at Senebat Lauela Gorge in Kuff National Park, Ruins of Cyrrini, 5 km SE of El Beida, Libya.

No DNA is available from the northern African enclaves yet; it remains to be seen if these are true relict populations or if they have been introduced via human activity in historical times. Such transplantation are not unusual in *Euscorpius*; see for example, the populations of *E. flavicaudis* in England (Fet & Sissom, 2000), and Austrian populations of *E. tergestinus* (Huber *et al.*, 2001; as *E. carpathicus*).

Madeira. The single specimen known from the island of Madeira (Portuguese territory in the Atlantic Ocean) was first listed by Kinzelbach (1982) under "*E. mesotrichus*". An analysis of this specimen (deposited in the NMM) demonstrated that it has $eb=eb_a=5$, i.e. it is closest to the populations from Tunisia and Sardinia. The Madeira population of *Euscorpius* is the westernmost known. As with the North African populations, it remains to be shown if the one from Madeira was introduced or represents a true relict. Madeira is known for its relict Mediterranean-type biota.

Greece. A nomenclatural controversy surrounds some poorly studied Greek populations belonging to the "*E. carpathicus*" complex (Fet, 2000; Fet & Braunwalder, 2000; Fet & Sissom, 2000). Kinzelbach (1975) observed sympatry of two morphologically different forms in Greece (Thessaly) and separated *E. carpathicus* (L.) from another species, which he reported as "*E. mesotrichus* Hadži, 1929". This name, however, is permanently invalid since it refers to *E. carpathicus mesotrichus* Hadži, a junior primary homonym of *E. italicus mesotrichus* Hadži (Caporiacco, 1950; Fet 1997b) (ICZN Article 57.2). The name "*E. mesotrichus* Hadži" was used later by some authors (Michalis & Kattoulas, 1981; Kinzelbach, 1982, 1985; Kritscher, 1993), while others (Vachon, 1978, 1981; Fet, 1986, 1997a) did not comment on Kinzelbach's division.

Fet & Sissom (2000) agreed with the observation by Kinzelbach (1975) that at least two different species of the "*E. carpathicus*" complex are present in Thessaly, and tentatively accepted the name *E. tergestinus* for one of them as an available senior synonym of the homonymous *E. c. mesotrichus* Hadži (these names were first synonymized by Caporiacco, 1950). Our present study indicates that the Thessalian populations, indeed, belong to two species. However, neither of them is *E. tergestinus*; as defined recently by Fet & Soleglad (2002), this species is not found in Thessaly. One of Thessalian species, referred to as *E. carpathicus* s.str. by Kinzelbach (1975), is not yet identified: it does not belong to *E. carpathicus*(L.), which was recently restricted to Romania (Fet & Soleglad, 2002). Another Thessalian form, listed as *E. mesotrichus* by Kinzelbach (1975) and as *E. tergestinus* by Fet & Sissom (2000), according to the morphological features, belongs to *E. sicanus*. The DNA analysis also places the Thessalian populations of "*E. mesotrichus*" (*Ec*OL2, *Ec*KB1) into the *E. sicanus* clade. While in MP analysis the branching order is unresolved (Fig. 8, B), in the ML analysis (Fig. 8, A) these Thessalian populations form a sister group to *E. sicanus* populations from Sardinia, the Adriatic region, Sicilia, and Malta as an outgroup clade.

The distribution of *E. sicanus* in Greece is not limited to the populations from Mt. Olympus massif and northern Pindus Mts. (Kalambaka, valley of the Peneus River), the DNA of which we analysed. According to the museum data studied by V.F. and M.E.S. (which include the ample material previously discussed by Kinzelbach (1975) and Kritscher (1993)), this species is common in Greece found from Macedonia and Thessaly (with the Sporades) to Attica and Peloponnese (see map at Fig. 9, A). The specimens reported by Michalis & Kattoulas (1981) as "*E. mesotrichus*" from Lakonia, Peloponnese, also probably belong to the same species. Two "Group B" specimens of *E. carpathicus* reported by Fet (2000, p. 55) from Peloponnese (Mistras) also belong to *E. sicanus*. Judging from trichobothrial data of specimens (pp. 43-45, Fig. 3) recently reported from many localities from the Peloponnesus (Mistras) under *E. carpathicus* by Crucitti & Bubbico (2001) these populations also belong to *E. sicanus*. The Greek populations are the subject of a continuing study (Fet *et al.*, in preparation). Their morphology varies, but all have the unmistakable "*sicanus*" signature of *eb*=5; many populations (Mt. Olympus, Mt. Ossa, Sporades, Taygetos Mts.) also have eb_a=5. *E. sicanus* reaches its highest recorded altitude at Mt. Tsumerka, Pindus Mts., 1500 m a.s.l. (Kritscher, 1993, under "*E. mesotrichus*").

We thus confirm the presence of more than one form of the "*Euscorpius carpathicus*" complex in Thessaly, as first stated by Kinzelbach (1975). While one of these (erroneously cited as "*E. mesotrichus* Hadži") belongs to *E. sicanus*, the nomenclature of the other form, which has *eb*=4, remains to be established. It cannot be called *E. carpathicus*, since that species was shown to be restricted to Romania by Fet & Soleglad (2002). A number of former subspecies described in the genus *Euscorpius* have been recently elevated to the species rank using molecular and morphological criteria (*E. tergestinus, E. hadzii, E. koschewnikowi, E. balearicus, E. alpha, E. gamma*; see Gantenbein *et al.*, 2000, 2001; Scherabon *et al.*, 2000; Fet & Soleglad, 2002); other former subspecies have been synonymized with these species, therefore largely eliminating the need of subspecies category in *Euscorpius*.

It is important to notice that *E. sicanus* was not found on the majority of the Aegean islands (for trichobothrial data on specimens from 9 islands including Crete, see Fet, 1986, 2000). It was, however, recorded from the Sporades (Skiathos, Alonyssos, Skopelos) under *E. mesotrichus* by Kritscher (1993). Furthermore, a form with *eb*=5 was found on Tria Nisia, a small island group in the southwestern Aegean Sea (Fig. 9, A); this specimen was recorded by Werner (1936: 17) as *E. carpathicus*).

As a result of our study, one more valid species, *E. sicanus*, with a complex (and likely ancient) geographic distribution and with considerable intraspecific variation, is added to the genus *Euscorpius*. Further investigations on the "*Euscorpius carpathicus*" species complex are desirable, especially for a number of poorly studied (both named and unnamed) populations in the Balkans, Turkey, and Italy.

TAXONOMIC CONCLUSIONS

Euscorpius sicanus (C. L. Koch, 1837)

Scorpius sicanus C. L. Koch, 1837: 106. Pl. CVII-CVIII, Figs 247-248. TYPE MATERIAL. **Holotype** (female) from Messina, Sicily, Italy (leg. Wagner), formerly in J. Sturm's collection in Nuremberg (Birula, 1917), now presumed lost (Fet & Sissom, 2000). The designation of a neotype according to the ICZN (Article 75) is desirable for the purposes of taxonomic stability.

SYNONYMS

Scorpius canestrinii Fanzago, 1872: 78, Fig. 1, 1a, 1b, **syn. n. Lectotype** (designated by Kovařík, 1997: 182): female (HNHM 2277-214), Sardinia, Italy (coll. Canestrini, det. Fanzago). **Paralectotype**: 1 male (pictured by Vachon, 1978: Figs 1-7) (HNHM), Sardinia, Italy.

Euscorpius carpathicus linosae Caporiacco, 1950: 184, 227, **syn. n. Lectotype** (the only available specimen; designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74), female (MZUF 30/5970), Linosa Island, Pelagie Islands (Mediterranean Sea), Agrigento, Italy. **Paralectotypes** (depository unknown): 8 specimens, the same data as for the lectotype.

Euscorpius carpathicus garganicus Caporiacco, 1950: 189, 226, **syn. n. Lectotype** (designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74): male (MZUF 90/5902), San Domino Island, Tremiti Islands, Foggia, Apulia, Italy, 16 April 1940 (Pomini). **Paralectotypes** (all from Foggia, Apulia, Italy, coll. Pomini): 4 females, 3 males (MZUF 88/5903-5909), Caprara Island, Tremiti Islands, Foggia, Apulia, Italy, 13 April 1940; 3 females, 1 male (MZUF 86/5892-5895), Bosco Ginestra, Gargano, Apulia, 20 April 1940; 2 females (MZUF 86/5896-5897), Alveo del Lago S. Egidio, 20 April 1940; 1 male (MZUF 87/5910), Foresta Umbra, Gargano, Apulia, September 1940; 1 female (MZUF 92/5910), Sfilze, Gargano, Apulia, 25 April 1940; 3 females (MZUF 91/5899-5901), Sannicandro Garganico, Gargano, Apulia, 25 April 1940. Other paralectotypes (depository unknown): 44 specimens from Gargano and Tremiti.

Euscorpius carpathicus ilvanus Caporiacco, 1950: 195, 229 (in part), **syn. n. Lectotype** (designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74): male (MZUF 98/5745), Giannutri Island, Tuscany, Italy, 1878 (G.B. Toscanelli). **Paralectotypes** (all from Livorno, Tuscany, Italy): 5 females, 1 male (MZUF 98/5744, 99/5746-5751), same label as lectotype; 4 females, 7 males (MZUF 118/5725-5735), Cerboli Island, 1879 (G.B. Toscanelli): 1 female (MZUF 117/5755), Capraia Island, November 1927. Other paralectotypes (depository unknown): 14 males, Gorgona Island; 39 males, Giglio Island. *Note*: part of the original syntype series, i.e., specimens, from Elba Island (6 females, 2 males, MZUF 120/5736-5743, January 1879 (G.B. Toscanelli)) and from Capri Island (1 female, 2 males, MZUF 141/5752-5754, 31 July 1879 (Corio)) are excluded from this designation since they belong to *E. tergestinus*.

Euscorpius carpathicus argentarii Caporiacco, 1950: 196, 228, **syn. n. Lectotype** (designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74): female (MZUF 5977): Mt. Argentario, Grosseto, Tuscany, Italy, 3 November 1874 (Mayor). **Paralectotypes:** 6 females, 1 juv. male (MZUF 5978-5979, 6256-6260), from the same locality as the lectotype.

Euscorpius carpathicus palmarolae Caporiacco, 1950: 196, 228, **syn. n. Lectotype** (designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74), Palmarola Island, Pontine Islands (Tyrrhenian Sea), Latium, Italy, 1878 (G.B.Toscanelli). **Paralectotypes**: 2 females, 1 male (MZUF 111/5755, 5758-5759), from the same locality as the lectotype.

Euscorpius carpathicus calabriae Caporiacco, 1950: 200-201, 228 (in part), **syn. n. Lectotype** (designated here from the syntype series in order to preserve stability of nomenclature according to the ICZN Article 74), 1 female (MZUF 61/5887), Colle di Pizzo, Arena, Catanzaro, Calabria, Italy, 1874 (G. Cavanna); **Paralectotypes** (all from Calabria, Italy, coll. G. Cavanna): 6 females, 2 males (MZUF 61/5883-5886, 5888-5891), same locality as lectotype; 2 females (MZUF 57/5871, 5873), Filandari, Catanzaro, 13 April 1874; 1 female (MZUF 59/5874), Foresta della Mongiana near Mt. Pecoraro, Catanzaro, 25 June 1874; 1 female (MZUF 172/5868), Palmi, Reggio Calabria, 6 June 1874; 1 female, damaged (MZUF 170/5875), Timenovo (mountains near Oppido), Reggio Calabria, 22 May 1874. Other paralectotypes (depository unknown, all from Calabria, Italy): 3 males, Fago del Soldato; 1 female, Monte Consolino (Stilo); 19 males, Monte Oliveto; 17 males, Soveria Manetti; 1 female, Vibo Valenzia; female, Melossena Cave near Maratea (Potenza, Basilicata). *Note*: 5 specimens from the syntype series (MZUF 171/5876, 5879; 172/5869, 5870, 5880; Palmi, Reggio Calabria, 1874 (G. Cavanna)) do not match *E. calabriae* in morphology (*eb*=4) and are not included in the paralectotype list (they may belong to *E. tergestinus*).

REFERENCES (SELECTED)

Scorpius sicanus: C. L. Koch, 1850: 86; Fanzago, 1872: 83, Fig. 4.

Euscorpius carpathicus: Birula, 1909: 518; Werner, 1936: 17; Caporiacco, 1950: 178-209 (in part); Marcuzzi *et al.*, 1963: 81-88; Curčić, 1972: 84-86 (in part); Valle, 1975: 209-234 (in part); Crucitti, 1993: 289-291, Fig. 2 (in part); Fet & Braunwalder, 2000: 19, Fig. 3 (in part); Fet & Sissom, 2000: 357 (in part); Stathi & Mylonas, 2001: 289 (in part).

Euscorpius sicanus: Pavesi, 1876: 430; Birula, 1900: 15; Birula, 1917: 105; not Kulczyński, 1887: 349-354 (Tyrol), misidentification.

Euscorpius canestrinii: Birula, 1900: 15; Birula, 1917: 105.

Euscorpius carpathicus sicanus: Caporiacco, 1950: 183, 227; Valle, 1975: 219, 223; Vachon, 1975: 642-643, Fig. 31; Vachon & Jaques, 1977: 413; Vachon, 1978: 328; Lacroix, 1991a: 19, Fig. 64; Fet & Sissom, 2000: 365.

Euscorpius carpathicus canestrinii: Caporiacco, 1950: 184, 227; Valle, 1975: 233; Vachon & Jaques, 1977: 415, 431; Vachon, 1978: 321-230, Fig. 1-7; Vachon, 1981: 199, Fig. 7, 11; Lacroix, 1991a: 19, Fig. 58; Kovařík, 1997: 178, 182, Fig. 1-4; Fet & Sissom, 2000: 363.

Euscorpius mesotrichus: Kinzelbach, 1975: 30-38 (in part); Kinzelbach, 1982: 61-63 (in part); Kinzelbach, 1985, Map IV (in part); Michalis & Kattoulas, 1981: 109-110; Kritscher, 1993: 385-386 (in part).

Euscorpius carpathicus calabriae: Valle, 1975: 232; Bartolozzi *et al.*, 1987: 296; Lacroix, 1991a: 19 (*calabria*!); Fet & Sissom, 2000: 362.

Euscorpius carpathicus ilvanus: Valle, 1975: 219; Bartolozzi *et al.*, 1987: 296; Lacroix, 1991a: 19; Fet & Sissom, 2000: 364.

Euscorpius carpathicus garganicus: Bartolozzi *et al.*, 1987: 296-297; Lacroix, 1991a: 19.

Euscorpius carpathicus argentarii: Bartolozzi *et al.*, 1987: 296; Lacroix, 1991a: 19; Fet & Sissom, 2000: 361.

Euscorpius carpathicus palmarolae: Bartolozzi *et al.*, 1987: 296; Lacroix, 1991a: 19; Fet & Sissom, 2000: 362.

Euscorpius carpathicus linosae: Bartolozzi *et al.*, 1987: 296; Lacroix, 1991a: 19; Fet & Sissom, 2000: 364.

Euscorpius carpathicus candiota (not *Euscorpius candiota* Birula, 1903, misidentification): Kinzelbach, 1975: 34, 36-37 (in part); Schembri & Schembri, 1990: 20; Kritscher, 1992: 185-188, Figs. 1-4.

Euscorpius carpathicus carpathicus: Kritscher, 1993: 383-384 (in part), misidentification.

Euscorpius tergestinus (not *Scorpius tergestinus* C. L. Koch, 1837, misidentification). Fet & Sissom, 2000: 372 (in part; Greece).

MATERIAL STUDIED

Specimens used for DNA analysis (see above); type material of *E. c. linosae*, *E. c. garganicus*, *E. c. ilvanus*, *E. c. argentarii*, *E. c. palmarolae*, *E. c. calabriae* (see above) (MZUF); other museum materials: **GREECE.** 2 females (ZMH), Plataria, Epirus, 20 June 1986 (K. Michalis & P. Dolkeras); 1 juv. female (NMM 0176), road between Rodohori (=Rodochorion) and Naoussa, Macedonia, August 1972 (H. Georgiadis); 1 male (NMW 2130), Chortiatis near Thessaloniki, Macedonia, 9 October 1966 (J. Gruber); 1 male (NMW 16006), Mt. Tsumerka, 1700 m, Pindus Mts., 18 August 1990 (H. Sattmann); 14 females, 7 males (VF), Visitsa, 800 m, Mt. Pilion, Thessaly, 7 May 2001 (V. Fet); 32 females, 11 males (VF), Spilia, 800 m, Mt. Ossa (=Kissavos), Thessaly, 9 May 2001 (V. Fet); 4 females (VF), Kalambaka, 200 m, Thessaly, 14 May 2001 (V. Fet); 3 females, 1 male (NMW 16.035/1-4), Litohoro (=Lithochorion), near Mt. Olympus, Thessaly, 9 June 1984 (E. Kritscher); 1 female (VF), 3 km N of Litohoro, Mt. Olympus, 15 May 2001 (V. Fet); 1 female, 1 juv. male (NMM 0209a), Agios Dionysios, 820 m, Mt. Olympus, Thessaly, 28 August and 10 September 1973 (H. Pieper); 1 female, 1 juv. male (NMM 0206), between Petra and Kokkinopilos, 520 m, Mt. Olympus, Thessaly, 29 September 1973 (H. Pieper); 3 females (NMM 0261), Mt. Olympus, Thessaly, 26 May 1974 (H. Malicky); 6 females, 4 males (ZMH), Karditsa, 560 m, Thessaly, 24 June 1986 (K. Michalis & P. Dolkeras); 4 females (ZMH 30), Sykouri (=Sykourion), Thessaly (K. Michalis & P. Dolkeras); 1 male, 1 female (NMW 16040/1-2), Lazareta, Skiathos Island, Sporades, Thessaly, 24 June 1985 (E. Kritscher); 1 female (NMW 16041), Skopelos Island, Sporades, Thessaly 14 June 1985 (E. Kritscher); 2 females (NMW 16031/1-2), Milia, Alonissos Island, Sporades, Thessaly, 11 June 1985 (E. Kritscher); 1 juv. (NMW), Mt. Parnes, Attica, 1200 m, 18 May 1969 (H. Rausch); [illegible] females (NMNHS 68), Mistras, Laconia, Peloponnese, 18 September 1983 (P. Beron & V. Beshkov); 1 male (NMW 16039/2), road between Leptokaria and Karia, 14 km, Mani, Peloponnese, 9 June 1984 (E. Kritscher); 4 females, 4 males (NMM 0201) Taygetos Mts., W of Profitis Ilias, 1200 m, spruce forest, Peloponnese, 28 September 1973 (R. Kinzelbach); 1 male (NMW 2193), Tria Nisia (the southernmost island), Dodekanese Islands, Aegean Sea (O. Wettstein). **ITALY.** 5 specimens (NMW 11299), Messina, Sicily, 1906 (K. Holdhaas); 4 females, 3 males (ZISP 98-913), Sordogno, Sardinia (A. Krausse); 8 females, 3 males (ZMH), Mt. St Angelo, Gargano, Apulia, 6-8 September 1925; 1 female, 1 male juv. (ZMH), Capri Island, August 1928; 2 females, 1 male (ZMH), Trieste, September 1891 (F. Werner); 3 females, [illegible] males (ZMH), Trieste, 23 December 1901 (C. Attems). **MADEIRA.** 1 female (NMM 0204), [illegible] April 1971 (U. Hecker) (Kinzelbach, 1982; as identified as "*E. mesotrichus*"). **MALTA.** 2 specimens (NMW 1857), Wied-il-Babu, near Zurrico [=Wied Babu near Zurrieq], Malta, 16 April 1913; 1 female (NMW), Zurrico [=Zurrieq], Malta, 16 April 1913; 5 females, 1 male (NMW 15.040), Floriana, Malta, 15 June 1990 (E. Kritscher); 1 female (NMW 15.038), Marsalform [=Marsalforn], Gozo Island, 28 May 1990 (E. Kritscher); 6 females, 1 male (NMW 15.039), Marsalform [=Marsalforn], Gozo Island, 31 May 1990 (E. Kritscher). **TUNISIA.** 2 females (ZMH), Tunis, 23 May 1910 (Wegehn); 1 female, 1 male (NMW 2180), Djebel bou Kournine, 13 April 1913 (F. Werner). **LIBYA.** 1 male (NMW 2179), Tripoli, August 1906 (B. Klaptocz).

DISTRIBUTION

Italy (with Sardinia and Sicily), Malta, Greece, northern Africa (Tunisia, Libya, Egypt), Madeira.

TABLE 1. Correspondence of external patellar trichobothrial designations in *Euscorpius* by Valle (1975) and Vachon (1975).

Valle (1975) (scored for both sides)	Vachon (1975 and later) (scored for each side)
D1 (variable)	(*et*-right - 1) + (*et*-left - 1)
D2 (constant, always 8, i.e. 4 on each side)	2 from *et* and 2 from est on each side =4
D3 (constant, always 6, i.e. 3 on each side)	[(*est*-right - 2) + 1] + [(*est*-left - 2) +1] =6 (*est* is always 4)
D4 (variable)	*em*-right + em-left
B4 (constant, always 4, i.e. 2 on each side)	(*esb*-right + *esb*-left)=4 (*esb* is always 2)
B3 (variable)	eb_a-right + eb_a-left
B2+B1 (B2 is variable; B1 is always 2, as it includes only 1 on each side)	*eb*-right + *eb*-left

TABLE 2. Variation of external patellar trichobothrial series B2 (Valle, 1975) corresponding to series *eb* (Vachon, 1975).

Valle (1975)	Vachon (1975 and later)
B2	*eb*
6 (3-3)	4-4
7 (3-4 or 4-3)	4-5 or 5-4 (for an asymmetric individual); or 4-4 & 5-5 (when averaged per locality)
8 (4-4)	5-5

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