

The millipede *Pachyiulus krivolutskyi* Golovatch, 1977, the easternmost species of the eastern Mediterranean genus *Pachyiulus* Berlese, 1883, endemic to the western Caucasus (Diplopoda: Julida: Julidae)

Диплопода *Pachyiulus krivolutskyi* Golovatch, 1977, самый восточный вид восточно-средиземноморского рода *Pachyiulus* Berlese, 1883, эндемик Западного Кавказа (Diplopoda: Julida: Julidae)

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KEY WORDS: Diplopoda, Julidae, *Pachyiulus krivolutskyi*, morphism, clinal variation, distribution, Caucasus.

КЛЮЧЕВЫЕ СЛОВА: Diplopoda, Julidae, *Pachyiulus krivolutskyi*, морфизм, клинальная изменчивость, распространение, Кавказ.

ABSTRACT. *Pachyiulus krivolutskyi*, the largest and perhaps the most picturesque millipede in the Caucasus endemic to its western part, is properly redescribed based on abundant new material. Three main colour morphs are distinguished, all illustrated and mapped. Clinal variation is revealed, as the morphs show evident geographical patterns replacing each other from north to south.

РЕЗЮМЕ. На основе большого нового материала переописан *Pachyiulus krivolutskyi*, самая крупная и, пожалуй, самая колоритная многоножка-диплопода на Кавказе, эндемик его западной части. Выделены три главные цветовые морфы, закартированы их ареалы. У вида выявлена клинальная изменчивость, поскольку географически морфы сменяют друг друга с севера на юг.

Introduction

At least in Europe and in the Caucasus, the eastern Mediterranean millipede genus *Pachyiulus* Berlese, 1883, contains the largest species which often reach up to 9 cm in length and 7 mm in diameter [Enghoff, 1987]. This genus comprises about 20 species [Frederiksen et al., 2012] ranging from Italy in the west, through the Balkans, Hungary, Romania and the Crimea, to the Near East, Anatolia and the Caucasus in the east. The species are characteristically uniform in gonopod structure, the main differences referring to body coloration [Attems, 1940].

Unlike the Crimea, which supports only the widespread, likely anthropochore species *P. flavipes* Koch,

1847 [Lignau, 1905, sub *Julus flavipes unicolor*; Attems, 1907, sub *P. flavipes*], the Caucasus harbours an endemic species, *P. krivolutskyi* Golovatch, 1977. This species was first described as *Iulus foetidissimus* Muralewicz, 1907, but because of homonymy with *Iulus foetidissimus* Savi, 1819, it had to be renamed [Mauriès et al., 1997]. This species had repeatedly been referred to as *Julus (Pachyiulus) flavipes* (?) [Lignau, 1903], *Pachyiulus flavipes continentalis* [Lignau, 1911, 1915; Isaev, 1911], *Julus foetidissimus* [Muralewicz, 1911] or *P. foetidissimus* [Muralewicz, 1913; Lohmander, 1936; Lang, 1959; Kobakhidze, 1965; Striganova, 1969a, b; Striganova, Mazantseva, 1979; Lokšina, Golovatch, 1979; Talikadze, 1984] until Mauriès et al. [1997] validated *Pachyiulus krivolutskyi* as the proper replacement name. *P. krivolutskyi* was originally described from western Georgia and said to be distinguished from *P. foetidissimus* primarily by the lack of a colour pattern [Golovatch, 1977].

In the checklists by Lokšina, Golovatch [1979] and Talikadze [1984], both *P. foetidissimus* and *P. krivolutskyi* were regarded as independent species, while Lohmander [1936] recorded a ♀ of *P. flavipes* from near Sukhum, Abkhazia, an apparent introduction.

From the very start, *P. krivolutskyi* (= *P. foetidissimus*) was distinguished from all congeners by its remarkably repelling “garlic” odour [Muralewicz, 1907; Isaev, 1911; Lignau, 1903 etc.]. The stinking is so unbelievably strong that the presence of *P. krivolutskyi* in the field can be detected dozens of meters away from the site, usually a forest, where the animals actually

occur. Apparently, this striking odour prompted Muralewicz [1907] to name his species “foetidissimus”, which in Latin means “the most stinking”.

Among the Caucasian julid species, only *Amblyiulus continentalis* (Attems, 1903), from Hyrcania, possesses a similarly strong “garlic” odour [Golovatch, in litt.].

Another remarkable character is its usually very bright, yellow-and-black colour pattern which was first illustrated by Lignau [1903]. Occasionally, the pattern is absent, one of the reasons why Golovatch [1977] described *P. krivolutskyi*.

The present paper provides a review of this remarkable species which is the largest and perhaps the most picturesque millipede in the entire Caucasus, the easternmost congener endemic to the western part of the region.

Material and methods

All material has been shared between the collections of the Zoological Museum of the Moscow State University (ZMUM) and the private collection of the author (AE), both Russia. The specimens are stored in 70–75% ethanol. All adult specimens were measured with regard to body length, body diameter, and the number of podous and apodous segments was recorded. A “body segment formula” indicates the number of podous (including the gonopod-bearing segment) and apodous segments in an individual. This formula is x(-y) where x = sum of podous and apodous body segments, excluding telson, y = number of apodous body segments before telson. Photographs were taken using a Lomo MSP microscope and a Sony A camera.

In the catalogue section, D stands for a description or descriptive notes, R for new records, while M for a mere mention.

Results

Pachyiulus krivolutskyi Golovatch, 1977

Figs 1–27, Map.

Iulus foetidissimus Muralewicz, 1907: 342–344 (D).

Pachyiulus foetidissimus: Lohmander, 1936: 153–155 (R); Lang, 1959: 1791 (M); Kobakhidze, 1965: 394–395 (R); Striganova, 1969a: 822 (R); 1969b: 1624 (R); Striganova, Mazantseva, 1979: 416 (R); Lokšina, Golovatch, 1979: 387 (M); Talikadze, 1984: 143 (R).

Iulus (Pachyiulus) flavipes (?) [sic!]: Lignau, 1903: 113–115 (R).

Pachyiulus flavipes continentalis: Lignau, 1911: 45–54 (D, R); 1915: 379–380 (D, R); Isaev, 1911: 298 (R).

Pachyiulus krivolutskyi Golovatch, 1977: 46–48 (D).

Pachyiulus krivolutskyi: Lokšina, Golovatch, 1979: 387 (M); Talikadze, 1984: 143 (R); Mauriès et al., 1997: 282 (D); Chumachenko, 2012: 451 (R); 2016: 409 (R); Korobushkin et al., 2016: 25–26 (R).

MATERIAL. 2 ♀♀, 1 juv. (ZMUM p3445), **RUSSIA, Adygea Republic**, Caucasian Nature Reserve, Guzeripl, forest, 1967, leg. ?; 5 ♀♀ (ZMUM p3446), same locality and date, leg. ?; 2 ♂♂ (ZMUM p3447), same locality and date, leg. ?; 4 ♂♂ (ZMUM p3448), same locality and date; 18 ♂♂, 16 ♀♀, 1 juv. (ZMUM p3449), Caucasian Nature Reserve, Pasture Abago near Guzeripl, *Abies, Fagus, Acer, Betula* etc. forest, up to timber line and in subalpine meadow, 1700–1800 m a.s.l., litter, under bark and stones, 24–26.V.1983, leg. S. Golovatch; 1 ♀ (AE), Maikop, *Quercus* and *Fagus* forest, litter, 13.X.2007, leg. M. Shapovalov; 1 ♀ (AE), near Nickel, Belaya River valley, 25.VI.2007, leg. G. Chesnokov.

1 ♂ (ZMUM p3207), **RUSSIA, Krasnodar Prov.**, Sever-skaya Distr., Mt Derbiy ca 15 km SW of Ubinskaya, 800–850 m a.s.l., old *Quercus, Fagus, Fraxinus, Alnus* etc. forest, litter, bark, 2.VII.1986; 1 ♂, 2 ♀♀, 2 juv. (ZMUM p3208), same locality, 2–10 km S of Ubinskaya, *Quercus, Fagus, Carpinus* etc. forest, 300–450 m a.s.l., litter and under bark, 3–4.VII.1986; 3 ♂♂, 1 ♀, 2 juv. (ZMUM p3209), Mostovskoy Distr., Shedok N of Psebai, karst funnel, wet *Fagus, Acer, Quercus* etc. forest, litter and under bark, 650 m a.s.l., 4.VIII.1986; 2 ♂♂, 1 juv. (ZMUM p3210), Goryachiy Klyuch, 10 km S of Fanagoriyskaya, near Cave Fanagoriyskaya, mixed forest (*Fagus, Quercus, Picea* etc.), litter, under stones and in rotten logs, 30.X.1981; 1 ♂, 3 ♀♀ (ZMUM p3211), same locality, 12 km SW of Fanagoriyskaya, near Cave Fanagoriyskaya, *Fagus, Acer* etc. forest, litter, logs, 19.V.1983; 2 ♀♀ (ZMUM p3212), Caucasian Nature Reserve, Pslukh ca 20 km S of Krasnaya Polyana, Mt Kogot, *Fagus* and *Abies* forest up to timber-line, 1650–1850 m a.s.l., litter, under bark and stones, 20.V.1985; 2 ♂♂, 1 ♀, 1 juv. (ZMUM p3213), Caucasian Nature Reserve, Krasnaya Polyana, 600–750 m a.s.l., *Quercus, Fagus, Castanea, Carpinus* etc. forest, litter, under bark and stones, 8–9.VIII.1986, all leg. S. Golovatch; 3 ♂♂ (ZMUM p3440), Krasnaya Polyana, 6–8.VI.1978, leg. V. Dolin; 1 ♂ (ZMUM p3441), Khosta, *Buxus* grove, 24.VIII.1973, leg. V. Minoranskiy; 1 ♀ (ZMUM p3442), same locality, *Taxus* and *Buxus* forest with *Fagus*, litter and bark, 15.V.1985; 1 ♂, 3 ♀♀, 7 juv. (ZMUM p3206), Sochi, Lazarevskoye, Soloniki, deciduous forest, litter, 28.X.1981; 2 ♀♀ (ZMUM p3205), Tuapse Distr., 15 km SE of Novomikhailovskiy, Psebe, deciduous forest, litter, under stones and in rotten logs, 29.X.1981, all leg. S. Golovatch; 1 ♀ (ZMUM p3443), env. Gelendjik, 2.5 km ENE of Aderbievka, E slope of Markot'kh Range, forest, ca 400 m a.s.l., 44°36'26" N 38°04'29" E, 30.IV.2016, leg. K. Makarov & O. Makarov.

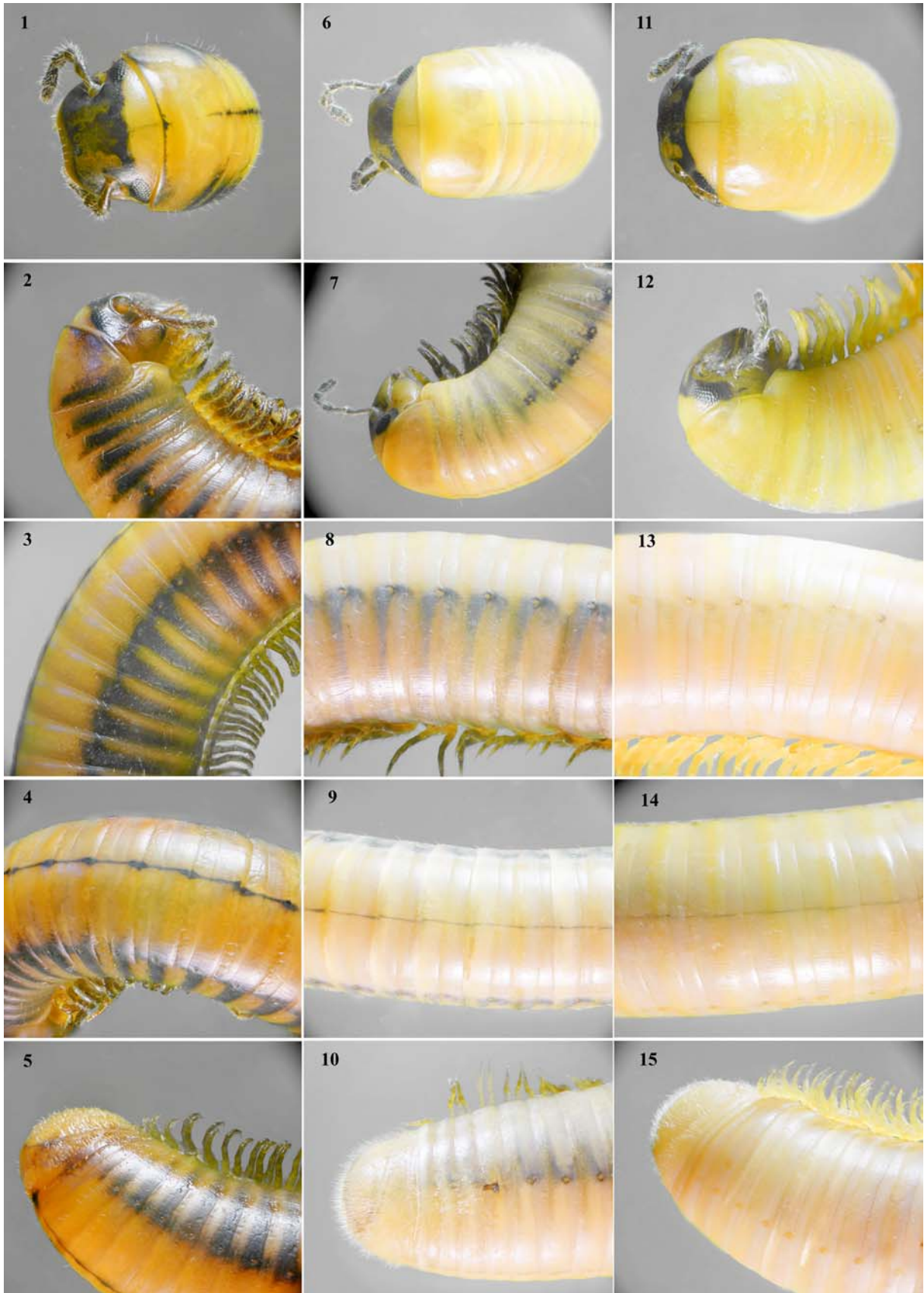
1 ♀, 1 juv. (ZMUM p3444), **RUSSIA, Karachaevo-Cherkessia**, ca 30 km S of Kurdjinovo, 4 km N of Damkhurts, 1050–1100 m a.s.l., Laba River valley, *Fagus, Acer, Picea* etc. forest, litter, bark, 4.VIII.1986, leg. S. Golovatch.

3 ♂♂, 1 ♀ (ZMUM p3450), **ABKHAZIA**, Sukhumi Distr., Bzyb Valley, Pskhu, 700–950 m a.s.l., *Fagus, Quercus, Castanea* etc. forest, litter, under bark and stones, 15–16.VIII.1986; 1 ♀ (ZMUM p3451), Myussera Nature Reserve, 20–130 m a.s.l., mixed deciduous forest (*Castanea, Alnus* etc.), litter, under bark and stones, 8–10.IV.1983; 2 ♀♀ (ZMUM p3452), same locality and date, all leg. S. Golovatch; 2 ♂♂, 5 ♀♀ (ZMUM p3453), Gulripsh Distr., Shaumyanovka, 9.V.1985, leg. A. Markosyan; 1 ♂, 1 ♀ (ZMUM p3454), Gumista Nature Reserve, Upper Tsumur, *Fagus, Ulmus, Rhododendron* forest, litter, 24.IX.1985; 1 ♂, 2 ♀♀ (ZMUM p3455), Djgerda, foothills of Kodor Mt. Range, litter, 21.IX.1985, all leg. I. Ushakov; 1 ♀ (ZMUM p3456), upper reaches of Galidzga River, VIII.1985, leg. E. Kvavadze.

2 ♂♂, 2 ♀♀ (ZMUM p3457), **GEORGIA**, Tkibuli Distr., Mukhura ca 15 km E of Tkibuli, 700–800 m a.s.l., *Castanea, Fagus, Carpinus* etc. forest, litter, under bark and stones, 7–9.V.1987, leg. S. Golovatch & K. Eskov; 3 ♂♂, 4 ♀♀, 2 juv. (ZMUM p3458), same

Figs 1–15. Colour morphs in *Pachyiulus krivolutskyi* Golovatch, 1977: 1–5 — ♂ from Adygea, morph A; 6–10 — ♂ from Abkhazia, morph B; 11–15 — ♂ from near Kutaisi, Georgia, morph C; 1, 6, 11 — anterior part body, dorsal views; 2, 7, 12 — same, lateral views; 3, 8, 13 — midbody segments, lateral views; 4, 9, 14 — same, dorsal views; 5, 10, 15 — caudal part of body, lateral views. Pictures taken not to scale.

Рис. 1–15. Цветовые морфы *Pachyiulus krivolutskyi* Golovatch, 1977: 1–5 — ♂ из Адыгеи, морфа А; 6–10 — ♂ из Абхазии, морфа В; 11–15 — ♂ из окрестностей Кутаиси (Грузия), морфа С; 1, 6, 11 — передняя часть тела, сверху; 2, 7, 12 — то же, сбоку; 3, 8, 13 — средняя часть тела, сбоку; 4, 9, 14 — то же, сверху; 5, 10, 15 — задняя часть тела, сбоку. Сфотографировано без масштаба.



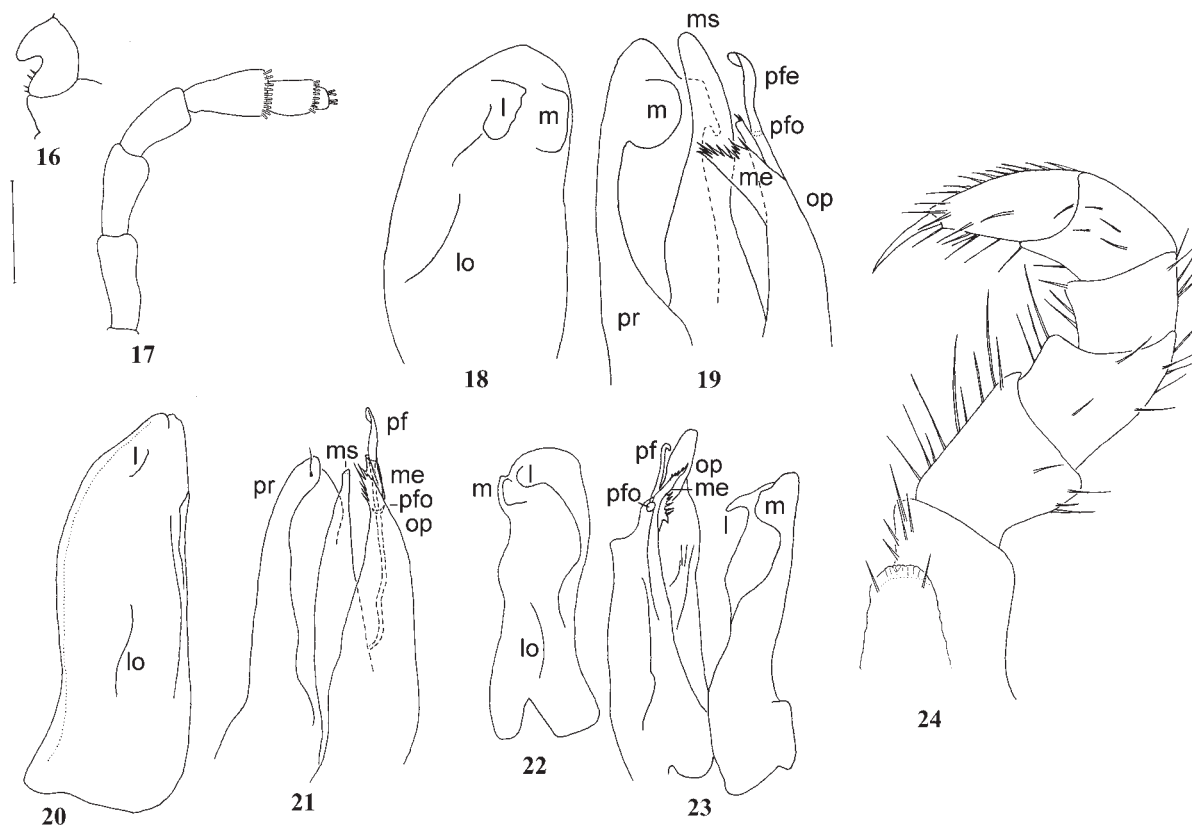
locality, 14 km E of Tkibuli, *Quercus* and *Fagus* forest, litter and under stones along spring, 23.X.1981; 1 ♀, 1 juv. (ZMUM p3459), Kutaisi Distr., Sataplia Nature Reserve, deciduous forest, litter and under stones, 25.X.1981, all leg. S. Golovatch; 1 ♀ (ZMUM p3460), same locality, 400 m a.s.l., *Fagus* forest, 5.VI.1981, leg. S. Golovatch and J. Martens; 1 ♂, 3 ♀♀ (ZMUM p3461), same locality, *Fagus* and *Carpinus* forest, litter, 15–17.IV.1988, leg. D. Logunov; 1 ♂ (ZMUM p3462), Svanetia, Khaishura River valley near Khaishi, 2–3 km upstream off mouth, 600 m a.s.l., *Quercus*, *Fagus* etc. forest, 5.IX.1986, leg. A. Ryvkin; 2 ♂♂, 1 ♀, 2 juv. (ZMUM p3463), Svanetia, 40 km W of Mestia, Kherkhvashi E of Nakra (= Naki), 1250–1700 m a.s.l., *Quercus*, *Fagus*, *Carpinus*, *Picea*, *Abies* etc. forest, litter and bark, 21.VIII–21.IX.1986; 1 ♀ (ZMUM p3464), 45 km W of Mestia, above Nakra (= Naki), 1700 m a.s.l., *Abies*, *Picea* etc. forest, litter and under stones, 3.IX.1986; 1 ♂ (ZMUM p3466), Svanetia, Mestia, 1500 m a.s.l., litter and under stones, 22.X.1979; 1 ♂, 1 juv. (ZMUM p3465), same locality, 1500 m a.s.l., *Betula* and *Rhododendron* on moraine, litter and under stones, 5, 16.IX.1986, all leg. S. Golovatch; 1 ♂ (ZMUM p3467), same locality, Nenskra Valley, Lukhi N of Khaishi, litter, 800 m a.s.l., 2.IX.1986; 1 ♀ (ZMUM p3468), same locality, Khumprer Valley, 1.5–2 km upstream off mouth, near Dizi, 1000 m a.s.l., forest, litter, 9.IX.1986, all leg. A. Ryvkin; 1 ♀ (ZMUM p3469), 10 km N of Jvari, 800 m a.s.l., *Buxus*, *Fagus*, *Picea*, *Taxus* etc. forest, litter, 20–21.VIII.1986, leg. S. Golovatch; 2 ♂♂, 2 ♀♀, 1 juv. (ZMUM p3470), Megrelikiy (= Egrisskiy) Mt. Range, NW slope of Mt

Tsekhuri, 1500–1800 m a.s.l., *Fagus* forest, litter, 18–19.VIII.1988, leg. I. Belousov.

REDESCRIPTION. Length of adults 41–68 mm, width 3.4–4.7 mm (♂), or length 45–90, width 4.0–5.9 (♀). Body segment formula (excluding telson) from 43(-2) to 59(-1) (♂), or from 44(-2) or 65(-2) (♀).

Body coloration of adults from entirely yellow to yellow-and-black; a thin axial line, antennae, ocellaria, as well as entire clypeolabrum and vertex (but neither occiput nor usually a paramedian pair of lighter spots above ocellaria) black; legs yellow to blackish; lateral parts of body from entirely yellow to infuscate due to a narrow, continuous, black line on each side level to ozopores, as well as brown to blackish metazonae below ozopores (Figs 1–15).

♂. Eye patches rounded, suboval, in adults composed of 39–48 small ocelli. Epicranial setae 1+1, supralabral setae 5–9, labral ones ca 40. Genae with small, lateral, rounded lamellae. Antennae short, rather slender and clavate, in situ reaching somite 2. Gnathochilarium with a group of long setae in distal part of stipes (ca 18); 6+1 setae on each lingual lamella. Length ratios of antennomeres 2–7 as 4.5:4.1:3.7:4.0:2.3:0.7, width ratios as 2.0:2.1:1.9:2.2:1.7:1.0, respectively. Antennomeres 5 and 6 each with a complete distodorsal corolla of sensory bacilli (Fig. 17).



Figs 16–24. *Pachyiulus krivolutskyi* Golovatch, 1977: 16–19, 24 — ♂ from Adygea, morph A; 20–21 — ♂ from near Kutaisi, morph C; 22–23 — ♂ from Abkhazia, morph A [after Lignau, 1915]; 16 — leg 1; 17 — antenna; 24 — left leg 2 and penes; 18, 20, 22 — promere; 19, 21, 23 — both gonopods; 16, 18, 20, 22, 24 — caudal view; 17 — lateral view; 19, 21, 23 — mesal view; Scale bar: 0.3 mm (16–21, 24), not to scale (22–23). Designations explained in text.

Рис. 16–24. *Pachyiulus krivolutskyi* Golovatch, 1977: 16–19, 24 — ♂ из Адыгеи, морфа А; 20–21 — ♂ из окрестностей Кутаиси (Грузия), морфа С; 22–23 — ♂ из Абхазии, морфа А [по Лгнау, 1915]; 16 — нога 1; 17 — антенна; 24 — левая нога 2 и penisы; 18, 20, 22 — промер; 19, 21, 23 — оба гонопода; 16, 18, 20, 22, 24 — сзади; 17 — сбоку; 19, 21, 23 — изнутри. Масштаб: 0,3 мм (16–21 и 24), без масштаба (22 и 23). Обозначения объяснены в тексте

Body subcylindrical, slender. Segments 6 and 7 enlarged compared to others. Suture dividing pro- and metazona distinctly constricting both zonites. Ozopores large, lying behind, but not touching suture. Prozonae almost smooth. Metazonae very densely striate, even more densely ventrad, more sparsely dorsally; ca 60 striae per about 1/4 of metazonal surface, i.e. between axial line and ozopore. A transverse row of sparse, thin, short setae at hind edge of metazonae, setae gradually growing denser and somewhat longer towards telson. Telson with very dense and short setae on epiproct and anal valves; without caudal projection of epiproct.

Legs relatively short. Anterior legs with broad soles on tibia and praefemur. Leg-pair 1 strongly reduced, unciform, with a group of short setae ventrally near base (Fig. 16). Leg-pair 2 unmodified; penes flat, rounded at apex (Fig. 24).

All three pieces of each gonopod half highly condensed (Figs 18–23). Promeres (**pr**) nearly as high as or, more usually, slightly shorter than opisthomeres (**op**), quite variable in shape, with one (more rarely) or two (usually) distal lobes or teeth (lateral **l** and mesal **m**) and one rounded, proximal, membranous lobe (**lo**). Mesomere branch (**ms**) with an acuminate or rounded apex. Opisthomere (**op**) with a pseudofovea (**pfo**) and a pseudoflagellum (**pf**), the latter typically recurved at tip and bearing a thin, membranous, densely and deeply fringed lamella (**me**) mesally at base.

♀. Same as in ♂, except supralabral setae being 5–7, while segments 6 and 7 not enlarged compared to others. Vulvae not studied.

Discussion

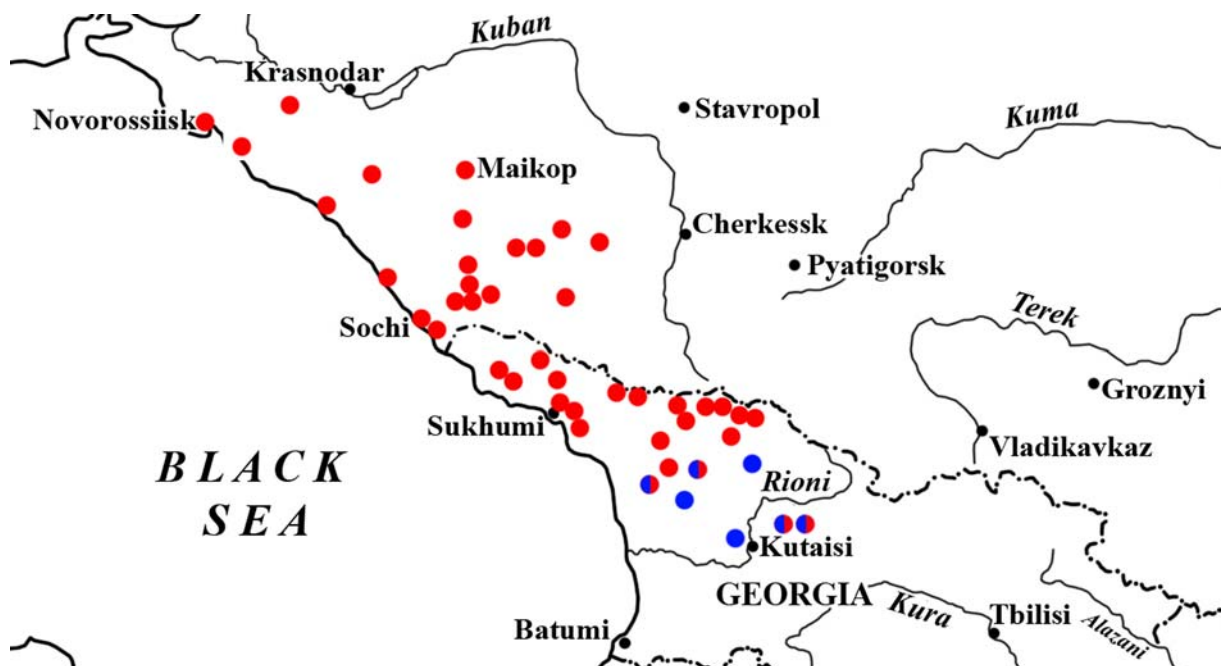
Three colour morphs can be distinguished in *P. krivolutskyi*, as follows.

Morph A: antennae, genae, most of head (except for a light band in occipital region and a paramedian pair of marbled lighter spots above ocellaria), anterior leg-pairs, a thin, continuous, axial line, a continuous longitudinal stripe at ozopore level on each side, and transverse bands on metazonae below ozopores are all black to blackish (Figs 1–5). This form is especially common and widespread, as it inhabits the northern and central parts of the distribution range, including all records from the Republic of Adygea, the Krasnodar Province, the Republic of Karachaevo-Cherkessia, the Sukhum District of Abkhazia, and Svanetia (the Mestia District) in Georgia (Map, red circles).

Morph B: antennae, legs, most of head (except for a broad light band in occipital region and a paramedian pair of light spots above ocellaria), a discontinuous lateral stripe level to ozopores on each side, a thin axial line, and transverse bands on metazonae below ozopores are all grey or greyish (Figs 6–10). This colour morph appears to be transitional between morphs A and C, also occupying a transitional area in Georgia and Abkhazia (Map, red-and-blue circles).

Morph C: only antennae, much of head, and a thin axial line are blackish to grey, the predominant colour being white to yellow (Figs 11–15). This colour morph inhabits the southern part of the distribution area, being restricted to the Kutaisi District of Georgia (blue circles in Map).

The distribution of the colour morphs of *P. krivolutskyi* shows what seems to be clinal variation. The northern and central parts of the distribution range are inhabited by morph A. Morph B occurs only south of



Map. Distribution of *P. krivolutskyi* Golovatch, 1977: red circles — morph A; red-and-blue circles — morph B; blue circles — morph C.
Карта. Распространение *P. krivolutskyi* Golovatch, 1977: красные круги — морфа А; красно-синие круги — морфа В; синие круги — морфа С.

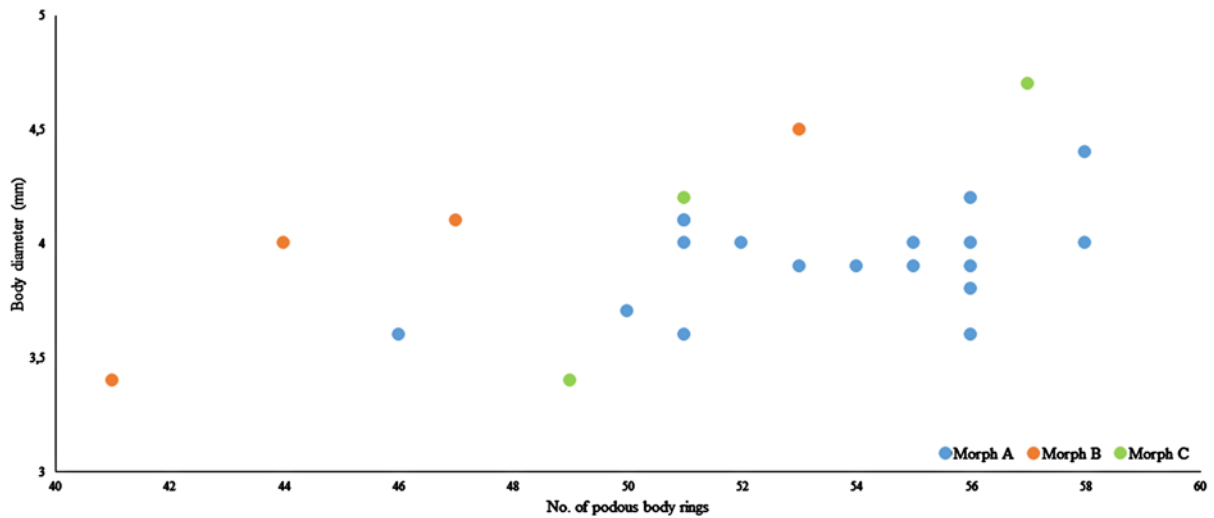


Fig. 25. Relationship between the number of podous body rings and body diameter in ♂♂ of *P. krivolutskyi*.

Рис. 25. Взаимосвязь между количеством сегментов и диаметром тела у ♂♂ *P. krivolutskyi*.

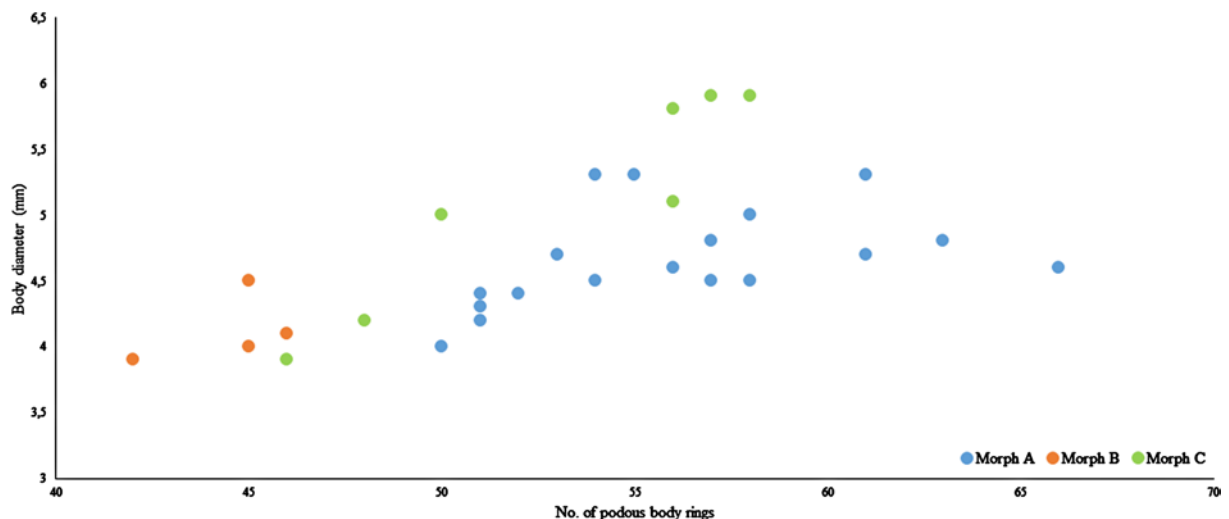


Fig. 26. Relationship between the number of podous body rings and body diameter in ♀♀ of *P. krivolutskyi*.

Рис. 26. Взаимосвязь между количеством сегментов и диаметром тела у ♀♀ *P. krivolutskyi*.

morph A and is intermediate in coloration between morphs A and C. Morph C is found only in the southern part of the distribution area. There seems to be a rather gradual north-to-south succession from morph A, through morph B, to morph C (Map).

The ♂♂ of *P. krivolutskyi* show certain morphological differences in gonopod structure as well. Usually the promere in morph A has two distinct distal lobes, **l** and **m** (Fig. 18), whereas that in morph C varies from having two similarly strong distal lobes, **l** and **m** [Golovatch, 1977], up to only a small lateral lobe (**l**), a vestigial mesal lobe and an apical seta (Figs 20–21). The mesomere in morph A is more usually rounded at the apex (Fig. 19), versus typically subacuminate in morph C (Fig. 21). The pseudoflagella of morph A are normally a little lower than to subequal in height to both

pro- and mesomere or to the mesomere alone (Fig 19), whereas in morph C the pseudoflagella tend to be longer, higher than to about as high as the mesomere (Golovatch [1977] and Fig. 21).

Based on all available information, however, there seems to be no evident correlation between body colour patterns (= morphs) and gonopod conformation. Variations in gonopod characters seem to be rather random, likely individual, at most micropopulational.

Measurements reveal no significant differences between the morphs either. Graphs of the relationship between the number of podous body rings and body diameter (Figs 25–26) show that individuals of both sexes of morph B have fewer body rings, but no differences in body diameter. Box-plots of the ratio of body length to diameter (Fig. 27) likewise demonstrate that

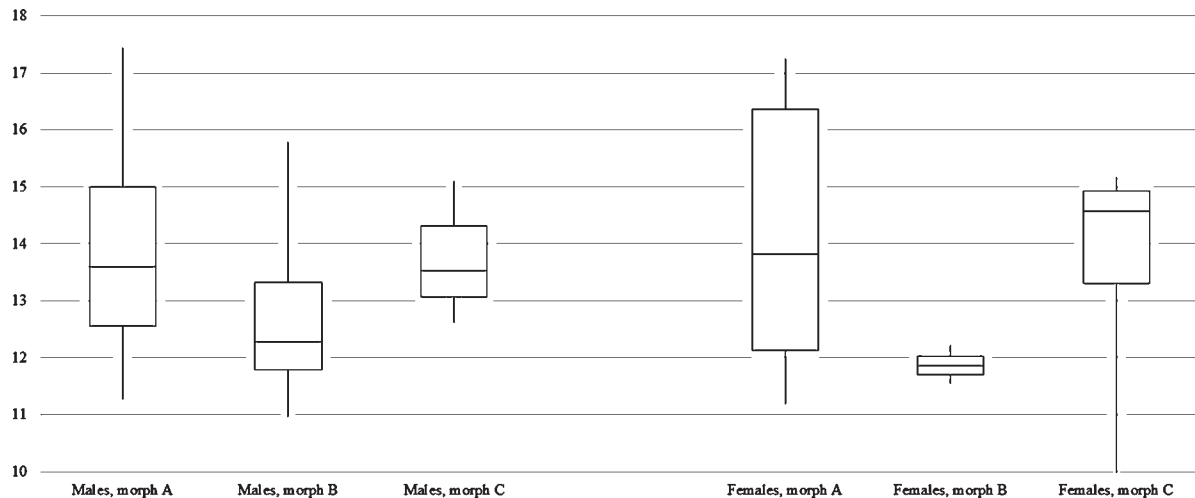


Fig. 27. Box-plots of the ratio of body length to diameter in *P. krivolutskiyi* (max, min, quartiles 1 & 3, median).

Рис. 27. Коробчатые диаграммы соотношения длины тела и диаметра у *P. krivolutskiyi* (максимум, минимум, квантили 1 и 3, медиана).

adults of morph B tend to be smaller in size than those of each other morph.

Molecular data, bar-coding in particular, would be most helpful in further refining the picture, but at the moment such information is unavailable.

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