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SECRETS OF THE UNDERGROUND VIETNAM: AN UNDERESTIMATED SPECIES DIVERSITY OF ASIAN MOLES (LIPOTYPHLA: TALPIDAE: *EUROSCAPTOR*)

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ABSTRACT

A study of the Southeast Asian moles of the genus *Euroscaptor* based on a combined approach, viz. DNA sequence data combined with a multivariate analysis of cranial characters, has revealed a high cryptic diversity of the group. An analysis of mitochondrial cytochrome *b* gene and five nuclear genes has revealed two deeply divergent clades: the western one (*E. klossi* + *E. malayana* + *E. longirostris* from Sichuan + *Euroscaptor* spp. from northern Vietnam and Yunnan, China), and the eastern one (*E. parvidens* s.l. + *E. subanura*). The pattern of genetic variation in the genus *Euroscaptor* discovered in the present study provides support for the existence of several cryptic lineages that could be treated as distinct species based on their genetic and morphological distinctness and geographical distribution. The moles from southern China and northern Vietnam form three distinct groups. The specimens from Sichuan (including the one collected from the type locality of *E. longirostris*) were clearly distinct from the northwestern Vietnam and Yunnan samples that were previously attributed to this species. We argue that the real distribution of *E. longirostris* is restricted to Sichuan, northward of Yangtze River, whereas the populations occurring southward of this isolation barrier evidently represent a new species *Euroscaptor orlovi* sp. nov. (northwestern Vietnam and Yunnan, southern China). Moreover, Red River that divides the western and eastern parts of northern Vietnam beyond doubt separates the population of *E. orlovi* from the moles occurring in northeastern Vietnam (Vinh Phuc and Cao Bang provinces); the latter are described here as *Euroscaptor kuznetsovi* sp. nov. Yet, genetic data are in favour of a close affinity of *E. subanura* with *E. parvidens*. A combined analysis of both genetic and morphological data has revealed a strong geographic segregation of *E. parvidens* samples. The populations from Dalat Plateau (southern Vietnam), including the moles from Loc Bao, Bi Dup and Chu Yang Sin, form a well-supported clade and can be considered true *E. parvidens*. The specimens from central Vietnam (Kon Tum and Quang Nam provinces) are significantly different from them, yet their monophyly has been supported by the mtDNA only. The moles from central Vietnam have been described here as a new subspecies *Euroscaptor parvidens ngoclinhensis* ssp. nov. All the studied samples of *E. subanura* have shown a low genetic and morphological variability despite their wide geographic range.

Key words: cryptic species, *Euroscaptor*, multilocus phylogeny, multivariate analyses, taxonomy

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ТАЙНЫ ПОДЗЕМНОГО ВЬЕТНАМА: НЕДООЦЕНЕННОЕ ВИДОВОЕ РАЗНООБРАЗИЕ АЗИАТСКИХ КРОТОВ (LIPOTYRHLA: TALPIDAE: *EUROSCAPTOR*)

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РЕЗЮМЕ

Исследование азиатских кротов рода *Euroscaptor* с применением комплексного подхода, включающего анализ ДНК и многомерный анализ краниологических признаков, выявило высокую криптическую изменчивость этой группы. Анализ митохондриального гена цитохрома *b* и пяти ядерных генов показал существование двух сильно дивергировавших клад: западная клад (*E. klossi* + *E. malayana* + *E. longirostris* из Сычуани + *Euroscaptor* spp. из северного Вьетнама и Юньнани, Китай) и восточная клад (*E. parvidens* s.l. + *E. subanura*). Картина генетической изменчивости рода *Euroscaptor*, выявленная в нашем исследовании, свидетельствует о существовании нескольких криптических линий, которые, на основании их генетических и морфологических различий и географического распространения, могут рассматриваться как отдельные виды. Кроты из южного Китая и северного Вьетнама образуют три отдельные группы. Экземпляры из Сычуани (включая экземпляр из типового местонахождения *E. longirostris*) заметно отличаются от кротов из северо-западного Вьетнама и Юньнани, которых ранее относили к этому виду. Мы считаем, что распространение *E. longirostris* ограничивается Сычуанью, к северу от р. Янцзы, тогда как популяции, обитающие к югу от этого изолирующего барьера, относятся к новому виду *Euroscaptor orlovi* sp. nov. (северо-западный Вьетнам и Юньнань, южный Китай). Река Красная, разделяющая западные и восточные районы северного Вьетнама, отделяет популяции *E. orlovi* от кротов, обитающих в северо-восточном Вьетнаме (провинции Виньфук и Каобанг), которые описаны здесь как новый вид *Euroscaptor kuznetsovi* sp. nov. Генетические данные свидетельствуют о близком родстве *E. subanura* и *E. parvidens*. Анализ генетических и морфологических данных выявил значительные географические различия между исследованными выборками *E. parvidens*. Популяции с Далатского плато (южный Вьетнам), включая кротов из Локбао, Бидупа и Чуянгсина, образуют отдельную кладу с хорошей поддержкой и могут рассматриваться как собственно *E. parvidens*. Экземпляры из центрального Вьетнама (провинции Контум и Куангнам) заметно отличаются от них, хотя монофилия этой группы подержана только данными по митохондриальной ДНК. Кроты из центрального Вьетнама описаны здесь как новый подвид *Euroscaptor parvidens ngoclinhensis* sp. nov. Исследованные выборки *E. subanura* характеризуются низкой генетической и морфологической изменчивостью, несмотря на широкое распространение.

Ключевые слова: криптические виды, *Euroscaptor*, мультилокусная филогения, многомерный анализ, таксономия

Table 1. List of the original material for *Euroscaptor* used for genetic and morphological analysis: species name, ID of specimens, collection and geographic location. The samples were retrieved from the following museum collections: ZMMU – Zoological Museum of Moscow State University, Russia; ZIN – Zoological Institute of the Russian Academy of Sciences, Saint Petersburg, Russia, BMNH – Natural History Museum, London, UK.

Species	Specimen code in phylogenetic trees (Figs. 2–3 ref.)	Museum catalog number where it is available	Collecting locality and locality code (Fig. 1 ref.)
<i>Euroscaptor parvidens</i>	Eupar 33	ZIN 96663	Vietnam, Kon Tum Province, Dac Glei District, 2–3 km west of Ngoc Linh Mt., 15°05'N, 107°57'E (6)
	Eupar 84	ZIN 96664	
	Eupar 85	ZIN 96665	
	Eupar AVA 14-038	ZIN 101920	
	Eupar AVA 14-041	ZIN 101921	Vietnam, Dak Lak Province, Krong Bong District, Chu Yang Sin National Park, 12°25'26"N, 108°21'52"E (7)
	Eupar AVA 14-074	ZIN 101922	
	Eupar AVA 14-075	ZIN 101923	
	Eupar AVA 14-037	ZIN 102246	
	Eupar AVA 14-082	ZIN 102247	Vietnam, Lam Dong Province, Lac Duong District, 5 km NE of Long Lanh Village, Bi Dup – Nui Ba Nature Reserve, 12°10'44"N, 108°40'44"E (8)
	Eupar 12	ZIN 98916	
	Eupar 15	ZIN 98917	
	Eupar 16	ZIN 98918	
	Eupar 17	ZIN 98919	
		ZMMU S-173400	Vietnam, Lam Dong Province, Bao Lam District, Loc Bao Forestry, 11°44.304'N, 107°42.140'E (9)
	Eupar 09.04.13-2	ZMMU S-195070	
	Eupar 09.04.13-1	ZIN 101901	
	Eupar 15.04.13-2	ZMMU S-195071	
<i>Euroscaptor sp.1</i>	Eupar 14.04.13-1	ZIN 101902	Vietnam, Lao Cai Province, 6 km west of Sa Pa, north slope of Fansipan Mt., near Tram Ton forest station, 22°21'N, 103°46'E (1)
	Eu 18	ZIN 96318	
	Eu 146	ZIN 98142	
	Eu 167	ZIN 97789	
		ZIN 101559	Vietnam, Lao Cai Province, Sa Pa (1)
<i>Euroscaptor sp.2</i>		BMNH 33.4.1.148	
	Eu 99335	ZIN 99335	China, Yunnan Province, Jingdong County (10)
	Eu AVA 12-288	ZIN 101531	Vietnam, Vinh Phuc Province, vicinity of Tam Dao, 21°27'06"N, 105°38'09"E (2)
	Eu AVA 12-289	ZIN 101532	
<i>Euroscaptor longirostris</i>		ZMMU S-161162	China, Sichuan Province, Chodsigou Valley (north of Lunganfu Town), 32°21'N, 104°20'E (11)
		ZIN 6354	
		ZIN 6374	
		ZIN 6373	
		BMNH 55.429	China, Sichuan Province, Tsao-Po
		BMNH 55.430	
		BMNH 55.431	
		BMNH 55.433	
		BMNH 55.435	China, Sichuan Province, Omi-San (12)
		BMNH 11.2.1.24	
<i>Euroscaptor subanura</i>		BMNH 99.3.1.9	China, Sichuan Province, Yangliupa
	Eusub AVA 12-276		Vietnam, Tuyen Quang Province, Son Duong District, Hiep Hoa Commune, 3 km east of Vuoc Ly Village, (northwestern slope of Tam Dao Mountain), 21°38'08"N, 105°27'35"E (3)
	Eusub AVA 12-277	ZIN 101533	
	Eusub AVA 12-278	ZIN 101534	
		ZIN 101535	
	Eusub AVA 13-030	ZIN 101897	Vietnam, Ba Vi District, 50 km west of Hanoi, vicinity of Ba Vi Resort, 21°04'58"N, 105°22'54"E (5)
	Eusub AVA 13-033	ZIN 101898	
	Eusub AVA 13-036	ZIN 101899	
	Eusub AVA 13-037	ZIN 101900	
	Eusub AVA 14-098	ZIN 101924	Vietnam, Phu Tho Province, Thanh Son District, Xuan Son National Park, 21°08'11"N, 104°56'11"E (4)
	Eusub AVA 14-103	ZIN 101925	
	Eusub AVA 14-104	ZIN 101926	
	Eusub AVA 14-108	ZIN 102248	
	Eusub AVA 14-115	ZIN 101927	
	Eusub AVA 14-117		
		ZIN 102249	
		ZIN 102252	
		ZIN 102254	
		ZIN 102255	

E. parvidens and *E. subanura* (Fig. 10). The coronoid process with a narrow apex, similar to *E. kuznetsovi* sp. nov. and *E. longirostris*, whereas it short, with a wide apex in *E. parvidens* and *E. subanura* (see Figs 8–9).

Etymology. The new species is named in honour of Dr. Nikolai L. Orlov (Zoological Institute, Russian Academy of Sciences, Saint Petersburg, Russia) in recognition of his remarkable contributions to the study of animals of Vietnam.

Distribution. Found in northern Vietnam (Lao Cai Province, Sa Pa District) and southern China (Yunnan Province). It may have a wider distribution in the highlands of northern Laos and in north-western Vietnam, probably westward of Red River.

Remarks. The species is reported as *Euroscaptor* sp. 1 in the results of both genetic and morphological analyses.

***Euroscaptor kuznetsovi* sp. nov.**
(Figs 8C, 10C)

Type locality.

Holotype. ZIN 101531, collector's number AVA 12–288, male, body in ethanol, skull extracted, VIETNAM, Vinh Phuc Province, vicinity of Tam Dao, 21°27'06"N, 105°38'09"E, altitude 750 m a.s.l.; collected 24 November 2012 by A.V. Abramov.

Paratypes. ZIN 101532, collector's number AVA 12–289, male, body in ethanol, skull extracted, collected 25 November 2012 by A.V. Abramov; ZMMU S–161162, male, skin, skull, collected 6 February 1993 by G.V. Kuznetsov; both specimens from the same locality as the holotype.

Diagnosis. Large-sized mole, comparable to *E. longirostris* and *E. orlovi* sp. nov. Pelage blackish brown. Tail long and club-shaped. Rostral part of skull elongated and relatively wide. Posterolingual border of P4 deeply concave. Anterior parts of auditory bullae flattened and straddling. A new species distinguished by the mitochondrial gene cytochrome *b* and five nuclear genes (*BRCA1*, *BRCA2*, *ApoB*, *RAG1* and *A2ab*) (see Figs 2–4).

Description and comparisons. Head and body length 132–136 mm, with a long tail, 11.4–12.5% of head and body length. Tail club-shaped, evenly covered with long overhairs. Dorsal and ventral pelage blackish-brown. Body elongated. Skull with a long and narrow rostrum (Fig. 8C). All upper premolars with 2 roots, P1 and P2 similar in height, P3 much wider than them, P1–P2 with metastyles, P4 with small

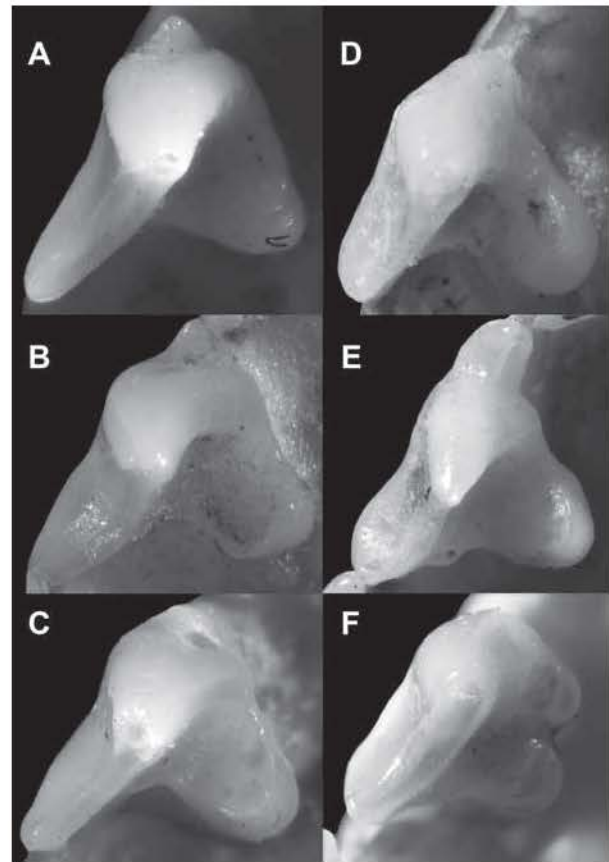


Fig. 10. Upper fourth premolar in SE Asian moles. A – *E. longirostris* (ZIN 6374, China, Sichuan), B – *E. orlovi* sp. nov. (ZIN 96318, holotype, Vietnam, Sa Pa), C – *E. kuznetsovi* sp. nov. (ZIN 101531, holotype, Vietnam, Tam Dao), D – *E. parvidens* (ZIN 101901, Vietnam, Loc Bao), E – *E. parvidens ngoclinhensis* ssp. nov. (ZIN 96663, holotype, Vietnam, Ngoc Linh), F – *E. subanura* (ZIN 101535, Vietnam, Vuoc Ly). Scale bar = 10 mm.

parastyle, talon of a moderate size, shorter than metastyle part, the posterolingual border of the tooth deeply concave (Fig. 10C). The coronoid process with a narrow apex. Condyle-angular region of mandible not oblong.

Tail long and club-shaped unlike short, bulb-shaped tail in *E. parvidens* and *E. subanura*. New species differs from *E. longirostris* in the larger skull size and relatively short molar rows. Larger on average than *E. parvidens* and *E. subanura*. It differs from *E. longirostris* and *E. orlovi* sp. nov. in their relatively wide rostral part of the skull, however it much wider in *E. malayana* and *E. klossi*. The new species has P1 and P2 similar in height, whereas in *E. orlovi* sp. nov. and *E. longirostris* P1 larger than P2. Posterolingual

border of P4 deeply concave in *E. kuznetsovi* sp. nov., *E. orlovi* sp. nov., and *E. longirostris*, but it shallowly concave in *E. parvidens* and *E. subanura* (Fig. 10). Anterior parts of auditory bullae flatted and straddling concave in *E. kuznetsovi* sp. nov., *E. orlovi* sp. nov. and *E. longirostris*, but it inflated and converge in *E. parvidens* and *E. subanura*. The coronoid process is narrow, differing markedly in shape from that of *E. parvidens* and *E. subanura* (see Fig. 9).

Etymology. The new species is named in honour of Dr. German V. Kuznetsov (A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow) in recognition of his many contributions to the study of mammals of Vietnam.

Distribution. Distributed in north-eastern Vietnam. It is recorded from Vinh Phuc Province (Tam Dao) and Cao Bang Province (Nguyen Binh District). Found at the elevations of 750–950 m a.s.l. Probably, the record from Guangxi, south-eastern China (Hoffman and Lunde 2008) belongs to this species as well.

Remarks. The species is reported as *Euroscaptor* sp. 2 in the results of both genetic and morphological analyses.

***Euroscaptor parvidens ngoclinhensis* subsp. nov.**
(Figs 9B, 10E)

Holotype. ZIN 96663, collector's number 33, female, body in ethanol, skull extracted, VIETNAM, Kon Tum Province, Dac Glei District, 2–3 km W of Ngoc Linh Mt., 15°05'N, 107°57'E, altitude 1700–1750 m a.s.l.; collected 26 March 2006 by A.V. Abramov.

Paratypes. ZIN 96664, collector's number 84, female, body in ethanol, skull extracted; ZIN 96665, collector's number 85, female, body in ethanol, skull extracted, collected 7 April 2006 by A.V. Abramov from the same locality as the holotype.

Diagnosis. Small-sized mole, comparable only to *E. subanura*, and smaller on average in its external and cranial measurements than the nominotypical *E. parvidens*. The fourth upper premolar with a well developed parastyle. A new species distinguished by the mitochondrial gene cytochrome *b* (see Fig. 2).

Description and comparisons. Head and body length 120–123 mm, with a short tail, 5.8–6.1% of head and body length. Tail bulb-shaped, covered with long overhairs. Dorsal and ventral pelage dark brown. Body elongated with rump greatly enlarged poste-

riorly. Skull (Fig. 8 B) with a long and moderately wide rostrum. Upper and lower tooththrows short. The upper premolars P1 and P3 similar in height and have 2 roots, P2 much smaller them and has one root. P1–P3 with remarkable metastyles. P4 with well-developed parastyle, talon wide and similar in size with metastyle part, the posterolingual border of the tooth shallowly concave (Fig. 10). The coronoid process short, with a wide apex. The angular process well-developed, with a wide base. Condyle-angular region of mandible oblong.

New subspecies differs from the nominotypical *E. parvidens* in the smaller body and skull sizes and in the relatively short upper and lower tooththrows. The parastyle of P4 is weakly developed in *E. parvidens*. P1 in *E. parvidens parvidens* is narrow, without metastyle, whereas in *E. parvidens ngoclinhensis* ssp. nov. the tooth is similar in width to P3 and has metastyle. In *E. subanura*, P4 has a well-developed additional tubercle located anteriorly to protocone (Fig. 10F), which absent from both subspecies of *E. parvidens*.

Etymology. The subspecies is named after the Ngoc Linh Mountain in Kon Tum Province of Vietnam, from where it was collected for the first time.

Distribution. Known from the Central Highlands of Vietnam (Kon Tum and Quang Nam provinces). Probably, the moles from Gia Lai Province (Abramov et al. 2013a) belong to this subspecies.

Remarks. The species is reported as *Euroscaptor parvidens* lineage 2 in the results of both genetic and morphological analyses.

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