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Rhizotrogus tedeschii, a new species from the alpine zone of the Pollino Massif, southern Italy (Coleoptera: Scarabaeidae, Melolonthinae)

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Abstract
A new species of *Rhizotrogus* from southern Italy (Calabria, Pollino Massif) is described and illustrated. *Rhizotrogus tedeschii* n. sp. is a high-altitude, day-active species, very similar to *R. cicatricosus*, from which differs by characters of external morphology and genitalia. Images of its environment, and natural history observations are also provided. The intraspecific variation of *R. cicatricosus* is also briefly addressed.

Keywords: Italy, Calabria, Rhizotrogini, taxonomy, morphology, bionomy, endophallus, variability.

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Introduction

The genus *Rhizotrogus* Latreille, 1825, as redefined by Coca-Abia (2003), includes about 44 accepted species. The great majority of them is confined to more or less narrow ranges in the west-Mediterranean countries, in particular in the Iberian Peninsula, and only a few species reach central Europe or the central Mediterranean area (Bezděk 2016).

The fauna of the Italian Peninsula is rather poor and currently includes five or six species, four of them widely distributed also outside the peninsula (*R. aestivus* (A.G. Olivier, 1789), *R. cicatricosus* Mulsant, 1842, *R. maculicollis* (A. Villa & G. Villa, 1833) and *R. marginipes* Mulsant, 1842), while two are subendemic: *R. siculus* Baraud, 1970, described from Sicily and also recorded for Calabria, and *R. sassariensis* Perris, 1869, described from Sardinia. The latter has also been recorded for peninsular Italy since Baraud (1972), but most likely due to misidentifications, and the species is probably confined only to Sardinia (Uliana, unpublished). The nearby insular fauna adds three further taxa, one endemic to Sicily (*R. romanoi* Sabatinelli, 1975), one endemic to the Maltese Archipelago (*R. maltensis* (Rössner & Zorn, 2013), discussed in Uliana & Gallerati (2022), and one Ibero-Maghrebinian species also recorded from Pantelleria (*R. pallidipennis* C.E. Blanchard, 1851).

During a recent entomological survey in Southern Italy (S Basilicata/N Calabria regions, Mt Pollino Massif), a high-altitude, day-active population of a *Rhizotrogus* species of uncertain identity was discovered by Michele Tedeschi (together with Sergio Monzini), who alerted the authors about his observation. A successful field investigation by the authors followed, allowing to observe and sample a dense population of the beetle. It proved to belong to a new species close to *R. cicatricosus* Mulsant, 1842, which is here described.

The taxonomic assessment of the new taxon required to explore the intraspecific and geographic variability of *R. cicatricosus*, which is also briefly addressed on the basis of the comparison of specimens from different parts of its broad distribution range.

Materials and methods

Specimens of *Rhizotrogus tedeschii* n. sp. were hand collected or netted during visual survey of their flying site, which was visited by authors two times, on 27 and 28 May 2018.

Acronyms of collections

HNHM: Hungarian Natural History Museum, Budapest, Hungary
MSNMI: Museo di Storia Naturale di Milano, Italy
MSNVE: Museo di Storia Naturale di Venezia Giancarlo Ligabue, Venezia, Italy
MSNVR: Museo di Storia Naturale di Verona, Italy
MTCM: private collection Michele Tedeschi, Milano, Italy
MUCC: private collection Marco Uliana, Codevigo, Italy
OHCS: private collection Oliver Hillert, Schöneiche bei Berlin, Germany
SMCM: private collection Sergio Monzini, Milano, Italy
VGCS: private collection Valerio Gallerati, San Pietro in Casale, Italy

Comparative material examined. 88 ♂♂ and 25♀♀ of *Rhizotrogus cicatricosus* were examined, covering a substantial section of its documented range (Fig. 1). 33 endophalli of *R. tedeschii* n. sp. and 48 of *R. cicatricosus*, from all available populations, have been everted. See Results for details.

Morphometry. Following a preliminary evaluation for potentially diagnostic morphometric traits, the following measurements were collected on 30 males of *R. tedeschii* n. sp. and on 40 males of *R. cicatricosus*, including all specimens available from France (17) and Spain (2), and 21 specimens from the remaining populations, all from the Northern Apennines.

BS: body size, expressed as length from the anterior margin of the pronotum to the apex of elytra
CW: width of clypeus
ANTL: length of antennomere 1, measured on undissected antenna in dorsal view
ANTW: maximum width of antennomere 1, in dorsal view.
EBL: maximum length of the epipleural setae in the basal (post humeral) trait (averaged measure of the three longest setae)
EML: maximum length of the epipleural setae in the medial trait (averaged measure of the three longest setae)
EAL: maximum length of the epipleural setae in the subapical round trait (averaged measure of the three longest setae)
EMD: distance between epipleural setae in the medial trait (averaged measure of ten consecutive intervals)
EAD: distance between epipleural setae in the apical round trait (averaged measure of ten consecutive intervals)

BS, CW, ANTL and ANTW measurements were taken using a Meiji Techno RZ stereoscope (magnification 7.5-75x) with a graduate eyepiece. All measurements involving epipleural setae (EBL, EML, EAL, EMD, EAD) were taken on all-in-focus images through ImageJ software, in order to achieve better accuracy on curved traits. In addition, the count of metatibial teeth was collected on the same specimens. Since the number of teeth is commonly asymmetric, the count was collected for each metatibia.

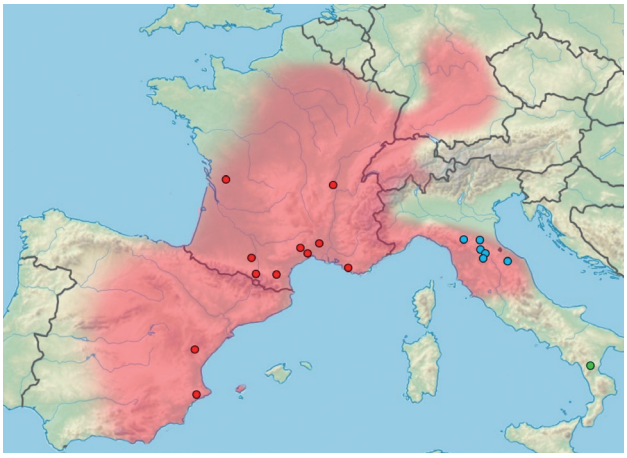


Fig. 1 – Ranges of studied species and distribution of examined specimens. Red shadowing: range of *Rhizotrogus cicatricosus* (from Allenspach 1970; Coca-Abia & Martin-Piera 1998; Ballerio et al. 2014; Bezdek 2016; Schaffrath 2015; Haselböck 2018). Red dots: locations of the examined specimens of *R. cicatricosus* from W Europe (see material and methods); blue dots: locations of the examined specimens of *R. cicatricosus* from Appennines; green dot: *R. tedeschii* n. sp.

Absolute and comparative variability of these body traits was explored, and the most significant results, allowing to differentiate populations, are provided.

Analysis of *R. cicatricosus* was carried out considering samples from north of the Alps (France and Spain) as a distinct group from those from south of the Alps (Italy), in order to explore any distance-related potential differentiation between purportedly conspecific populations

Statistical analyses were performed on morphometric indices obtained from the variables described above, by using Real-Statistics software (Zaiontz 2022).

The normal distribution of data was assessed using Shapiro-Wilk test, while the homogeneity of variances was tested with Levene's test. Most of the studied traits (i.e. BL, EML/EAL and EAL/EAD) showed normal distribution and non-homogeneous variance (heteroskedasticity), therefore they were analyzed using Welch's ANOVA (which is an ANOVA modified for heteroskedastic data), whereas the significant difference between groups was studied using post-hoc Games-Howell. However, ANTL/ANTW data showed a non-normal distribution and homogeneous variances, so the significant difference within and between groups was analyzed using the non-parametric Kruskal-Wallis test followed by post-hoc Dunn's Test.

Treatment of endophalli. Endophalli have been inflated by injection of white UV curable gel. Dry endophalli have been preliminarily rehydrated, softened with NaOH solution, and rinsed.

Terminology. Anatomical nomenclature according to Cristóvão & Vaz de Mello (2020), and Coca-Abia & Martin-Piera (1998). Nomenclature of female terminalia according to Dupuis (2005).

Images. Photos of the habitus and of endophalli were taken with a Pentax K-1D camera and Rodenstock Rodagon 2.8/50mm lens mounted on a bellow extendable up to 290 mm. Photos of antennae were taken with a Canon Eos 600D camera and a MP-E 65mm lens. All-in focus images were produced collecting stack of photos with semi-automatic system MJKZZ QOOL Rail 250, processed with CombineZP software and enhanced with Photoshop CS6 software.

Results

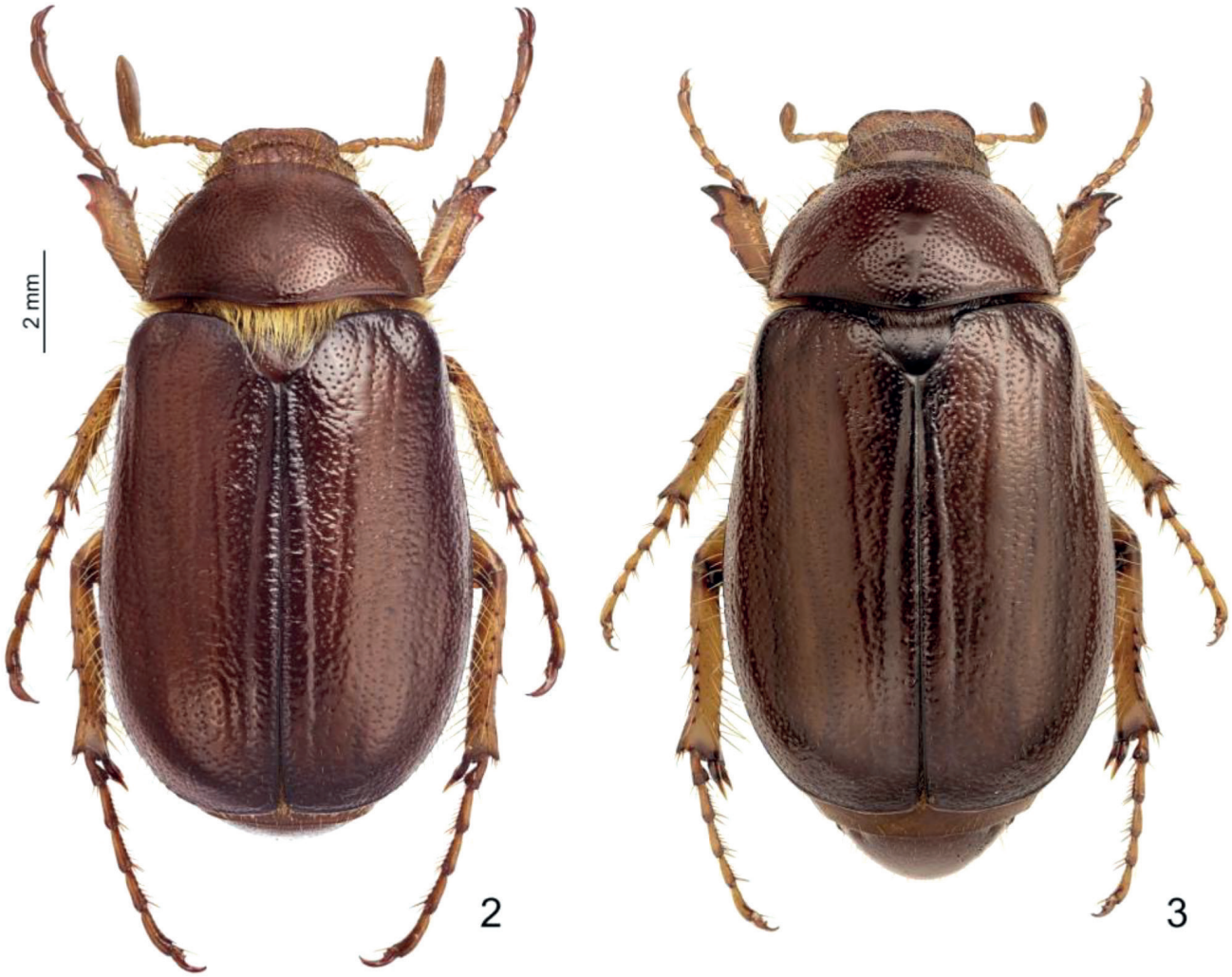
Rhizotrogus cicatricosus Mulsant, 1842

Material examined

Number of males is followed by number of everted endophalli, between brackets.

Spain: • Montes Universales, Fuente del Tajo, 1700 m, 12 June 2002, leg. H. Rietz, 1♂ (1), OHC • Alicante, Font Partegat, Altana, 31 March 2011, leg. H. Rietz, 1♂ (1), OHC.

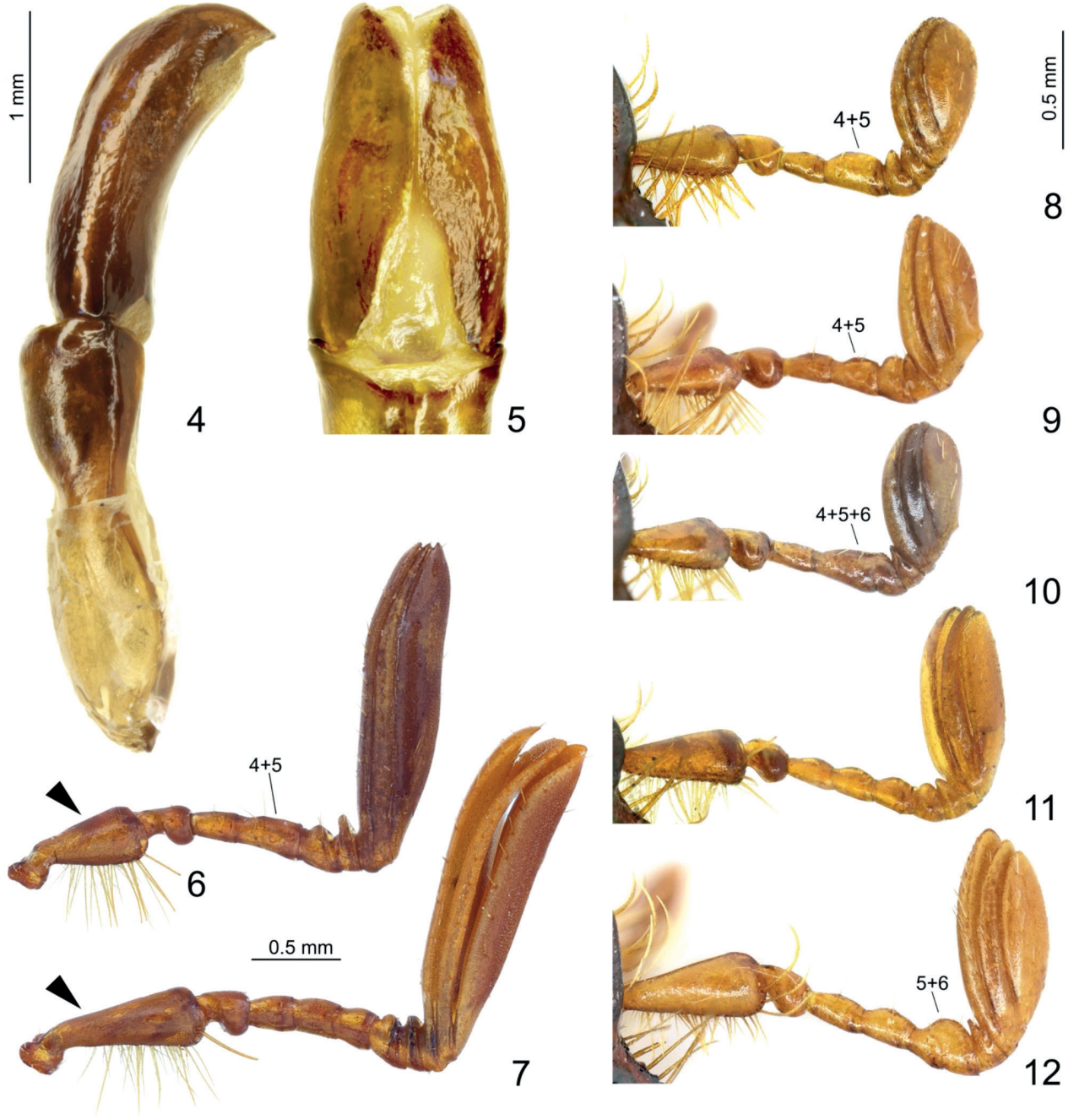
France: • Herault, St. Gély, June 1953, leg. Schaefer, 2♂♂ (2), MSNVR; • Le Beausset, January 1903, no legit, 1♂, MSNVR; • Le Beausset, March 1901, no legit, 1♂ (1), 1♀, MSNVR; • 11, Massac, env. du Col de Cascagne, 623 m, 8 April 2017, no legit, 4♂♂ (4), 3♀♀, MUCC; • Pyrenees orientales, Martinet, 1 May 1934, leg. Tasso, Schatzmayr, Koch, 1♀, MSNVR; • St. Guilhem Le Desert, 20 March 1983, no legit, 1♂ (1), MUCC; • Lyon, [no date], ex coll. Porta, 1♂, MSNVR; • Haute Garonne, Doumerc Clermont-le-Fort, 8 March 2015, leg. H. Brustel, 4♂♂ (2), MUCC; • Cognac, 20 April 1949, no legit, 2♂♂ (1), HNHM; • Nimes,



Figs 2-3 – *Rhizotrogus tedeschii* n. sp., habitus of male (**2**, holotype) and female (**3**, paratype).

13 March 1929, leg. J. Thérond, 1♂ (1), HNHM; • "Gallia", "Friv / 3157" [no other data], 1♂, HNHM.

Italy: • Emilia Romagna (BO), Castel d'Aiano, M.te Spe, 14 April 2013, leg. L. Colacurcio, 1♀, MUCC; • same as previous, except 04 May 2013, 1♀, MUCC; • Emilia Romagna (BO), Monzuno, 25 March 2017 leg. V. Gallerati 2♂ (1), 1♀, VGCS; • Emilia Romagna (RA), Casola Valsenio, 200 m, 04 April 2012 leg. C.A. Casadio, 1♀, VGCS; • same as previous, except 23-25 March 2016, 1♂ (1), 1♀, MUCC; • same as previous, except 25-28 March 2016, 1♀, VGCS; • same as previous, except 05 April 2016, 1♀, VGCS • same as previous, except 18-24 March 2017, 16♂♂ (1), 1♀, MUCC; • same as previous, except March 2019, 3♂♂, 3♀♀, MUCC; • same as previous, except 8-12 March 2020, 5♂♂ (1),



Figs 4-12 – Anatomical details of *R. tedeschii* and *R. cicatricosus*. **4,** aedeagus in lateral view of *R. tedeschii* (holotype); **5,** paramera in dorsal view of *R. tedeschii* (holotype). **6-7**, comparison between male antennae of *R. tedeschii* n. sp. (**6**, specimen with 9 antennomeres) and of *R. cicatricosus* (**7**); Arrowhead evidencing antennomere 1. **8-10**, variability of female antenna of *R. tedeschii* n sp.: **8**, common condition, with original antennomeres 4 and 5 non-disjointed and forming a thicker antennomere; **9**, article 4+5 similar to others; **10**, non-disjonction extending to original antennomere 6, resulting in a 8-segmented antenna; **11-12**, variability of female antenna of *R. cicatricosus*: **11**, normally 10-segmented antenna; **12**, 9-segmented antenna with non-disjunction of antennomeres 5-6.

(MUCC); • same as previous, except 18-28 March 2017, leg. V. Gallerati, 6♂, 6♀, VGCS; • same as previous, except 15-25 March 2018, leg. V. Gallerati, 22♂ (17), VGCS; • same as previous, except 25-30 March 2018, leg. V. Gallerati, 4♂ (1), 1♀ VGCS; • Romagna (FC), Premilcuore, 7 June 1987, leg. Callegari, 1♂, MSNVE; • Romagna (FC), Corniolo, 12 April 1986, leg. Callegari, 2♂♂, MSNVE; • Toscana (AR), Camaldoli, 900 m, April 1962, leg. Callegari, 7♂♂ (2), 1♀, MSNVE; • Umbria (PG), Scheggia e Pascelupo, 07 June 2011, leg. M. Bocci, 1♀, examined on photos.

Comments. The morphology of endophalli (Figs 15-26, 35-37) and some of the morphometric characters evaluated (Figs 55-56, Tabs 1-2) evidenced moderate differences between Spanish and French populations versus Italian ones (all from Northern Apennines). In particular, in Italian populations, subapical epipleural setae resulted to be on average longer compared to the distance between them (ratio EAL/EAD), and the endophallus appears to be on average squatter (the frontal side more convex) and with raspulae more developed (Figs 23-26, 37). This shape of endophallus was observed also in one specimen from SE France (Fig. 22). Both characters are, however, subject to a considerable variation within each population and within each set of populations.

Other traits, such as the general morphology, size, length of subapical epipleural setae compared to the medial ones, and elongation of antennomere 1 in males did not show relevant differences between the two areas. Since no relevant nor clear-cut differences emerged between the two sets, and since their ranges are assumed to be in continuity, we consider reasonable treating these populations as a single taxon, in accordance with the currently accepted taxonomy (last scrutinized by Martin-Piera & Coca-Abia 1992 and Coca-Abia & Martín-Piera 1998).

The observed variability is however suggestive of parapatrically diverging evolutionary clines, whose proper assessment may be worth deeper exploration. See Discussion for further details and comparison with *R. tedeschii* n. sp.

Rhizotrogus tedeschii Uliana & Gallerati, **new species**

Comparative diagnosis. A species of *Rhizotrogus* close to *R. cicatricosus*, and distinct from it for the smaller size, darker integuments, antennomere 1 of male stouter, females with 9 antennomeres due to non-disjunction of antennomeres 4-5 (rarely with 8 antennomeres due to non-disjunction of 4-6), endophallus with different shape, female terminalia with subcoxite less developed. Secondary differential characters are to be found in the micropunctation of pronotum absent or sparser, in the epipleural setae shorter than those of the nearest known populations of *R. cicatricosus*, and in the smaller average number of teeth on metatibia.

Figs 13-14 – Comparison between elytra of fresh specimens of *Rhizotrogus cicatricosus* (**13**, from Casola Valsenio, Italy) and of *R. tedeschii* n. sp. (**14**, topotypical paratype). Photos were taken in the same lighting condition, to evidence the different the color of integument.

Material examined

Number of males is followed by the number of everted endophalli, between brackets.

Holotype ♂, deposited in MUCC, currently housed at MSNVE**,** labeled "Italia, Calabria (CS), Morano Calabro, Serra del Prete, 39.911, 16.147, 1950-2110m, 27-28.V.2018 leg. M.Uliana"**.**

Paratypes: • same data of the holotype, 59♂♂ (20), 6♀♀, MUCC; • same data as the holotype, but leg. V. Gallerati, 84♂♂ (11), 2♀♀, VGCS. • Italia, Basilicata (PZ), Monte Pollino, Serra del Prete, 39.924, 16.159, 2000 m, 25.V.2018, leg. M. Tedeschi, 2♂ (2), 1♀ (MTCM). • same data as previous, but leg. S. Monzini, 2♂, 1♀ (SMCM).

Description of the male, holotype

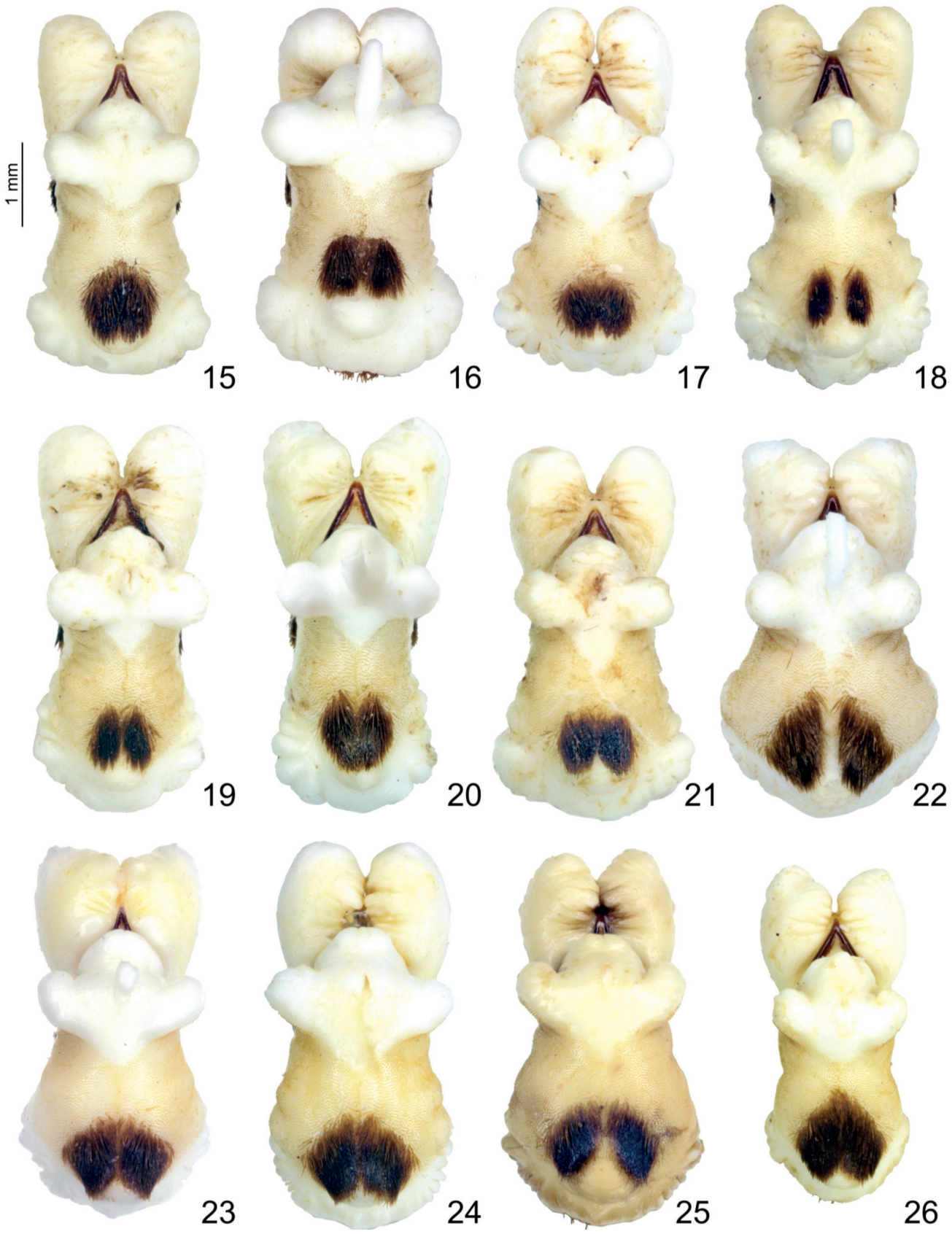
Habitus as in Fig. 2.

Size. BS 12.7 mm; body length including head and pygidium 14.0 mm.

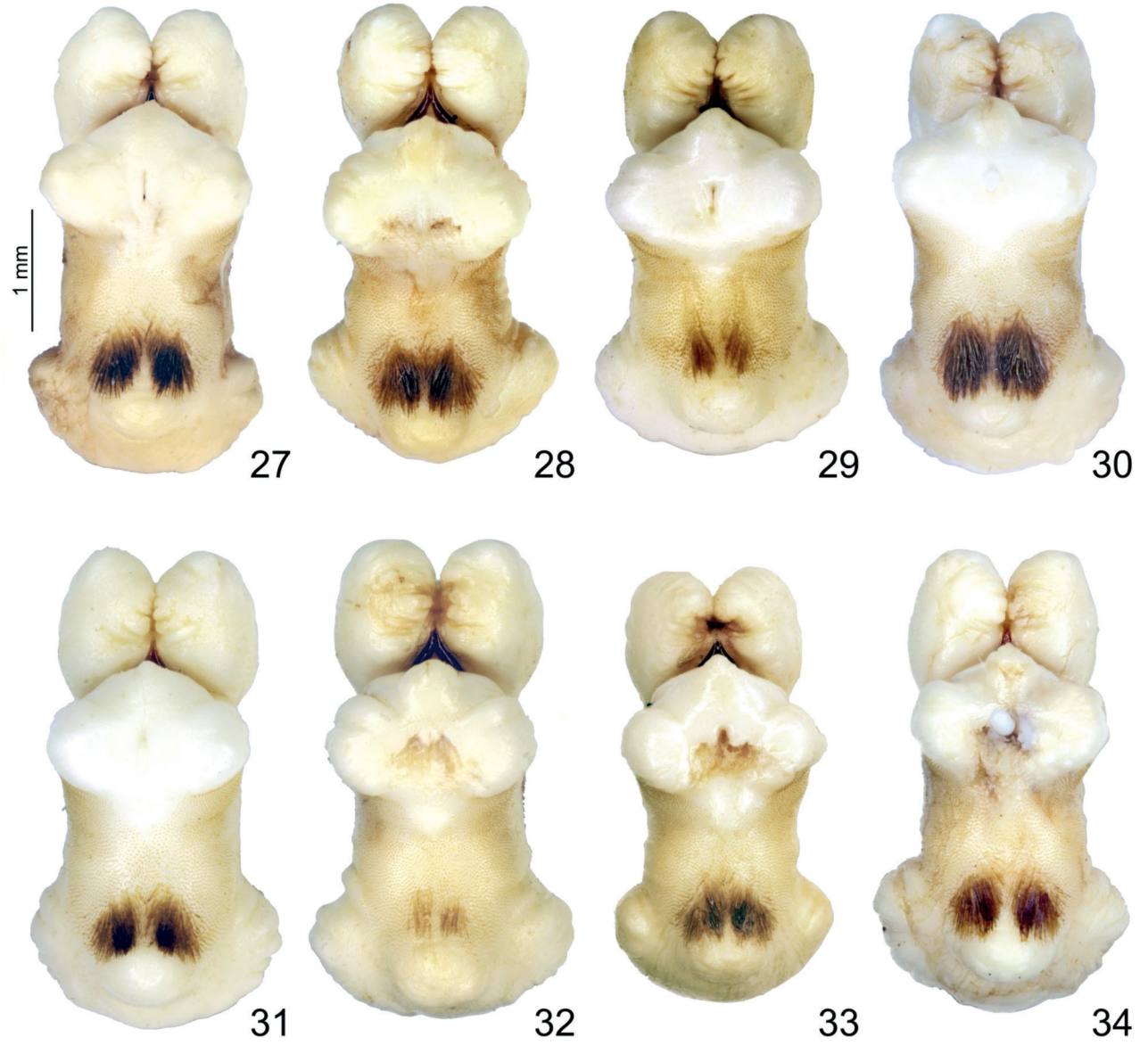
Color. Dorsal side brown, head and pronotum very slightly lighter than elytra, pygidium more noticeably lighter than elytra. Legs and ventral side light brown.

Morphology. Clypeus subtrapezoidal, almost flat, margins narrowly raised, anterior margin slightly concave. Fronto-clypeal suture well evident, slightly bisinuate. Frons convex, with trace of a barely marked transversal carina connected to the fronto-clypeal suture by a medial longitudinal bulge. The whole head densely and irregularly punctured, punctures often merging, slightly broader between the frontal carina and the fronto-clypeal suture. Clypeus and frons behind the carina subglabrous, just with tiny, raised, micro-setae. Frons in front of the carina with moderately long, erect setae.

Pronotum 1.64 times as wide as long, covered by dense and quite regular punctures, much smaller than those on head, never merging with each other, in the discal area separated by distances similar to a puncture's diameter. A small



Figs 15-26 – Variability of endophalli of *Rhizotrogus cicatricosus*, frontal view. **15**, Spain, Fuente del Tajo; **16**, Spain, Font Partegat; **17**, France, Cognac; **18**, France, Clermont-le-Fort; **19-20**, France, Massac; **21**, France, St. Gély; **22**, France, Le Beausset; **23-25**, Italy, Casola Valsenio; **26**, Italy, Camaldoli.



Figs 27-34 – Variability of endophalli of *Rhizotrogus tedeschii* n. sp., frontal view (topotypical paratypes).

irregular unpunctured area is present in the medial part of the basal half. Surface moderately shining, completely covered by fine microreticulation. Sides regularly convex, anterior angles obtuse, narrowly rounded, posterior angles obtuse, broadly rounded. Surface glabrous, except for long setae along the anterior and the lateral margins.

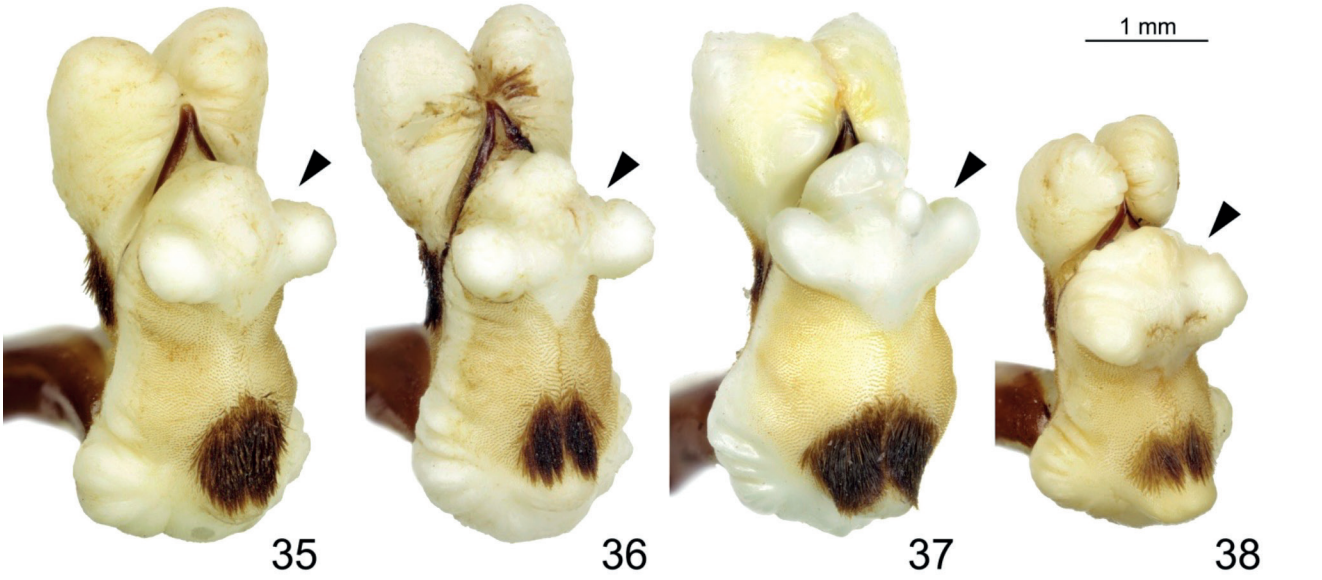
Scutellum glabrous, microreticulated, with an irregular row of punctures along margins, central part smooth.

Elytra 1.33 times as wide as long, broadest in the distal half. Compared to pronotum, surface more shining, with microreticulation present but less marked. Punctures slightly smaller than those of pronotum, sparse, more superficial, often indistinct among the moderate wrinkles of the integument, especially in the dorsal area. Sutural interstria raised, broadening towards the apex. Three additional striae are weakly impressed between sutural stria and humerus. Surface glabrous, except for few very sparse tiny setae towards the apex, the longest measuring about 0.16 mm. Epipleura with moderately long and stiff setae, decreasing in length from humeral area to the apical round.

Pygidium microreticulated, bearing punctures similar to that of pronotum, irregularly distributed, more dense along the basal and the medial area. Punctures of the basal half bearing small adpressed setae, the longest about 0.2 mm long. Some longer setae are present in the apical portion of the margin.

Abdomen with ventrites 1 and 4 bearing sparse setae, ventrites 2 and 3 with just an irregular row of setae in the medial part, interrupted in the middle.

Antenna. 1st antennomere 1.81 times as long as wide (ANTL/ANTW). Antennal club 1.58 times as long as



Figs 35-38 – Endophalli, oblique view, of *R. cicatricosus* (**35**, Spain, Fuente del Tajo; **36**, France, Massac; **37**, Italy, Casola Valsenio) and *R. tedeschii* (**38**, topotypical paratype). Arrowhead evidencing the difference in the degree of protrusion of diverticula.

antennomeres 2-7. Antennomeres 4-5 partially non-disjointed, antennomeres 6 and 7 compressed, with anterior margin moderately produced.

Legs. Anterior tibia 3-toothed, proximal tooth weak, medial tooth closer to the apical one. Medial and posterior tibiae with a transversal carina slight after half length. Posterior tibiae with 6 scarcely developed teeth on the dorsal margin. Metatarsus 1.13 times as long as the metatibia.

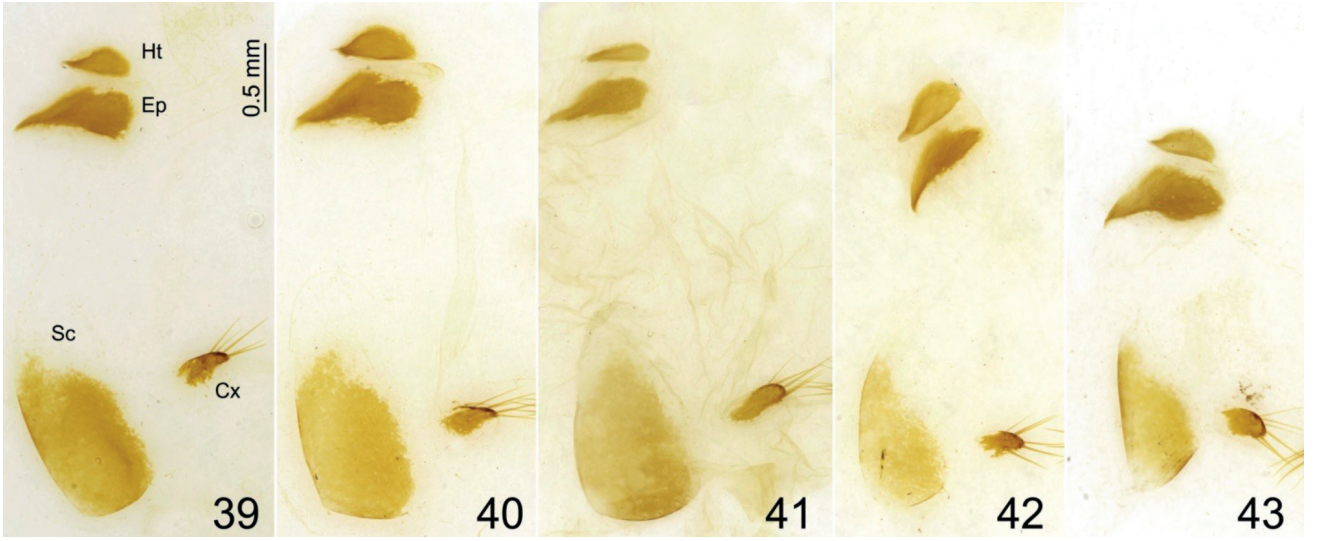
Aedeagus as in Figs 4-5. Endophallus not everted (cfr. endophalli of paratypes).

Relevant variation of male paratypes. Size: BS 11.3-13.4 mm, body length including head and pygidium 12.8-15.7 mm. Variation of other morphometric traits is summarized in Tab. 1 and in Figs 55-57. Antennomeres 4-5 ranging from completely disjointed to completely non-disjointed and thus producing a 9-segmented antenna with no anomalous sized or shaped antennomeres; occasionally the non-disjunction involves to a variable degree also the subsequent article (originally, article 6).

About 55% of specimens with pronotum bearing sparse micropunctation among the main punctures.

Amount and distribution of punctures on scutellum very variable, punctures may be almost completely absent to present also in the medial area.

Endophalli as in Figs 27-34 and 38.

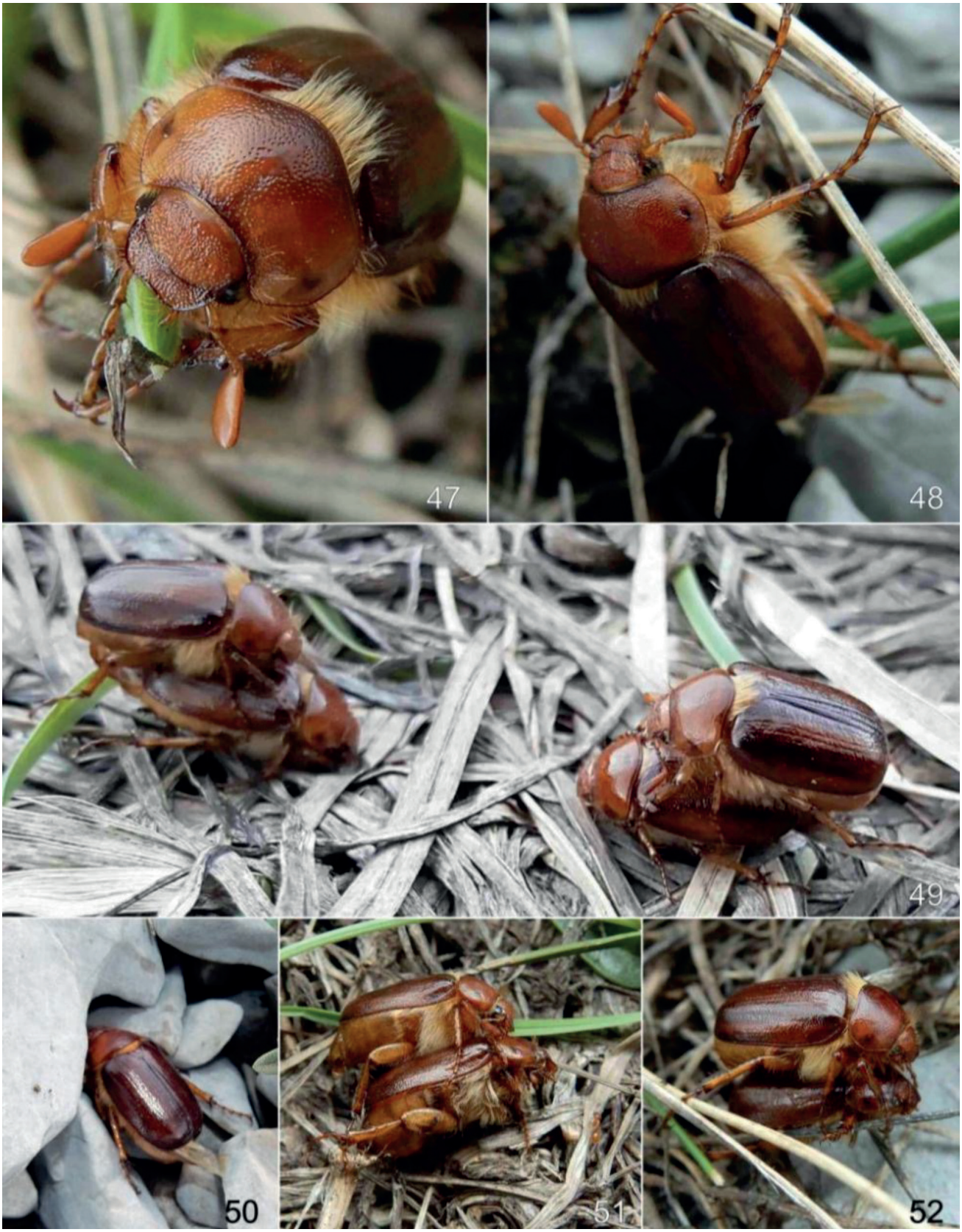


Figs 39-43 – Female terminalia (left side, accesory glands omitted) of *R. cicatricosus* (**39-40**, Italy, Casola Valsenio; **41**, France, Martinet) and *R. tedeschii* (**42-43**, paratypes). **Cx:** coxite, **Ep:** epipleurite, **Ht:** hemitergite, **Sc:** subcoxite.

Figs 44-46 – Habitus of *Rhizotrogus cicatricosus* in life. **44**, female from Italy, Scheggia e Pascelupo (photo courtesy of Maura Bocci); **45**, male from Italy, Casola Valsenio (photo courtesy of Carlo Arrigo Casadio); **46**, male from France, Ferrières-les-Verreries (photo courtesy of Titouen Roguet, fandefaune.free.fr).

Description of the female. Only relevant differences from males are mentioned. **Habitus** as in Fig. 3. **Body** moderately stouter, pygidium more protruding. **Antennae** ordinarily with 9 antennomeres (Figs 8-9), rarely 8 (Fig. 10). With reference to the 10-jointed antenna ordinarily expected in *Rhizotrogus* a non-disjunction affects original antennomeres 4-5, and rarely extends to 4-6. The resulting antennomere 4+5 is commonly thicker than the adjoining ones (Fig. 8) and not bearing evident signs of fusion or missed disjunction, occasionally is not different from the others at all (Fig. 9). In 9-segmented antennae, the two antennomeres preceding the club (originally, antennomeres 6 and 7) are compressed, with ordinary appearance and size. **Tarsi** shorter, metatarsus ca 0.9x as long as metatibia. **Terminalia** as in Figs 42-43.

Etymology. The species is dedicated to Michele Tedeschi (Milano), carabidologist, who first observed the new taxon and kindly entrusted MU for its study. Noun in the genitive case.



Figs 47-52 – Habitus and behaviour of *Rhizotrogus tedeschii* n. sp. in life. **47-48**, males resting on low grasses; **49**, two pairs mating at ground; **50**, male trying to crawl beneath rocks following a female trail; **51-52**, two different males trying to mate with the dry remains of a female (scavenger ants visible in Fig. 51). In Fig. 52, the female had been moved to a second site.

Distribution. Known only from the peak of Serra del Prete, Pollino Massif, above 1900 m, along the ridge parting the administrative provinces of Potenza (Basilicata region) and Cosenza (Calabria region). The species was sampled in two collecting sites, about 1.8 Km distant from each other, one in each of the mentioned provinces. The collecting area is widely separated from the known range of *R. cicatricosus* (Fig. 1).

Natural history observations. The collecting area of *Rhizotrogus tedeschii* n. sp. (Figs 53-54) is characterized by slopes covered by alpine meadows on limestone rocks. Rocky outcrops and surface debris are extensively present, with consequently broadly interrupted grass cover. Most of the specimens, indeed, have been collected in a particularly rocky spot, placed at 1960 m (Fig. 54), but spare adults were observed throughout almost all our path above the tree line, between about 1900 and 2110 m, thus very close to the mountain top (2180 m) (Fig. 53). The two collecting sites were very similar.

Adults of *R. tedeschii* n. sp. are active during the daytime: males were observed in flight and mating between approximately 10.00 and 14.00 (GMT+1, corresponding to 11.00-15.00 Summer Time). However, the beginning of activity is likely to have started before, since about 10.00 a.m. is the earliest time when we reached the site, and we noted immediately males in flight. Conversely, we consider quite reliable our observations of the stop of activity approximately at 14.00: in each of the two days of observation, with good weather, we could observe a progressive reduction of flight, until the complete disappearance of adults at the beginning of the afternoon. Thus, activity stopped about five hours before the dusk (sunset at 19.15).

Adults showed a clearly thermo-heliophilous behavior, with activity peaking during moments of full sunlight, and repeatedly dropping with the onset of passing clouds.

Flight of males occurred mostly close to the soil surface, but spare individuals were observed up to about 2.5 meters height at least. Their dispersal was apparently purported to searching for females: rare specimens were observed while standing on grasses (Figs 47-48), none of them feeding. Females calling males and mating (Fig. 49) were observed only at the soil level, and occasionally under stones. In some cases, males were observed trying to sneak under rocky debris, presumably following chemical trails released by females (Fig. 50). Repeated mating attempts, by different males, were observed with the remains of a female, in spite of its poor condition (dry, with abdomen completely emptied and occupied by minute ants) (Figs 51-52).

Figs 53-54 – Habitat of *Rhizotrogus tedeschii* n. sp., main observing and sampling site near the top of Serra del Prete (39.911, 16.147), 1960 m. **53**, view towards NE, where spare specimens were also observed along the crest (red circle); **54**: detail of site, with extensive rocky debris, view towards SW.

	tedeschii	***cicatricosus* (ITA)**	***cicatricosus* (FR, SP)**	***cicatricosus* (ITA, FR, SP)**	**p-value**
BS (mm)	11.3-13.4 x̄=12.1	13.1-15.8 x̄=14.2	12.8-16.0 x̄=14.1	12.8-16.0 x̄=14.2	$2.1*10^{-14}$
ANTL/ANTW	1.55-1.90 x̄=1.75	2.00-2.27 x̄=2.29	2.09-2.75 x̄= 2.34	2.00-2.75 x̄=2.32	$8.75*10^{-12}$
EAL/EAD	1.47-2.48 x̄=1.87	2.92-4.77 x̄=3.80	1.38-3.69 x̄=2.45	1.38-4.77 x̄=3.20	$4.1*10^{-13}$
EML/EAL	1.43-2.55 x̄=1.87	1.11-1.74 x̄=1.42	1.12-1.93 x̄=1.51	1.11-1.93 x̄=1.46	$3.7*10^{-8}$
Number of metatibial teeth	3-7	5-9	3-7	3-9	-

Table 1 – Summary of measurements for discussed morphometric traits (range and mean (x̄)), and results of statistical analyses related (p-values from Welch's ANOVA or Kruskal-Wallis, see Material and methods). All p-values are consistent with a highly significant difference among the tested groups ($p < 0.01$).

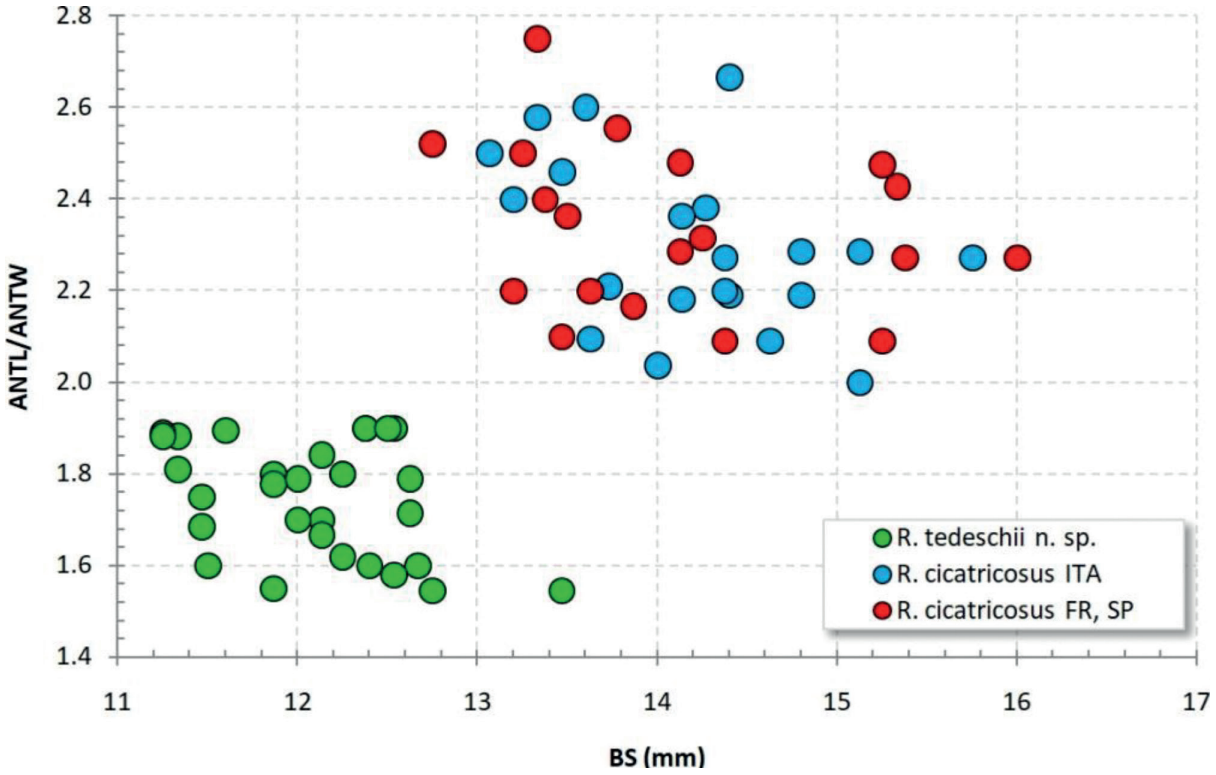


Fig. 55 – Distribution of two diagnostic morphometric traits in males. BS: body length, head and pygidium excluded, ANTL/ANTW: elongation of antennomere 1.

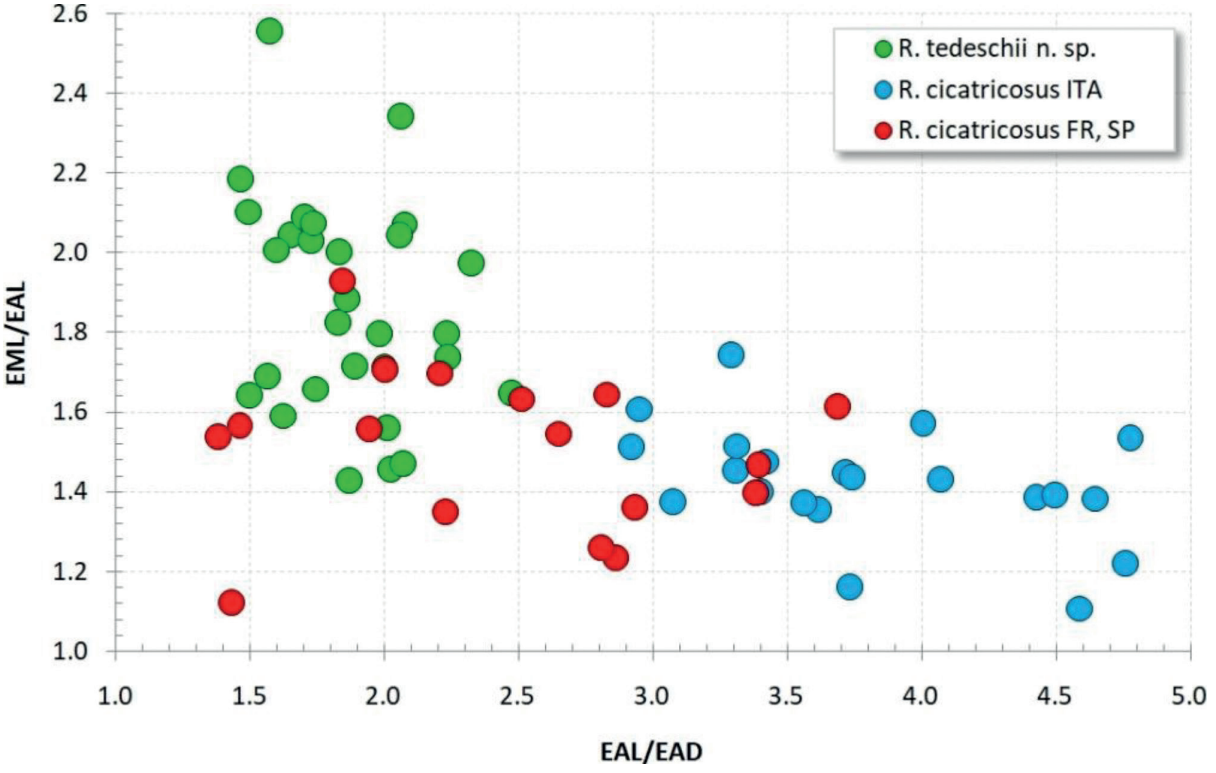


Fig. 56 – Distribution of two morphometrics traits relative to epipleural setation in males. EAL/EAD: ratio between length of setae and their distance at the subapical round; EML/EAL: ratio between the length of setae at the medial part and at the subapical round.

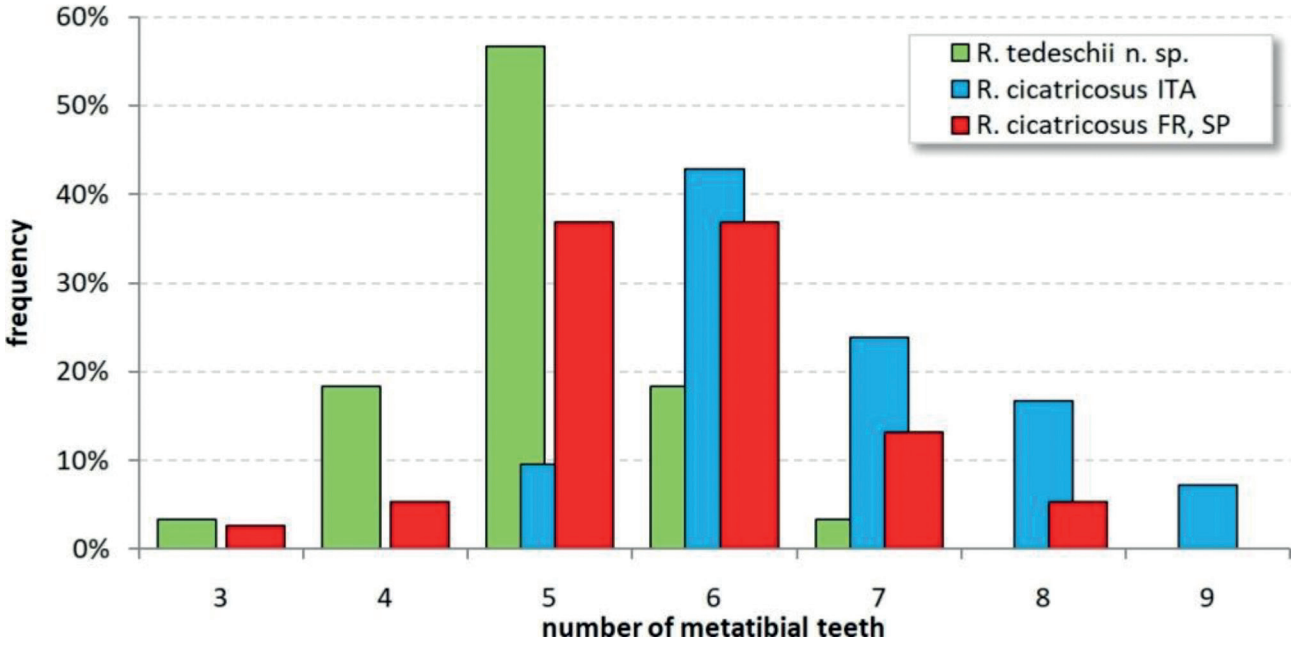


Fig. 57. Distribution of the number of metatibial teeth.

Unlike *R. tedeschii* n. sp., its close relative *Rhizotrogus cicatricosus* is mostly active during the dusk and at the beginning of the night, and is attracted by light. Reports for such phenology are available for western and south-eastern France, in the regions of Charente (Baraud 1972: 162; 1977: 13) and Provence (Paulian 1959: 206), Germany (Rosenhauer 1871; Prediger 1902; 1904; Petry 1929; Horion 1958; and Haselböck 2018) and Italy. The flight of the population from Casola Valsenio starts about at the sunset and lasts for about one hour, with an air temperature of 10-14 °C, flight is followed by mating on the grass. In the same locality, phototropic behavior was also observed (A. Casadio, pers. comm.); nocturnal activity and attraction by light was also observed at Scheggia e Pascelupo (M. Bocci, pers. comm. and Bocci 2012). There are however several reports for *R. cicatricosus* observed in activity from noon to the afternoon in southern France, reported in Paulian (1959: 206), Baraud (1972: 162), and also in iNaturalist (Bas 2020; Roguet 2022), while we are not aware of observations earlier in the morning.

The two species appear to share a similar preference for the geological substrate, since also *R. cicatricosus* seems to be commonly associated to grasslands standing on limestone or gypsum (Kolbe 1921; Horion 1958; Ballerio et al. 2014; Schaffrath 2015).

Discussion

Taxonomic background. *R. tedeschii* n. sp. is morphologically very close to the widespread *R. cicatricosus* (cf. map in Fig. 1), described from southern France, based on specimens from Nismes (currently, Nîmes) and Montpellier, though the author was also aware of its presence in Anveyron and Lyon (Mulsant 1842: 435).

The taxonomy of *R. cicatricosus*, together with that of other close taxa, has been thoroughly revised by Martin-Piera & Coca-Abia (1992) and then by Coca-Abia and Martin-Piera (1998), in the context of the revision of the whole genus *Rhizotrogus*. Based on examination of

group 1	group 2	p-value							
		BS		ANTL/ANTW		EAL/EAD		EML/EAL	
tedeschii	*cicatricosus* (ITA)	●●	$2.7*10^{-13}$	●●	$5.7*10^{-9}$	●●	$8.9*10^{-13}$	●●	$6.9*10^{-9}$
tedeschii	*cicatricosus* (FR, SP)	●●	$1.0*10^{-8}$	●●	$1.0*10^{-9}$	●	$1.2*10^{-2}$	●●	$2.3*10^{-5}$
cicatricosus (ITA)	*cicatricosus* (FR, SP)		0.94		0.67	●●	$1.2*10^{-6}$		0.33

Table 2 – Results (p-values) of the post-hoc tests (i.e. Games-Howell test or Dunn's test, see Material and methods) aimed to test the significance of differences between the considered single groups. ● = significative statistical difference ($p<0.05$). ●● = highly significative statistical difference ($p<0.01$).

abundant material, mostly from Iberian peninsula, they documented for *R. cicatricosus* an intraspecific variability larger than previously understood, and synonymized under this name other taxa.

The type of *R. cicatricosus* was not checked in neither of the two revisions. However, considering the original description and the Rhizotrogini occurring in Southern France there is no reasonable doubt about its identity. Among material studied by us, there are specimens from Southern France, including one male from Nîmes (hence, topotypical) and two from Saint-Gély, about 2 kilometers away from Montpellier. We consider these males confidently conspecific with the populations studied by Mulsant.

The taxonomic reassessment of the genus *Rhizotrogus* by Coca-Abia and Martin-Piera (1998) took extensively into account the examination of the endophallus. However, observations were done by flattening the endophallus membrane on a stage, and were thus limited to tigilla and endophallites, that in *Rhizotrogus* consist in tufts of setiform sclerifications (raspulae). We verified that the study of its inflated shape allows to highlight differences that would be otherwise overlooked and that prove to be helpful in delimiting species-level taxa.

Diagnostic traits are discussed below.

Body color. *R. tedeschii* n. sp. is darker than *R. cicatricosus*: elytra, in particular, are more or less dark brown, while in *R. cicatricosus* elytra and the whole body are typically rusty orange-brown. It should be noted that a correct evaluation of the integument color on preserved specimens of light-colored Rhizotrogini may be problematic, since integuments are semi-transparent and the darkening of soft tissues and apparently also of the integument itself frequently occurs after death. A comparison between elytra dissected from fresh specimens is shown in Figs 13-14. Alive specimens of both species are shown in Figs 44-46 (*R. cicatricosus*) and 47-48 (*R. tedeschii*). In alive specimens of *R. tedeschii* head and pronotum are often more reddish and visibly lighter than elytra, a condition that is not noticeable in dry specimens (Figs 2-3).

Antennomeres. With reference to ordinary 10-segmented antennae of *Rhizotrogus* species, an anomalous segmentation (non-disjoint articles) is common in females of *R. cicatricosus*, and present in all females of *R. tedeschii* n. sp. we examined. However, the modified condition is different between the two species. In *R. cicatricosus*, the non-disjunction affects original antennomeres 5 and 6, and a partial split is commonly recognizable in the resulting antennomere 5+6 (occasionally, the split is non recognizable); antennomeres 3 and 4 are normal, and between the modified antennomeres and the club, only one (normal) antennomere is present (original antennomere 7) (Fig. 12). In *R. tedeschii* the non-disjunction affects at least original antennomeres 4 and 5, consequently between the modified antennomere 4+5 and the antennal club, two normally developed antennomeres are present (Figs 8-9). Occasionally, the modified antennomere 4+5 may have the same appearance of the adjoining ones (Fig. 9). Rarely, original antennomere 6 may also be more or less merged to the preceding ones (Fig. 10).

Conversely, the condition of male antennomeres seems not diagnostic: non-disjunction of antennomeres 4+5 is observed in some males of *R. tedeschii* (Fig. 6), while in *R. cicatricosus* occasional non-disjunction may involve articles 3-4, 4-5, and 5-6.

Cases of reduction in the expected number of antennomeres are reported for other species of *Rhizotrogus* and other genera of Rhizotrogini, and are sometimes source of misidentification (Uliana & Gallerati 2022).

Endophallus. As mentioned above, the everted endophallus of *R. cicatricosus* shows some intraspecific variation, that appears to be partly intrapopulational and partly geographical related.

However, all studied populations of *R. cicatricosus* share two common traits that we consider diagnostic towards *R. tedeschii* n. sp.: the diverticules at sides of the ejaculatory ductus are well protruding, often bent upwards or onwards, and the main body of the structure, in frontal view, gradually broadens (i.e., sides diverge) towards the bottom (Figs 15-26 and 35-38). Conversely, in *R. tedeschii* (Figs 27-34 and 38) the mentioned diverticules are expressed in form of two non-protruding bulges, barely distinct from the main body, and the main body itself has roughly parallel sides abruptly enlarging before the bottom.

The development of raspulae is variable in both species, in particular in *R. tedeschii*, where they range from almost absent to well-developed. In *R. cicatricosus* their variability is less exaggerated: they are generally well developed and on average much more than in *R. tedeschii*. A broad variability in the development of raspulae was reported for *R. pallidipennis* by Martin-Piera & Coca-Abia (1992) and Coca-Abia & Martín-Piera (1998), while no mention of significant intraspecific variability was noted for other species of the genus.

Female genitalia. In *R. tedeschii* n. sp. the subcoxite appears slightly less developed than in *R. cicatricosus* (Figs 39-43).

Morphometric traits. Body size (BS), elongation of first antennomere (ratio ANTL/ANTW), and, to some degree, condition of epipleural setae (ratios EAL/EAD and EML/EAL) allow to differentiate *Rhizotrogus tedeschii* n. sp. from *R. cicatricosus* (Tab. 1).

R. tedeschii is on average smaller than *R. cicatricosus*, although the two ranges slightly overlap. Total body length of the two species, including head and pygidium, resulted in 12.8-15.7 for *R. tedeschii* and 14.7-18.4 for

R. cicatricosus. The first antennomere of *R. tedeschii* is visibly stouter than *R. cicatricosus* (Figs 6-7), with ranges of variability close to each other but not overlapping. These two traits are plotted in Fig. 55. For both of them statistic tests confirmed the presence of highly significant difference between *R. tedeschii* and both sets of *R. cicatricosus*, while showed no difference amongst the latter two (Tab. 2).

Following our preliminary exploration, limited to populations from the Apennines, length and density of epipleural setae also appeared different between the two species (see Figs 13-14). However, French and Spanish populations filled the gap between the two species, since their broad variability overlaps to the ranges of the other two sets (traits plotted in Fig. 56). On the other hand, statistical analysis evidenced significant differences for both tested traits (Table 2). In particular, the ratio EML/EAL is different between the two species with a very high degree of confidence, while it is not different between the two sets of *R. cicatricosus*: thus, in *R. tedeschii* the subapical epipleural setae are shorter compared to the medial ones than they are in *R. cicatricosus*. Differences in the ratio EAL/EAD resulted significant or highly significant between all groups assessed, including the two sets of *R. cicatricosus* compared against each other. Notably, this ratio also clearly separates *R. tedeschii* from the nearest populations of *R. cicatricosus*, as there is no overlapping between their two ranges (Fig. 56).

The number of posterior tibial teeth behaves somehow similar: the difference between *R. tedeschii* and that of the Italian populations of *R. cicatricosus* is blurred by the intermediate condition and broader variability of the French and Spanish ones (Fig. 57).

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