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Scientific Letter

Arriving at the correct taxonomy: a comment on "A new and highly divergent mitochondrial lineage in the Small Five-toed Jerboa, *Scarturus elater*, from Iran"

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Abstract

We reanalyzed 657 base pairs of mitochondrial cytochrome *b* (cyt*b*) sequences of small five-toed jerboas *Scarturus* from Iran, which had been published as *Allactaga* by Mohammadi et al. (2016) in Zoology in the Middle East. We show that taxonomic names are available for the three main clusters they recognized: *S. hotsoni*, *S. elater*, and *S. toussi*. The last two species each contained two lineages, both in our analysis, as well as in those published earlier. We recommend the taxonomic identification of specimens in molecular analyses and call for deposition of voucher material in responsible public collections.

Main Text

Frequently, the initial step in biological research is identification in which a preexisting taxonomic name is assigned to the individuals of a given species. The name enables one to search for the existing information or to undertake comparisons with other organisms. Accurate species identification is crucial and misidentifications may have major consequences in basic and applied research (Bickford et al., 2007; Costa et al., 2015; Lourenço, 2016; Kryštufek et al., 2019; Taylor et al., 2019). Reference material, either in the form of museum vouchers or deposited nucleotide sequences, is frequently essential for accurate identification.

In a recent work, Mohammadi et al. (2016) readdressed the evolutionary history of small five-toed jerboas (*Allactaga* Cuvier, now *Scarturus* Gloger; see Michaux and Shenbrot, 2017) in Iran by using mitochondrial cytochrome *b* (cyt*b*) marker. They identified five clusters which they either called lineages or clades. Because the nodes in their tree (Figure 2 in Mohammadi et al., 2016) lack information on statistical support, and genuine monophylies are therefore unknown, we shall call them clusters. Mohammadi et al. (2016) concluded that (1) "the clear separation of the mtA lineage from the remaining specimens …. may suggest the occurrence of a new *Allactaga* species", (2) the remaining clusters match subspecies of *A. elater* Lichtenstein, and (3) "*A. toussi* might not be a true species but instead a morphological variant of *A. elater*". We found their taxonomic interpretation of small five-toed jerboas of Iran surprising and decided to repeat their analyses. We included in our assessment all cyt*b* sequences used by Mohammadi et al. (2016). To these we added published sequences of *Scarturus elater*, *S. toussi*, *S. hotsoni* Thomas, *S. euphratica* Thomas, and *S. williamsi*

Thomas. A complete list of sequences with GenBank accession numbers and references appears in the Appendix. A number of these sequences, except those from Moshtaghi et al. (2016), are backed by museum vouchers housed in the Zoological Museum of Ferdowsi University of Mashhad, Iran (examined by the first author), Slovenian Museum of Natural History Ljubljana (Boris Kryštufek), General Commission for Scientific Agricultural Research, Damascus, Syria (now most probably lost; examined by Boris Kryštufek), and Department of Biology, Selçuk University, Konya, Turkey (determined by Professor Atilla Arslan). This allowed us to link with great confidence the haplotypes with existing taxonomic names.

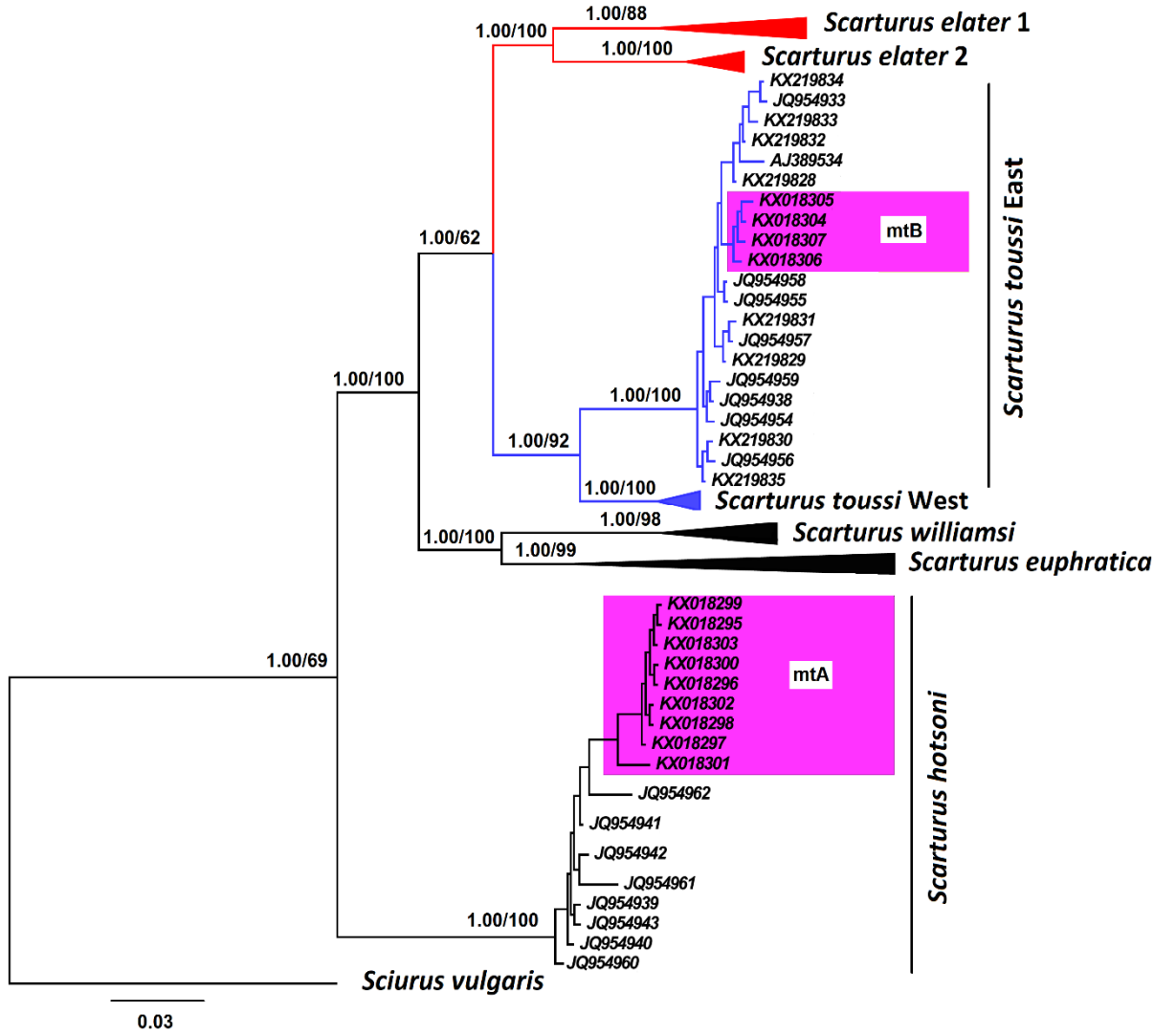

Figure 1: Bayesian Inference tree summarizing phylogenetic relationships among 98 cytochrome *b* sequences representing all five-toed jerboas (*Scarturus*) from Iran and adjacent regions. All sequences were downloaded from GenBank (see Appendix for accession numbers). Sequences published by Mohammadi et al. (2016) are labeled as ´mtA´ and ´mtB´ and highlight in pink. Taxonomic names for lineages are on the right-hand side and follow Moshtaghi et al. (2016). The first and second numbers on the branches correspond to posterior probability (BPP) and bootstrap (BP) values in the BI and ML tree analyses, respectively.

Our phylogenetic analysis involved 98 cyt*b* sequences (657 bp) and followed the protocol described in Moshtaghi et al. (2016). Bayesian Inference (BI) and Maximum Likelihood (ML) analyses gave trees of very similar topologies, therefore only the BI tree is shown in Figure 1. Small five-toed jerboas were in four major lineages which had strong support (BPP=1.0, BP≥0.88). All sequences from the cluster ´mtA´ of Mohammadi et al. (2016) aligned with reference samples of *S. hotsoni* and the cluster ´mtB´ emerged as identical with ´*S. toussi* East´ of Moshtaghi et al. (2016). Furthermore, clusters 6 and 7 of Mohammadi et al. (2016) nested inside´*S. elater* 2´ and ´*S. elater* 1´ of Moshtaghi et al. (2016), respectively. Therefore, the topology of Mohammadi’s et al. (2016) tree can be unambiguously interpreted with the existing body of taxonomic knowledge. Moreover, morphological examination of museum vouchers would equally ensure the application of proper taxonomic names, as *S. hotsoni* can be reliably distinguished from other small five-toed jerboas in southwestern Asia by its swollen bullae (Corbet, 1978). Although morphological differences between *S. elater* and *S. toussi* are less prominent, they are stable and allow safe classification of individuals (Darvish et al., 2008). For further phylogeographic structuring of *S. toussi* and *S. elater*, we direct the reader to Dianat et al. (2013), Moshtaghi et al. (2016) and Bannikova et al. (2018).

Palearctic mammals are among the best-known on the planet, and there is a solid foundation for studying their evolution and taxonomy. Despite this, it is imperative that any researcher gain important taxonomic knowledge on the group of interest before any work is undertaken. This should also involve the identification of specimens by traditional morphological characteristics which link modern phylogenetic analysis with the traditional Linnaean taxonomy (Schlick-Steiner et al., 2007).

Finally, we call for long-term preservation of vouchers and their deposition in responsible public collections to enable sound integrative taxonomic studies. Taxonomic results are crucial for species delimitation and all subsequent steps, like mapping distributional ranges, assessing risk for public health and planning conservation management.

Acknowledgements

This communication is dedicated to late Professor Jamshid Darvish who worked hard to disentangle the taxonomy of Iranian rodents in general and the jerboas in particular. Among other contributions, he also established the Zoological Museum of Ferdowsi University of Mashhad. We would like to thank Atilla Arslan for checking the identity of *Scarturus* deposited in the Selçuk University, Konya, Christiane Denys (Museum National d'Histoire Naturelle) for thoughtful comments on an earlier draft. Bruce D. Patterson (Field Museum of Natural History) is acknowledged for English editing.

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Appendix: Voucher Number/Sample ID, Accession Number, Species, Locality and Reference of the analyzed samples. Note that in quoted sources, including GenBank, all the sequences are labeled by the generic name *Allactaga*. Collection Acronyms: DBSU – Department of Biology, Selçuk University, Konya, Turkey; GCSAR – General Commission for Scientific Agricultural Research, Damascus, Syria; PMS – Slovenian Museum of Natural History, Ljubljana, Slovenia; ZMFUM – Zoological Museum of Ferdowsi University of Mashhad, Mashhad, Iran.

Sample ID/ Voucher Number	Accession Numbers	Species/Clades Moshtaghi et al. (2016)	Locality	Reference
-	KX018295	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018296	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018297	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018298	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018299	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018300	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018301	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018302	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018303	*Scarturus hotsoni*	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
ZMFUM2674	JQ954928	*Scarturus elater* 1	Iran, Golestan	Dianat et al. (2013)
ZMFUM2128	JQ954931	*Scarturus elater* 1	Iran, Kashmar	Dianat et al. (2013)
ZMFUM 1429	JQ954932	*Scarturus elater* 1	Iran, Kashmar	Dianat et al. (2013)
ZMFUM1377	KX219804	*Scarturus elater* 1	Iran, Kashmar	Moshtaghi et al. (2016)
ZMFUM1412	KX219805	*Scarturus elater* 1	Iran, Kashmar	Moshtaghi et al. (2016)
ZMFUM2084	KX219806	*Scarturus elater* 1	Iran, Kashmar	Moshtaghi et al. (2016)
ZMFUM1740	KX219807	*Scarturus elater* 1	Iran, Torbate Heydarieh	Moshtaghi et al. (2016)
ZMFUM3542	KX219808	*Scarturus elater* 1	Iran, Gonabad	Moshtaghi et al. (2016)
ZMFUM1905	KX219809	*Scarturus elater* 1	Iran, Gonbad	Moshtaghi et al. (2016)
ZMFUM2704	KX219810	*Scarturus elater* 1	Iran, Kashmar	Moshtaghi et al. (2016)
ZMFUM2749	KX219811	*Scarturus elater* 1	Iran, Golestan	Moshtaghi et al. (2016)
ZMFUM2842	KX219812	*Scarturus elater* 1	Iran, Bojnord	Moshtaghi et al. (2016)
ZMFUM2862	KX219813	*Scarturus elater* 1	Iran, Bojnord	Moshtaghi et al. (2016)
ZMFUM1374	KX219814	*Scarturus elater* 1	Iran, Kashmar	Moshtaghi et al. (2016)
ZMFUM2897	KX219815	*Scarturus elater* 1	Iran, Bojnord	Moshtaghi et al. (2016)
ZMFUM2675	JQ954927	*Scarturus elater* 2	Iran, Golestan	Dianat et al. (2013)
ZMFUM2676	JQ954929	*Scarturus elater* 2	Iran, Golestan	Dianat et al. (2013)
ZMFUM2677	JQ954930	*Scarturus elater* 2	Iran, Golestan	Dianat et al. (2013)
ZMFUM2732	KX219816	*Scarturus elater* 2	Iran, Golestan	Moshtaghi et al. (2016)
ZMFUM2738	KX219817	*Scarturus elater* 2	Iran, Golestan	Moshtaghi et al. (2016)
ZMFUM2751	KX219818	*Scarturus elater* 2	Iran, Golestan	Moshtaghi et al. (2016)
ZMFUM3547	KX219819	*Scarturus elater* 2	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM3548	KX219820	*Scarturus elater* 2	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM3554	KX219821	*Scarturus elater* 2	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM3601	KX219822	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM3602	KX219823	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM3603	KX219824	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM3604	KX219825	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM3609	KX219826	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM3613	KX219827	*Scarturus elater* 2	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM1533	JQ954953	*Scarturus euphratica*	Iran, Ilam	Dianat et al. (2013)

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Appendix. (Continued)

Sample ID/ Voucher number	Accession Numbers	Species/clades Moshtaghi et al. (2016)	Locality	Reference
PMS18492	KC465451	*S. williamsi*	Lebanon	Kryštufek et al. (2013)
-	KC465452	*S. williamsi*	Lebanon	Kryštufek et al. (2013)
DBSU10-245	KC465442	*Scarturus euphratica*	Turkey	Kryštufek et al. (2013)
DBSU10-246	KC465443	*Scarturus euphratica*	Turkey	Kryštufek et al. (2013)
DBSU10-247	KC465444	*Scarturus euphratica*	Turkey	Kryštufek et al. (2013)
DBSU10-248	KC465445	*Scarturus euphratica*	Turkey	Kryštufek et al. (2013)
GCSAR1936	KC465446	*Scarturus euphratica*	Syria	Kryštufek et al. (2013)
GCSAR1948	KC465447	*Scarturus euphratica*	Syria	Kryštufek et al. (2013)
GCSAR1949	KC465448	*Scarturus euphratica*	Syria	Kryštufek et al. (2013)
GCSAR1954	KC465449	*Scarturus euphratica*	Syria	Kryštufek et al. (2013)
GCSAR1962	KC465450	*Scarturus euphratica*	Syria	Kryštufek et al. (2013)
ZMFUM2682	JQ954939	*Scarturus hotsoni*	Iran, Esfahan, Pukand	Dianat et al. (2013)
ZMFUM2684	JQ954940	*Scarturus hotsoni*	Iran, Esfahan, Peykan	Dianat et al. (2013)
ZMFUM2686	JQ954941	*Scarturus hotsoni*	Iran, Esfahan, Aminabad	Dianat et al. (2013)
ZMFUM2687	JQ954942	*Scarturus hotsoni*	Iran, Esfahan, Aminabad	Dianat et al. (2013)
ZMFUM2685	JQ954943	*Scarturus hotsoni*	Iran, Esfahan, Peykan	Dianat et al. (2013)
ZMFUM1277	JQ954960	*Scarturus hotsoni*	Iran, Yazd	Dianat et al. (2013)
ZMFUM1521	JQ954961	*Scarturus hotsoni*	Iran, Yazd	Dianat et al. (2013)
ZMFUM1533	JQ954962	*Scarturus hotsoni*	Iran, Yazd	Dianat et al. (2013)
ZMFUMT1045	AJ389534	*Scarturus toussi* East	Iran	Dianat et al. (2013)
ZMFUM1431	JQ954933	*Scarturus toussi* East	Iran, Sarakhs	Dianat et al. (2013)
ZMFUM1416	JQ954938	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM2694	JQ954954	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM2695	JQ954955	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM2696	JQ954956	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM1415	JQ954957	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM1418	JQ954958	*Scarturus toussi* East	Iran, Cheshme Gilas	Dianat et al. (2013)
ZMFUM2130	JQ954959	*Scarturus toussi* East	Iran, Sarakhs	Dianat et al. (2013)
-	KX018304	*Scarturus toussi* East	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018305	*Scarturus toussi* East	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018306	*Scarturus toussi* East	Iran, Damghan, Qusheh	Mohammadi et al. (2016)
-	KX018307	*Scarturus toussi* East	Iran, Damghan, Qusheh	Mohammadi et al. (2016)

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Appendix. (Continued)

Sample ID/ Voucher number	Accession Numbers	Species/clades Moshtaghi et al. (2016)	Locality	Reference
ZMFUM2864	KX219828	*Scarturus toussi* East	Iran, Bojnord	Moshtaghi et al. (2016)
ZMFUM3557	KX219829	*Scarturus toussi* East	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM3558	KX219830	*Scarturus toussi* East	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM3553	KX219831	*Scarturus toussi* East	Iran, Sarakhs	Moshtaghi et al. (2016)
ZMFUM2875	KX219832	*Scarturus toussi* East	Iran, Bojnord	Moshtaghi et al. (2016)
ZMFUM1434	KX219833	*Scarturus toussi* East	Iran, Tabas	Moshtaghi et al. (2016)
ZMFUM1438	KX219834	*Scarturus toussi* East	Iran, Sabzevar	Moshtaghi et al. (2016)
ZMFUM3614	KX219835	*Scarturus toussi* East	Iran, Torbate Jam	Moshtaghi et al. (2016)
ZMFUM2678	JQ954934	*Scarturus toussi* West	Iran, Esfahan, Mirabad	Dianat et al. (2013)
ZMFUM2679	JQ954935	*Scarturus toussi* West	Iran, Tehran	Dianat et al. (2013)
ZMFUM2680	JQ954936	*Scarturus toussi* West	Iran, Tehran	Dianat et al. (2013)
ZMFUM2681	JQ954937	*Scarturus toussi* West	Iran, Tehran	Dianat et al. (2013)
ZMFUM2680	KX219836	*Scarturus toussi* West	Iran, Tehran	Moshtaghi et al. (2016)
ZMFUM4503	KX219837	*Scarturus toussi* West	Iran, Hamedan	Moshtaghi et al. (2016)
ZMFUM2691	JQ954947	*Scarturus williamsi*	Iran, Hamedan	Dianat et al. (2013)
ZMFUM2693	JQ954949	*Scarturus williamsi*	Iran, Zanjan	Dianat et al. (2013)
ZMFUM2138	JQ954951	*Scarturus williamsi*	Iran, Ardebil	Dianat et al. (2013)
DBSU10-235	KC465439	*Scarturus williamsi*	Turkey	Kryštufek et al. (2013)
DBSU11-298	KC465440	*Scarturus williamsi*	Turkey	Kryštufek et al. (2013)
DBSU11-299	KC465441	*Scarturus williamsi*	Turkey	Kryštufek et al. (2013)
ZMFUM2688	JQ954944	*Scarturus williamsi*	Iran, Chaharmahal and Bakhtiari	Dianat et al. (2013)
ZMFUM 2689	JQ954945	*Scarturus williamsi*	Iran, Chaharmahal and Bakhtiari	Dianat et al. (2013)
ZMFUM2690	JQ954946	*Scarturus williamsi*	Iran, Hamedan	Dianat et al. (2013)
ZMFUM2692	JQ954948	*Scarturus williamsi*	Iran, Zanjan	Dianat et al. (2013)
ZMFUM2125	JQ954950	*Scarturus williamsi*	Iran, Ardebil	Dianat et al. (2013)
ZMFUM2139	JQ954952	*Scarturus williamsi*	Iran, Ardebil	Dianat et al. (2013)