Notes on zoogeography and taxonomy of the badgers (Carnivora: Mustelidae: *Meles*) and some of their fleas (Siphonaptera: Ceratophyllidae: *Paraceras*)

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A comparative morphological analysis of the fleas from the *melis-flabellum* species group of the genus *Paraceras* (Siphonaptera, Ceratophyllidae) is undertaken. Differences in the structure of the clasper and the 8th tergite allow considering *P. melis* and *P. flabellum* separate species. Morphological characters of the Japanese form of *Paraceras* make possible to treat it as an independent taxon. The distribution ranges of three badger species of the genus *Meles* (Carnivora, Mustelidae) are shown to correspond to those of their specific parasites, i.e. the fleas of the *melis-flabellum* species group of the genus *Paraceras*. *Paraceras melis* is restricted to the range of the European badger, *Meles meles* (Europe, the Caucasus, northern Iran and southern Kirgizia), while *Paraceras flabellum* is limited by the range of the Asian badger, *Meles leucurus* (Kazakhstan, Middle Asia, Siberia, China).

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The genus *Paraceras* includes 11-12 species, all being specific parasites of Carnivora (chiefly Mustelidae, but also Viverridae and Herpestidae) (Traub et al., 1983). The species of this genus are primarily restricted to South Asia, with only two of them, *P. melis* (Walker, 1856) and *P. flabellum* (Curtis, 1832), mainly parasitic on the badger species of the genus *Meles*, displaying a wider, Palaearctic distribution.

There are different views on taxonomy of the group "*melis-flabellum*". Some authors (Smit, 1969; Traub et al., 1983) treated these forms as subspecies of *P. melis* reasoning from the fact that their females are poorly distinguishable. Other authors (Ioff, 1949; Mikulin, 1958, 1960; Sazonova, 1963; Ioff et al., 1965; Tiflov et al., 1977) considered them to be separate species. Besides, there is a form related to this group, namely *P. sinensis* (Liu, 1935), which has also been considered by different authors a subspecies of either *P. melis* or *P. flabellum* (Sakaguti, 1962; Smit, 1969).

The absence of or poorly marked somatic differences in females of some species is quite common in the order Siphonaptera. Nevertheless, males of such species can differ rather considerably. In our opinion, the differences (Fig. 1: A, B, C) between the males of *P. meles* and *P. flabellum*, namely, elongate bristles on the 2nd and 3rd posterior tarsi in the latter species, differences in the shape of hind margin of the digitoid (movable finger of the clasper) and in the shape of the 8th tergite (presence/absence of a projection on its posteriodorsal part), allow treating these forms as separate species. An added reason to think so is the stability of diagnostic characters of the digitoid, the immovable finger of the clasper and its hind margin.

In this connection, it seems curious to reconsider the taxonomic status of the *Paraceras* species from Japan, which is usually assigned to the subspecies *sinensis* (see Sakaguti, 1962). *P. sinensis* (Liu, 1935) was described from Sichuan (Suifu) as a separate species from female only. As discussed above, the females of the flea genus *Paraceras* are poorly distinguished, and this fact was a reason for considering the taxa *melis* and *flabellum* as a single species. However, the shape of the clasper in the Japanese form (Fig. 1: D) differs clearly from that of *P. flabellum* from different regions of China, including *sinensis* from Sichuan (Fig. 1: B). In the Japanese form, the dorsal margin of the movable finger is concave (almost straight in *melis* and *flabellum*); its hind margin is convex in males (concave or straight in *melis*). In the females of the Japanese

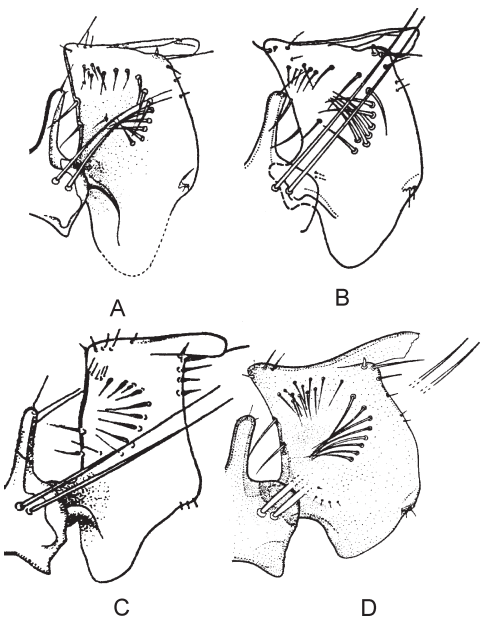

Fig. 1 (A-D). Clasper shape of various *Paraceras* species: **A**, *Paraceras flabellum* (after Ioff & Skalon, 1954); **B**, *Paraceras flabellum*, China (after Liu et al., 1986); **C**, *Paraceras melis* (after Ioff & Skalon, 1954); **D**, *Paraceras flabellum sinensis*, Japan (after Sakaguti, 1962).

form, the caudal margin of the 7th sternum is almost straight (Sakaguti, 1962). The described differences allow treating the Japanese form as a separate taxon, apparently of species rank. At the same time, by the structure of the clasper, the Chinese *Paraceras* (the so-called form "*sinensis*") are closer to the typical flabellum from Kazakhstan, Middle Asia and Siberia (Fig. 1: A, B).

Below is given a synopsis that account for the distribution of the members of the *melis-flabellum* species group. It is based both on new data gained from an examination of the collections of the Zoological Institute, St.Petersburg (ZIN) and on published information.

Paraceras melis is widespread in Western and Eastern Europe (Smit, 1957; Traub et al., 1983); it is known from Latvia (Eglitis, 1957) and Finland (Smit, 1969), recorded in different regions of the European part of Russia: Moscow, Ryazan and Kaliningrad provinces (Ioff, 1956; Sazonova, 1963), Leningrad Province, including the Karelian Isthmus (ZIN; Ioff, 1956; Smit, 1969). This species is found also in the interfluve of the Volga and the Kama rivers (Tatarstan: Zelenodolsky and Laishevsky Districts) (Ioff, 1954; Nazarova & Gorshkov, 1970). *P. melis* is widespread in the Ukraine, primarily in the forest and forest-steppe zones of Sumy, Kharkov and Zakarpatskaya provinces (Yurkina, 1961) and found in the Crimea (Wagner, 1916; Vshivkov & Skalon, 1961).

In the Caucasus, it is recorded from Dagestan (Labunets, 1961), Stavropol' Province (Ioff & Tiflov, 1954; Tiflov et al., 1977), Azerbaijan and Armenia (Avetisyan, 1969; Isaeva, 1971; Tiflov et al., 1977); the species is found also in northern Iran (ZIN; Ioff & Bondar, 1956) and Lebanon (Traub et al., 1983).

In Middle Asia, it was found in southern Kirgizia (near Bazar-Kurgan, Dzhelal-Abad Province) (Shvarts et al., 1959, 1960). Ioff (Ioff & Bondar, 1956; Ioff et al., 1965) held to the opinion that *P. melis* should be found in Turkmenistan, but so far none of *Paraceras* species has been recorded here (A. Kalustov, pers. comm.).

Paraceras flabellum is a typical Asian species widely distributed in Kazakhstan; it is found in the following localities: the Taisugan Desert, western Kazakhstan (Polyakova et al., 1977); near Chelkar-Tengiz Lake, Aktyubinsk Province (Garbuzova & Varshavskaya, 1971); north-eastern Kyzylkum, Kzyl-Orda Province (Stogov et al., 1974); Kustanai and East Kazakhstan provinces, the Tarbagatai (Mikulin, 1958, 1960); Taldy-Kurgan Province (terra typica), environs of Almaty and Dzharkent (Ioff, 1949); the Chu River valley (Shvarts et al., 1958). It is also recorded in northern Kirgizia (Ioff, 1949).

This species is reported from Omsk Province (Alifanov, 1960) and the Altai (Ioff, 1950). In eastern Siberia, it is found in Tuva and Chita Province (Emelyanova et al., 1963), Buryatia (Abramov, 2001a), and Jewish Autonomous Region (Gershkovich, 1954). The species is also known from north-eastern Mongolia (Goncharov et al., 1989). In the Russian Far East, *P. flabellum* was recorded in the Amur region and Primorsk Territory (Ioff et al., 1950; Ioff & Skalon, 1954). Ioff et al. (1965) noticed that in the Tien Shan (Almaty Province and northern part of Kirgizia) the range of this species is adjacent to that of *P. melis*.

The fleas of the "*sinensis*" form are recorded from Manchuria, South and South-Western China (including Sichuan) and Korea (Traub et al., 1983; Liu et al., 1986; Yu et al., 1990). The Japanese form of *Paraceras* is known from Honshu, Shikoku and Kyushu (Sakaguti, 1962).

We emphasize that there is a high correlation between the distribution of the specific badger fleas of the genus *Paraceras* and that of different badger species of the genus *Meles* (Fig. 2). It is interesting to note that views on the taxonomy and composition of the genus *Meles* (Carnivora, Mustelidae) are very similar to those of their fleas. The badgers are widespread in Eurasia; their range covers Europe, except for the north-

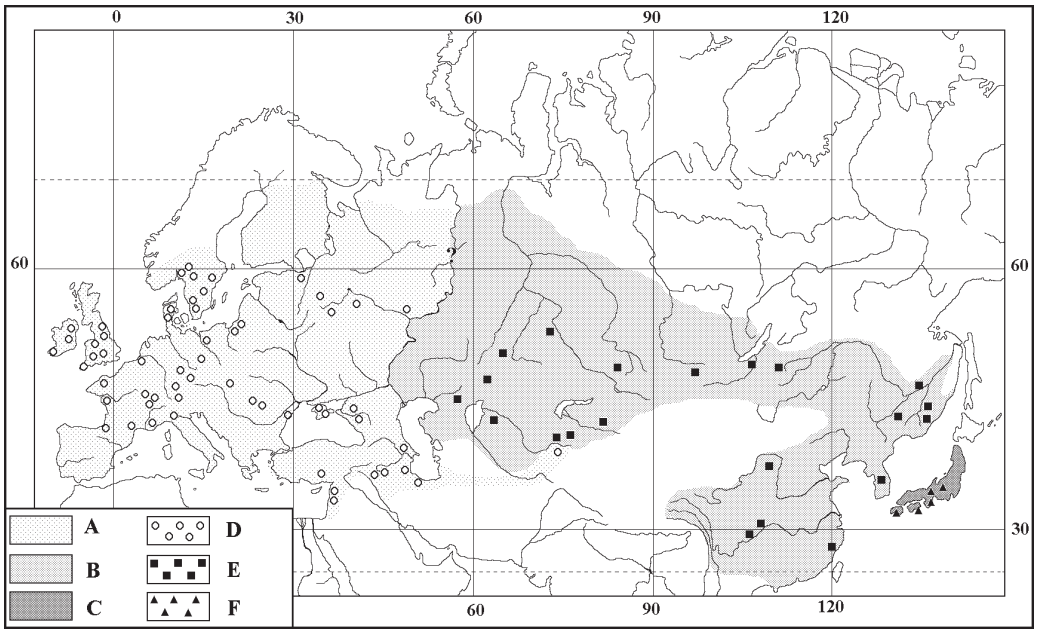

Fig. 2 (A-F). Comparative distribution of *Meles* and *Paraceras*: **A**, *Meles meles*; **B**, *Meles leucurus*; **C**, *Meles anakuma*; **D**, *Paraceras melis*; **E**, *Paraceras flabellum*; **F**, Japanese form of *Paraceras.*

ernmost regions, the Near East, Middle Asia (as south as Palestine and Mesopotamia), South Siberia, Mongolia, Tibet, Eastern Asia (from the Amur region to Yunnan) and the Japanese Islands (except for Hokkaido).

It is universally recognized that geographic variation of the badger is considerable. Many forms of different taxonomic ranks are described, and there are different views on species composition of *Meles*; see Abramov (2001b) for a review.

Some authors held to the opinion that all the Eurasian badgers belong to a single species, *Meles meles* (L., 1758) (Ellerman & Morrison-Scott, 1951; Petrov, 1953; Novikov, 1956; Heptner et al., 1967; Corbet, 1978; Long & Killingley, 1983; Wozencraft, 1993); the others (Kastschenko, 1902; Satunin, 1914; Ognev, 1931; Baryshnikov & Potapova, 1990; Stubbe et al., 1998; Abramov, 2001b, 2002; Baryshnikov, 2001) have treated the European and Asian badgers as separate species.

In our opinion, considerable differences in the proportions of skulls, face mask pattern and body coloration (Abramov, 2001b), size and numbers of roots of Pm_2, degree of reduction of Pm^1 and Pm_1, and structure of the morphotypes Pm^4, M^1 and M_1 (Baryshnikov & Potapova, 1990), structure of the os malleus (Abramov & Baryshnikov, 1995) and the baculum (Baryshnikov & Abramov, 1997; Stubbe et al., 1998; Abramov, 2002) make it possible to treat the European and Asian badgers as separate species. At the same time, there are strong grounds to believe that the Japanese badgers, which differ both from the European and from Asian ones, are to be considered separate species as well. For instance, this opinion is well corroborated by an analysis of craniological characters (Lynch, 1994; Abramov, 2001b), which demonstrated that the Japanese badgers significantly differ from other forms of *Meles* in the size and proportions of skull and molars. Differences in the structure of the baculum between the three above forms are stronger than, for example, between other closely related groups of the mustelids: the polecats *Mustela putorius, M. eversmanii*, and *M. nigripes*, or the martens *Martes martes, M. zibellina, M. americana*, and *M. melampus* (see Abramov, 2002). A comparative analysis of the mitochondrial DNA also revealed considerable differences between the Japanese, European (Leningrad Province) and Siberian (Transbaikalia) badgers (Kurose et al., 2001).

Thus, our opinion is that the Palaearctic genus *Meles* includes three species: the European badger *M. meles* (L., 1758), the Asian badger *M. leucurus* (Hodgson, 1847) and the Japanese badger *M. anakuma* Temminck, 1844.

The European badger, *M. meles* (L., 1758), is

distributed in Europe, except for the north of Scandinavia and the tundra zone, from the British Isles eastward to the Volga River, Asia Minor and the Near East, the Caucasus, northern Iran and Afghanistan, southern regions of Middle Asia, where it occurs in southern Turkmenistan (valleys of the Atrek and Sumbar rivers, the foothills of Bolshoy Balkhan Mts., Kopetdagh and Kugitang Mts.), along tributaries of the upper Amudaria River, lower reaches of the Pyandzh River and the Pamir. It is also recorded from the Alai and Fergana valleys.

The Asian badger, *M. leucurus* (Hodgson, 1847), inhabits regions to the east of the Volga River, the Urals, South Siberia, the South of the Russian Far East (absent from Sakhalin), Kazakhstan, Uzbekistan and northern Turkmenistan (in Turkmenistan, two badger species are separated by the Karakum Desert). It is also known from the northern and eastern Tien Shan (to the north of the Ferganskiy Range), Mongolia, China, including Tibet, and the Korean Peninsula. In European Russia, the western limit of the Asian badger's range is running from the Caspian Sea along the left bank of the Volga River and the lower Kama River. The border between two species is yet uncertain in Kirov Province and western part of the Urals; there is a single locality on the right bank of the Volga River (Samarskaya Luka; = meander), where the Asian badger is proved to occur (Vekhnik & Abramov, in press).

The Japanese badger, *M. anakuma* Temminck, 1844, occurs at the Japanese Islands (except for Hokkaido).

As illustrated in Fig. 2, the distributions of the badger fleas of the genus *Paraceras* are correlated to a great extent with those of the three badger species: *P. melis* is found within the range of the European badger only (Europe, the Caucasus, northern Iran, southern Kirgizia); *P. flabellum*, in the limits of the Asian badger's range (Kazakhstan, Middle Asia, Siberia, China). In the Tien Shan Mts., the ranges of both flea species are adjacent (or, perhaps, overlap), as the badgers' ranges do. In the Japanese Islands, there is a peculiar form of *Paraceras*, the taxonomic status of which needs clarifying. Specific taxonomic status of the fleas parasitizing the European, Asian and Japanese badgers can be considered an additional argument in favour of a full specific status of the taxa *Meles meles, M. leucurus, M. anakuma*.

Petrov (1953) proposed two apparent hypotheses describing the evolution of forms of the genus *Meles*. According to one of them, the badger had originated in the forest landscapes of the Mediterranean, and then penetrated eastward to forestless and steppe landscapes of the Asian continent. The second hypothesis refers to the origin of *Meles* in Asian savannas and its subsequent expansion westward and eastward. Taking into consideration that the centre of species diversity of the flea genus *Paraceras* lies in Central and South Asia, the hypothesis of the Asian origin of the badgers (the hosts of the flea species group *melis-flabellum*) seems to be somewhat more realistic.

Species of the order Siphonaptera are known to demonstrate different types of host-parasitic relationships, from monoxenous to polyxenous ones, with species restricted to a single host usually constituting a smaller part (ca. 10%) of the total number in the order. The abovementioned species of *Paraceras* can be referred to monoxenous, as their ranges correspond to those of the badgers of the genus *Meles*. In our opinion, the coincidence of the flea and badger ranges seems to be an interesting example of coevolutionary relationships of parasites and their hosts.

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