

New method for taxonomic descriptions with coded notation, producing dynamic and interchangeable outputs

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Abstract

A new proposal for taxonomic species description is presented to replace the traditional descriptive texts. This is an attempt to enhance the species description rate and to make the description output available to other scientific disciplines, machine learning, lucid identification keys, big data analysis and its applications. The method consists in presenting the description of the overall morphology in a coded matrix, following a character list with detailed observed conditions for each character. The method is supposed to be dynamic and open to amendments and new data addition as they become available. We test the new method describing five new species of Collembola Symphypleona of the genus Pararrhopalites as a generalized model and made the coded output available. We conclude that a coded taxonomic description is an advance to the traditional taxonomic text, with potential to enhance the global descriptions rate. The generated data is a dynamic matrix that can be expanded with any data that becomes available, also it can be easily used in other fields of science, allowing non-experts to access the data for phylogenetic, biogeographic, ecological studies and big data analysis. Furthermore, it is a step forward to a general template to semi-automated taxon recognition and auxiliary tools for species description using machine learning.

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Title

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Running Title

CODED TAXONOMIC DESCRIPTION

Abstract

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KEYWORDS

Coded species description, Diversity decline, Taxonomy, Collembola, Machine learning

INTRODUCTION

Taxonomy has been the focus of debate since the XIX century, and even recently the recognition of the taxonomic research is subject of discussion (Packer et al., 2018, Zeppelini et al., 2021). The global diversity crisis exposes the urgency for investment in taxonomy to reveal the largely unknown species diversity. Using Collembola as a parameter, where about 20% of its estimated diversity is known (Hopkin 1997), between 100 and 120 new species are described each year, and it would take to taxonomists more than 400 years to uncover and describe all the unknown species diversity (Potapov et al., 2020). To be able to understand the diversification processes in Collembola, we need to speed up the rates of species description. This is a matter of concern in every area of entomology, and in some extent, the whole zoology.

Collembola Lubbock, 1870 are minute wingless arthropods, basal hexapods found in every terrestrial habitat on the planet, including soil, leaf litter, canopy trees and caves (Bellinger et al., 1996-2023, Hopkin 1997). There are about 9000 described species, and its diversity is extensively underestimated and poorly known (Bellinger et al., 1996-2023, Hopkin 1997). They play important role in the food web and the global metabolism (Bardgett & van der Putten 2014, Filser et al., 2016, Potapov et al., 2023, Rusek 1998).

Similar to many other taxonomic groups of meso and micro fauna, Collembola taxonomy is largely based on morphological analysis, observing, and describing discrete variations in diagnostic characters. The most abundant morphological source of information for species definition in Collembola is the number, distribution, and shape of cuticular chaetae, this is called chaetotaxy. The current morphological approaches for inference of homology, chaetotaxic systems for chaetal identification, are often room for great subjectivity depending on what is seen and what is visible under an optic microscope, and often different chaetotaxy systems are hardly comparable (Betsch 1997, Betsch & Waller 1994, Bretfeld 1990, 1999, Potapov et al., 2020). The challenges and perspectives for Collembola taxonomy is discussed in detail, and the need for an integrative taxonomy and international efforts to direct financial support and expertise recognition to face the global biodiversity crisis, was also the focus of debate (Potapov et al., 2020, Zeppelini et al., 2021).

The impact of recent technologies of high-resolution imaging, molecular sequencing and machine learning will be a great deal towards taxonomic techniques that can improve new and known taxa recognition (Potapov et al., 2020). Integrative taxonomy, combining morphological and molecular data to define species limits is likely to be a trend for most taxonomic groups, not only Collembola.

There is, however, a particular aspect in Collembola (and nearly every taxon of the micro-fauna) that affects

the viability of including molecular sequences in new species descriptions, in many, if not most cases. It is rather a logistic problem, but many times there is not an alternative. The problem is that almost all new species are discovered under light microscope, which means that the specimen was mounted in a slide, after being cleared under several different techniques of chemical washes, which destroy the tissues and, consequently, genetic material.

It is only after the taxonomic identification, that a species is recognized as new for science or undescribed. More often than not, the material analyzed is a limited set of specimens, and there is no available material for molecular analysis after the taxonomic identification and morphologic study. Accepting that molecular analysis facilities are available, many times the biological specimens needed for molecular sequencing may be available only in a future, after the species is described. Even when Scanning Electron Microscopy (SEM) is possible, depending on the structure, it is hard to get images of all diagnostic features and light microscopy may be needed as well. However, high-resolution imaging and molecular data are powerful tools, and may be indispensable for accurate taxonomic research and species delimitation. Therefore, the morphologic descriptions must be dynamic, open to easy amendment and additional data insertion. Furthermore, it must be presented in an interchangeable language, to allow the information to flow across different disciplines.

Among all methods applied to the external morphology study of Collembola, chaetotaxy is certainly the most complex and extensively detailed (Betsch & Waller 1994, Cassagnau 1974, Deharveng 1983, Fjellberg 1999, Jordana & Baquero 2005, Nayrolles 1988, 1990a, 1990b, Potapov 2001, Szeptycki 1979, 1972, Yosii 1960). There are many chaetae and groups of chaetae that vary in position and shape in such a way that they allow a great deal of homology inferences. However, the most advanced approaches are also very complex, which makes interpretation difficult and increases ambiguity. These aspects circumscribe the deep taxonomic research to restricted groups of experts, posing difficulties to comparative studies even among different Orders of Collembola. In addition, the traditional descriptive texts with morphological and chaetotaxic information are difficult to integrate with machine learning and computational novelties, which could give a lot of agility to phylogenetic analysis, big data comparison, biogeography, and their various applications (Potapov et al. 2020).

Despite all advances in technological instruments and methods, taxonomic descriptions are still written basically in the format as it was about two centuries ago, with a hermetic language in nearly incomprehensible texts for non-experts. This is often a greater barrier to communication among different areas of science, than the access of high-tech equipment and analytical facilities.

The proposal of a coded and illustrated description of new species that can be easily imported, transformed, amended, corrected, or expanded is presented as an alternative to the traditional descriptive taxonomic method.

The strength of the coded description is that new characters, whether morphological, molecular, ecological, can be easily added to the list and improve the descriptive matrix as new information is produced. These matrices can be uploaded to public libraries and kept up to date with all available information about the species, and linked to data bases as GBIF, ZooBank and electronic taxonomic catalogs available in different parts of the world *e.g.*, fauna.jbrj.gov.br/fauna/listaBrasil (Zeppelini et al., 2023); www.collembola.org (Bellinger et al., 1996-2023) .

MATERIALS AND METHODS

Coded Taxonomic Description

The Order Symphypleona Börner, 1901 shows some ambiguity in current morphological methods, particularly when describing the head and body chaetotaxy (Betsch 1997, Betsch & Waller 1994, Bretfeld 1990, 1999, Christiansen & Bellinger 1998). The Order is composed by springtails with globular body shape, as result of modification and fusion of thoracic and abdominal segments I-IV, this condition hinders the direct assignment of segments identity.

An approach that can reduce the ambiguity of the taxonomic descriptions, is the description of body parts

into coded morphological units, straightforwardly representing the actual body segments and appendicular whorls (Hopkin 1997, Jura et al., 1987, Nayrolles 1988, 1990a, 1990b, 1991, Tomizuka & Machida 2015), in such a way that any species can be compared from the coded data base. This is in replacement to the traditional descriptive text, many times with ambiguous terminology, and often applying different and not directly comparable chaetotaxic systems. The coded notation method would lead to a more comprehensive analysis of the chaetotaxy, as well as a direct availability of the data for comparative studies. Furthermore, a coded description can easily be amended, molecular data can be added in the character list and matrix, and new complementary morphological features can be inserted as new information is available.

The qualitative description of the shape and size of the different chaeta is also subject to a great deal of ambiguity and poor definition, the adjectives are not standard and the very definition of what is a macro, meso or microchaeta is not always clear. Therefore, a bank of shapes with high quality images is imperative to discard all the subjective descriptions. There are several chaetae banks published for different groups of Collembola, including some with precise line drawings (Betsch 1980, Christiansen 1966, Deharveng 1983, Nayrolles 1991), and some with SEM photography (Cipola et al., 2020, de Lima et al., 2022, Lukić et al., 2010, Zeppelini et al., 2022, Zhang & Deharveng 2015), it is a matter of time to have a fully reliable chaetal shapes collection, so a specific chaeta can be addressed directly by its reference in the bank, in the coded description.

A standard, fully coded method for species description may be an improvement to the traditional descriptive text, it may allow to use machine learning and high-quality imaging to enhance the efficiency of species descriptions and diversity recognition, offering a powerful tool to understanding of global processes, and face the diversity decline.

Chaetal fields and morphological units

We attempt to access the chaetotaxy of the head and great abdomen of Collembola, by identifying body segments arranged in each tagma (Figs. 1-2), or whorl in each appendage (Figs. 3-5) (Hopkin 1997, Jura et al., 1987, Nayrolles 1988, 1990a, 1990b, 1991, Tomizuka & Machida 2015). Each segment has its own set of chaetae, and more than one chaetal field may occur in a single body segment. A chaetal field is a group of associated chaetae that are consistently observed in a given body segment, often associated with some landmark on the cuticle (Figs. 6-7).

The morphological units are the actual observed character in a given species. Once recognized all the chaetal fields, the characters are listed, and its inherent character states are described. Each morphological unit in the character list is given a code (0, 1, 2) to each observed condition. It is important to note that it is not a phylogenetic matrix, once the codes in the resulting matrix are not supposed to include hypothesis of ordering or polarity, and both apomorphies and plesiomorphies may be listed as character, instead, it is a descriptive coded character state matrix.

Head, body, and appendages chaetotaxy

Chaetotaxic systems attempt to labeling each chaeta along the body, where the label indicates a specific chaeta and its position in the body of the animal, then a qualitative description is made (*e.g.* spinelike chaeta, macrochaeta, club shaped sensillum, palmate, serrate, lanceolate), bringing subjectivity in the interpretation of a specific chaeta labeling, and by the many different adjectives that can apply for a given shape, depending on the author.

Here we map regions that can be compared in different taxonomic groups, the chaetal fields, within each head and body segment (Fig. 1-2), and to appendages (Figs. 3-5), and refer to a shape for the chaeta in an image data set, the chaetae bank, with images of each kind of chaeta found in the taxon (Fig. 8).

The chaetotaxy of individualized chaeta is replaced by a code describing the total number of chaetae in the chaetal field, and the qualitative description of the different kind of chaetae found in each chaetal field, is replaced by the respective number in the chaetae bank that represents the actual observed shape and size, to compose the morphological unit definition (see Table 1).

Coded descriptive dataset

The information of the whole collection of data of each species, result in a dataset as synthesized in table 1, this is the final morphologic description outcome and represents the complete and up to date set of information for each studied species. However, it is dynamic and open to additional information, when available.

The coded dataset is hierarchically ordered in four columns namely, Tagma, Segment, Chaetal field and Morphological unit (Table 1), a fifth column is inserted with the coded information of the species (Fig. 1). The lines of the resulting dataset bring the different features of the chaetotaxy and general morphology (*e.g.*, eyes, foot complex). The cells in the column of morphological unit, are the actual features to be observed in the specimen, where each one is a recognizable morphological unit of the animal whole morphology, that is described and coded in the character list (Appendix 1).

Using an example of a defined character and its code according to appendix 1, we have: Antennal / ANT / ANT M + L / 3+1+3 4(9)3(7), where Antennal indicates the segment, ANT is the chaetal field (see Fig. 1A), ANT M+L is the morphologic unit, 3+1+3 are the observed chaetae in the respective chaetal field (3 paired and 1 axial according to bilateral simetry), and 4(9)3(10) means that there are four type “9” chaetae, and three type “7” chaetae (total 7 chaetae or 3 +1+3), the types are defined by comparison among the photos in figure 8. To the combination of chaetae number and type is given a numeric code (this example is coded 0 in the character list Appendix 1).

Testing the coded description

To test the proposed system, we describe five new species of the genus *Pararrhopalites* Bonet & Tellez, 1947 (zoobank.org:pub:9ED865EA-F95A-4CBE-947C-3A5C6CD81907), from the Order Symphypleona, using *P. fallaciosus* **sp. n.**, as the explanatory example in the SEM overall morphologic analysis. First, we describe *P. fallaciosus* **sp. n.**, where all the chaetal fields are delimited, and the species is morphologically defined. The character list is derived from this revision and presented in appendix 1. The final descriptions for the remaining new species will bring the code only (Morphologic unit code).

Here we propose the coded description for *Pararrhopalites*, a genus of Symphypleona, however, once fully established, the system must be applicable to the Orders Poduromorpha and Entomobryomorpha as well. Ideally a similar approach could be used to any other zoological taxa.

To proceed the segmental delimitation and definition, we addressed the results from developmental biology (Hopkin 1997, Jura et al., 1987, Tomizuka & Machida 2015), and the chaetal fields were defined using SEM (Tescan Vegas III) to map the clusters of chaetae associated to cuticular landmarks. Cephalic chaetotaxy, great abdomen chaetotaxy, and small abdomen (abdominal segment VI) chaetotaxy followed the system proposed by Betsch & Waller (1994) and Betsch (1997). For the appendages, we followed Nayrolles (1988, 1990a, 1990b, 1991) for antennae, legs and furcula; and tenaculum after Richards (1968).

The chaetotaxic systems were used to verify the congruence of the morphological landmarks and associated groups of chaetae which display constant expression (*i.e.*, chaetal fields). All chaetotaxic information, the actual observed character condition, was described in the character list, and coded accordingly (Appendix 1).

The descriptions are presented as a list of coded characters in the descriptive plate of each newly described species. The exception is made to *P. fallaciosus* **sp. n.**, where the morphologic units are described in the matrix corresponding to the chaetotaxy system cited above, as an example of what the observed features are (before coding). The detailed chaetotaxy analysis for all the five species described here is available in the supplementary material.

RESULTS

Coded Description of *Pararrhopalites fallaciosus* **sp. n.**

Collembola Lubbock, 1870

Symphyleona Börner, 1901

Sminthuroidea Bretfeld, 1994

Sminthuridae Lubbock, 1862

Sminthurinae Lubbock, 1862

Pararrhopalites Bonet & Tellez, 1947 (=Neosphyrotheca Salmon, 1964)

Pararrhopalites fallaciosus **sp. n.**

zoobank.org:act:C9126B2C-EB0F-4AC3-BD10-066A54998541

(Figs. 1-8)

Type material. Holotype female in slide (#20441/CRFS/UEPB): Brazil, Minas Gerais state, Caeté municipality, F-29 SSH, 19°49'22.18"S 43°41'51.61"W, 26.IV.2022, Ativo ambiental *et al.* coll. Paratypes in slides (#20439, #20440/CRFS/UEPB): 2 females, same data as holotype.

Additional materials <https://doi.org/10.15468/pbxmgz>

Etymology. *Pararrhopalites fallaciosus* **sp. n.** is a reference to the similarities with a *P. queirozi* Brito, Lima & Zeppelini, 2019, that can lead to an elusive identification.

Habitat and distribution

The species was collected in drilling holes, occurring in the Subterranean Shallow Habitat (SSH), its known distribution is restricted to the type locality, despite the sampling efforts in nearby areas and in the whole region, an important mining area which is being consistently sampled in the last decade.

Good's Biogeographic zone 27 (Culik & Zeppelini 2003, Good 1974). The climate according to Köppen's system is As (Köppen 1936, de Sá Júnior *et al.*, 2012, Shear 1966), presenting dry winters and wet summers, average temperatures of 18°C during winter and 22°C in summer (valid for all the five species described here).

Remarks

The new species resembles *P. queirozi* in the shape of the subanal appendage and cephalic chaetotaxy but can be clearly distinguished by the number of subsegments of Ant. IV (eight in *P. queirozi*, 10 in the new species), the presence of inner tooth in all unguis, and apical filament exceeding the tip of the unguis in all three empodial complexes in *P. queirozi*. The new species is similar to *P. hermesisp. n.* in the shape of subanal appendages, the lack of inner tooth of all unguis. They differ by the number of eyes (1+1 in *P. fallaciosus sp. n.* and 0+0 in *P. hermesisp. n.*), number of subsegments in Ant. IV (10 and nine respectively), the lack of corner tooth in all unguiculi and mucro with inner lamella smooth in *P. hermesisp. n.* The reduced number of chaetae on the dorsal posterior part of the great abdomen (17+17) also differentiate *P. fallaciosus sp. n.* from other species of the queirozi-group (all the species which share the same female subanal appendages).

Pararrhopalites hermesisp. n.

zoobank.org:act:554455DB-364D-4C48-A0A9-33CC578C4E02

(Figs. 8, 9-13)

Type material. Holotype female in slide (#6040/CRFS/UEPB): Brazil, Minas Gerais state, Nova Lima municipality, cave RM-33, 20°02'05.30"S, 43°59'40.20"W, 30.VI.2014, Bioespeleo *et al.* coll. Paratype in slide (#6038/CRFS/UEPB): 1 female, Brazil, Minas Gerais State, Nova Lima municipality, RM-33, 20°02'05.30"S, 43°59'40.20"W, 02.IV.2014, Bioespeleo *et al.* coll. Paratype in slide (#6039/CRFS/UEPB): 1

female, same data as holotype. Paratype in slide (#6042/CRFS/UEPB): 1 male, Brazil, Minas Gerais State, Nova Lima municipality, RM-03, 20°02'37.50"S 44°00'22.40"W, 31.III.2014, Bioespeleo *et al.* coll. Paratype in slide (#18060/CRFS/UEPB): 1 female, Brazil, Minas Gerais State, Nova Lima municipality, RM-33, 20°02'05.30"S, 43°59'40.20"W, 21.X.2017, A. S. Reis & R. Zampaulo coll.

Additional materials <https://doi.org/10.15468/pbæmgz>

Etymology. *Pararrhopalites hermesi* **sp. n.** is named after the Greek god Hermes, in allusion to the wings of his flying shoes, quite similar in shape to the subanal appendages of this species.

Habitat and distribution

This species is known from caves and SSH in a range over 200 km across different lithologies. It is a regionally widespread SSH species, but it is not abundant, as there are less than 20 records of this species.

Remarks

This species is part of a group with a specific kind of subanal appendages (number 28 in Fig. 8), which includes *P. queirozi* and *P. fallaciosus* **sp. n.** The species has an intermediary number of subsegments on Ant. IV (nine subsegments), has no eyes, lacks the corner tooth in all unguiculi, and the inner lamella of the mucro is smooth. This combination of features can easily differentiate the three species.

Despite its wide distribution, *P. hermesi* **sp. n.** presents some features that may be indicative of its relation to the SSH environment, for instance eye reduction, Ant. IV shorter (nine subsegments), overall small body size, and the reduction of the corner tooth and apical filament on unguiculus.

Pararrhopalites atypicus **sp. n.**

zoobank.org:act:14BAAE02-F5FB-4169-BCE8-9AFC6DE4FBB1

(Figs. 8, 14-18)

Type material. Holotype female in slide (#2142/CRFS/UEPB): Brazil, Minas Gerais State, Mariana municipality, cave FN-05, 20°13'17.81"S 43°26'02.93"W, 12.XII.2012, Bioespeleo *et al.* coll. Paratypes in slides (#2139, #2140, #2141, #2143, #2144/CRFS/UEPB): 4 females and 1 male, same data as holotype.

Additional materials <https://doi.org/10.15468/pbæmgz>

Etymology. *P. atypicus* **sp. n.** is Latin for unusual, as this is the only species of this region which lacks the interantennal sensillar triangle, known so far.

Habitat and distribution

This species is restricted to a single area, there are only 10 records for three small caves in the same iron rock formation. The species is most likely distributed along the *canga*, a SSH formation resulting of weathering of the iron rock, that often connect caves in the same lithology.

Remarks

This species resembles *P. sideroicus* Zeppelini & Brito, 2014 and *P. ubiquum* Zeppelini, Lima & Brito, 2018, in the shape of the subanal appendages and general body chaetotaxy but differ from all the species of the genus with records in this area by lacking the interantennal sensillar triangle, this feature seems to be shared by both the species of the queirozi-group and the ubiquum-group. The presence of only three chaetae in the dorsal cephalic area DII is also very unusual for the genus and the reduced number of chaetae in the dorsal posterior part of the great abdomen can be diagnostic for this species.

Pararrhopalites ritaleeae **sp. n.**

zoobank.org:act:C531BF30-7489-449F-B0A1-2B4F1BBF67EF

(Figs. 8, 19-23)

Type material. Holotype female in slide (#4942/CRFS/UEPB): Brazil, Minas Gerais state, Itabirito municipality, cave VL-35, 20°18'28.30"S, 43°56'32.30"W, 18.VI.2013, Mascarenhas *et al.* coll. Paratypes in slides (#2577, #2587, #2595/CRFS/UEPB): 3 females, Brazil, Minas Gerais state, Itabirito municipality, cave VL-35, 20°18'28.30"S, 43°56'32.30"W, 07-10.V.2013, Mascarenhas *et al.* coll. Paratypes in slides (#4938, #4940, #4943/CRFS/UEPB): 2 female and 1 male, same data as holotype.

Additional materials <https://doi.org/10.15468/pbæmgz>

Etymology. *Pararrhopalites ritaleeae* **sp. n.** is named *in memoria* m after Rita Lee a Brazilian singer deceased may, 2023.

Habitat and distribution

Pararrhopalites ritaleeae **sp. n.** is the most abundant species presented here, but its distribution is restricted to a group of seven caves in the same iron rock formation in the type locality. It is known only from caves, but surface samplings are needed to survey the epigeic fauna.

Remarks

This species is also part of the ubiquum-group and resembles the other species of the group by the shape of the subanal appendages and general body chaetotaxy. The absence of eyes is observed in *P. ubiquum*, and the apical filament of the unguiculus III exceeding the tip of the unguis is similar to *P. sideroicus*. The features that differentiate *P. ritaleeae* **sp. n.** are the mucro inner lamella smooth, Ant IV with nine subsegments, unguiculus III apical filament exceeding unguis tip, Abd. IV lateral chaetae lacking.

D. Dias Silva contributed with insights on the chaetal fields definition and body chaetotaxy of *P. fallaciosus* **sp. n.**

Pararrhopalites ironicus **sp. n.**

zoobank.org:act:47BFB22F-967A-437D-A9FA-63F1675FB00B

(Figs. 8, 24-28)

Type material. Holotype female in slide (#18545/CRFS/UEPB): Brazil, Minas Gerais state, Barão dos Cocais municipality, cave BRU-0028, 19°52'49.00"S, 43°26'13.50"W, 20-24.IX.2021, Spelayon *et al.* coll. Paratypes in slides (#18555, #18566/CRFS/UEPB): 2 females, same data as holotype. Paratypes in slides (#19047, #19048, #19059/CRFS/UEPB): 2 females and 1 male, Brazil, Minas Gerais state, Barão dos Cocais municipality, cave MDIR-0028, 19°52'49.00"S, 43°26'13.50"W, 14-18.III.2022, Spelayon *et al.* coll.

No additional materials available.

Etymology. *Pararrhopalites ironicus* **sp. n.**, from iron and the Greek suffix “*icus*” (belonging or related to), in allusion to its relation to the iron rock.

Habitat and distribution

Pararrhopalites ironicus **sp. n.** is a very restricted species, represented by only six records from two caves in the same iron rock formation, called *Serra do Tamanduá*, the caves are 2700 m away from each other, and connected by SSH. It is a rare species, likely to be confined to the subterranean environment.

Remarks

This is one more species of the ubiquum-group, this species is very similar to *P. sideroicus*, *P. ubiquum*, *P. atypicus* **sp. n.**, and *P. ritaleeae* **sp. n.** in the general body chaetotaxy. The main differences are to be found in the dorsal cephalic chaetotaxy. *Pararrhopalites ironicus* **sp. n.** can be differentiated from those species by presenting only five spines (type 8 in Fig. 8), the Ant. I with Only five chaetae, the apical organ of Ant. III chaeta ape is a normal chaeta (type 21 in Fig. 8), unguiculus III apical filament reaching but not exceeding the tip of the unguis and lacking the corner tooth.

DISCUSSION

To access the global species diversity, it is mandatory to enhance the description rates of new taxa, mainly where the diversity is least known. A description protocol that can communicate the morphologic characters in a coded notation, allows the application of new technologies in the research and machine learning, which may be a major turnover in the discipline, and affect the species description rates. The scarcity of trained taxonomists and the hermeticity of the taxonomic description manuscripts, are the biggest barriers to the advance of the knowledge on the species diversity and evolutionary processes of diversification, both clue elements to understand the global diversity decline.

In the study of Collembola, as well as in many other groups, the information content of a traditional taxonomic text is often difficult to access and cannot be transported to analytical software without a detailed revision of the species description, which many times demands an expert in the taxon. The traditional format is also almost impossible to be used for machine learning, as there are many differences in the presentation of the data, that can make the comparison among different manuscripts impossible to non-experts and to artificial intelligence. The open character list of the coded description allows easy insertion and correction of the information, and either the character lists, the chaetae banks and the coded species descriptions are fully compatible with technologies that work with data matrices.

Our results can be synthesized in the following conclusions:

- 1 – The coded taxonomic description is a notation method that produces interchangeable data, fully available for different scientific disciplines. The data can be used by non-specialists for different purposes in science.
- 2 – The method makes it possible to add any source of new data to the description when it became available. It is dynamic and open as a continuous list of characters, the updating of the knowledge of a given species is not dependent of a traditional taxonomic revision.
- 3 – The method allows machine learning that can help to speed the species description rates and taxon identification where they are least known. This can be an important tool to fight global diversity crisis.
- 4 – Coded description is meant to Collembola but may be applied to any taxonomic group, reducing the ambiguity of narrative descriptions. When it is widely used, the comparative analysis will be almost a straightforward process.

AUTHOR CONTRIBUTIONS

Douglas Zeppelini : Conceptualization; investigation; writing - original draft preparation; methodology; validation; visualization; writing - review and editing; formal analysis; project administration; data curation; supervision; resources. **Misael Augusto de Oliveira Neto** : data curation, visualization. **João Victor Lemos Cavalcante de Oliveira** : formal analysis; investigation, validation, data curation. **Aila Soares Ferreira** : formal analysis; investigation, validation, data curation. **Roniere Andrade de Brito** : formal analysis; investigation, validation, data curation. **Bruna Carolline Honório Lopes** : formal analysis; investigation, validation, data curation. **Nathan Paiva Brito** : investigation. **Luis Carlos Stievano** : investigation. **Estevam Cipriano Araujo de Lima** : formal analysis; investigation, validation, data curation.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Coleção de Referência de Fauna de So-lo at <https://www.gbif.org/dataset/8cf92f87-eace-4d1c-96a9-49c3f5998351>, and in the Support Information

File.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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TABLE 1 Morphologic description of *P. fallaciosus* sp. n. The table brings the state of each morphologic unit observed in the species. The code for each state is presented in the character list (Appendix 1). EN, eyes number; D, dorsal head; C, clypeus; LR, labrum; Ant, antennal segment; MD, mandibular segment; MX, maxilar segment; LB, labium; LBT, labial triangle; Th, thorax; Abd, abdomen; SCX, subcoxa; CX coxa; TR, trochanter; FE, femur; Tib, tibiotarsus; PT, pretarsus; TR, tenacular ramus; TC, tenacular corpus; MN, manubrium; DN, dens; ov, oval organ; M, medial dorsal head; L, lateral dorsal head; a, anterior; m, medial; md, mid-dorsal; p, posterior; pd, postero-dorsal; pl, pre labral; v, ventral; d, dorsal; l, lateral; “-”, absent; “+”, present, “>”, bigger than; “<”, shorter than. (N) Numbers in parentheses represent the shape of the chaeta in the chaetae bank (Figure 8).

Tagma	Segment	Chaetal field	Morphologic unit	Morphologic unit state
HEAD	Eye	Eyes number	Pigments	-
			EN	1+1
			DI M + L	5+5 4(9)6(8)
			DII M + L	3+1+3 7(8)
	Clypeal	C	DIII M + L	0+0
			CI	3+3 6(10)
			CII	5+1+5 11(10)
			CIII	2+1+2 5(10)
			CIV	1+1+1 3(10)
			LR a + m + p + pl	4+5+5+6 20(10)
			ANT M + L	3+1+3 4(9)3(7)
	Labral	ANT	MDI (d+v)	2+2+1+1ov 4(10)2(11)
			MDII (d+v)	8+8+2+2ov 16(10)4(11)
			MDIII (d+v)	10+10 20(10)
	Antennal	MD	DMX + MX	2+2 4(10)
			LBT	4+4 8(10)
			LB	2+2 4(10)
	Mandibular	MX	ThI	0+0
			ThII	1+1 2(24)
			ThIII	3+3 2(24)2(26)2(23)
			AbdI a + m + p	3+3 6(25)
BODY	Thorax	Thorax I		
		Thorax II		
		Thorax III		
	Abdomen	Abdomen I		

APPENDAGES	Antenna	Abdomen II	AbdII a + m + p (d + l)	8+8 8(25)8(26)
		Abdomen III	AbdIII a + m + p (d)	10+10 8(25)6(26)6(31)
			AbdIII a + m (l)	5+5 10(26)
		Abdomen IV	AbdIV ad + md + pd	17+17 4(25)30(27)
			AbdIV (l)	3+3 6(26)
			BPI	2+2 4(26)
			BPII	1+1 2(26)
			BPIII l + m	13+13 10(26)16(18)
		Abdomen V	AbdV a + m + p	7+7 12(26)2(31)
		Abdomen VI	AbdVI as	4+4 8(26)
			AbdVI ms	2+2 4(26)
			AbdVI mps	3+1+3 7(30)
			AbdVI ps	1+1+1 3(26)
			AbdVI aai + ai	8+8 16(26)
			AbdVI mi	3+3 6(26)
			AbdVI mpi	4+4 6(26)2(28)
			AbdVI pi	3+3 6(26)
		Antenna I	AntI	6 5(9)1(21)
		Antenna II	AntIIA	7 6(9)1(21)
			AntII -0+	3 3(9)
			AntIIB	4 4(9)
		Antenna III	AntIIIA	8 2(6)1(2)1(21)1(20)3(9)
			AntIII -0+	8 4(9)4(5)
			AntIIIB	4 4(9)
		Antenna IV	Subsegments	10
		number of chaeta/whorl	AntIVAI + II + III	34 1(3)1(1)2(4)6(10)24(5)
			AntIVMA	8 1(4)6(5)
			AntIVM	9 1(4)8(5)
			AntIVMB	8 1(4)7(5)
			AntIVBA	3 3(5)
			AntIVBM	3 3(5)
			AntIVBB	4 4(5)
	Legs	Subcoxa	SCXI	1 1(26)
			SCXII	1 1(26)
			SCXIII	2 2(26)
		Coxa	CXI	1 1(26)
			CXII	3 3(26)
			CXIII	5 5(26)
		Trocanter	TRI	5 5(26)
			TRII	6 6(26)
			TRIII	6 1(15)5(26)
		Femur	FEI	15 15(26)
			FEII	14 14(26)
			FEIII	12 12(26)
		Tibiotarsus	TibI I	9 1(13)8(14)
			TibI II	8 1(13)7(16)
			TibI III	8 1(13)7(16)
			TibI IV	14 1(13)13(16)?
			TibI V	8 1(13)7(16)
			TibI.FS	2 2(16)
			TibI.FP	3 3(16)

		TibII I	9 1(13)8(14)
		TibII II	8 1(13)7(16)
		TibII III	8 1(13)7(16)
		TibII IV	14 1(13)13(16)
		TibII V	8 1(13)7(16)
		TibII FS	3 3(16)
		TibII FP	3 3(16)
		TibIII I	9 1(13)8(14)
		TibIII II	8 1(13)7(16)
		TibIII III	8 1(13)7(16)
		TibIII IV	14 2(13)12(16)
		TibIII V	8 1(13)7(16)
		TibIII FS	3 3(16)
		TibIII FP	3 3(16)
	Pretarsus	PTI	1+1 2(12)
		PTII	1+1 2(12)
		PTIII	1+1 2(12)
	Unguis	Unguis I inner tooth	-
		Unguis I tunica	-
		Unguis II inner tooth	-
		Unguis II tunica	-
		Unguis III inner tooth	-
		Unguis III tunica	-
	Unguiculus	Unguiculus I filament	>
		Unguiculus I tooth	+
		Unguiculus II filament	>
		Unguiculus II tooth	+
		Unguiculus III filament	<
		Unguiculus III tooth	+
	Collophore	Collophore	1+1 2(19)
Tenaculo	Tenaculo	TR	3+3 teeth
		TC a + p	2 2(18)
Furcula	Manubrio	MN	5+5 10(16)
	Dente	DNI	5 1(16)4(22)
		DNII	3 3(16)
		DNIII	3 3(16)
		DNIV	3 3(16)
		DNV	3 3(16)
		DNVI	2 2(16)
		DNB	4 4(16)
		DNAnt	4,2,2,1,1
	Mucro	Mucro	Both lamellae serrated

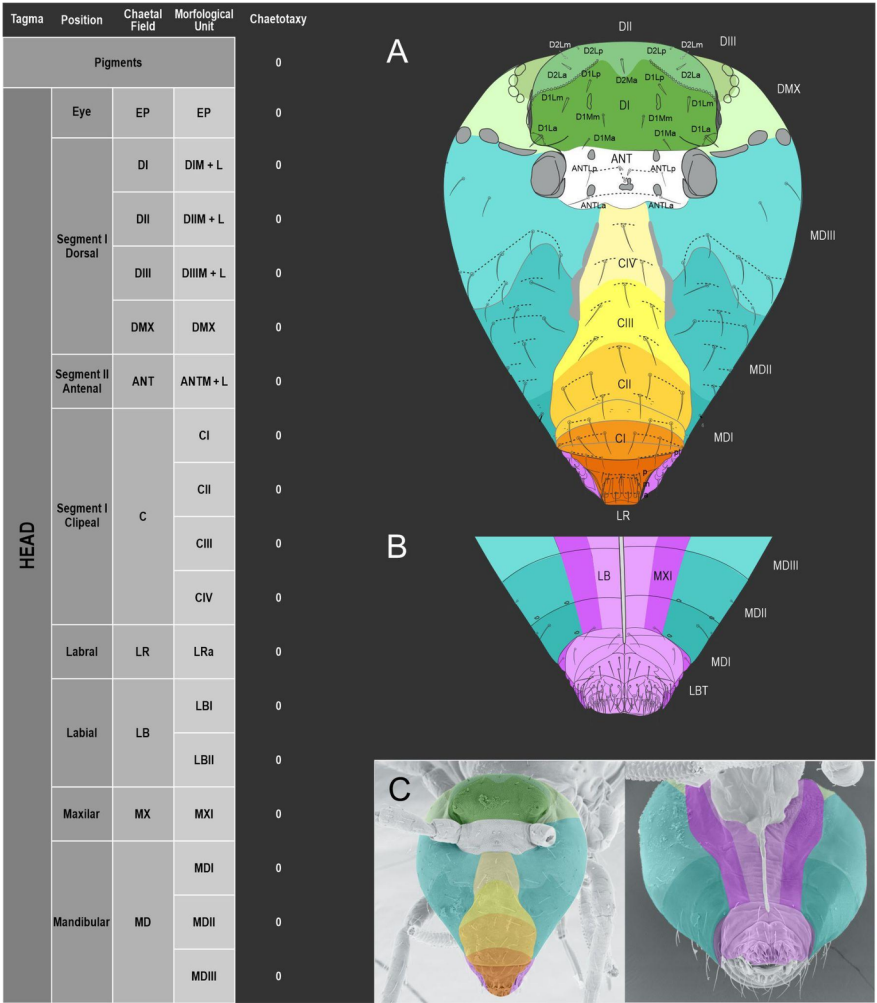


FIGURE 1 *P. fallaciosus* sp. n. cephalic chaetotaxy and descriptive table. A, dorsal cephalic schematic chaetotaxy; B, ventral cephalic schematic chaetotaxy; C, dorsal and ventral cephalic SEM. Abbreviations in the descriptive table as in Table 1.

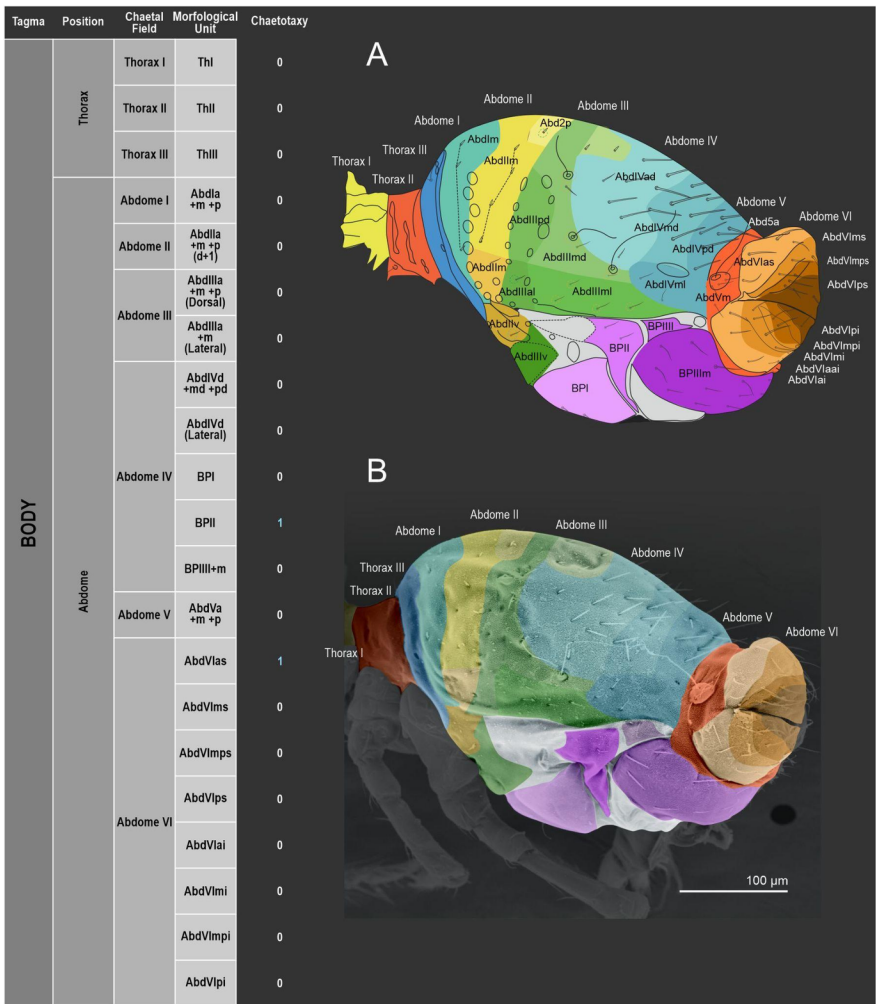


FIGURE 2 *P. fallaciosus* sp. n. body chaetotaxy and descriptive table. A, whole body schematic chaetotaxy; B,

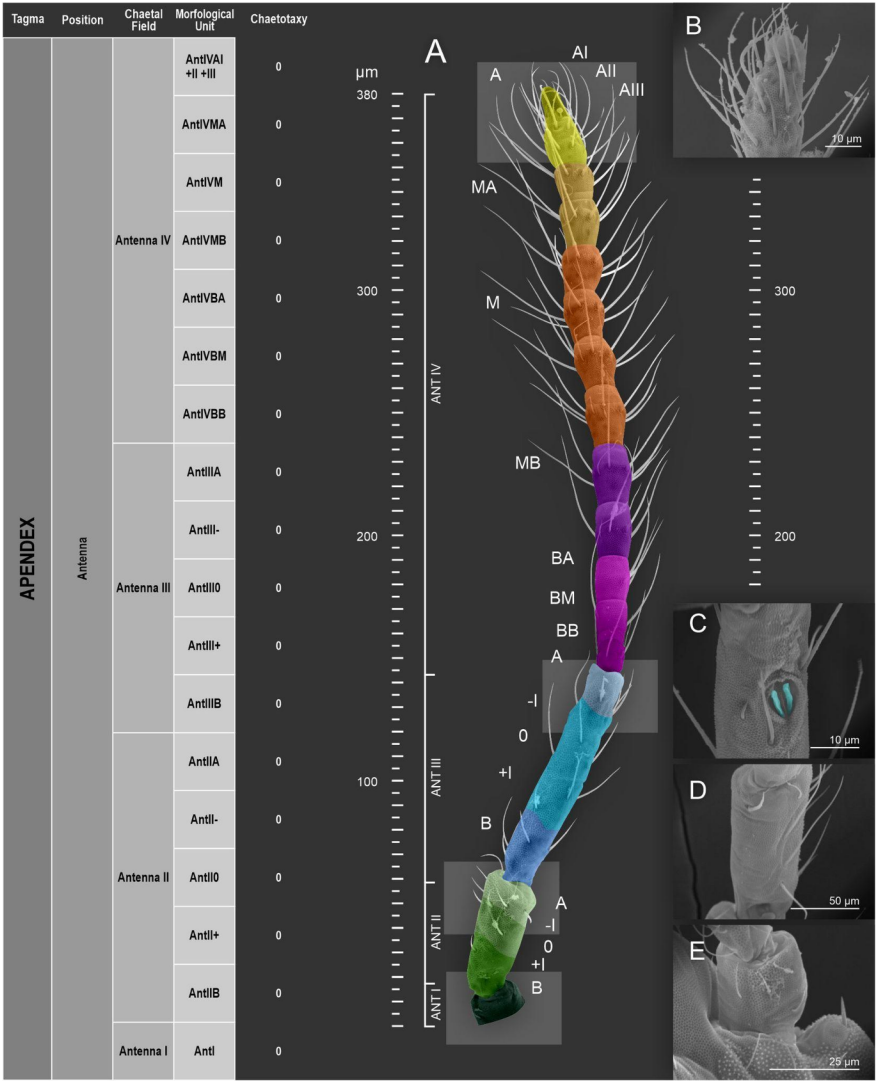


FIGURE 3 *P. fallaciosus* sp. n. antennal chaetotaxy SEM and descriptive table. A, whole antennal chaetotaxy; B, Ant. IV apical subsegment; C

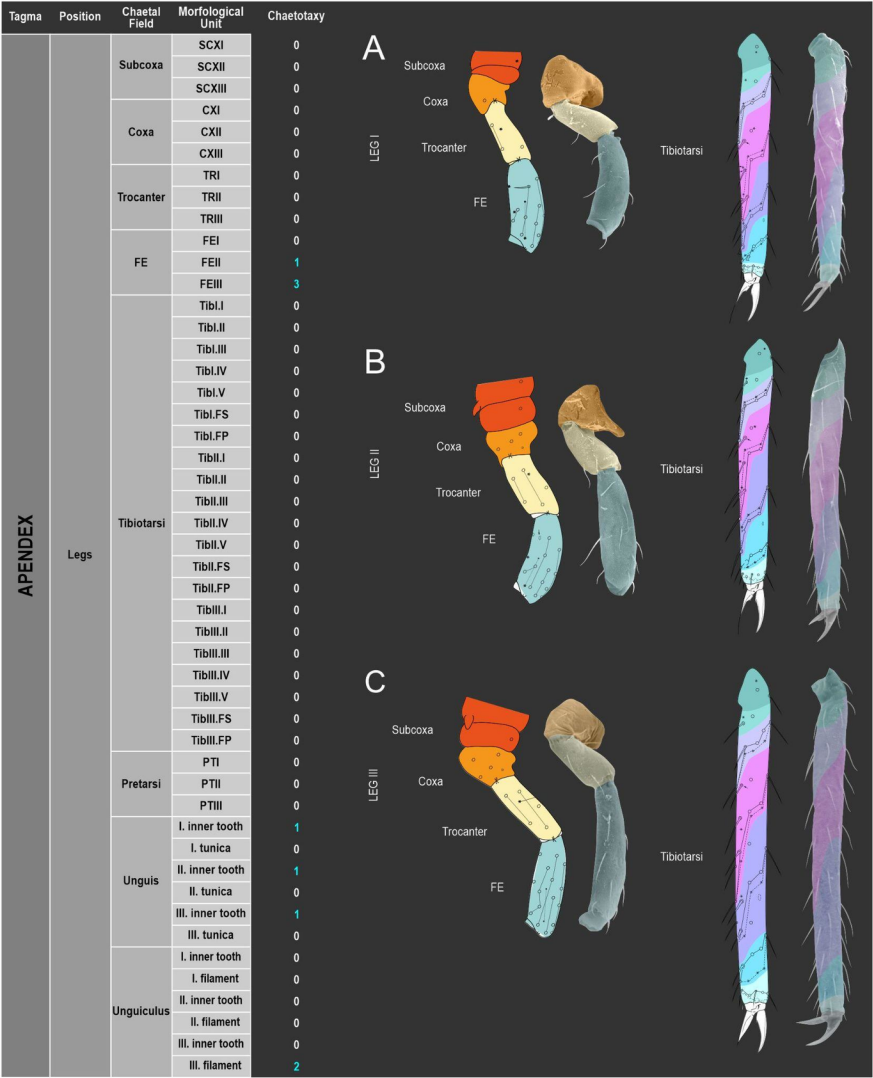


FIGURE 4 *P. fallaciosus* sp. n. legs chaetotaxy and descriptive table. A, leg I; B, leg II; C, leg III. For each represented leg, the left side is a

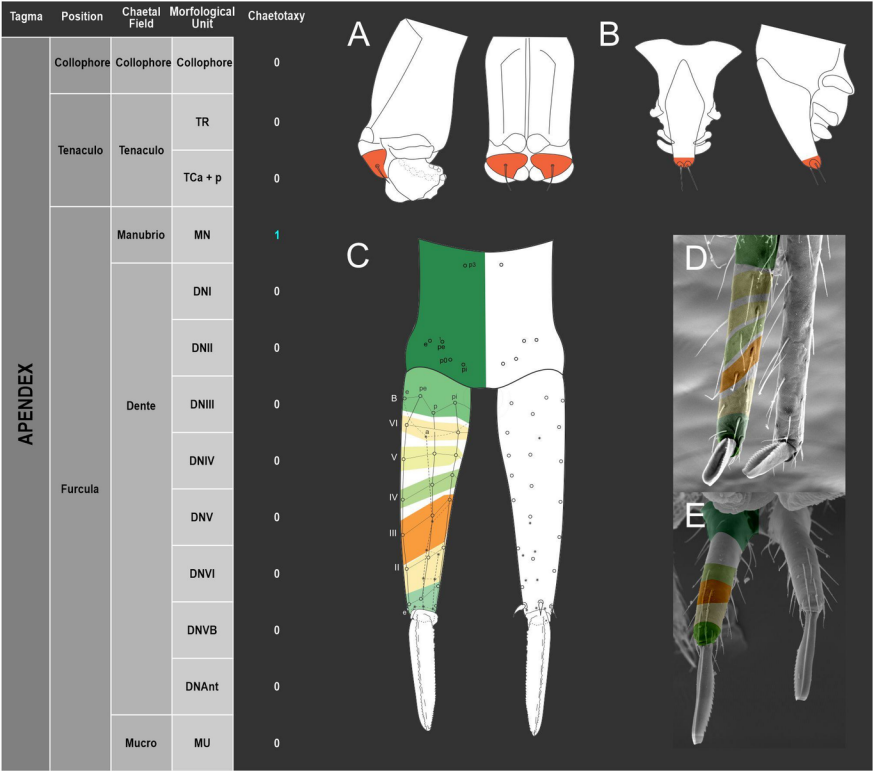


FIGURE 5 *P. fallaciosus* sp. n. Abdominal appendages chaetotaxy. A, ventral tube lateral view and anterior view; B, tenaculum anterior view and lateral view; C, furcula schematic chaetotaxy; D, furcula posterior view SEM; E, furcula anterior view SEM.

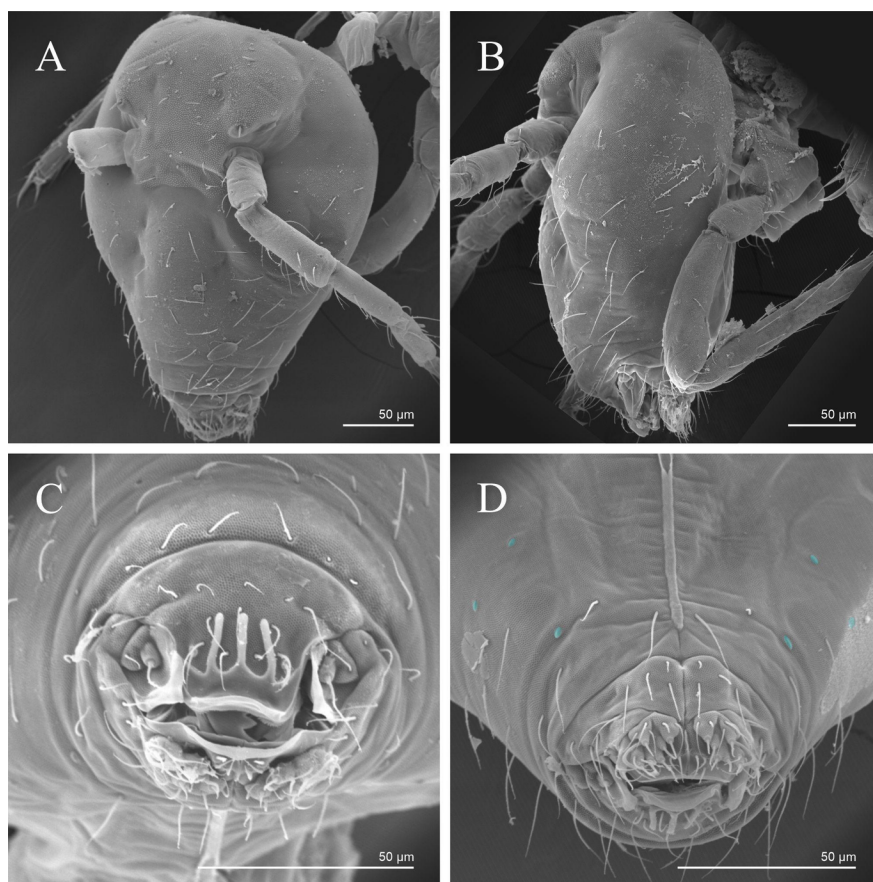


FIGURE 6 *P. fallaciosus* sp. n. SEM of the head showing the chaetotaxy and cuticular landmarks. A, dorsal view; B, lateral view; C, labrum; D, labium and adjacent chaetae (oval organs in blue).

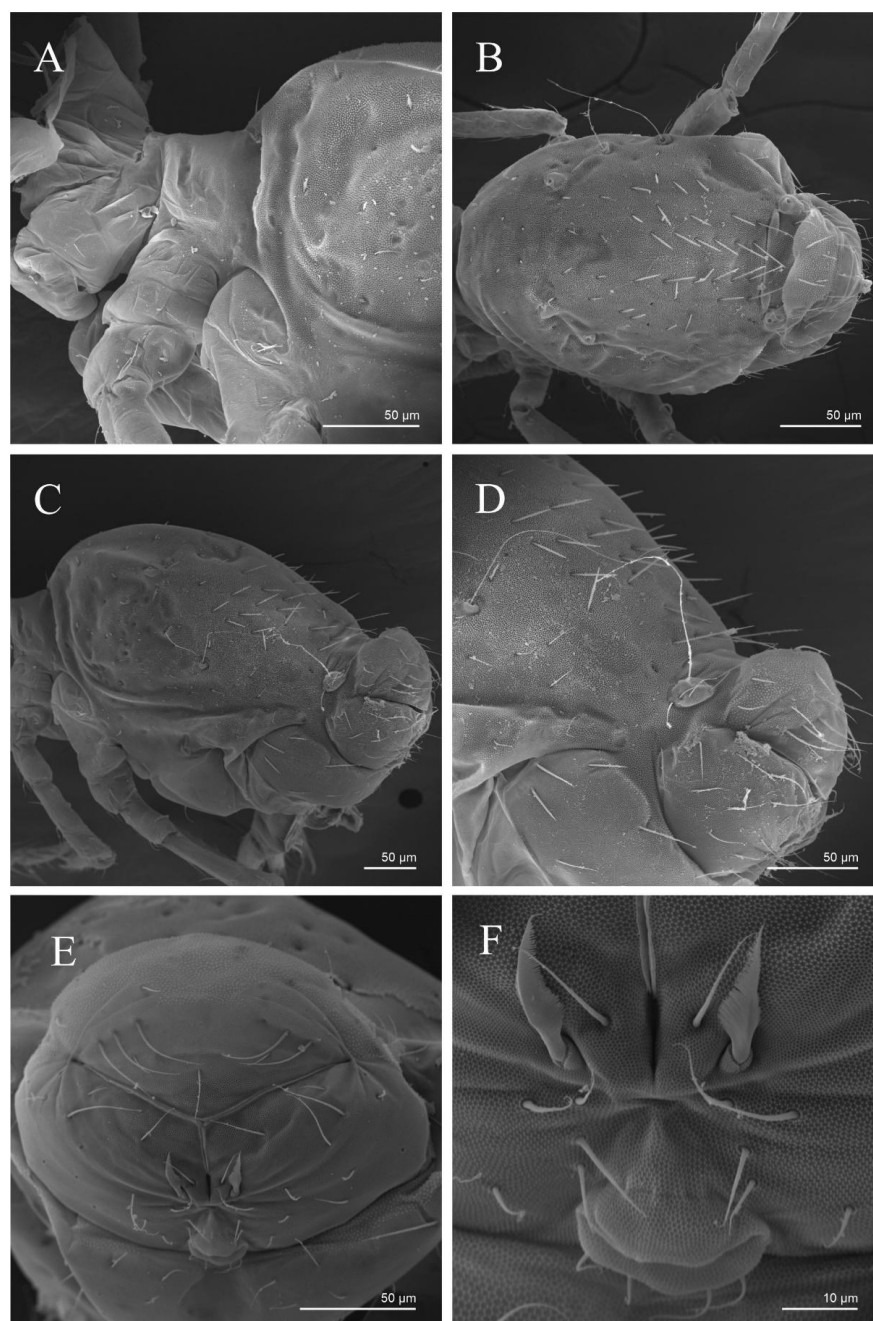


FIGURE 7 *P. fallaciosus* sp. n. SEM of the body showing general chaetotaxy and cuticular landmarks. A, thorax and abd. I-II lateral view; B, whole abdomen dorsal view; C, whole abdomen lateral view, D, abd. IV-VI lateral view; E, female anal valve posterior view; F, female subanal appendages and genital opening.

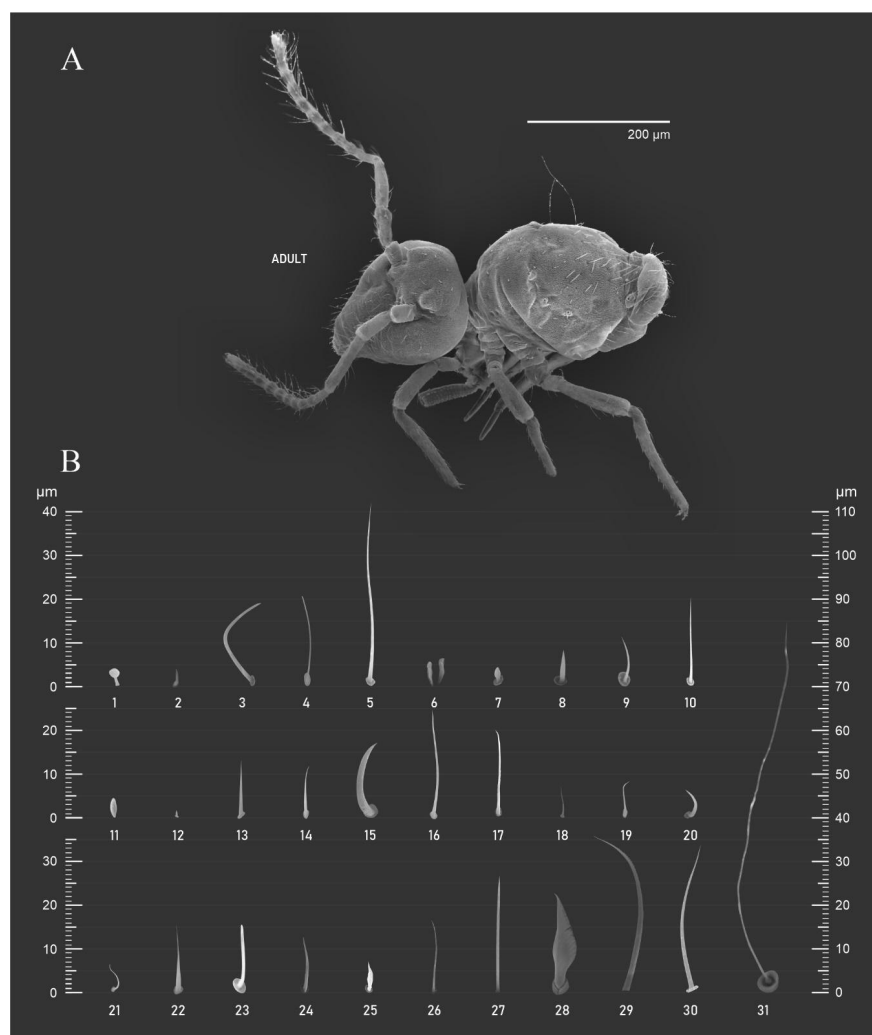


FIGURE 8 Chaetae bank, it is a collection of SEM photographs of different chaetae found along the body, the chaetae are representatives of their shapes and sizes, but not of their position in the body, therefore a given shape and size represented by a photo in the bank may occur in different parts of the body. A, habitus *P. fallaciosus* sp. n. ; B, chaetae bank. 1 – Bulb sensillum (usually found in the apex of ant IV); 2 – Microsensillum (*e.g.* , Aai on the apical organ of Ant. III); 3 – Macrochaeta, curved with blunt tip (often associated to bulb sensillum on the apex of Ant. IV); 4 – Bristlelike mesochaeta; 5 – Smooth macrochaetae; 6 – Microsensillum with blunt apex (occurs in pairs on the Ant. III apical organ); 7 – Semi globular microsensillum; 8 – Spiniform mesochaeta 9 – Smooth curved mesochaeta; 10 – Smooth stout macrochaeta; 11 – Oval organ; 12 – Pre tarsal spine (other groups present a microchaeta instead); 13 – Slender spinelike mesochaeta; 14 – Smooth stout mesochaeta; 15 – Strongly spinelike macrochaeta (*e.g.* , metatrochanteral spine); 16 – Slender smooth macrochaeta; 17 – Smooth strong macrochaeta (similar to 10); 18 – Slender smooth microchaeta; 19 – Smooth stout microchaeta; 20 – Curved spinelike microchaeta; 21 – Bristlelike microchaeta; 22 – Spinelike mesochaeta; 23 – J-shaped blunt mesosensillum; 24 – Smooth mesochaeta; 25 – Heavily spiniform mesochaeta (similar to 8); 26 – Slender smooth mesochaeta; 27 – Smooth broad macrochaeta (similar to 10 and 17, but longer); 28 – Featherlike macrochaeta (subanal appendage); 29 – Broad lanceolate macrochaeta (subanal appendages, sometimes ciliated); 30 – Broad smooth macrochaeta; 31 – Trichobothria

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
HEAD	Pigments			0
	Eye	EP	EP	1
	Segment I Dorsal	DI	DIM + L	0
		DII	DIIM + L	1
		DIII	DIIM + L	0
		DMX	DMX	1
	Segment II Antenal	ANT	ANTM + L	0
	Segment I Clipeal	C	CI	0
			CII	0
			CIII	0
			CIV	0
	Labral	LR	LRa	0
	Labial	LB	LBI	0
			LBII	0
	Maxilar	MX	MXI	0
	Mandibular	MD	MDI	0
			MDII	0
			MDIII	1

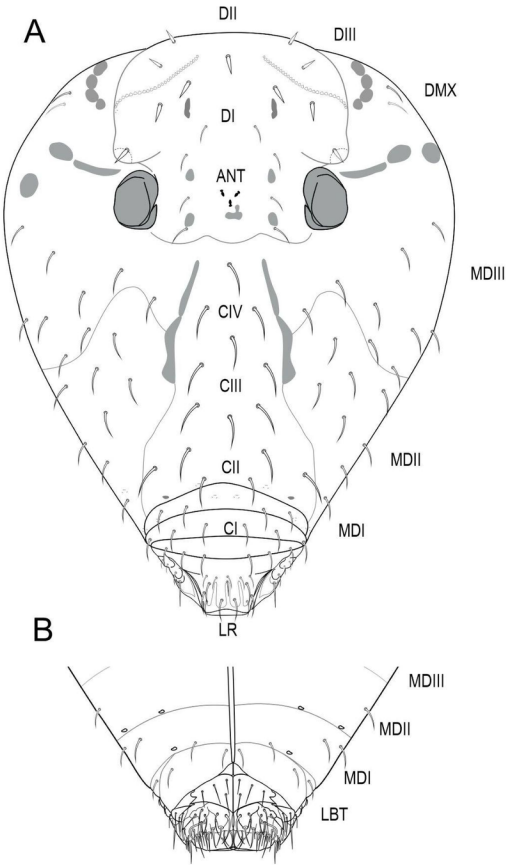


FIGURE 9 *P. hermesi* sp. n. cephalic chaetotaxy and descriptive table. A, dorsal cephalic schematic chaetotaxy; B, ventral cephalic schematic chaetotaxy.

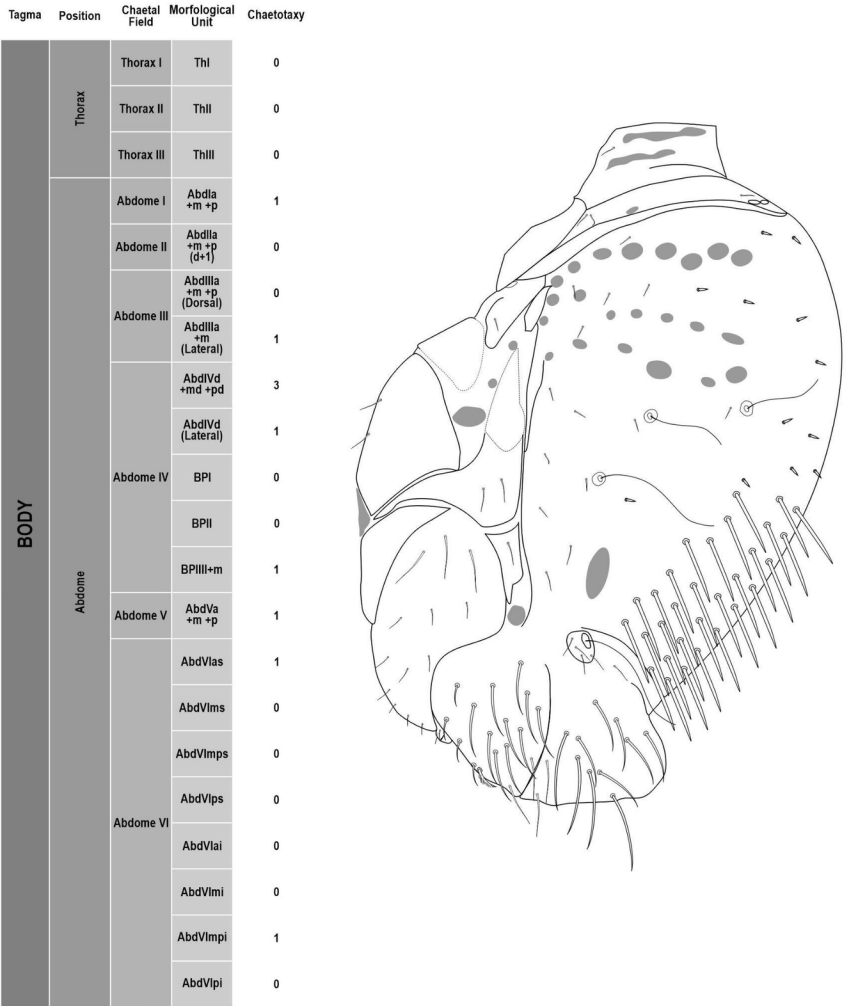


FIGURE 10 *P. hermesi* sp. n. body chaetotaxy and descriptive table.

Tagma	Position	Chaetal Field	Morfolological Unit	Chaetotaxy
APENDEX	Antenna	Antenna IV	AntlVAI +II +III	1
			AntlVMA	1
			AntlVM	1
			AntlVMB	0
			AntlVBA	2
			AntlVBM	2
			AntlVBB	0
		Antenna III	AntlIIA	1
			AntlII-	0
			AntlII0	1
			AntlII+	0
		Antenna II	AntlIIB	1
			AntlIIA	2
			AntlII-	0
			AntlII0	1
			AntlII+	0
			AntlIIB	0
		Antenna I	AntlI	0

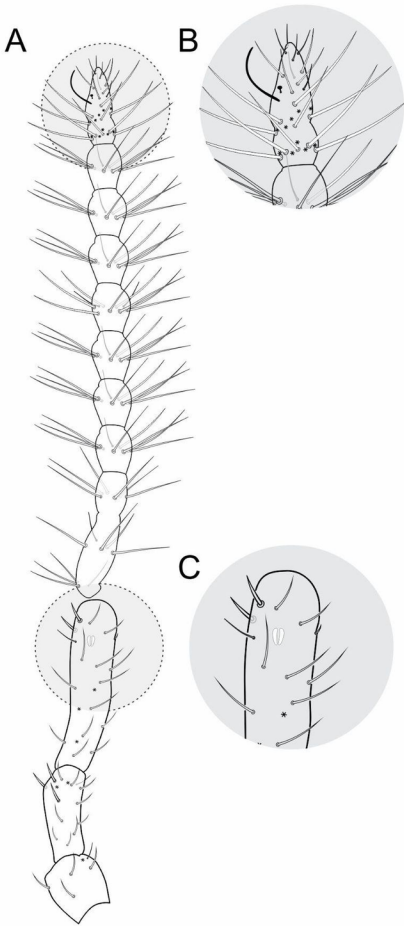


FIGURE 11 *P. hermesi* sp. n. antennal chaetotaxy and descriptive table. A, whole antennal chaetotaxy; B, Ant. IV apical subsegment; C, apical organ on Ant. III.

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
APENDEX	Legs	Subcoxa	SCXI	0
			SCXII	0
			SCXIII	0
		Coxa	CXI	0
			CXII	0
			CXIII	0
		Trochanter	TRI	0
			TRII	0
			TRIII	0
		FE	FEI	2
			FEII	2
			FEIII	3
		Tibiotarsi	Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
			Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
		Pretarsi	PTI	0
			PTII	0
			PTIII	0
		Unguis	I. inner tooth	1
			I. tunica	0
			II. inner tooth	1
			II. tunica	0
			III. inner tooth	1
			III. tunica	0
		Unguiculus	I. inner tooth	1
			I. filament	0
			II. inner tooth	1
			II. filament	1
			III. inner tooth	1
			III. filament	2

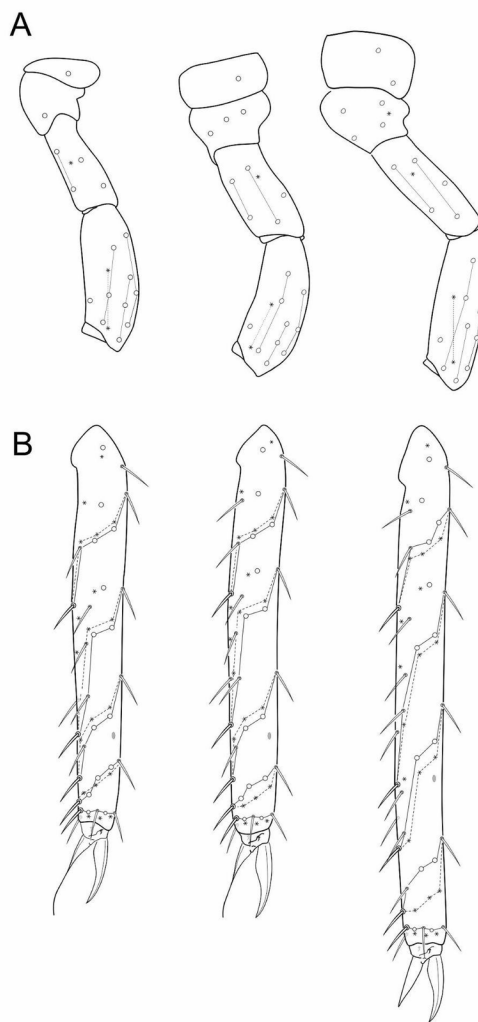


FIGURE 12 *P. hermesi* sp. n. legs chaetotaxy and descriptive table. A, subcoxa, coxa, trochanter and femur, legs I-III respectively; B, tibiotarsus and empodial complex, legs I-III respectively.

Tagma	Structure	Chaeta Field	Morphology Module	Chaetotaxy
APENDEX	Collophore	Collophore	Collophore	0
	Tenaculo	Tenaculo	TR	0
			TCa + p	0
	Furcula	Manubrio	MN	3
		Dente	DNI	0
			DNII	1
			DNIII	1
			DNIV	1
			DNV	1
			DNVI	0
			DNVB	0
			DNAnt	0
		Mucro	MU	1

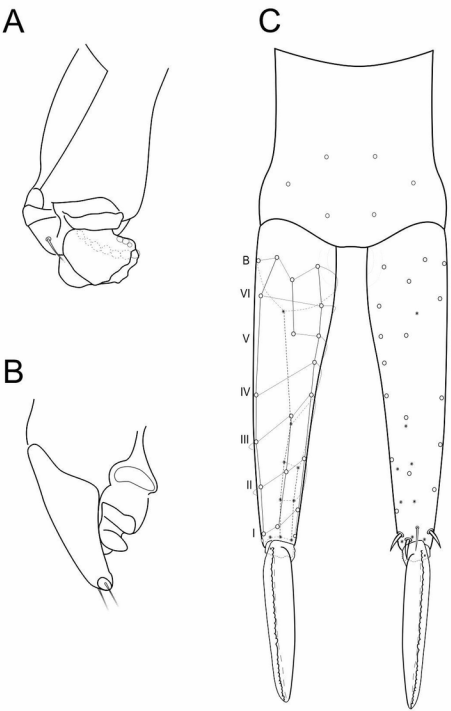


FIGURE 13 *P. hermesi* sp. n. abdominal appendages chaetotaxy. A, ventral tube lateral view; B, tenaculum lateral view; C, furcula chaetotaxy

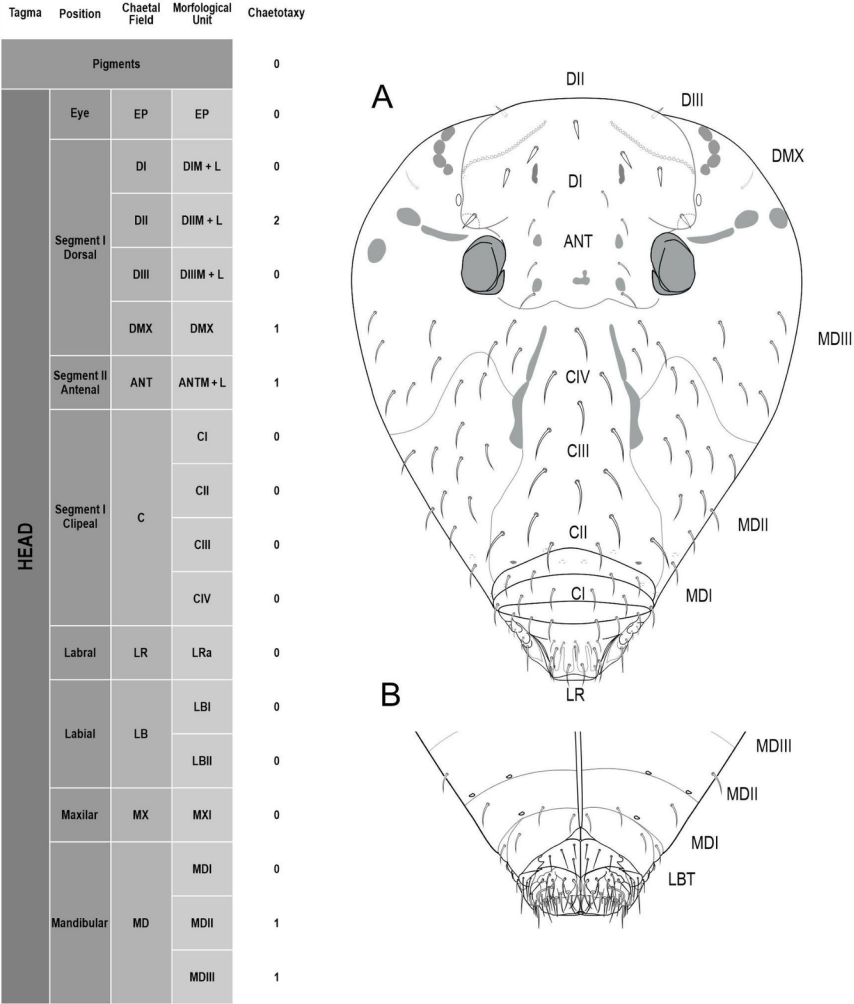


FIGURE 14 *P. atypicus* sp. n. cephalic chaetotaxy and descriptive table. A, dorsal cephalic schematic chaetotaxy; B, ventral cephalic schematic chaetotaxy.

Tagma	Position	Chaetal Field	Morfolological Unit	Chaetotaxy
BODY	Thorax	Thorax I	ThI	0
		Thorax II	ThII	1
		Thorax III	ThIII	0
	Abdome	Abdome I	AbdIa +m +p	1
		Abdome II	AbdIIa +m +p (d+1)	1
		Abdome III	AbdIIIa +m +p (Dorsal)	0
			AbdIIIa +m (Lateral)	0
		Abdome IV	AbdIVd +md +pd	0
			AbdIVd (Lateral)	0
			BPI	0
		Abdome V	BPII	2
			BPIII+m	2
			AbdVa +m +p	0
		Abdome VI	AbdVIas	2
			AbdVIm	0
			AbdVImp	0
			AbdVIps	0
			AbdVIai	0
			AbdVImi	0
			AbdVImpi	2
			AbdVIpi	0



FIGURE 15 *P. atypicus* sp. n. body chaetotaxy and descriptive table.

Tagma	Position	Chaetal Field	Morfolological Unit	Chaetotaxy
APENDEX	Antenna	Antenna IV	AntlVAI +II +III	3
			AntlVMA	0
			AntlVM	0
			AntlVMB	0
			AntlVBA	2
			AntlVBM	3
			AntlVBB	0
		Antenna III	AntlIIA	2
			AntlII-	0
			AntlII0	2
			AntlII+	0
		Antenna II	AntlIIB	1
			AntlIIA	0
			AntlII-	0
			AntlII0	0
		Antenna I	AntlI+	0
			AntlIIB	0
			AntlI	0

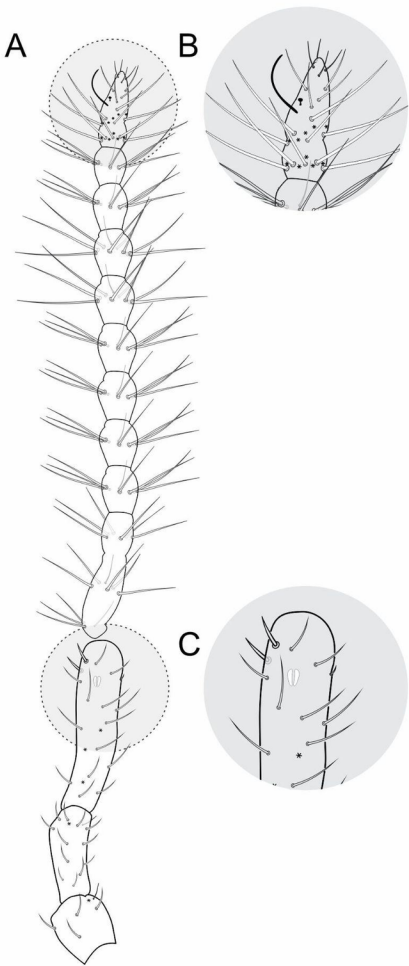


FIGURE 16 *P. atypicus* sp. n. antennal chaetotaxy and descriptive table. A, whole antennal chaetotaxy; B, Ant. IV apical subsegment; C, apical organ on Ant. III.

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
APENDEX	Legs	Subcoxa	SCXI	0
			SCXII	0
			SCXIII	0
		Coxa	CXI	0
			CXII	0
			CXIII	0
		Trochanter	TRI	0
			TRII	0
			TRIII	0
		FE	FEI	3
			FEII	0
			FEIII	2
		Tibia	Tibi I	0
			Tibi II	1
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
			Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
		Tibiotarsi	Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
			Tibi I	0
			Tibi II	0
			Tibi III	0
		Pretarsi	PTI	0
			PTII	0
			PTIII	0
		Unguis	I. inner tooth	1
			I. tunica	0
			II. inner tooth	1
			II. tunica	0
			III. inner tooth	1
			III. tunica	0
		Unguiculus	I. inner tooth	0
			I. filament	0
			II. inner tooth	0
			II. filament	0
			III. inner tooth	0
			III. filament	2

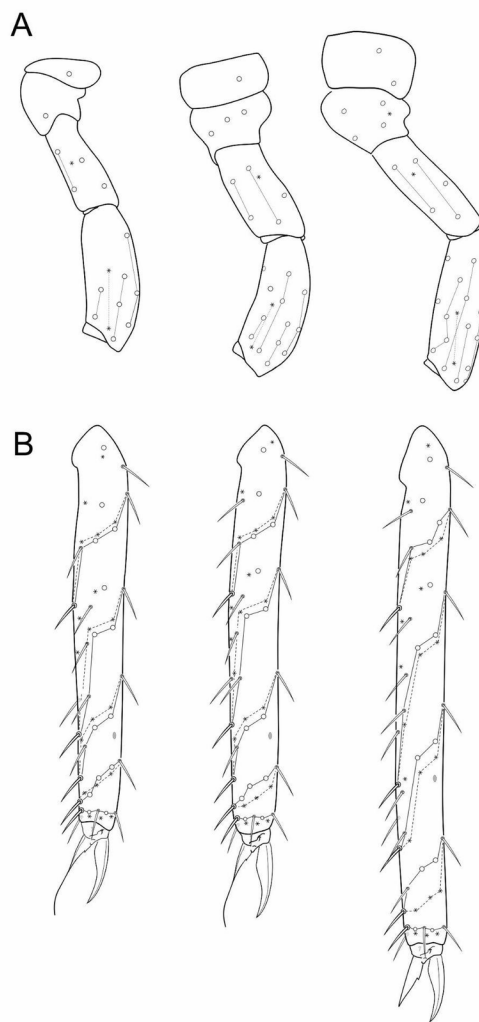


FIGURE 17 *P. atypicus* sp. n. legs chaetotaxy and descriptive table. A, subcoxa, coxa, trochanter and femur, legs I-III respectively; B, tibiotarsus and empodial complex, legs I-III respectively.

Tagma	Structure	Chaetal Field	Morfolology Module	Chaetotaxy
APENDEX	Collophore	Collophore	Collophore	0
	Tenaculo	Tenaculo	TR	0
			TCa + p	0
	Furcula	Manubrio	MN	2
		Dente	DNI	0
			DNII	0
			DNIII	0
			DNIV	0
			DNV	0
			DNVI	0
			DNVB	0
			DNAnt	0
		Mucro	MU	0

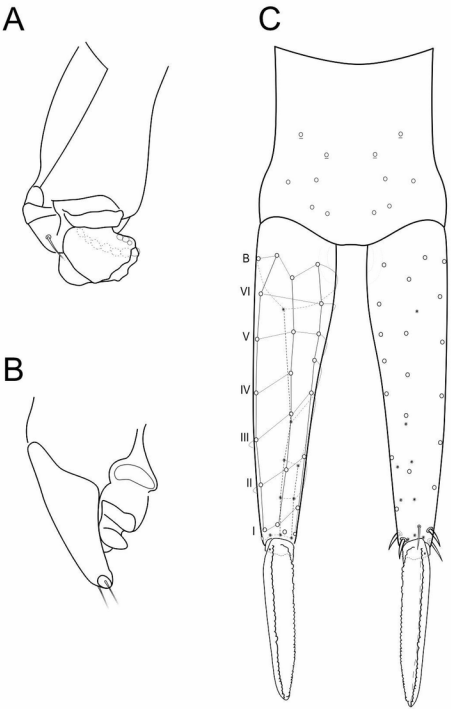


FIGURE 18 *P. atypicus* sp. n. abdominal appendages chaetotaxy. A, ventral tube lateral view; B, tenaculum lateral view; C, furcula chaetotaxy and mucronal lamellae.

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
HEAD	Pigments			0
	Eye	EP	EP	1
	Segment I Dorsal	DI	DIM + L	0
		DII	DIIM + L	0
		DIII	DIIM + L	0
		DMX	DMX	0
	Segment II Antenal	ANT	ANTM + L	0
	Segment I Clipeal	C	CI	0
			CII	0
			CIII	0
			CIV	0
	Labral	LR	LRa	0
	Labial	LB	LBI	0
			LBI	0
	Maxilar	MX	MXI	0
	Mandibular	MD	MDI	0
			MDII	0
			MDIII	0

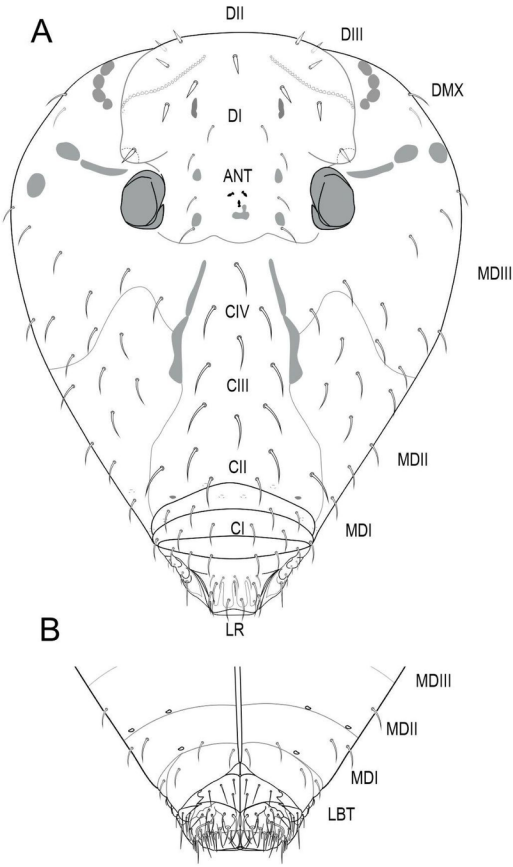


FIGURE 19 *P. ritaleae* sp. n. cephalic chaetotaxy and descriptive table. A, dorsal cephalic schematic chaetotaxy; B, ventral cephalic schematic chaetotaxy.

Tagma	Position	Chaetai Field	Morfological Unit	Chaetotaxy
BODY	Thorax	Thorax I	ThI	0
		Thorax II	ThII	0
		Thorax III	ThIII	0
	Abdome	Abdome I	AbdIa +m +p	1
		Abdome II	AbdIIa +m +p (d+1)	0
		Abdome III	AbdIIIa +m +p (Dorsal)	0
			AbdIIIa +m (Lateral)	0
		Abdome IV	AbdIVd +md +pd	1
			AbdIVd (Lateral)	2
			BPI	0
			BPII	1
			BPIII+m	0
		Abdome V	AbdVa +m +p	0
		Abdome VI	AbdVIas	3
			AbdVIms	0
			AbdVImps	0
			AbdVIps	0
			AbdVIai	0
			AbdVImi	0
			AbdVImpi	3
			AbdVIpi	0

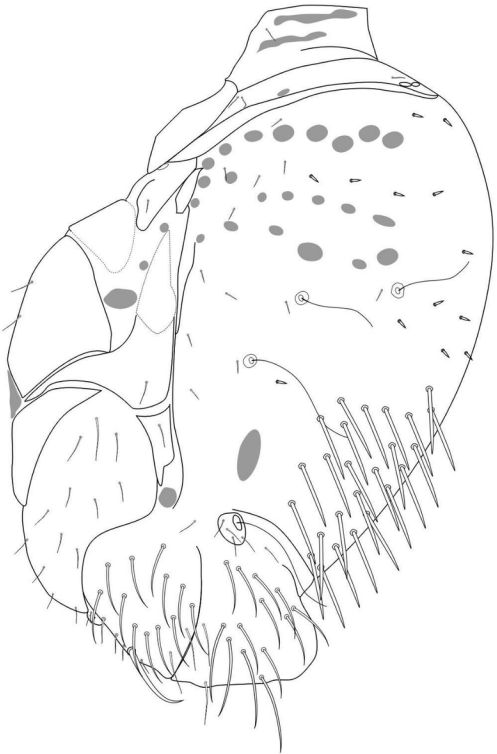


FIGURE 20 *P. ritaleeae* sp. n. body chaetotaxy and descriptive table.

Tagma	Position	Chaetal Field	Morfolological Unit	Chaetotaxy
APENDEX	Antenna	Antenna IV	AntIVAI +II +III	3
			AntIVMA	0
			AntIVM	0
			AntIVMB	0
			AntIVBA	2
			AntIVBM	2
			AntIVBB	0
		Antenna III	AntIIIA	0
			AntIIl-	0
			AntIIl0	3
			AntIIl+	0
		Antenna II	AntIIIB	1
			AntIIIA	2
			AntIIl-	0
			AntIIl0	2
			AntIIl+	0
			AntIIIB	0
		Antenna I	AntI	0

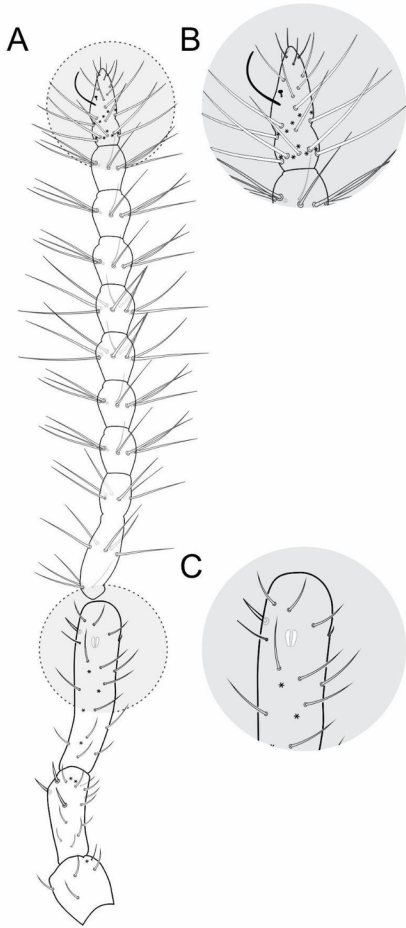


FIGURE 21 *P. ritalecae* sp. n. antennal chaetotaxy and descriptive table. A, whole antennal chaetotaxy; B, Ant. IV apical subsegment; C, apical organ on Ant. III.

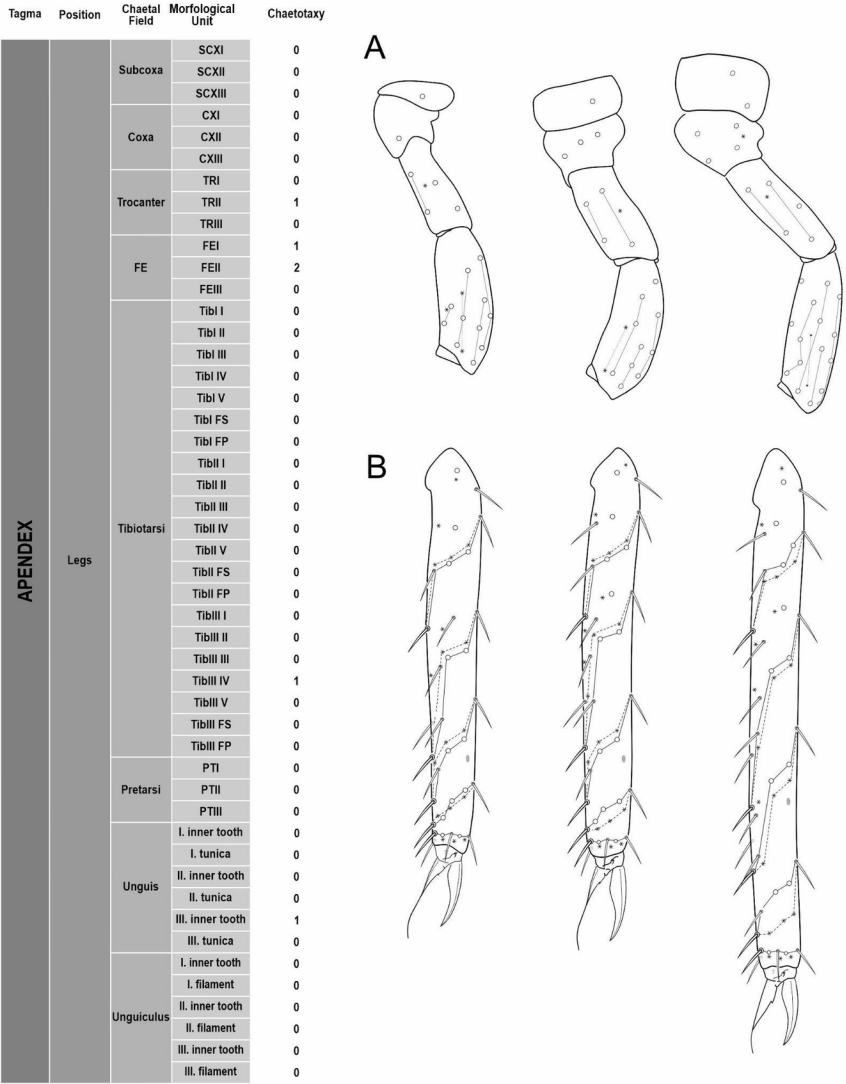


FIGURE 22 *P. ritalecae* sp. n. legs chaetotaxy and

Tagma	Structure	Chaetal Field	Morphology Module	Chaetotaxy
APENDEX	Collophore	Collophore	Collophore	0
	Tenaculo	Tenaculo		0
			TCa + p	0
	Furcula	Manubrio	MN	0
		Dente	DNI	0
			DNII	0
			DNIII	0
			DNIV	0
			DNV	0
			DNVI	0
			DNVB	0
			DNAnt	0
		Mucro	MU	1

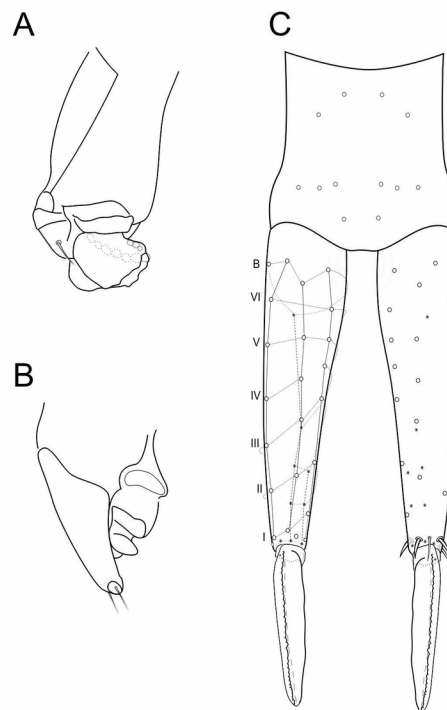


FIGURE 23 *P. ritaleeae* sp. n. abdominal appendages chaetotaxy. A, ventral tube lateral view; B, tenaculum lateral view; C, furcula chaetotaxy and mucronal lamellae. Circle with an underline means chaeta present or absent.

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
HEAD	Pigments			0
	Eye	EP	EP	0
	Segment I Dorsal	DI	DIM + L	0
		DII	DIIM + L	1
		DIII	DIIM + L	0
		DMX	DMX	0
	Segment II Antenal	ANT	ANTM + L	0
	Segment I Clipeal	C	CI	0
			CII	0
			CIII	0
			CIV	0
	Labral	LR	LRa	0
	Labial	LB	LBI	0
			LBII	0
	Maxilar	MX	MXI	0
	Mandibular	MD	MDI	0
			MDII	0
			MDIII	0

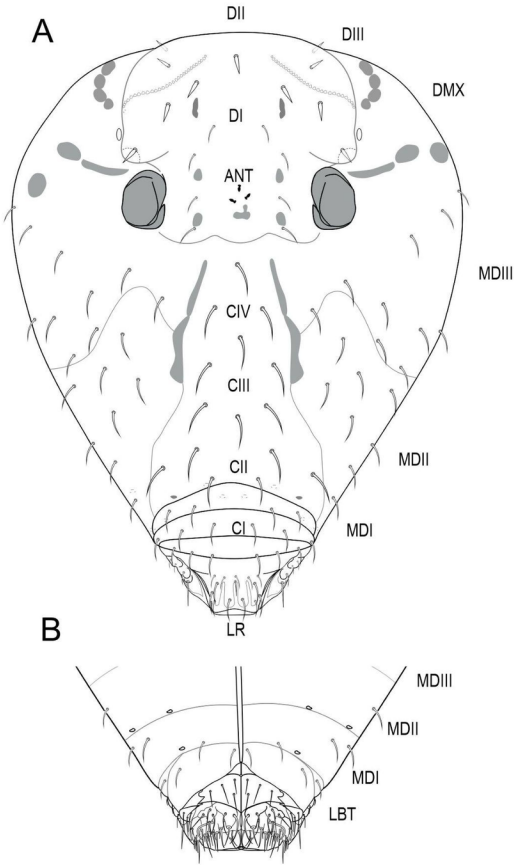


FIGURE 24 *P. ironicus* sp. n. cephalic

Tagma	Position	Chaetal Field	Morfological Unit	Chaetotaxy
BODY	Thorax	Thorax I	ThI	0
		Thorax II	ThII	0
		Thorax III	ThIII	0
	Abdome	Abdome I	AbdIa +m +p	0
		Abdome II	AbdIIa +m +p (d+1)	1
		Abdome III	AbdIIIa +m +p (Dorsal)	0
			AbdIIIa +m (Lateral)	0
		Abdome IV	AbdIVd +md +pd	2
			AbdIVd (Lateral)	1
			BPI	0
		Abdome V	BPII	1
			BPIII+m	1
			AbdVa +m +p	0
		Abdome VI	AbdVIas	0
			AbdVIms	0
			AbdVImps	0
			AbdVIps	0
			AbdVIai	0
			AbdVImi	0
			AbdVImpi	3
			AbdVIpi	0

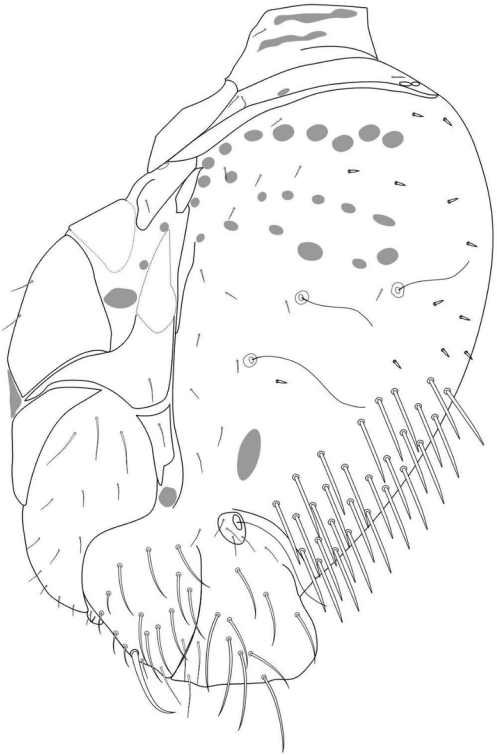


FIGURE 25 *P. ironicus* sp. n. body chaetotaxy and descriptive table.

Tagma	Position	Chaetal Field	Morfolological Unit	Chaetotaxy
APENDEX	Antenna	Antenna IV	AntIVAI +II +III	2
			AntIVMA	2
			AntIVM	0
			AntIVMB	0
			AntIVBA	1
			AntIVBM	1
			AntIVBB	0
		Antenna III	AntIIIA	3
			AntIIl-	0
			AntIIl0	3
			AntIIl+	0
		Antenna II	AntIIIB	0
			AntIIA	1
			AntIIl-	0
			AntIIl0	2
		Antenna I	AntIIl+	0
			AntIIIB	0
			AntI	1

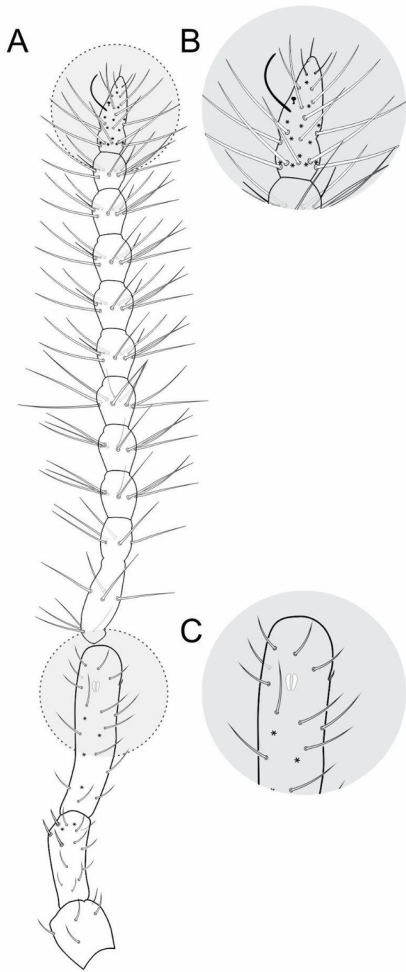


FIGURE 26 *P. ironicus* sp. n. antennal chaetotaxy and descriptive table. A, whole antennal chaetotaxy; B, Ant. IV apical subsegment; C, apical organ on Ant. III.

Tagma	Position	Chaetal Field	Morphological Unit	Chaetotaxy
APENDEX	Legs	Subcoxa	SCXI	0
			SCXII	0
			SCXIII	0
		Coxa	CXI	0
			CXII	0
			CXIII	0
		Trochanter	TRI	0
			TRII	0
			TRIII	0
		FE	FEI	1
			FEII	1
			FEIII	1
		Tibiotarsi	Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
			Tibi I	0
			Tibi II	0
			Tibi III	0
			Tibi IV	0
			Tibi V	0
			Tibi FS	0
			Tibi FP	0
		Pretarsi	PTI	0
			PTII	0
			PTIII	0
		Unguis	I. inner tooth	1
			I. tunica	0
			II. inner tooth	1
			II. tunica	0
			III. inner tooth	1
		Unguiculus	III. tunica	0
			I. inner tooth	0
			I. filament	0
			II. inner tooth	0
			II. filament	0
			III. inner tooth	1
			III. filament	1

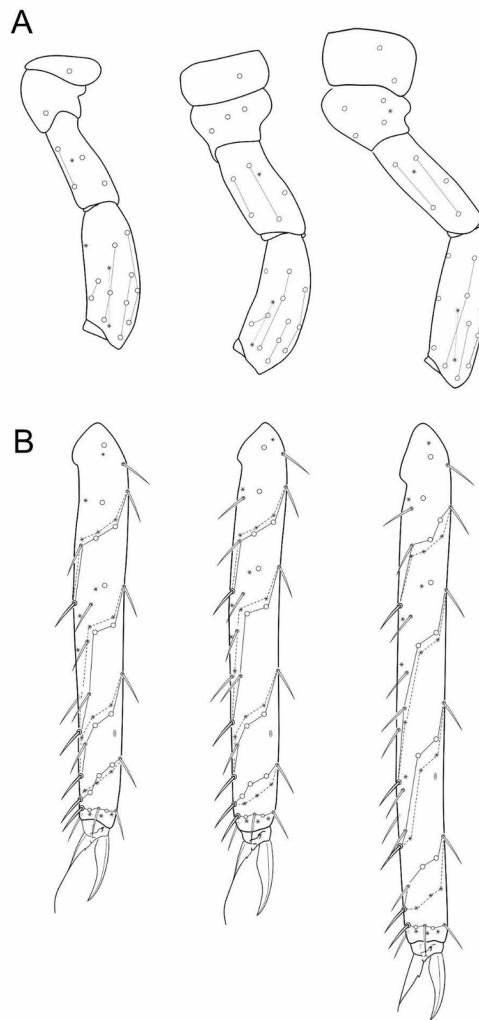


FIGURE 27 *P. ironicus* sp. n. legs chaetotaxy and descriptive table. A, subcoxa, coxa, trochanter and femur, legs I-III respectively; B, tibiotarsus and empodial

Tagma	Structure	Chaetal Field	Morphology Module	Chaetotaxy
APENDEX	Collophore	Collophore	Collophore	0
	Tenaculo	Tenaculo	TR	0
			TCa + p	0
	Furcula	Manubrio	MN	1
		Dente	DNI	0
			DNII	0
			DNIII	0
			DNIV	0
			DNV	0
			DNVI	0
			DNVB	0
			DNAnt	0
		Mucro	MU	0

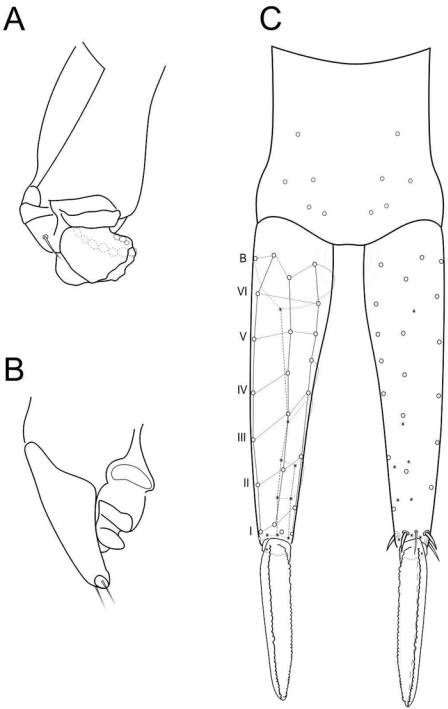


FIGURE 28 *P. ironicus* sp. n. abdominal appendages chaetotaxy. A, ventral tube lateral view; B, tenaculum lateral view; C, furcula chaetotaxy and mucronal lamellae. Circle with an underline means chaeta present or absent.

APPENDIX 1

The following list of characters is presented in a sequence from the first cephalic segment to the sixth abdominal segment. It is a perfect match of Table 1 and is also represented by an individualized table in each species description plate. This list presents the observed conditions of each character included in our study, a total of 115 morphological characters are listed.

Color pattern

Pigments:

0 – Absent

1 – Present

Body color:

0 – White

1 – Pale yellow

Head

Eye number:

0 – 1+1

1 – 0+0

2 - 2+2

Dorsal cephalic chaetotaxy

Area DI total chaetae M + L:

0 - 5+5 4(9)6(8)

1 - Different combination

Area DII total chaetae M + L:

0 - 3+1+3 7(8)

1 - 2+1+2 5(8)

2 - 1+1+1 3(8)

Area DIII total chaetae M + L:

0 - 0+0

1 - Different combination

Clypeal chaetotaxy

Clypeal area CI:

0 - 3+3 6(10)

1 - Different combination

Clypeal area CII:

0 - 5+1+5 11(10)

1 - Different combination

Clypeal area CIII:

0 - 2+1+2 5(10)

1 - Different combination

Clypeal area CIV:

0 - 1+1+1 3(10)

1 - Different combination

Labral chaetotaxy

Labral formula a + m + p + pl:

0 - 4+5+5+6 20(10)

1 - Different combination

Antennal area

Antennal area chaetotaxy M + L:

0 - 3+1+3 4(9)3(7)

1 - 2+2 4(9)

Mandibular segment chaetotaxy

Area MDI (dorsal+ventral):

0 – 2+2+1+1ov 4(10)2(11)

1 – Different combination

Area MDII (d+v):

0 – 8+8+2+2ov 16(10)4(11)

1 – 12+12 2+2ov 24(10)4(11)

Area MDIII (d+v):

0 – 10+10 20(10)

1 – 9+9 18(10)

Maxilar segment chaetotaxy

Areas DMX and MX total chaetae

0 – 2+2 4(10)

1 – 1+1 2(10)

Labial segment chaetotaxy

Labial triangle total chaetae:

0 – 4+4 8(10)

1 – Different combination

Labial remaining chaetae:

0 – 2+2 4(10)

1 – Different combination

Body

Thoracic chaetotaxy

Thorax I total chaetae:

0 – 0+0

1 – at least 1+1

Thorax II total chaetae:

0 – 1+1 2(24)

1 – 0+0

2 – Different combination

Thorax III total chaetae:

0 – 3+3 2(24)2(26)2(23)

1 – Different combination

Abdominal chaetotaxy

Abdome I a + m + p total chaetal:

0 – 3+3 6(25)

1 – 3+3 4(25)2(26)

Abdome II a + m + p (d + l) total chaetae:

0 – 8+8 8(25)8(26)

1 – 7+7 8(25)6(26)

Abdome III a + m + p (dorsal) total chaetae:

0 – 10+10 8(25)6(26)6(31)

1 – Different combination

Abdomen III a + m (lateral) total chaetae:

0 – 5+5 10(26)

1 – 5+5 8(26)2(23)

Abdomen IV ad + md + pd total chaetae (dorsal):

0 – 17+17 4(25)30(27)

1 – 27+27 4(25)50(27)

2 – 28+28 56(27)

3 – 30+30 60(27)

Abdomen IV total chaetae (lateral):

0 – 3+3 6(26)

1 – 2+2 4(26)

2 – 0+0

Abdomen IV area BPI total chaetae:

0 – 2+2 4(26)

1 – Different combination

Abdomen IV area BP II total chaetae:

0 – 2+2 4(26)

1 – 1+1 2(26)

2 – 0+0

Abdomen area BP III l + m total chaetae:

0 – 13+13 10(26)16(18)

1 – 13+13 6(26)20(18)

2 – 13+13 6(17)16(26)4(18)

Abdomen V a + m + p total chaetae:

0 – 7+7 12(26)2(31)

1 – 6+6 10(26)2(31)

Abdomen VI **as** total chaetae:

0 – 3+3 6(26)

1 – 4+4 8(26)

2 – 6+6 12(26)

3 – 7+7 14 (26)

Abdomen VI **ms** total chaetae:

0 – 2+2 4(26)

1 – Different combination

Abdomen VI **mps** total chaetae:

0 – 3+1+3 7(30)

1 – Different combination

Abdomen VI **ps** total chaetae:

0 – 1+1+1 3(26)

1 – Different combination

Abdomen VI **aai** + **ai** total chaetae:

0 – 8+8 16(26)

1 – Different combination

Abdomen VI **mi** total chaetae:

0 – 3+3 6(26)

1 – Different combination

Abdomen VI **mpi** total chaetae:

0 – 4+4 6(26)2(28)

1 – 5+5 8(26)2(28)

2 – 4+4 6(26)2(29)

3 – 5+5 8(26)2(29)

Abdomen VI **pi** total chaetae:

0 – 3+3 6(26)

1 – Different combination

Appendages

Antenna

Antenna I total chaetae:

0 – 6 5(9)1(21)

1 – 5 4(9)1(21)

Antenna II whorl **A** total chaetae:

0 – 7 6(9)1(21)

1 – 7 2(20)1(21)4(9)

2 – 8 2(20)1(21)5(9)

Antenna II whorls - , **0** and + total chaetae:

0 – 3 3(9)

1 – 3 1(20)2(9)

2 – 4 1(20)3(9)

Antenna II whorl **B** total chaetae:

0 – 4 4(9)

1 – Different combination

Antenna III whorl **A** total chaetae:

0 – 8 2(6)1(2)1(21)1(20)3(9)

1 – 8 2(6)1(2)1(21)2(20)2(9)

2 – 8 2(6)1(2)2(20)3(9)

3 – 8 2(6)1(2)5(9)

Antenna III whorls - , **0** and + total chaetae:

0 – 8 4(9)4(5)

1 – 9 1(9)8(10)

2 – 9 9(10)

3 – 10 10(10)

Antenna III whorl **B** total chaetae:

0 – 4 4(9)

1 – 5 5(9)

Antenna IV subsegments:

0 – 10 subsegments

1 – 9 subsegments

2 – Less than 9 subsegments

3 – More than 10 subsegments

Antenna IV **AI** + **AII** + **AIII** total chaetae:

0 – 34 1(3)1(1)2(4)6(10)24(5)

1 – 32 1(3)1(1)2(4)8(10)20(5)

2 – 31 1(3)1(1)5(10)24(5)

3 – 30 1(3)1(1)8(10)20(5)

Antenna IV **MA** total chaetae per whorl:

0 – 8 1(4)7(5)

1 – 9 1(4)8(5)

2 – 10 2(4)8(5)

Antenna IV **M** total chaetae per whorl:

0 – 9 1(4)8(5)

1 – 10 2(4)8(5)

Antenna IV **MB** total chaetae per whorl:

0 – 8 1(4)7(5)

1 – 9 1(4)8(5)

Antenna IV **BA** total chaetae:

0 – 3 3(5)

1 – 5 5(5)

2 – 6 6(5)

Antenna IV **BM** total chaetae:

0 – 3 3(5)

1 – 4 4(5)

2 – 5 5(5)

3 – 6 5(5)1(4)

Antenna IV **BB** total chaetae:

0 – 4 4(5)

1 – Different combination

Legs

Subcoxa I total chaetae:

0 – 1 1(26)

1 – Different combination

Subcoxa II total chaetae:

0 – 1 1(26)

1 – Different combination

Subcoxa III total chaetae:

0 – 2 2(26)

1 – Different combination

Coxa I total chaetae:

0 – 1 1(26)

1 – Different combination

Coxa II total chaetae:

0 – 3 3(26)

1 – Different combination

Coxa III total chaetae:

0 – 5 5(26)

1 – Different combination

Trochanter I total chaetae:

0 – 5 5(26)

1 – Different combination

Trochanter II total chaetae:

0 – 6 6(26)

1 – 5 5(26)

Trochanter III total chaetae:

0 – 6 1(15)5(26)

1 – Different combination

Femur I total chaetae:

0 – 15 15(26)

1 – 14 14(26)

2 – 12 12(26)

3 – 10 10(26)

Femur II total chaetae:

0 – 15 13(26)2(13)

1 – 14 14(26)

2 – 12 12(26)

Femur III total chaetae:

0 – 18 18(26)

1 – 14 13(26)1(21)

2 – 14 14(26)

3 – 12 12(26)

Tibiotarsus I whorl I total chaetae:

0 – 9 1(13)8(14)

1 – Different combination

Tibiotarsus I whorl II total chaetae:

0 – 8 1(13)7(16)

1 – 9 1(13)8(16)

Tibiotarsus I whorl III total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus I whorl IV total chaeta:

0 – 14 1(13)13(16)

1 – 12 1(13)11(16)

Tibiotarsus I whorl V total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus I **FS** area total chaetae:

0 – 2 2(16)

1 – Different combination

Tibiotarsus I **FP** area total chaetae:

0 – 3 3(16)

1 – Different combination

Tibiotarsus II whorl I total chaetae:

0 – 9 1(13)8(14)

1 – Different combination

Tibiotarsus II whorl II total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus II whorl III total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus II whorl IV total chaetae:

0 – 14 1(13)13(16)

1 – Different combination

Tibiotarsus II whorl V total chaeta:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus II **FS** area total chaetae:

0 – 3 3(16)

1 – Different combination

Tibiotarsus II **FP** area total chaetae:

0 – 3 3(16)

1 – Different combination

Tibiotarsus III whorl I total chaetae:

0 – 9 1(13)8(14)

1 – Different combination

Tibiotarsus III whorl II total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus III whorl III total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus III whorl IV total chaetae:

0 – 14 2(13)12(16)

1 – Different combination

Tibiotarsus III whorl V total chaetae:

0 – 8 1(13)7(16)

1 – Different combination

Tibiotarsus III **FS** area total chaetae:

0 – 3 3(16)

1 – Different combination

Tibiotarsus III **FP** area total chaetae:

0 – 3 3(16)

1 – Different combination

Pretarsus I pre tarsal chaetae:

0 – 1+1 2(12)

1 – Different combination

Pretarsus II pre tarsal chaetae:

0 – 1+1 2(12)

1 – Different combination

Pretarsus III pre tarsal chaetae:

0 – 1+1 2(12)

1 – Different combination

Unguis I inner tooth:

0 – present

1 – absent

Unguis I tunica:

0 – absent

1 – present

Unguis II inner tooth:

0 – present

1 – absent

Unguis II tunica:

0 – absent

1 – present

Unguis III inner tooth:

0 – present

1 – absent

Unguis III tunica:

0 – absent

1 – present

Unguiculus I apical filament:

0 – exceeding the unguis tip

1 – reaching the unguis tip

Unguiculus I empodial tooth:

0 – present

1 – absent

Unguiculus II apical filament:

0 – exceeding the unguis tip

1 – reaching the unguis tip

Unguiculus II empodial tooth:

0 – present

1 – absent

Unguiculus III apical filament:

0 – exceeding the unguis tip

1 – reaching the unguis tip

2 – shorter than unguis tip

Unguiculus III empodial tooth:

0 – present

1 – absent

Collophore total chaetae:

0 – 1+1 2(19)

1 – different combination

Tenaculum rami:

0 – 3+3 teeth

1 – different combination

Tenaculum Corpus (a+p):

0 – 2 2(18)

1 – different combination

Manubrium total chaetae:

0 – 6+6 12(16)

1 – 5+5 10(16)

2 – 4+4 8(16)

3 – 3+3 4(16)2(22)

Dental whorl I total chaetae:

0 – 5 1(16)4(22)

1 – different combination

Dental whorl II total chaetae:

0 – 3 3(16)

1 – 3 1(16)2(22)

Dental whorl III total chaetae:

0 – 3 3(16)

1 – 3 1(16)2(22)

Dental whorl IV total chaetae:

0 – 3 3(16)

1 – 2 2(22)

Dental whorl V total chaetae:

0 – 3 3(16)

1 – 2 1(16)1(22)

Dental whorl VI total chaetae:

0 – 2 2(16)

1 – different combination

Dental basal area **B** total chaetae:

0 – 4 4(16)

1 – different combination

Dental anterior chaetotaxy:

0 – 4,2,2,1,1

1 – different combination

Mucro lamellae:

0 – Both lamellae serrated

1 – Internal lamella smooth