

An Initial Assessment of the Collembola (Hexapoda) Fauna of the Bula Hyrcanian Forest (Iran) at the Interface of Two Biodiversity Hotspots

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Abstract

The Hyrcanian Forests of northern Iran, a UNESCO World Heritage Site, are renowned for their exceptional biodiversity, hosting numerous relict, threatened, and endemic species. Located at the intersection of the Caucasus and Irano-Anatolian biodiversity hotspots, these forests have been extensively studied for vascular plants, but soil arthropods like springtails (Collembola) remain largely understudied.

This study aims to fill this gap by conducting a comprehensive survey of the Collembola fauna in the Bula Forest, Mazandaran Province. Sampling covered various substrates (decaying wood, moss, soil and leaf litter) in three forest types: a UNESCO-listed natural forest, a preserved planted forest, and an unpreserved natural forest.

73 Collembola species, belonging to 39 genera and 12 families were recorded. *Pseudachorutes vasylii* Kaprus’ & Weiner, 2009, *Paranura* Axelson, 1902 (Neanuridae) and *Pseudanurophorus* Stach 1922 (Isotomidae) were documented for the first time in Iran. *Drepanura* Schött 1891 (Entomobryidae), *Pachytoma* Bagnall, 1949 (Isotomidae), *Mesaphorura hylophila* Rusek, 1982, and *Mesaphorura macrochaeta* Rusek, 1976 (Tullbergiidae) represent first records for the Hyrcanian Forests.

To provide a comprehensive overview of Collembola biodiversity in the Hyrcanian forests, the present analysis of samples collected in Bula Forest was integrated with a thorough review of published records from the provinces of Mazandaran, Gilan and Golestan - all of which encompass significant portions of this ancient forest.

This study offers one of the most comprehensive inventories of Collembola in the Bula Forest, providing insights into species distribution across microhabitats. The remarkable Collembola diversity underscores the importance of this region for biodiversity conservation.

Keywords Checklist | Collembola | Hyrcanian Forest | new records | springtails | UNESCO World Heritage | biodiversity hotspot | Irano-Anatolian | Caucasus.

Introduction

The Hyrcanian Forests of Iran form a continuous band of deciduous forest stretching 850 km along the slopes of the Tالش and Alborz mountains, covering the southern and south-eastern shores of the Caspian Sea. The central and northernmost edge of these forests are included in the Caucasus Biodiversity Hotspot while the southern zones run alongside the Iranian-Anatolian Biodiversity Hotspot (Figure 1A&B), which is among the least studied biodiversity hotspots (Mittermeier et al. 2004, Zachos & Habel 2011). Covering 1.85 million hectares in Iran and 50,000 hectares in Azerbaijan, these forests have existed for between 25 and 50 million years, surviving the Quaternary ice ages and preserving numerous relict, threatened and endemic species such as the Persian leopard and the wild goat (Tohidifar et al. 2016). Their biodiversity, endemism, ecological integrity and extent are remarkable, earning them a place on UNESCO's World Heritage List in July 2019. Although the diversity of vertebrates and vascular flora is well known, with 3,200 vascular plants, the diversity of other less studied groups, such as arthropods, remains to be explored. This study aims to fill this gap by inventorying Collembola, a little studied but diverse group of soil fauna, in different parts of the Hyrcanian Forests.

The Hyrcanian Forests of Iran form a unique deciduous forest that stretches along the southern coast of the Caspian Sea. They extend from southern Azerbaijan to about 900 km in the eastern and northern provinces of Iran, including Guilan, Mazandaran and Golestan. These forests form the outermost boundary of the West Eurasian broadleaf forests to the alpine thorn cushion corridors and forest-free dry vegetation of the Iranian highlands and Central Asia (Akhani et al. 2010, Tohidifar et al. 2016). The history of these broadleaf forests goes back 25 to 50 million years, when they covered most of this northern temperate region before retreating during the Quaternary glaciations and then expanding again as the climate became milder. These forests thus represent one of the most important glacial refugia of arcto-tertiary forest vegetation, where a number of tertiary relics survived the Ice Age and developed numerous endemic taxa of flora and fauna (Vakili et al. 2021).

These mountain forests are rich in biodiversity and provide many ecological, environmental and economic services (e.g. commercial wood products, groundwater retention, provision of supplementary forest products, wildlife habitat and erosion control Haghdoost et al. 2011).

The most important tree species in these forests are *Fagus orientalis* (oriental beech), *Carpinus betulus* (European hornbeam), *Acer velutinum* (velvet maple), *Quercus*

castaneifolia (Caucasian oak), *Acer cappadocicum* (Cappadocian maple), *Alnus subcordata* (alder) and *Tilia platyphyllos* (large-leaved lime) (Haghdoost et al. 2011, Mehrafrooz Mayvan et al. 2015).

Despite their immense national and international significance, the Hyrcanian Forests and the rich biodiversity they harbour face many threats, endangering both forest cover and overall ecosystem health. Since 1950, the area of the Hyrcanian Forests has dramatically declined from 2,750,000 ha (Saei 1950) to just 1,850,000 ha, a reduction of approximately one third (32.7%). Human activities, directly or indirectly, have been the primary drivers of these threats (Tohidifar et al. 2016).

Recognizing the Hyrcanian Forests as World Heritage Sites has the potential to enhance their global popularity and foster a stronger sense of stewardship among local communities. This recognition can promote awareness of the forests' outstanding heritage and facilitate the exchange of experiences and knowledge with other World Heritage Sites (Tohidifar et al. 2016, Homami Totmaj et al. 2021).

UNESCO World Heritage Sites in Hyrcanian Forests span 15 regions, including Golestan National Park, Abr Forest, Jahan-Nama Forest, Bula Forest, Alimestan Forest, Vaz Forest, Kojur region of Nowshahr, Chahar bagh region of Chalus, Khoshkeh Daran Forest, Gasht-e Rudkhan, Siahrudbar of Guilan, and the Lisar protected area. These regions are renowned for their remarkable plant and animal diversity (Naqinezhad et al. 2008, Nourzad Moghaddam et al. 2018, Homami Totmaj et al. 2021, Vakili et al. 2021).

Collembola (springtails) are among the earliest soil colonisers in terrestrial systems, particularly forests (Chahartaghi et al. 2005, Kuznetsova & Ivanova 2020). They play a crucial role in the decomposition of plant litter, nutrient cycling, formation of soil microstructure and modification of plant growth and have therefore received considerable attention (Hopkin 1997, Gange 2000, Filser 2002, Petersen 2002). Local biodiversity of Collembola can be remarkably high, reaching over 100 species per site, and densities of up to 200,000 individuals per square metre have been recorded (Rusek 1998, Harta et al. 2021).

Globally, approximately 9,000 Collembola species have been described, of which Iran accounts for 323 species as of 2024. Notably, two-thirds of these species (215 species) are reported from the Hyrcanian Forests (see references in the text). The number of endemic species described from these forests is steadily increasing (Shayanmehr et al. 2013, Yoosefi Lafooraki et al. 2020a, Yahyapour et al. 2021, Yahyapour et al. 2022a, Shayanmehr et al. 2024). However, many species in various parts of the Hyrcanian Forests, particularly UNESCO-listed areas, remain unstudied.

Most research on Collembola in Iran consists of qualitative faunistic surveys, and there is scant quantitative data on their diversity and density. The only notable study, by Mehrafrooz Mayvan et al. (2015), examined the depth distribution of Collembola, revealing patterns akin to those in temperate forests. Seasonal dynamics were observed, with the highest densities in winter, indicating that reduced summer moisture is a critical limiting factor.

Our primary objective was to conduct a preliminary inventory of Collembola diversity in this under-explored region. While the inventory based on samples collected in the Bula Forest remains incomplete, we successfully identified nearly all Poduromorpha species. However, other groups, such as Neelipleona and Symphypleona, have only been superficially investigated, underscoring the need for further research.

In order to complete our knowledge of the Collembola biodiversity of this forest massif, we also carried out a literature review to list all the species that have been identified so far in this forest massif.

Methods

Collembola Sampling in Bula Forest

The present work is based on surveys carried out in 2021 and 2022 in the Bula Forest (Figure 1A). To increase the chances of observing different species and to get a first assessment of the spatial variability of Collembola communities, we sampled three sites at different altitudes and with contrasting forest management: a preserved natural forest (UNESCO heritage), hereafter “PNF” (N36°03'46.08", E53°18'37.92", 1670 m), a preserved anthropised (planted) forest hereafter “PAF” (N36°02'10.72", E53°16'51.68", 1600 m) and a non-preserved natural forest, hereafter “NPF” (N36°03'41.27", E53°14'02.27", 1425 m, Figure 1B&C). The three sites are formally located in a region belonging to the Iranian-Anatolian Hotspot, but only a few kilometres from the border with the Caucasus Hotspot and they are part of a forest massif that lies largely within the Caucasus Hotspot (Figure 1C, Hoffman et al. 2016).

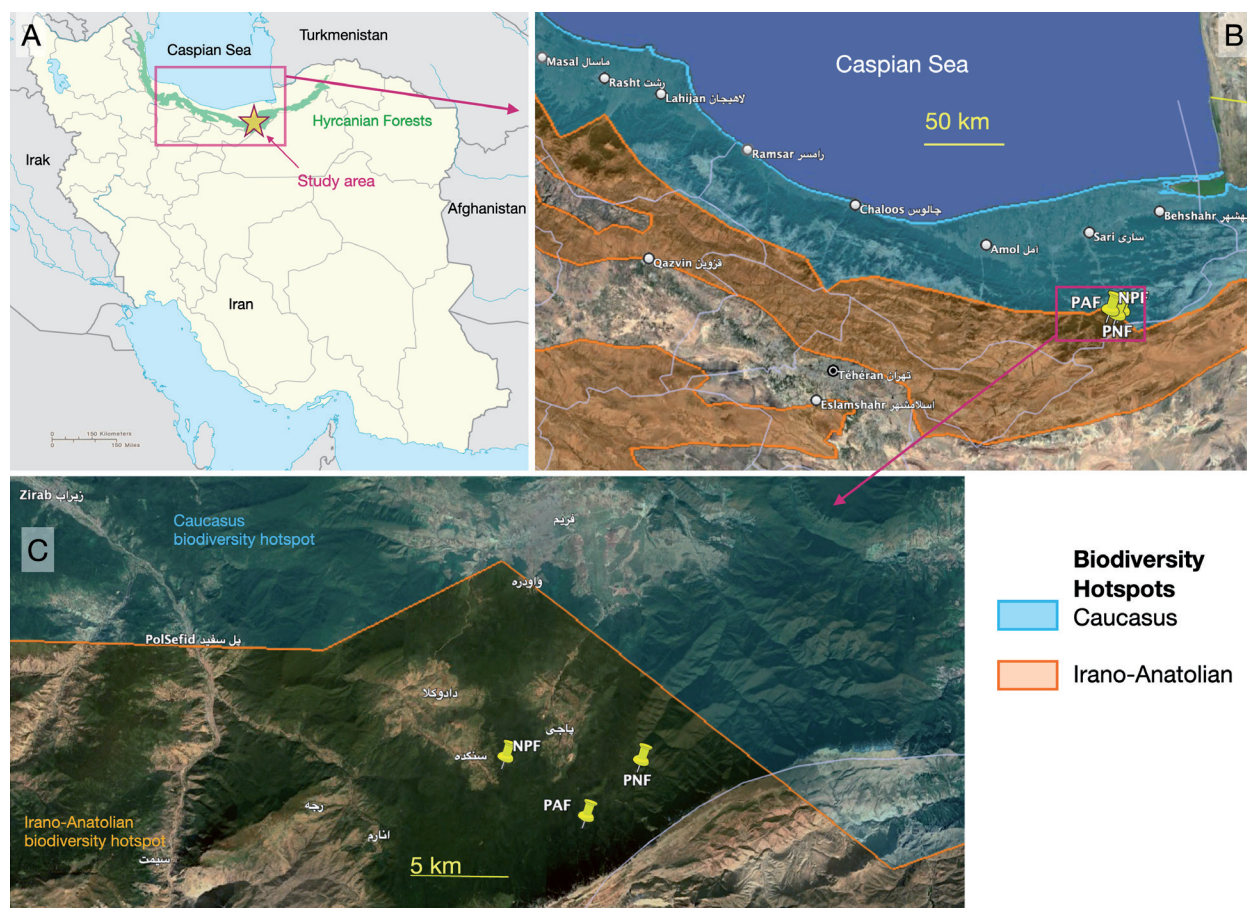


Figure 1. Location of the study area. The map of Iran (panel A) shows the Hyrcanian Forests in green along the Caspian Sea. The study area, marked with a star, is situated in the Bula Forest (Mazandaran, Sari). A rectangle indicates the region enlarged in panel B, which delineates the geographical boundaries of two biodiversity hotspots that stretch along the Caspian Sea: the Caucasus (blue) and the Irano-Anatolian (orange) biodiversity hotspots (Hoffman et al. 2016). Additionally, panel B identifies the three sampled forest sites: a planted anthropised forest (PAF), a preserved natural forest (PNF) and a non-preserved natural forest (NPF). Panel C provides a more detailed view of their exact locations, revealing that all three sites lie within a few kilometres of the border between these two biodiversity hotspots.

Within each of the three sites (PAF, PNF and NPF), sampling was conducted at different localities (72 in total), spaced approximately 30 paces apart. This was done twice, once in late April 2021 and again in early June 2022. Samples were collected from one to three microhabitat types: dead wood, moss, and soil with leaf litter. In 2021, between three and four samples were collected per microhabitat type and sampling localities were labelled Bu01, Bu02, ... Bu14. In 2022, between five and ten samples were collected per microhabitat type, with sampling localities labelled 01Bu, 02Bu... 60Bu (Table S1, Supplementary Material). For each of the 72 localities, one, two or three microhabitats (wood, soil and/or moss) were sampled. This resulted in a total of 90 samples (30 samples per site).

Soil and leaf litter samples were obtained using a soil core (5 cm in diameter) to a consistent depth of 0–10 cm. Moss and woody debris samples were collected in 500 mL plastic containers. All samples were labelled and transported to the laboratory on the same day. Soil fauna was then extracted using Berlese-Tullgren extractors.

In some instances, species identification was uncertain. When a species could not be definitively identified but was distinguishable as a unique morphospecies, we

assigned it a specific code (e.g., sp.01, sp.02). In cases where specimens were identifiable only to the genus level—often due to poor preservation or juvenile stages—they were labelled as “Genus sp.” and excluded from the final species count.

Compilation of Regional Collembola Fauna

To compile a comprehensive overview of Collembola biodiversity in the Hyrcanian forests, we combined our analyses of samples from the Bula Forest with a thorough review of published records from the provinces of Mazandaran, Gilan, and Golestan—each representing major sections of this ancient forest. Mazandaran hosts a large portion of the Hyrcanian Forest, with dense and diverse woodlands. Gilan, to the west, is characterised by its humid climate and lush vegetation. Golestan, to the east, also encompasses significant forested areas.

We compiled all literature referencing Collembola in these regions, starting with existing checklists of Iranian species (e.g. Cox 1982, Falahati Hossein Abad et al. 2013a, Shayanmehr et al. 2013, Mehrafrooz Mayvan et

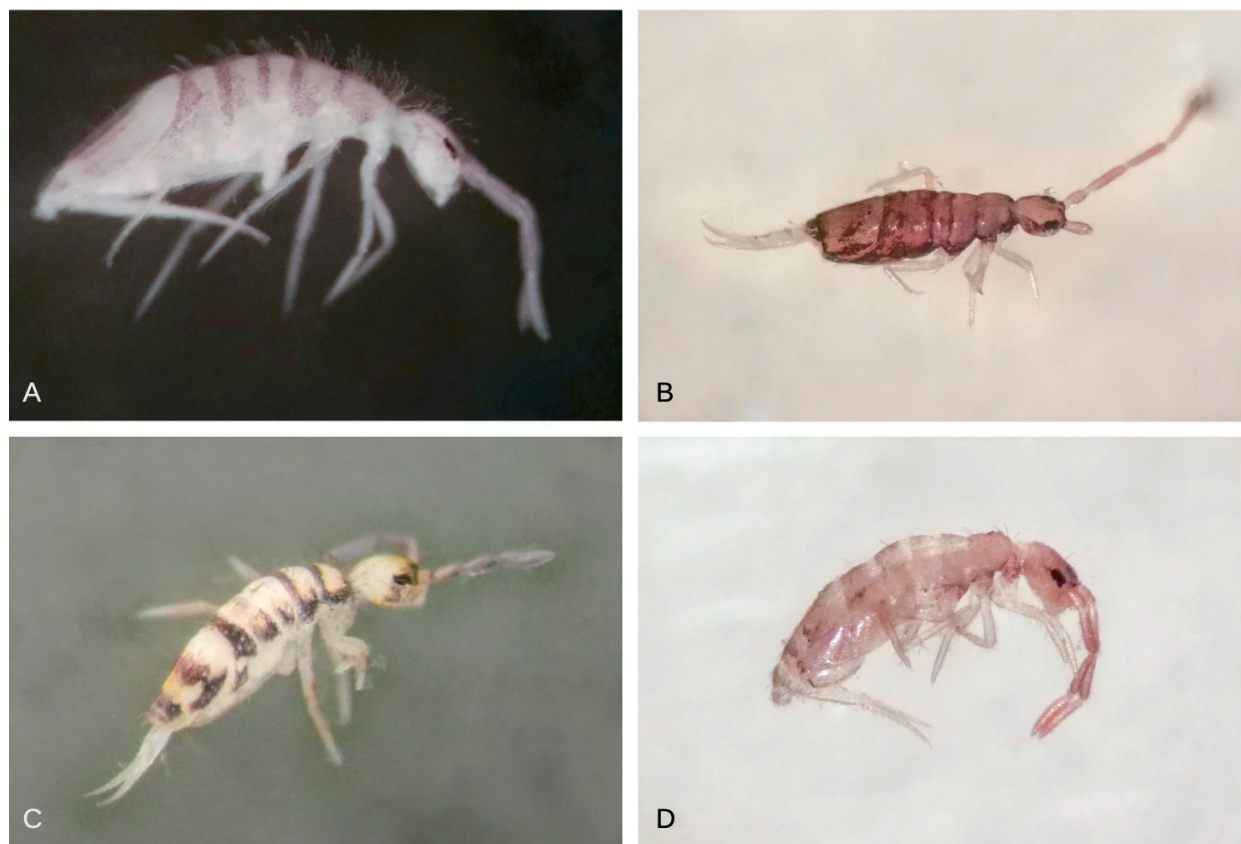


Figure 2. Entomobryinae habitus: (A) *Drepanura* sp.01, (B) *Entomobrya atrocincta*, (C) *Entomobrya corticalis*, (D) *Entomobrya nicoleti*.

al. 2021, Mehrafroz Mayvan et al. 2023, Shayanmehr et al. 2023). In addition, we reviewed primary descriptions and taxonomic sources for each species (see references in the systematic account).

Abbreviations. Iranian provinces: GI: Guilan region; GO: Golestan region; MAZ: Mazandaran region; Morphology: Abd.: Abdomen; PAO: Postantennal organ; Th.: Thorax.

Results

The present checklist is based on 2021 and 2022 field studies and previously published works on Hyrcanian Forests.

Systematic account

Class Collembola Lubbock, 1870

Order Entomobryomorpha Börner, 1913

Family Entomobryidae Tömösvary, 1882

Subfamily Entomobryinae Schäffer, 1896

Genus *Drepanura* Schött, 1891

Drepanura sp.01 (Figure 2A)

Bula localities: Bu01, Bu02, Bu03, Bu08, Bu09, Bu11, Bu12, Bu13, Bu14, 1Bu, 2Bu, 3Bu, 5Bu, 6Bu, 11Bu, 13Bu, 14Bu, 15Bu, 16Bu, 19Bu, 21Bu, 22Bu, 24Bu, 25Bu, 26Bu, 31Bu, 34Bu, 35Bu, 36Bu, 37Bu, 39Bu, 41Bu, 43Bu, 44Bu, 45Bu, 51Bu, 53Bu, 54Bu, 55Bu, 56Bu, 57Bu and 58Bu. Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV longer than twice Abd. III, dens tapering and crenulated, no scales, mucro falcate with a spine, 2 trichobothria on Abd. IV, many tergal macrochaetae, 8+8 eyes, large macrochaetae on anterior margin of Th. II. First mention of the genus for the Hyrcanian Forests.



Figure 3. Entomobryinae habitus: (A) *Entomobrya nigrocincta* female, (B) *E. nigrocincta* male, (C) *Entomobrya* sp.01, (D) *Mesentotoma* sp.01.

Genus *Entomobrya* Rondani, 1861

Entomobrya atrocincta Schött, 1896 (Figure 2B)

Bula locality: Bu14. Other Hyrcanian distribution: GO: Hosseini et al. (2016); MAZ: Yahyapour (2012), Yoosefi Lafooraki (2014), Darvish-Motevalli (2016), Ghasemi Cherati (2017), Yahyapour et al. (2020a), Ghasemi Cherati et al. (2022), Vahedi Moghadam et al. (2022) Yahyapour et al. (2022b). Habitat: wood. Site: NPF.

Remarks: Ground colour yellowish, Th. II with antero-lateral and posterior transversal stripe Abd. III with posterior transversal band.

Entomobrya corticalis (Nicolet, 1842) (Figure 2C)

Bula localities: Bu03, Bu01, Bu12, Bu13, 19Bu, 29Bu, 34Bu, 38Bu and 60Bu. Other Hyrcanian distribution: GI: Cox (1982); GO: Khanahmadi (2018); MAZ: Yahyapour et al. (2018), Yahyapour et al. (2019). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Th. II-III white surrounded by purple, Abd. III purple, purple band in middle of Abd. IV and Abd. V entirely purple.

Entomobrya nicoleti (Lubbock, 1870) (Figure 2D)

Bula localities: Bu02, Bu04, Bu08, Bu09, Bu12 and Bu13. Other Hyrcanian distribution: GO: Hosseini et al. (2016). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Ground colour palish with patterns on the sides but no bands or stripes.

Entomobrya nigrocincta Denis, 1923 (Figure 3A-B)

Bula localities: Bu01, Bu02, Bu08, Bu09, Bu11, Bu12, Bu13, Bu14 and 1Bu. Other Hyrcanian distribution: MAZ: Yahyapour et al. (2018), Yahyapour et al. (2019), Bakhshi et al. (2022), Zamani Khormandichali et al.

(2024). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: female, ground colour yellowish with purple transversal bands on posterior part of each dorsal tergite with an additional band in the middle of Abd. IV; male, orange with anterior side of Th. II palish and posterior part of Th. II to Abd. I black, tips of the antenna (Ant. II-IV) black.

Entomobrya sp.01 (Figure 3C)

Bula localities: Bu08, Bu11 and 56Bu. Habitats: moss and wood. Sites: NPF and PNF.

Remarks: Ground colour pale-yellowish with greyish Th. II, posterior part of Th. III, Abd. II, middle of Abd. III and posterior part of Abd. IV to Abd. VI.

Genus *Mesentotoma* Salmon, 1942

Mesentotoma sp.01 (Figure 3D)

Bula localities: Bu02 and Bu09. Habitat: wood. Sites: PAF and PNF.

Remarks: Entomobryinae without scales, 8+8 eyes, Ant. IV with apical vesicle, no dental spines, mucro with 2 teeth and without basal spine.

Genus *Sinella* Brook, 1882

Sinella sp.01 (Figure 4B)

Bula locality: 10Bu, 56Bu. Habitat: soil, wood. Site: PAF, NPF.

Remark: both specimens are juveniles, identification is difficult.



Figure 4. Entomobryidae habitus: (A) *Seira domestica*, (B) *Sinella* sp.01.

Subfamily Lepidocyrtinae Wahlgren, 1906
Genus *Lepidocyrtus* Bourlet, 1839

Lepidocyrtus bicoloris Mateos, 2012 (Figure 5A)

Bula localities: Bu07, Bu11, Bu13, 19Bu, 20Bu, 30Bu, 38Bu and 52Bu. Other Hyrcanian distribution: MAZ: Bakhshi et al. (2022). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate with sub-apical spine, tergal macrochaetae reduced, scales ribless finely denticulate and apically rounded, scales present on dens, Ant. IV not swollen; bluish with white Abd. IV.

Lepidocyrtus sp.01 (Figure 5B)

Bula localities: 10Bu, 11Bu, 29Bu, 31Bu, 53Bu and 56Bu. Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate with sub-apical spine, tergal macrochaetae reduced, scales ribless finely denticulate and apically rounded, scales present on dens, Ant. IV not swollen; Pale colour,

ventral side white, darker on the back with grey-blueish colour.

Lepidocyrtus sp.02

Bula locality: Bu09. Habitat: wood. Site: PNF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate with sub-apical spine, tergal macrochaetae reduced, scales ribless finely denticulate and apically rounded, scales present on dens, Ant. IV not swollen; yellowish colour.

Lepidocyrtus sp.03 (Figure 5C)

Bula localities: Bu04, Bu09, Bu13, Bu14, 57Bu and 58Bu.

Habitats: soil and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate with sub-apical spine, tergal macrochaetae reduced, scales ribless finely denticulate and apically rounded, scales present on dens, Ant. IV not swollen; black-bluish with a white strip on the 4th segment.

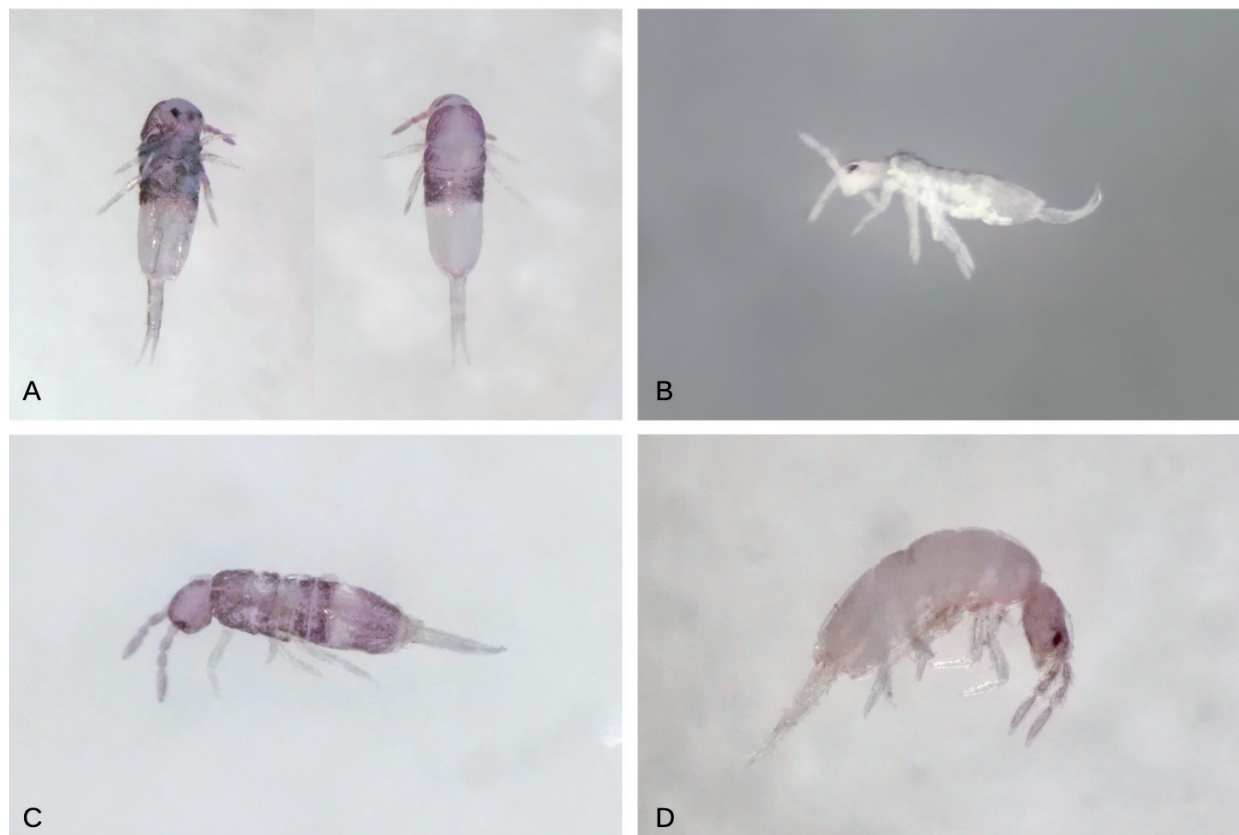


Figure 5. Lepidocyrtinae habitus: (A) *Lepidocyrtus bicoloris*, (B) *Lepidocyrtus* sp.01, (C) *Lepidocyrtus* sp.03, (D) *Pseudosinella octopunctata*.

Genus *Pseudosinella* Schäffer, 1897

Pseudosinella cf. *decipiens* Denis, 1924

Bula localities: Bu03, Shayanmehr et al. (2024). Habitat: wood. Site: PAF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate, Ant. IV somewhat swollen; without eyes, scales and basal spine present, empodium simple, unpaired distal tooth of unguis between the teeth, tenent hair short and acuminate.

Pseudosinella immaculata (Lie-Pettersen, 1896)

Bula locality: Bu02, Shayanmehr et al. (2024). Habitat: wood. Site: PAF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate, Ant. IV somewhat swollen; without eyes, unpaired distal tooth beyond the teeth, tenent hair long and clavate.

Pseudosinella octopunctata (Caroli, 1914) (Figure 5D)

Bula locality: Bu08. Other Hyrcanian distribution: GI: Cox (1982); GO: Hosseini et al. (2016); MAZ: Cox (1982), Yahyapour (2012), Shoeibi et al. (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Mehrafrooz Mayvan et al. (2015), Darvish-Motevalli (2016), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022), Vahedi Moghadam et al. (2022), Zamani Khormandichali et al. (2024)Yahyapour et al. (2022b). Habitat: soil. Site: PNF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate, Ant. IV somewhat swollen; 4+4 eyes.

Pseudosinella sp.01

Bula localities: Bu04 and Bu13. Habitats: soil and wood. Sites: PAF and NPF.

Remarks: Abd. IV more than twice as long as Abd. III, dens tapering and crenulated, mucro bidentate without basal spine, scales present, Ant. IV somewhat swollen; body bluish, without eyes.

Subfamily Seirinae Yosii, 1931

Genus *Seira* Lubbock, 1870

Seira domestica (Nicolet, 1842) (Figure 4A)

Bula localities: Bu01, Bu02, Bu03, Bu04, Bu07, Bu08, Bu09, Bu10, Bu11, Bu12, Bu13, Bu14, 25Bu, 38Bu and 40Bu. Other Hyrcanian distribution: GI: Daghighi (2012), Daghighi et al. (2013a); GO: Hosseini et al. (2015), Hosseini et al. (2016); MAZ: Yahyapour (2012),

Darvish-Motevalli (2016), Ghasemi Cherati (2017), Yahyapour et al. (2018), Yahyapour et al. (2019), Yahyapour et al. (2020a), Ghasemi Cherati et al. (2022), Zamani Khormandichali et al. (2024)Yahyapour et al. (2022b). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV with 3+3 botriotrichae, mucro falcate without spine, scales present, some pointed (Seirinae); Abd. II with 5 central macrochaetae, Th. II with 4 medio central macrochaetae, Abd. I with 6 central macrochaetae, Th. II with more than 8 macrochaetae on PmC group (Cipola 2018, Cipola et al. 2020).

Family Orchesellidae Börner, 1906

Subfamily Heteromurinae Absolon & Kseneman, 1942

Genus *Heteromurus* Mari Mutt, 1979

Heteromurus major (Moniez, 1889) (Figure 6A)

Bula localities: Bu03, Bu02, Bu08, Bu09, Bu11, Bu12, Bu13, Bu14, 1Bu, 2Bu, 3Bu, 11Bu, 18Bu, 19Bu, 21Bu, 28Bu, 31Bu, 32Bu, 33Bu, 39Bu, 40Bu, 42Bu, 45Bu, 47Bu, 51Bu, 52Bu, 53Bu, 56Bu and 59Bu. Other Hyrcanian distribution: GI: Cox (1982), Daghighi (2012), Daghighi et al. (2013a)GO: Hosseini et al. (2015), Hosseini et al. (2016), Moradi et al. (2019); MAZ: Cox (1982), Yahyapour (2012), Shoeibi et al. (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Mehrafrooz Mayvan et al. (2015), Darvish-Motevalli (2016), Hosseini et al. (2016), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Yahyapour et al. (2018), Yahyapour et al. (2019), Bakhshi et al. (2022), Ghasemi Cherati et al. (2022), Vahedi Moghadam et al. (2022), Zamani Khormandichali et al. (2024)Yahyapour et al. (2022b). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Heteromurus nitidus (Templeton, 1836) (Figure 6B)

Bula localities: Bu04 and 8Bu. Other Hyrcanian distribution: GI: Cox (1982); GO: Hosseini et al. (2015), Hosseini et al. (2016); MAZ: Cox (1982), Shoeibi et al. (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Mehrafrooz Mayvan et al. (2015), Darvish-Motevalli (2016), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Bakhshi et al. (2022), Ghasemi Cherati et al. (2022), Vahedi Moghadam et al. (2022), Zamani Khormandichali et al. (2024). Habitats: soil and wood. Site: PAF.

Heteromurus variabilis Martynova, 1974 (Figure 6C)

Bula localities: Bu08 and Bu09. Other Hyrcanian distribution: MAZ: Vahedi Moghadam et al. (2022), Zamani Khormandichali et al. (2024). Habitats: soil and moss. Site: PNF.

Heteromurus sp.

Bula localities: 19Bu. Habitat: wood. Site: PAF.

Remark: Unidentified specimen of *Heteromurus* (could belong to one of the above-mentioned species).

Subfamily Orchesellinae Börner, 1906 Genus *Orchesella* Templeton, 1836

Orchesella cincta (Linnæus, 1758) (Figure 6D)

Bula localities: Bu03, Bu09, Bu12, Bu13, Bu14, 11Bu, 12Bu, 13Bu, 15Bu, 19Bu, 20Bu, 27Bu, 32Bu, 33Bu, 35Bu, 36Bu, 48Bu, 51Bu, 52Bu, 57Bu, 59Bu and 60Bu. Other Hyrcanian distribution: GO: Hosseini et al. (2016); MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Yahyapour et al. (2018), Yahyapour et al. (2019), Yahyapour et al. (2020a), Ghasemi Cherati et al. (2022), Vahedi Moghadam

et al. (2022)Yahyapour et al. (2022b). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Dorsal side of Abd. II pale and dorsal side of Abd. III fully pigmented.

Family Isotomidae Schäffer, 1896

Subfamily Anurophorinae Börner, 1901 Genus *Anurophorus* Nicolet, 1842

Anurophorus alpinus Potapov & Stebaeva, 1990
(Figure 7A)

Bula localities: Bu09, Bu13, 19Bu and 54Bu; Shayanmehr et al. (2024). Habitats: soil, wood and moss. Sites: NPF, PAF and PNF.

Remarks: All abdominal segments separate, furca absent, 8+8 eyes, no spine-like papillae, Ant I with 1 ventrolateral sensilla and 2 mirosensillae. Th. I with 1+1 ventromedial chaetae, empodium at most 2/7 as long as inner edge of claw.



Figure 6. Orchesellidae habitus: (A) *Heteromurus major*, (B) *Heteromurus nitidus*, (C) *Heteromurus variabilis*, (D) *Orchesella cincta*.

Anurophorus silvaticus Potapov & Stebaeva, 1990
(Figure 7B)

Bula localities: Bu04, 10Bu, 40Bu, 41Bu, 50Bu and 51Bu. Other Hyrcanian distribution: MAZ: Yoosefi Lafooraki et al. (2019), Yoosefi Lafooraki et al. (2020b), Vahedi Moghadam et al. (2022). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: All abdominal segments separate, furca absent, 8+8 eyes, no spine-like papillae, Ant I with 1 ventrolateral sensilla and 2 mirosensillae. last abdominal segments almost smooth, abdominal sensillae longer than half mesochaetae, empodium at least 1/3 as long as inner edge of claw.

Genus *Folsomia* Willem, 1902

Folsomia candida Willem, 1902

Bula locality: 20Bu. Other Hyrcanian distribution: GI: Cox (1982), Yoosefi Lafooraki et al. (2020a); GO: Yoosefi Lafooraki et al. (2020a); MAZ: Yahyapour (2012), Yoosefi Lafooraki et al. (2020a). Habitat: wood. Site: PAF.

Remarks: Abd IV-V-VI fused, no eyes, mucro bidentate.

Folsomia inoculata Stach, 1946 (Figure 7C)

Bula locality: 38Bu. Other Hyrcanian distribution: MAZ: Yahyapour et al. (2020a); Yahyapour et al. (2022b). Habitat: wood. Site: PNF.

Remarks: Abd IV-V-VI fused, no eyes, Ant. I with 2 ventrolateral microsensillae, mucro bidentate, PAO slender.

Folsomia penicula Bagnall, 1939 (Figure 7D)

Bula localities: Bu02, Bu03, Bu07, Bu08, Bu09, Bu11, 1Bu, 2Bu, 3Bu, 6Bu, 7Bu, 8Bu, 9Bu, 10Bu, 11Bu, 13Bu, 16Bu, 17Bu, 18Bu, 19Bu, 20Bu, 23Bu, 25Bu, 26Bu, 27Bu, 29Bu, 30Bu, 35Bu, 36Bu, 37Bu, 40Bu, 44Bu, 45Bu, 47Bu, 48Bu, 49Bu, 50Bu, 56Bu, 57Bu and 60Bu.

Other Hyrcanian distribution: GI: Daghighi (2012), Daghighi et al. (2013b,a), Yoosefi Lafooraki et al. (2020a); GO: Falahati Hossein Abad et al. (2013b,a), Yoosefi Lafooraki et al. (2020a); MAZ: Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Mehrafrooz Mayvan et al. (2015), Ghasemi Cherati (2017), Yahyapour et al. (2019), Yoosefi Lafooraki et al. (2020a), Bakhshi et al. (2022), Zamani Khormandichali et al. (2024). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.



Figure 7. Anurophorinae habitus: (A) *Anurophorus alpinus*, (B) *Anurophorus silvaticus*, (C) *Folsomia inoculata*, (D) *Folsomia penicula*.

Remarks: Abd IV-V-VI fused, 2+2 eyes, PAO constricted, Ant I with 3 sensillae (1 long between 2 short), pigmented.

Folsomia sp.01

Bula localities: 40Bu and 60Bu. Habitats: wood. Sites: NPF and PNF.

Remarks: Abd IV-V-VI fused, no eyes, white.

Genus *Isotomiella* Bagnall, 1939

Isotomiella minor (Schäffer, 1896) (Figure 8A)

Bula localities: 1Bu, 8Bu, 8Bu, 10Bu, 25Bu, 27Bu, 29Bu, 30Bu, 40Bu, 47Bu, 48Bu and 50Bu. Other Hyrcanian distribution: GI: Cox (1982), Daghighi (2012), Daghighi et al. (2013b,a), Yoosefi Lafooraki et al. (2020a) GO: Hosseini et al. (2016), Yoosefi Lafooraki et al. (2020a); MAZ: Yahyapour (2012), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Mehrafrooz Mayvan et al. (2015), Ghasemi Cherati (2017), Yoosefi Lafooraki et al. (2020a). Habitats: soil and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. IV and V separate, furca well developed, mucro tridentate, eyes, PAO and pigments absent, long macrochaetae.

Genus *Pseudanurophorus* Stach, 1922

Pseudanurophorus sp.01

Bula locality: 4Bu. Habitat: soil. Site: PAF.

Remarks: Anurophorinae without furca or anal spines. First citation of the genus for Iran.

Subfamily Isotominae Schäffer, 1896

Genus *Isotomurus* Börner, 1903

Isotomurus sp.01 (Figure 8B)

Bula localities: Bu07, 42Bu, 48Bu and 52Bu. Habitats: soil and moss. Sites: NPF and PNF.

Remarks: Isotominae plurichaetotic, abdomen with trichobothria, without coloured band or patches.

Isotomurus sp.02 (Figure 8C)

Bula localities: Bu01, Bu02 and Bu12. Habitat: soil. Sites: NPF and PAF.

Remarks: Isotominae plurichaetotic, abdomen with trichobothria, small, purple with dorsomedian longitudinal darker band.



Figure 8. *Isotomiella* and *Isotomurus* habitus: (A) *Isotomiella minor*, (B) *Isotomurus* sp.01, (C) *Isotomurus* sp.02, (D) *Isotomurus* sp.03.

Isotomurus sp.03 (Figure 8D)

Bula localities: Bu02, Bu03, Bu04 and Bu09. Habitats: moss and wood. Sites: PAF and PNF.

Remarks: Isotominae plurichaetotic, abdomen with trichobothria, large, with longitudinal coloured patterns.

Genus *Parisotoma* Bagnall, 1940

Parisotoma notabilis (Schäffer, 1896) (Figure 9A)

Bula localities: Bu01, Bu02, Bu03, Bu04, Bu07, Bu08, Bu09, 1Bu, 5Bu, 7Bu, 8Bu, 13Bu, 14Bu, 19Bu, 27Bu, 28Bu, 29Bu, 30Bu, 35Bu, 36Bu, 39Bu, 40Bu, 45Bu, 48Bu, 53Bu, 56Bu, 58Bu, 59Bu and 60Bu.

Other Hyrcanian distribution: GI: Daghighi (2012); Daghighi et al. (2013b,a); Yoosefi Lafooraki et al. (2020a); GO: Hosseini et al. (2016), Khanahmadi (2018), Yoosefi Lafooraki et al. (2020a); MAZ: Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Yahyapour et al. (2019), Yoosefi Lafooraki et al. (2020a), Bakhshi et al. (2022), Zamani Khormandichali et al. (2024).

Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Genus *Vertagopus* Börner, 1906

Vertagopus persicus Potapov, Yoosefi & Shayanmehr, 2020 (Figure 9B)

Bula localities: Bu03, Bu09, 11Bu, 16Bu, 17Bu, 20Bu, 36Bu, 37Bu, 38Bu and 51Bu. Other Hyrcanian distribution: GI, GO, MAZ: Yoosefi Lafooraki et al. (2020b). Habitats: soil, moss and wood. Sites: PAF, NPF and PNF.

Remarks: Isotominae with Abd. IV, V and VI separated, no trichobothria, tibiotarsi with short clavate hairs, dens long, crenulated and thinner distally, mucro with 4 teeth and apical tooth way smaller than the subapical, s-chaetae on body tergites as: 5,5/4,4,4,5,6.

Subfamily Pachyotominae Potapov, 2001 Genus *Pachyotoma* Bagnall, 1949

Pachyotoma sp.01 (Figure 9C)

Bula localities: 49Bu, 52Bu and 53Bu. Habitats: soil and moss. Site: NPF.

Remarks: Poduromorpha-like habitus, plump, cuticle with strong secondary granulation, well developed furca, dens cylindrical without crenulation, dark colour, no distinct macrochaetae. First citation of the genus for the Hyrcanian Forest.

Subfamily Proisotominae Stach, 1947 Genus *Folsomides* Stach, 1922

Folsomides sp.01

Bula locality: 40Bu. Habitat: wood. Site: PNF.

Remarks: number of eyes reduced, ventral tube with 3+3 laterodistal chaetae, sensillae on a mid-tergal position on Abd. I-III, Abd. V-VI at an angle from Abd. I-IV.

Genus *Proisotoma* Börner, 1901

Proisotoma minuta (Tullberg, 1871) (Figure 9D)

Bula locality: Bu07. Other Hyrcanian distribution: GI: Cox (1982); Yoosefi Lafooraki et al. (2020a); GO: Hosseini et al. (2016); Yoosefi Lafooraki et al. (2020a); MAZ: Cox (1982), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Yoosefi Lafooraki et al. (2020a). Habitat: soil. Site: PNF.

Remarks: Slender and grey Anurophorinae, 8+8 eyes, PAO 3-4 times as long as an omma, anterior side of manubrium with chaetae (but less than 8), Abd. V and VI separate.

Proisotoma sp.01 (Figure 9E)

Bula locality: 40Bu. Habitat: wood. Site: PNF.

Remarks: Slender and pale Anurophorinae, 8+8 eyes, PAO 3-4 times as long as an omma, anterior side of manubrium with chaetae (but less than 8), Abd. V and VI separate.

Family Tomoceridae Schäffer, 1896

Genus *Tomocerus* Nicolet, 1842

Tomocerus minor (Lubbock, 1862) (Figure 9F)

Bula localities: Bu03, Bu09, Bu11, Bu13, 1Bu, 5Bu, 11Bu, 13Bu, 14Bu, 15Bu, 16Bu, 18Bu, 19Bu, 31Bu, 33Bu, 36Bu, 37Bu, 38Bu, 42Bu, 49Bu, 51Bu, 52Bu, 53Bu, 56Bu, 57Bu, 58Bu, 59Bu and 60Bu. Other Hyrcanian distribution: GI: Cox (1982); GO: Hosseini et al. (2016); MAZ: Cox (1982), Bakhshi et al. (2022). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Abd. III and IV subequal, scales present on the body, Ant. III long and annulated, eyepatch quadrangular, tridentate spines on dens, mucro elongate with several teeth.



Figure 9. Isotomidae and Tomoceridae habitus: (A) *Parisotoma notabilis*, (B) *Vertagopus persicus*, (C) *Pachytoma* sp.01, (D) *Proisotoma minuta*, (E) *Proisotoma* sp.01, (F) *Tomocerus minor*.

Order Poduromorpha Börner, 1913 Family Hypogastruridae Börner, 1906

Genus *Ceratophysella* Börner, 1932

Ceratophysella stercoraria (Stach, 1963) (Figure 10A-C)

Bula localities: Bu03, Bu04, Bu07, Bu09, Bu07, Bu08, Bu11, Bu11, 1Bu, 3Bu, 6Bu, 7Bu, 9Bu, 10Bu, 16Bu, 17Bu, 19Bu, 20Bu, 27Bu, 30Bu, 31Bu, 32Bu, 36Bu, 37Bu, 37Bu, 38Bu, 45Bu and 51Bu. Other Hyrcanian

distribution: GO: Khanahmadi (2018); MAZ: Yoosefi Lafooraki (2014), Mehrafrooz Mayvan et al. (2015), Yoosefi Lafooraki & Shayanmehr (2015a), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Yahyapour et al. (2019), Bakhshi et al. (2022), Vahedi Moghadam et al. (2022), Shayanmehr et al. (2023), Zamani Khormandichali et al. (2024) Yahyapour et al. (2022b) Salimi et al. (2025). Habitat: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: species easily recognizable with the following combination of characters: Abd. IV with chaetae pl

shorter than p2 and 3+3 medial chaetae and Abd. V with a semi-circular hump.

Ceratophysella sp.01 (Figure 10D)

Bula localities: 2Bu, 28Bu and 33Bu. Habitats: soil and moss. Sites: PAF and PNF.

Remarks: That species keys out close to *C. impedita* Skarzynski, 2002 but with a very specific molar plate and no inner teeth on the claw, different from *C. impedita*.

Genus *Schoettella* Schäffer, 1896

Schoettella ununguiculata (Tullberg, 1869)

Bula locality: Bu01. Other Hyrcanian distribution: MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a), Zamani Khormandichali et al. (2024). Habitat: moss. Site: PAF.

Remarks: typical hypogastrurid with 8+8 eyes, small anal spines and no empodium.

Genus *Xenylla* Tullberg, 1869

Xenylla brevisimilis Stach, 1949 (Figure 11A-D)

Bula locality: 56Bu. Other Hyrcanian distribution: MAZ: Shayanmehr et al. (2023), Zamani Khormandichali et al. (2024). Habitat: wood. Site: NPF.

Remarks: Hypogastruridae with 5+5 eyes, small anal spines and no PAO; L1 on head longer than L3, dens with 2 chaetae, tenaculum with 3+3 teeth, mucrodens longer than inner edge of claw III (1-1.3x), a2 absent on Abd V.

Xenylla maritima Tullberg, 1869 (Figure 11E)

Bula locality: Bu01. Other Hyrcanian distribution: GI: Cox (1982); MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a). Habitat: moss. Site: PAF.

Remarks: Hypogastruridae with 5+5 eyes, small anal spines and no PAO; L1 on head longer than L3, dens with 2 chaetae, tenaculum with 3+3 teeth, external maxillary lobe with 3 sublobal hairs, mucrodens longer than inner edge of claw III (2.3x), a2 absent on Abd V.

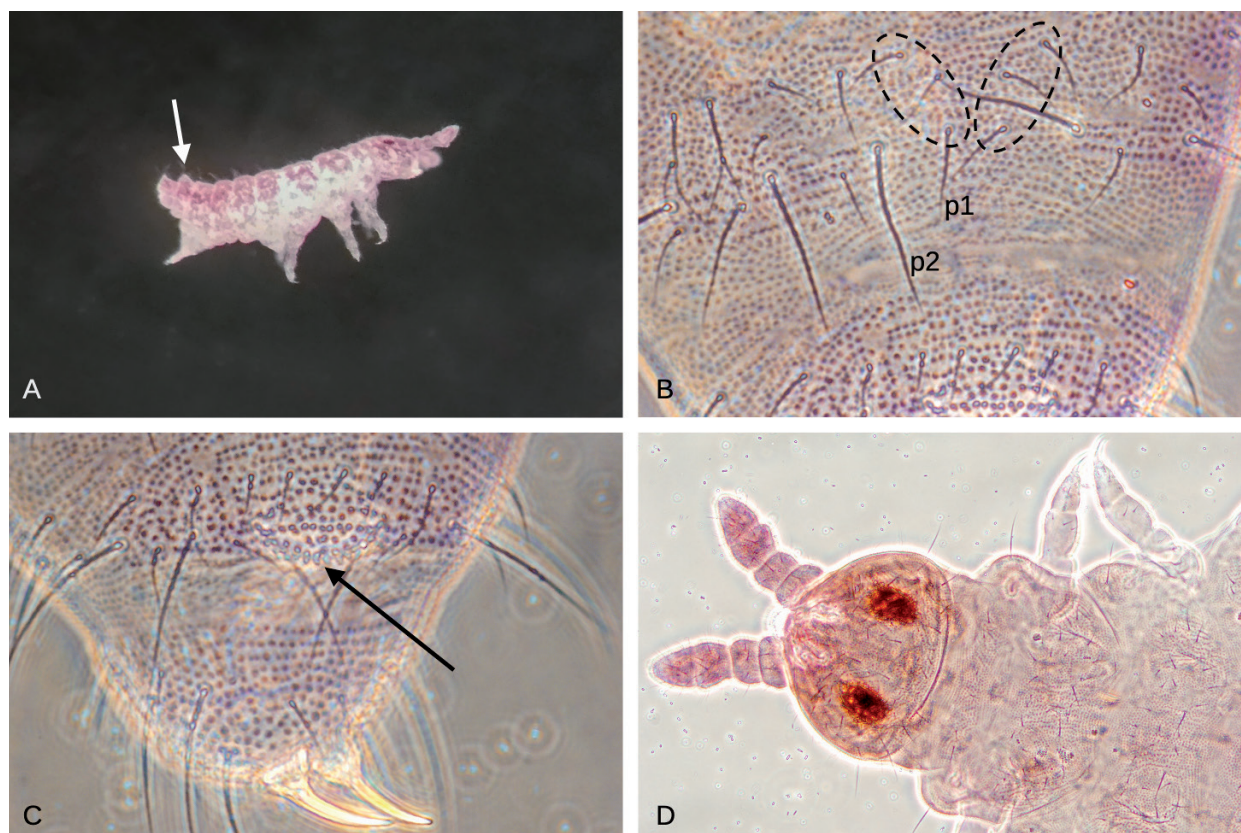


Figure 10. Hypogastruridae, *Ceratophysella stercoraria*: (A) habitus, arrow showing the semi-circular hump, (B) Abd. IV with chaetae p1 shorter than p2 and 3+3 medial chaetae, (C) Abd. V with a semi-circular hump (arrow); (D) *Ceratophysella* sp.01 habitus.



Figure 11. Hypogastruridae, *Xenylla brevisimilis*: (A) habitus, (B) abdomen with anal spines, (C) ventral side of Th. II-III showing sternal chaetae (arrows), (D) ventral side of abdomen showing tenaculum and furca (arrows); (E) *Xenylla maritima* habitus; (F) *Xenylla mediterranea* habitus.

Xenylla mediterranea da Gama, 1964 (Figure 11F)

Bula locality: 54Bu. Other Hyrcanian distribution: MAZ: Mohammadi Nodeheki et al. (2018). Habitat: moss. Site: NPF.

Remarks: Hypogastruridae with 5+5 eyes, small anal spines and no PAO; L1 on head longer than L3, dens with 2 chaetae, tenaculum with 2+2 teeth, external maxillary lobe with 1 sublobal hair, mucrodens longer than inner edge of claw III (1-1.6x), a2 absent on Abd V.

Xenylla szeptyckii Skarzynski, Piwnik & Porco, 2018 (Figure 12A)

Bula localities: 8Bu and 12Bu. Other Hyrcanian distribution: MAZ: Yahyapour et al. (2021). Habitats: soil and moss. Site: PAF.

Remarks: Hypogastruridae with 5+5 eyes, small anal spines and no PAO; L1 on head longer than L3, dens with 2 chaetae, tenaculum with 3+3 teeth, external maxillary lobe with 2 sublobal hairs, mucrodens longer than inner edge of claw III (1.6-2x), a2 absent on Abd V.

Xenylla tullbergi Börner, 1903 (Figure 12B)

Bula localities: Bu02, Bu12, Bu13 and Bu14. Habitats: moss and wood. Sites: PAF and NPF.

Remarks: L1 on head shorter than L3, dens with 1 chaetae, tenaculum with 2+2 teeth, mucrodens shorter than inner edge of claw III, a2 present on Abd V. First citation of the species for the Hyrcanian Forest.

Xenylla sp.

Bula locality: Bu01. Habitat: moss. Site: PAF.

Remark: Unidentified specimen of *Xenylla* (could belong to one of the above-mentioned species).

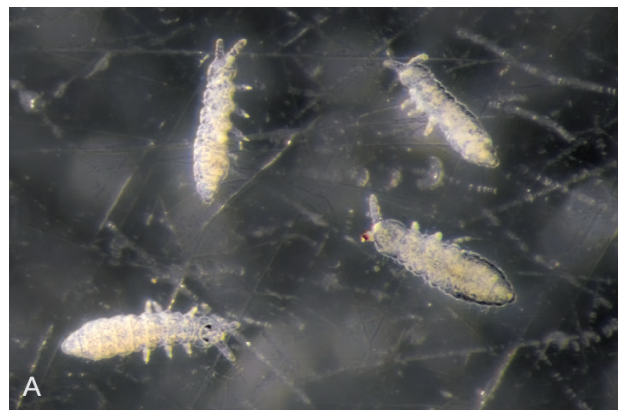


Figure 12. *Xenylla* habitus: (A) *Xenylla szeptyckii*, (B) *Xenylla tullbergi*.

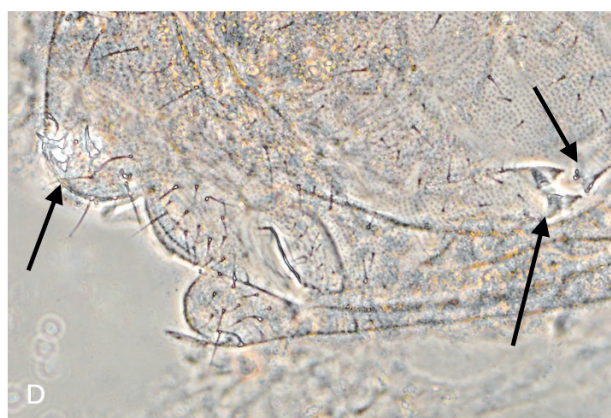


Figure 13. *Friesea* sp.01: (A) habitus, (B) habitus on slide, (C) head showing mouthparts, specially mandible and the typical maxillae head (arrows), (D) abdomen showing 3 anal spines, tenaculum and furca (arrows).

Family Neanuridae Börner, 1901

Subfamily Frieseinae Massoud, 1967

Genus *Friesea* Dalla Torre, 1895

Friesea sp.01 (Figure 13)

Bula localities: 4Bu, 11Bu, 18Bu, 19Bu and 35Bu.

Habitats: soil, moss and wood. Sites: PAF and PNF.

Remarks: species with mucro at stage 2, 8+8 eyes, 4+4 chaetae on Th. I, 3 anal spines, clavate chaetae on Abd.

VI. It is close to *F. claviseta* Axelson, 1900 but not same number of tita chaetae and a0 missing on the head. Probably a new species.

Subfamily Neanurinae Börner, 1901

Genus *Deutonura* Cassagnau, 1979

Deutonura persica Smolis, Shayanmehr & Yoosefi-Lafooraki, 2018 (Figure 14)

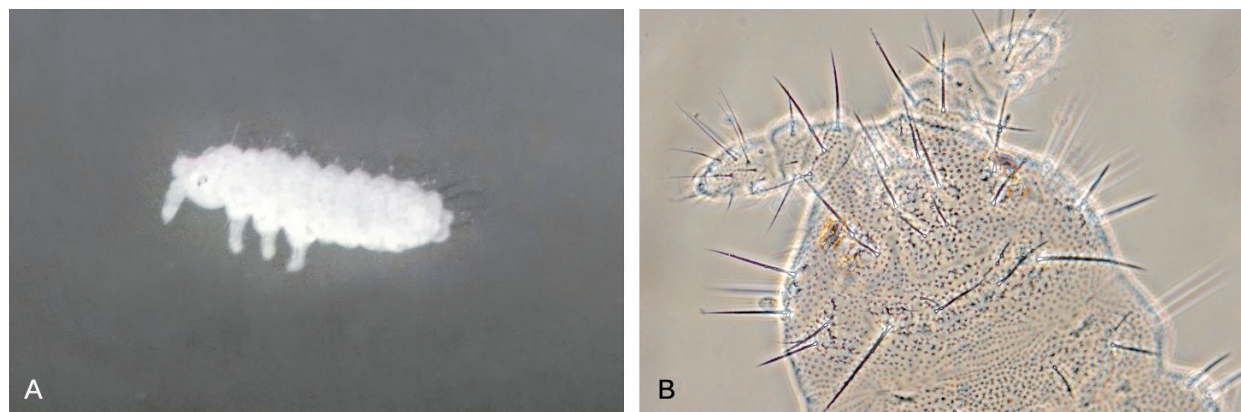


Figure 14. *Deutonura persica*: (A) habitus, (B) head showing the reduced chaetotaxy.

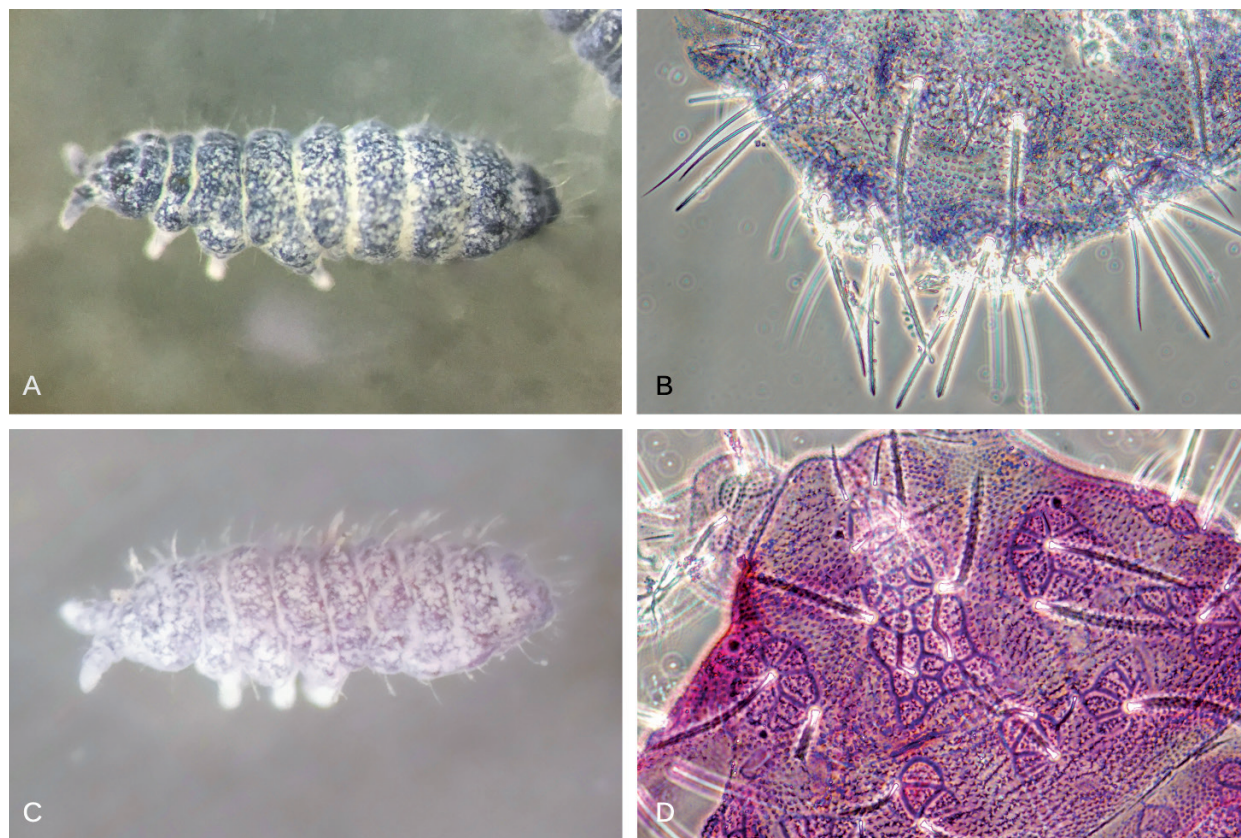


Figure 15. *Endonura agnieskae*: (A) habitus, (B) Abd. V and VI, three tubercles on Abd. V; *Endonura ceratolabralis*: (C) habitus, (D) head without chaeta O.

Bula localities: 17Bu, 18Bu, 25Bu and 38Bu. Other Hyrcanian distribution: GI: Smolis & Skarżyński (2020); MAZ: Smolis et al. (2018), Smolis & Skarżyński (2020), Bakhshi et al. (2022). Habitats: soil and wood. Sites: PAF and PNF.

Remark: 2+2 dark eyes, head without chaetae C, Th. III with 3+s chaetae De.

Deutonura cf sengleti Smolis & Skarżyński, 2020

Bula localities: 16Bu and 18Bu. Other Hyrcanian distribution: GI, MAZ: Smolis & Skarżyński (2020). Habitat: wood. Site: PAF.

Remarks: 2+2 dark eyes, head with chaetae C, Th. I tubercles Di and De fused, presence of the male ventral organ, Abd. V with 3 tubercles (1 Di+Di and 2 De+DI/L), Di2-De2 parallel to Di1-De1.

Deutonura sp.

Bula locality: 16Bu. Habitat: wood. Site: PAF.

Remark: Unidentified specimen of *Deutonura* (could belong to one of the above-mentioned species).

Genus *Endonura* Cassagnau, 1979

Endonura agnieskae Smolis & Skarzynski, 2020 (Figure 15A-B)

Bula localities: 37Bu and 38Bu. Other Hyrcanian distribution: GI, MAZ: Smolis & Skarżyński (2020), Bakhshi et al. (2022). Habitat: wood. Site: PNF.

Remarks: *Endonura* with wide labrum, 2+2 large dark eyes, head without chaetae C, claw toothed.

Endonura ceratolabralis Smolis, Kahrarian, Piwnik & Skarzynski, 2016 (Figure 15C-D)

Bula localities: Bu07, Bu09 and 1Bu. Other Hyrcanian distribution: GI, MAZ: Smolis & Skarżyński (2020), Bakhshi et al. (2022). Habitat: soil. Sites: PAF and PNF.

Remarks: *Endonura* with long labrum, 2+2 dark eyes, head with chaetae C, claw without tooth.

Endonura sp.

Bula locality: Bu11 Habitat: soil. Site: NPF.

Remark: Unidentified specimen of *Endonura* (could belong to one of the above-mentioned species).

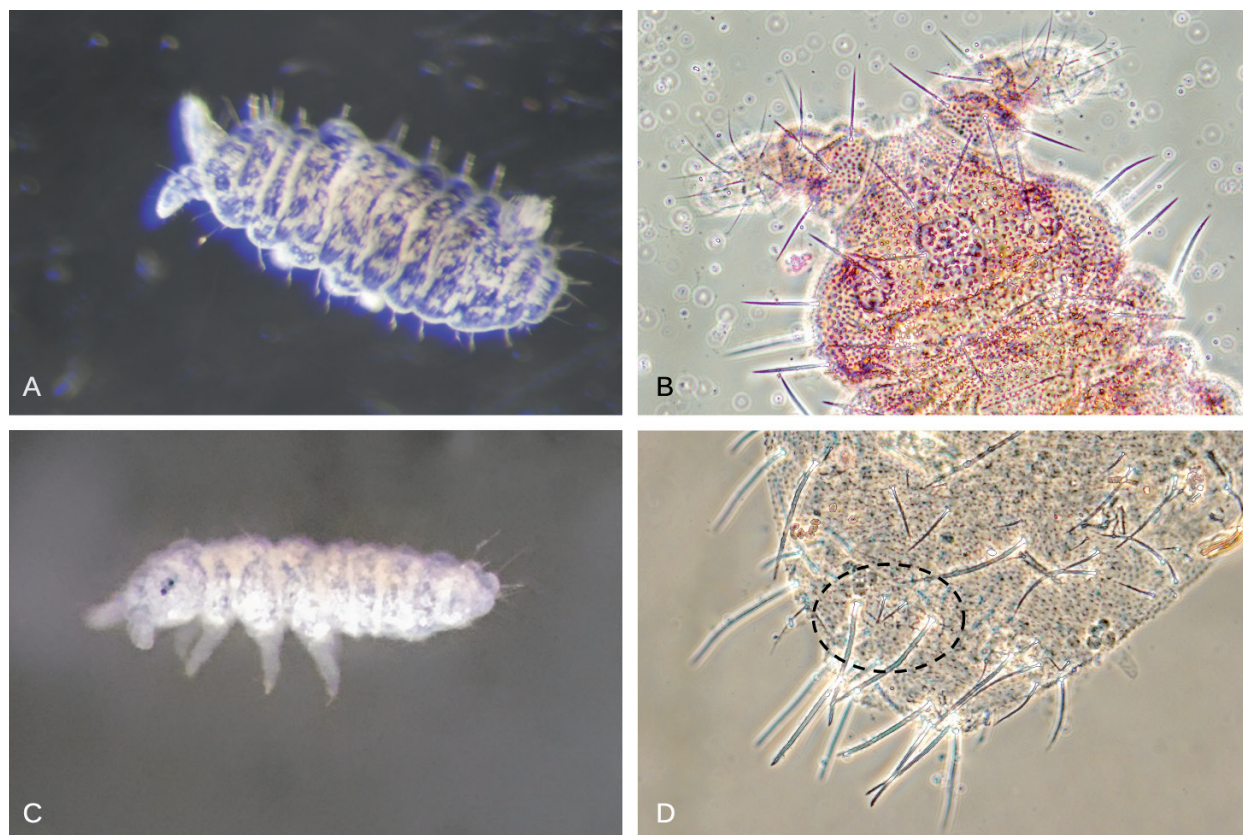


Figure 16. *Neanura deharvengi*: (A) habitus, (B) head with extreme reduction of chaetotaxy and fused lateral tubercles; *Paranura* sp.01: (C) habitus, (D) Abd. V with fused Di tubercles.

Genus *Neanura* MacGillivray, 1893

Neanura deharvengi Smolis, Shayanmehr & Yoosefi-Lafooraki, 2018 (Figure 16A-B)

Bula localities: 15Bu, 19Bu and 50Bu. Other Hyrcanian distribution: GI: Smolis & Skarżyński (2020); MAZ: Smolis et al. (2018), Smolis & Skarżyński (2020), Shayanmehr et al. (2023). Habitats: soil, moss and wood. Sites: NPF and PAF.

Remarks: 3+3 eyes, head with tubercles Af and Cl separate, Th. I without tubercles Di, Di-De crossed type, Abd. V with Di-Di fused, head with extreme reduction of chaetotaxy and fused lateral tubercles.

Genus *Paranura* Axelson, 1902

Paranura sp.01 (Figure 16C-D)

Bula locality: 38Bu. Habitat: wood. Site: PNF.

Remarks: Head with 2+2 eyes, 3 Oc chaetae and chaeta O present, Abd. V with 3+3 Di chaetae, Thorax II–III with 3 and 4 ordinary chaetae De respectively. This species keys out close to *P. tibiotsalis* Deharveng, 1989 but differs by tubercles Di fused on Abd. V. Probably a new species. First citation of the genus for Iran.

**Subfamily Pseudachorutinae Börner, 1906
Genus *Micranurida* Börner, 1901**

Micranurida sp.01 (Figure 17A)

Bula locality: 1Bu. Habitat: soil. Site: PAF.

Remarks: Specimen with 2+2 eyes, PAO with 10-11 vesicles, apical vesicle simple, tibiotarsi I, II, III with 19, 19, 18 chaetae (number difficult to assess). A combination of characters unknown in described *Micranurida* to date.

Micranurida sp.02

Bula locality: 11Bu. Habitat: moss. Site: PAF.

Remarks: PAO with 7 vesicles, slide rather poor.

Genus *Pseudachorutes* Tullberg, 1871

Pseudachorutes hyrcanicus Kaprus', Shayanmehr & Yahyapour, 2022 (Figure 17B-D)

Bula localities: Bu07, Bu13, 5Bu, 28Bu, 31Bu and 59Bu. Other Hyrcanian distribution: MAZ: Shayanmehr et al. (2022). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: 8+8 eyes, PAO with 16-18 vesicles, Ant. IV apical vesicle trilobed, Th. I with 3+3 chaetae, claw

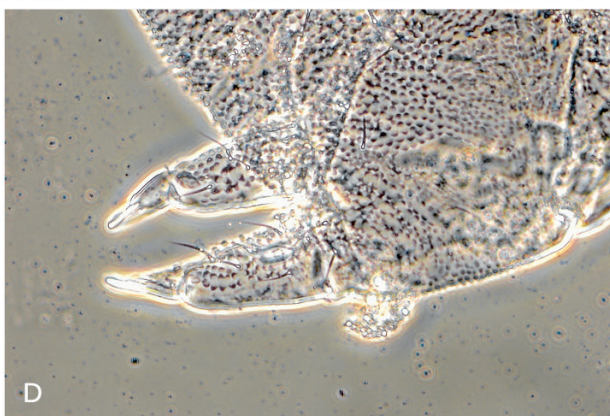
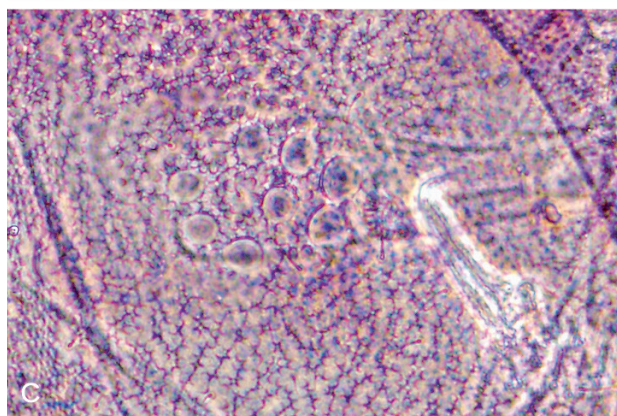


Figure 17. *Micranurida* sp.01: (A) habitus; *Pseudachorutes hyrcanicus*: (B) habitus, (C) eyes and PAO, (D) furca.

with 1 inner and no lateral teeth, ventral tube with 3+3 chaetae, furca well developed, dens with 5 chaetae, tibiotarsi I, II, III with 18,18,17 chaetae. Species known only from Hyrcanian Forest to date.

Pseudachorutes kurdistanicus Kaprus', Shayanmehr & Ghobari, 2022 (Figure 18A-C)

Bula localities: 37Bu, 48Bu, 58Bu and 60Bu. Habitats: soil and wood. Sites: NPF and PNF. Remarks: 8+8 eyes, PAO with 11-12 vesicles, Ant. IV apical vesicle trilobed, Th. I with 3+3 chaetae, claw with 1 inner and no lateral teeth, ventral tube with 3+3 chaetae, furca well developed, dens with 6 chaetae, tibiotarsi I, II, III with 18,18,17. First citation of the species for the Hyrcanian Forest.

Pseudachorutes vasylii Kaprus' & Weiner, 2009 (Figure 18D)

Bula localities: 20Bu, 37Bu and 38Bu. Habitat: wood. Sites: PAF and PNF.

Remarks: Ant IV apical vesicle simple or slightly bilobed, 8+8 eyes, PAO with 5 to 7 vesicles, labium with organit x; furcula well developed, dens with 6+6 chaetae, mucro simple spoon like, ventral tube with 4+4 chaetae; tibiotarsi I, II and III with 19, 19 and 18

setae, respectively; chaetae a2 absent of Abd V. First citation of the species for Iran.

Pseudachorutes sp.

Bula localities: Bu12 and 58Bu. Habitats: soil and wood.

Site: NPF.

Remark: Unidentified specimens of *Pseudachorutes* (could belong to one of the above-mentioned species).

Family Odontellidae Massoud, 1967

Genus *Superodontella* Stach, 1949

Superodontella tyverica Kaprus', 2009 (Figure 19)

Bula localities: Bu07, 16Bu, 17Bu, 20Bu and 42Bu; Shayanmehr et al. (2024). Habitats: soil and wood.

Sites: NPF, PAF and PNF.

Remarks: Anal spines absent but strong granular papillae present instead.

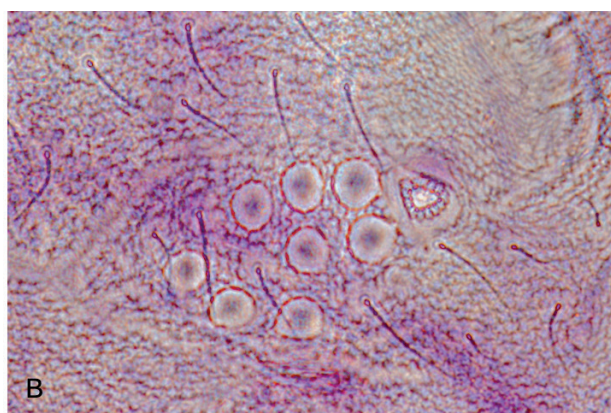


Figure 18. *Pseudachorutes kurdistanicus*: (A) habitus, (B) eyes and PAO, (C) furca; *Pseudachorutes vasylii*: (D) habitus, ventral.

Family Onychiuridae Lubbock, 1913

Subfamily Onychiurinae Börner, 1901 Genus *Orthonychiurus* Stach, 1954

Orthonychiurus stachianus (Bagnall, 1939)

Bula locality: Bu08. Other Hyrcanian distribution: MAZ:

Alijani-Ardeshir et al. (2017). Habitat: soil. Site: PNF.

Remarks: Pseudocelli formula 32/0(1)22/3334(5)2(3), no anal spines.

Genus *Protaphorura* Absolon, 1901

Protaphorura bicampata (Gisin, 1956) (Figure 20A)

Bula localities: 1Bu, 2Bu, 5Bu, 18Bu, 19Bu, 25Bu, 26Bu, 28Bu, 30Bu, 31Bu, 38Bu, 39Bu, 40Bu and 50Bu. Other Hyrcanian distribution: MAZ: Cox (1982). Habitats: soil, moss and wood. Sites: NPF, PAF and PNF.

Remarks: Pseudocelli formula 33/022/33333, pseudocelli present on subcoxa 1, anal spines present.

Protaphorura golestonica Kaprus', Shayanmehr & Kahrarian 2017

Bula locality: Bu08. Other Hyrcanian distribution: GO: Kaprus et al. (2017), Khanahmadi (2018); MAZ: Yahyapour et al. (2020b), Bakhshi et al. (2022). Habitat: soil. Site: PNF.

Remarks: Pseudocelli formula 32/022/33333, 2+2 pseudocelli ventrally on the head, no pseudocelli on subcoxa 1, anal spines present.

Protaphorura levantina (Christiansen, 1956) (Figure 20B)

Bula localities: 29Bu and 47Bu. Other Hyrcanian distribution: GO: Hosseini et al. (2016); MAZ: Yahyapour et al. (2020b), Bakhshi et al. (2022), Shayanmehr et al. (2023). Habitat: soil. Sites: NPF and PNF.

Remarks: Pseudocelli formula 32/022/33342, pseudocelli present on subcoxa 1, anal spines present.

Protaphorura sp.

Bula localities: Bu04, 8Bu, 10Bu, 15Bu, 20Bu, 22Bu, 24Bu and 27Bu. Habitats: soil, moss and wood. Sites: PAF and PNF.

Remark: Unidentified specimens of *Protaphorura* (could belong to one of the above-mentioned species).

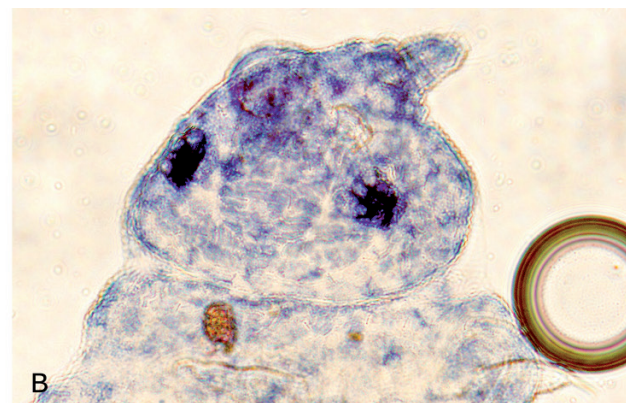


Figure 19. *Superodontella tyverica*: (A) habitus, (B) head showing the conical antennae.



Figure 20. Onychiuridae habitus: (A) *Protaphorura bicampata*, (B) *Protaphorura levantina*.

Family Tullbergiidae Bagnall, 1935

Genus *Mesaphorura* Börner, 1901

Mesaphorura critica Ellis, 1976

Bula locality: 13Bu. Other Hyrcanian distribution: GO: Hosseini et al. (2016). Habitat: moss. Site: PAF.

Remarks: Th. III with chaetae a2, Abd. V without a2, anal valves without chaetae l2'.

Mesaphorura hylophila Rusek, 1982

Bula localities: 39Bu, 48Bu and 50Bu. Habitats: soil and wood. Sites: NPF and PNF.

Remarks: Th. III without a2, Abd. IV with p1 as microchaetae and p2 as mesochaetae, Abd. V without a2, anal valves without chaetae l2'. First citation of the species for the Hyrcanian Forest. Distribution in Iran. Kermanshah (Harasam) province (Shayanmehr et al. 2020).

Mesaphorura macrochaeta Rusek, 1976

Bula locality: Bu04. Habitat: wood. Site: PAF.

Remarks: Pseudocelli formula 11/011/10011/, Th. III

with a2, Abd. IV with p1 as macrochaetae and p2 as microchaetae, anal valves with chaetae l2'. First citation of the species for the Hyrcanian Forest. Distribution in Iran. Kermanshah province (Shayanmehr et al. 2020).

Mesaphorura yosii (Rusek, 1967) (Figure 21)

Bula localities: Bu12, 7Bu, 8Bu, 18Bu, 19Bu, 28Bu, 30Bu, 40Bu, 44Bu, 56Bu and 60Bu. Other Hyrcanian distribution: GO: Hosseini et al. (2016). Habitats: soil and wood. Sites: NPF, PAF and PNF.

Remarks: Pseudocelli formula 11/011/10011/, Th. III with a2, Abd. IV with p1 as macrochaetae and p2 as microchaetae (contrary to *Mesaphorura* key in (Dunger & Schlitt 2011), Abd. V with a2, anal valves with chaetae l2'.

Mesaphorura sp.

Bula localities: Bu13, 24Bu, 26Bu, 29Bu and 43Bu.

Habitats: soil and wood. Sites: NPF and PNF.

Remark: Unidentified specimens of *Mesaphorura* (could belong to one of the above-mentioned species).

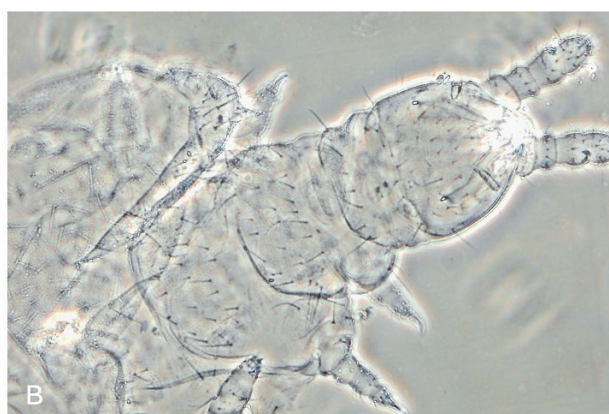


Figure 21. *Mesaphorura yosii*: (A) habitus, (B) details on slide.



Figure 22. *Wankeliella bescidica*: (A) habitus, (B) details on slide.

Genus *Wankeliella* Rusek, 1975

Wankeliella bescidica Smolis & Skarzynski, 2003 (Figure 22)

Bula localities: Bu13 and 9Bu; Shayanmehr et al. (2024). Habitat: soil. Sites: NPF and PAF.

Remarks: PAO with 6-7 v-shaped vesicles, Abd. VI with two anal spines and a pair of transverse crescentic ridges. The Bula Forest is the only place where the genus *Wankeliella* has been recorded in Iran.

**Order Neelipleona Massoud, 1971
Family Neelidae Folsom, 1996****Genus *Megalothorax* Willem, 1900**

Megalothorax sp.01 (Figure 23A)

Bula localities: 3Bu, 10Bu, 40Bu, 47Bu, 48Bu, 49Bu, 57Bu and 59Bu. Habitats: soil and wood. Sites: NPF, PAF and PNF.

**Order Symphypleona Börner, 1901
Family Katiannidae Börner, 1913****Genus *Sminthurinus* Börner, 1901**

Sminthurinus elegans (Fitch, 1863) (Figure 23B)

Bula locality: Bu01. Other Hyrcanian distribution: GO: Falahati Hossein Abad et al. (2013a); MAZ: Cox (1982), Yahyapour (2012), Yoosefi Lafooraki (2014), Mehrafrooz Mayvan et al. (2015), Yoosefi Lafooraki & Shayanmehr (2015b), Ghasemi Cherati (2017), Zamani Khormandichali et al. (2024) Yahyapour et al. (2022b). Habitat: soil. Site: PAF.

Remarks: Dens anteriorly without subapical chaetae and posteriorly with 1 outer subapical and 3 proximal chaetae, large abdomen with clear longitudinal stripe and no cross ones.



Figure 23. Neelipleona and Symphypleona habitus: (A) *Megalothorax* sp.01, (B) *Sminthurinus elegans*, (C) *Spatulosminthurus* sp.01, (D) *Lipothrix* sp.01.

Family Sminthuridae Lubbock, 1862

Subfamily Sminthurinae Lubbock, 1862

Genus *Spatulosminthurus* Betsch & Betsch-Pinot, 1983

Spatulosminthurus sp.01 Figure 23C

Bula locality: Bu01, 9Bu, 28Bu, 32Bu, 33Bu and 53Bu; Shayanmehr et al. (2024). Habitats: soil and moss. Sites: PAF and PNF.

Remarks: Sminthuridae without the neosminthuroid chaetae, trochanter III without spines, tita with spatulate distal chaetae. The Bula Forest is the only place where the genus *Spatulosminthurus* has been recorded in Iran.

Subfamily Sphyrothecinae Betsch, 1980

Genus *Lipothrix* Börner, 1906

Lipothrix sp.01 (Figure 23D)

Bula locality: 11Bu, 19Bu, 20Bu, 33Bu, 36Bu and 58Bu. Habitats: wood and moss. Sites: NPF, PAF and PNF.

Remark. Sminthuridae with one pair of neosminthuroid chaetae, mucro with inner sides serrated and outer side smooth, chaetae on tibiotarsi not clavate, body with strong blunt chaetae, Ant. IV divide into 5-6 subsegments.

Other unidentified Symphypleona

Bula localities: 2Bu, 6Bu, 20Bu, 55Bu, 58Bu and 59Bu. Habitats: soil, moss and wood. Sites: NPF and PAF.

Remark: Unidentified specimens of Symphypleona. They could belong, or not, to one of the above-mentioned species.

Hyrceanian species not recorded in Bula Forest

Some other species, listed below were recorded in Hyrceanian Forests but not found during our Bula Forest survey.

Entomobryomorpha

Entomobryidae

Coecobrya tenebricosa (Folsom, 1902), MAZ: Alijani-Ardeshtir et al. (2017).

Entomobrya lanuginosa (Nicolet, 1842), MAZ: Cox (1982).

Entomobrya lindbergi Stach, 1960, GI: Daghighi (2012), Daghighi et al. (2013a)Shoeibi et al. (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014).

Entomobrya multifasciata (Tullberg, 1871), GO: Hosseini et al. (2016); MAZ: Yahyapour (2012), Yoosefi Lafooraki (2014), Darvish-Motevalli (2016), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Yahyapour et al. (2022b).

Entomobrya nivalis (Linnaeus, 1758), GO: Hosseini et al. (2016).

Entomobrya numidica Baquero et al. 2009, GO: Hosseini et al. (2016).

Entomobrya obscurella Brown, 1926, MAZ: Shayanmehr & Yahyapour (2019); Ghasemi Cherati et al. (2022); Zamani Khormandichali et al. (2024).

Entomobrya schoetti Stach, 1922, MAZ: Yahyapour et al. (2018), Yahyapour et al. (2019).

Mesentotoma dollfusi (Denis, 1924), MAZ: Yahyapour (2012), Darvish-Motevalli (2016), Yahyapour et al. (2022b).

Mesentotoma subdollfusi Jacquemart, 1974, GI: Daghighi (2012), Daghighi et al. (2013b); GO: Hosseini et al. (2015), Hosseini et al. (2016) MAZ: Darvish-Motevalli (2016), Zamani Khormandichali et al. (2024).

Sinella curviseta Brook, 1882, MAZ: Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Darvish-Motevalli (2016), Alijani-Ardeshtir et al. (2017).

Lepidocyrtus cyaneus Tullberg, 1871, GI, MAZ: Cox (1982), Yahyapour et al. (2022b); GO: Hosseini et al. (2016).

Lepidocyrtus lanuginosus (Gmelin, 1788), GI: Cox (1982); GO: Hosseini et al. (2016); MAZ: Cox (1982), Bakhshi et al. (2022).

Lepidocyrtus ruber Schött, 1902, GI, MAZ: Cox (1982).

Pseudosinella alba (Packard, 1873), GI: Daghighi (2012), Daghighi et al. (2013a).

Pseudosinella imparipunctata Loksa 1966, GI, MAZ: Cox (1982).

Willowsia nigromaculata (Lubbock, 1873), GI: Daghighi (2012), Daghighi et al. (2013a).

Isotomidae

Anurophorus coiffaiti Cassagnau & Delamare-Deboutteville, 1955, GI: Daghighi (2012), Daghighi et al. (2013b); GO: Falahati Hossein Abad et al. (2013b).

Anurophorus septentrionalis Palissa, 1966, MAZ: (Mohammadi Nodehaki & Shayanmehr 2020).

- Folsomia asiatica* Martynova, 1971, GO: Yoosefi Lafooraki et al. (2020a).
- Folsomia brevifurca* (Bagnall, 1949), MAZ: Cox (1982).
- Folsomia fimetaria* (Linnaeus, 1758), GI: Cox (1982).
- Folsomia ksenemani* Stach, 1947, MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2014), Yoosefi-Lafooraki & Shayanmehr (2014).
- Folsomia manolachei* Bagnall, 1939, GO: Yoosefi Lafooraki et al. (2020a); MAZ: Bakhshi et al. (2022); Vahedi Moghadam et al. (2022).
- Folsomia quadrioculata* (Tullberg, 1871), GI, GO, MAZ: Yoosefi Lafooraki et al. (2020a); GI: Cox (1982).
- Folsomia similis* Bagnall, 1939, GI: Daghighi (2012).
- Folsomia trisetata* Jordana & Ardanaz, 1981, MAZ: Bakhshi et al. (2022).
- Hemisotoma orientalis* (Stach, 1947), GI, MAZ: Cox (1982).
- Hemisotoma pontica* (Stach, 1947), GI: Cox (1982); GO: Yoosefi Lafooraki et al. (2020a); KH: Thibaud et al. (2011); MAZ: Cox (1982), Yahyapour (2012), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Darvish-Motevalli (2016), Alijani-Ardeshtir et al. (2017), Yoosefi Lafooraki et al. (2020a).
- Hemisotoma thermophila* (Axelson, 1900), GI: Cox (1982), Daghighi (2012), Daghighi et al. (2013b,a), Yoosefi Lafooraki et al. (2020b); GO: Yoosefi Lafooraki et al. (2020a); MAZ: Cox (1982), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Balvasi et al. (2015), Yoosefi Lafooraki et al. (2020a).
- Isotomodes golestani* Yoosefi Lafooraki, Hajizadeh, Shayanmehr & Hosseini, 2020, GO: Yoosefi Lafooraki et al. (2020a).
- Desoria neglecta* (Schäffer, 1900), MAZ: Zamani Khormandichali et al. (2024).
- Isotoma cf. riparia* (Nicolet, 1842), MAZ: Alijani-Ardeshtir et al. (2017).
- Isotoma iranica* Arbea & Kahrarian, 2015, GO: Yoosefi Lafooraki et al. (2020a); MAZ: Zamani Khormandichali et al. (2024).
- Isotoma viridis* Bourlet, 1839, GO: Khanahmadi (2018); MAZ: Yahyapour (2012), Alijani-Ardeshtir et al. (2017).
- Isotomurus afghanicus* Yosii, 1966, MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Bakhshi et al. (2022), Yoosefi Lafooraki et al. (2023), Yoosefi Lafooraki et al. (2023).
- Isotomurus antennalis* (Bagnall, 1940), MAZ: Alijani-Ardeshtir et al. (2017).
- Isotomurus balteata* (Reuter, 1876), GO: Hosseini & et al. (2016).
- Isotomurus fucicolus* (Schött, 1893), MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Yoosefi Lafooraki et al. (2020a).
- Isotomurus hyrcanicus* Yoosefi Lafooraki & Shayanmehr 2023, GO: Yoosefi Lafooraki et al. (2023); MAZ: Yoosefi Lafooraki et al. (2023), Zamani Khormandichali et al. (2024).
- Isotomurus katule* Yoosefi Lafooraki & Shayanmehr, 2023, GO: Yoosefi Lafooraki et al. (2023); MAZ: Zamani Khormandichali et al. (2024).
- Isotomurus maculatus* (Schäffer, 1896), GO: Falahati Hossein Abad et al. (2013b); MAZ: Yoosefi Lafooraki et al. (2023).
- Isotomurus matanicus* Shayanmehr, Yoosefi & Zamani, 2024, MAZ: Zamani Khormandichali et al. (2024).
- Isotomurus palustris* (Müller, 1776), GI: Cox (1982), Yoosefi Lafooraki et al. (2020a); GO: Hosseini et al. (2016), Yoosefi Lafooraki et al. (2020a); MAZ: Zamani (2016), Yoosefi Lafooraki et al. (2020a), Yahyapour et al. (2022b).
- Isotomurus potapovi* Yoosefi Lafooraki & Shayanmehr, 2023, GI, GO: Yoosefi Lafooraki et al. (2023); MAZ: Yoosefi Lafooraki et al. (2023), Zamani Khormandichali et al. (2024).
- Isotomurus punctiferus* Yosii, 1963, GI: Daghighi (2012), Daghighi et al. (2013b,a), Yoosefi Lafooraki et al. (2020a), Yoosefi Lafooraki et al. (2023); GO: Falahati Hossein Abad et al. (2013b,a).
- Pseudisotoma sensibilis* (Tullberg, 1876), MAZ: Yoosefi Lafooraki (2014).
- Bagnalleva tenella* (Reuter, 1895), GI: Daghighi (2012), Daghighi et al. (2013b,a).
- Ballistura schötti* (Dalla Torre, 1895), GI: Cox (1982).
- Folsomides angularis* (Axelson, 1905), GI: Daghighi (2012); Daghighi et al. (2013b,a); Yoosefi Lafooraki et al. (2020a).
- Folsomides parvulus* Stach, 1922, GI: Daghighi (2012), Daghighi et al. (2013b,a); GO: Hosseini et al. (2016), Yoosefi Lafooraki et al. (2020a), Bakhshi et al. (2022); MAZ: Yahyapour (2012), Yoosefi-Lafooraki & Shayanmehr (2014), Alijani-Ardeshtir et al. (2017), Yahyapour et al. (2019), Bakhshi et al. (2022), Zamani Khormandichali et al. (2024); Yahyapour et al. (2022b).
- Proisotoma minima* Absolon, 1901, GO: Khanahmadi (2018); MAZ: Yahyapour (2012), Yoosefi-Lafooraki & Shayanmehr (2014), Yahyapour et al. (2020a).
- Proisotoma subminuta* Denis, 1931, GI: Daghighi (2012), Daghighi et al. (2013b,a), Yoosefi Lafooraki et al. (2020a); GO: Yoosefi Lafooraki et al. (2020a);

MAZ: Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014).

Oncopoduridae

Oncopodura ambigua Christiansen, 1957, GI, MAZ: Cox (1982).

Oncopodura hamata Carl & Lebedinsky 1905, GI: Daghighi (2012).

Orchesellidae

Heteromurus gigans Mari Mutt & Stomp, 1980, MAZ: Ghasemi Cherati (2017), Yahyapour et al. (2020a), Ghasemi Cherati et al. (2022); Yahyapour et al. (2022b).

Heteromurus sexoculatus Brown, 1926, MAZ: Cox (1982).

Orchesella spectabilis Tullberg, 1871, MAZ: Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022).

Paronellidae

Cyphoderus agnotus Börner, 1906, GO: Hosseini et al. (2016).

Cyphoderus albinus Nicolet, 1842, GI: Daghighi (2012); MAZ: Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Darvish-Motevalli (2016).

Tomoceridae

Plutomurus danialensis Barjadze, Kováč & Mehrafrooz Mayvan, 2024, MAZ: Barjadze et al. (2024).

Pogonognathellus flavescens (Tullberg, 1871), MAZ: Yahyapour et al. (2018).

Tomocerina minuta (Tullberg, 1876), MAZ: Yahyapour et al. (2021), Bakhshi et al. (2022).

Tomocerus vulgaris (Tullberg, 1871), GI, MAZ: Cox (1982), Yoosefi Lafooraki (2014), Yoosefi-Lafooraki & Shayanmehr (2014), Balvasi et al. (2015), Mehrafrooz Mayvan et al. (2015), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017), Yahyapour et al. (2020a), Vahedi Moghadam et al. (2022); GO: Khanahmadi (2018); MAZ: Yahyapour et al. (2022b).

Neelipleona

Neelidae

Megalothorax incertus Börner, 1903, MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2014), Shayanmehr & Yahyapour (2019).

Megalothorax perspicillum Schneider & D'Haese, 2013, MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2014).

Megalothorax willemi Schneider & D'Haese, 2013, MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2014), Ghasemi Cherati (2017).

Neelus murinus Folsom, 1896, MAZ: Cox (1982), Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022).

Poduromorpha

Brachystomellidae

Brachystomella nubila Gisin, 1957, GI: Cox (1982).

Brachystomella parvula (Schäffer, 1896), GI: Cox (1982).

Hypogastruridae

Ceratophysella alani (Babenko, 1994), GO: Khanahmadi (2018).

Ceratophysella denticulata (Bagnall, 1941), GI: Cox (1982); MAZ: Yahyapour (2012), Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a), Alijani-Ardeshtir et al. (2017), Yahyapour et al. (2020a), Bakhshi et al. (2022), Shayanmehr et al. (2023); GO: Khanahmadi (2018); Yahyapour et al. (2022b).

Ceratophysella engadinensis (Gisin, 1949), MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a).

Ceratophysella succinea (Gisin, 1949), MAZ: Shayanmehr et al. (2023).

Hypogastrura tullbergi (Schäffer, 1900), GI: Cox (1982); MAZ: Cox (1982), Yoosefi Lafooraki & Shayanmehr (2015a).

Hypogastrura manubrialis (Tullberg, 1869), GI, GO: Cox (1982); MAZ: Yoosefi Lafooraki & Shayanmehr (2015a), Alijani-Ardeshtir et al. (2017), Shayanmehr et al. (2020), Vahedi Moghadam et al. (2022), Zamani Khormandichali et al. (2024).

Hypogastrura martiani Skarżyński & Kaprus', 2009, MAZ: Mohammadi Nodeheki et al. (2017).

Hypogastrura papillata Gisin, 1949, MAZ: Bakhshi et al. (2022).

Hypogastrura purpurescens (Lubbock, 1868), MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a).
Hypogastrura socialis (Uzel, 1891), MAZ: Zamani Khormandichali et al. (2024).
Hypogastrura vernalis (Carl, 1901), MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki & Shayanmehr (2015a), Mohammadi Nodeheki et al. (2017), Shayanmehr et al. (2020), Shayanmehr et al. (2023).
Willemia denisi Mills, 1932, GI: Daghighi (2012).
Triacanthella intermedia Dunger & Zivadinovic, 1984, MAZ: Yoosefi Lafooraki & Shayanmehr (2015a).
Choreutinula inermis (Tullberg, 1871), GI: Daghighi (2012).
Xenylla brevisimilis Stach, 1949, MAZ: Shayanmehr et al. (2023), Zamani Khormandichali et al. (2024).
Xenylla humicola (Fabricius, 1780), GI: Cox (1982); KH: Thibaud et al. (2011).
Xenylla welchi Folsom, 1916, MAZ: Yahyapour & Shayanmehr (2011), Yoosefi Lafooraki & Shayanmehr (2015a) Yahyapour et al. (2022b).

Neanuridae

Friesea afurcata (Denis, 1926), GO: Khanahmadi et al. (2018); MAZ: Shayanmehr et al. (2023)
Friesea claviseta Axelson, 1900, MAZ: Mohammadi Nodeheki et al. (2018), Vahedi Moghadam et al. (2022)
Friesea espunaensis Arbea & Jordana, 1993, MAZ: Yahyapour et al. (2021)
Friesea mirabilis (Tullberg, 1871), GI: Cox (1982); GO: Khanahmadi (2018)
Morulina verrucosa Börner, 1903, GI: Daghighi (2012)
Bilobella aurantiaca (Caroli, 1912), GI, MAZ: Cox (1982), Yoosefi Lafooraki & Shayanmehr (2015a)
Cryptonura abmalensis Arbea, Yahyapour & Shayanmehr, 2022, MAZ: Yahyapour et al. (2022a).
Cryptonura anthrenoidea (Ellis, 1976), MAZ: Shayanmehr et al. (2023)
Cryptonura dohezarensis Arbea, Yahyapour & Shayanmehr, 2022, MAZ: Yahyapour et al. (2022a).
Cryptonura maxima Smolis et al., 2012, GO: Smolis et al. (2012); MAZ: Smolis & Skarżyński (2020).
Cryptonura persica Smolis et al., 2012, GO: Smolis et al. (2012)
Cryptonura sariensis Arbea, Yahyapour & Shayanmehr, 2022, MAZ: Yahyapour et al. (2022a)
Deutonura breviseta Smolis & Skarżyński, 2020, GI, MAZ: Smolis & Skarżyński (2020)
Deutonura decolorata (Gama & Gisin, 1964), MAZ: Cox (1982), Yoosefi Lafooraki & Shayanmehr (2015a)

Endonura annae Smolis & Skarżyński, 2020, GI, MAZ: Smolis & Skarżyński (2020).
Endonura longirostris Smolis et al. 2017, GO: Smolis & Skarżyński (2020); MAZ: Smolis et al. (2017); Smolis & Skarżyński (2020).
Endonura paracentaurea Smolis et al. 2017, GI: Smolis & Skarżyński (2020); MAZ: Smolis et al. (2017); Smolis & Skarżyński (2020).
Endonura schwendingeri Smolis & Skarżyński, 2020, GI: Smolis & Skarżyński (2020).
Neanura muscorum (Templeton, 1836), GI: Cox (1982), Smolis & Skarżyński (2020); MAZ: Yahyapour (2012), Yoosefi Lafooraki & Shayanmehr (2015a), Shayanmehr et al. (2020)
Neanura persica Arbea, Yahyapour & Shayanmehr, 2022, MAZ: Yahyapour et al. (2022b,a)
Paravietnura rostrata Smolis & Skarżyński, 2020, GI: Smolis & Skarżyński (2020).
Persanura hyrcanica Mehrafrooz Mayvan, Shayanmehr, Smolis & Skarżyński, 2015, MAZ: Mehrafrooz Mayvan et al. (2015).
Vitronura sp, MAZ: Yoosefi Lafooraki (2014), Yahyapour et al. (2022a).
Aethiopella sp, MAZ: Yahyapour et al. (2020a)
Anurida ellipsoides Stach, 1949, GI: Cox (1982)
Anurida thalassophila (Bagnall, 1939), GI: Cox (1982).
Micranurida sensillata Gisin, 1953), GI: Cox (1982).
Pseudachorutes caramel Kaprus' et al. 2007, MAZ: Shayanmehr et al. (2023)
Pseudachorutes corticicolus (Schäffer, 1896), MAZ: Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022)
Pseudachorutes dubius Krausbauer, 1898, GI: Cox (1982); MAZ: Mohammadi Nodeheki et al. (2018), Vahedi Moghadam et al. (2022).
Pseudachorutes laricis Arbea & Jordana, 1989, MAZ: Shayanmehr et al. (2023).
Pseudachorutes parvulus Börner, 1901, GI: Cox (1982).
Pseudachorutes subcrassus Tullberg, 1871, GI: Cox (1982); MAZ: Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022), Vahedi Moghadam et al. (2022).

Odontellidae

Axenyllodes bayeri (Kseneman, 1935), GI: Cox (1982).
Superodontella lamellifera (Axelson, 1903), MAZ: Bakhshi et al. (2014).
Superodontella montemaceli Arbea & Weiner, 1992, MAZ: Shayanmehr et al. (2023).
Superodontella rotunda Kaprus, 2009, MAZ: Shayanmehr et al. (2023).

Onychiuridae

- Allonychiurus* sp, GO: Hosseini et al. (2016).
Deuteraphorura dashtenazensis Arbea, Yahyapour & Shayanmehr, 2020, MAZ: Yahyapour et al. (2020b), Vahedi Moghadam et al. (2022), Shayanmehr et al. (2023).
Heteraphorura cf. japonica (Yosii, 1967), GO: Hosseini et al. (2016); MAZ: Mehrafrooz Mayvan et al. (2015), Alijani-Ardeshtir et al. (2017), Ghasemi Cherati (2017).
Heteraphorura iranica Kaprus', Shayanmehr & Kahrarian, 2017, GO, MAZ: Kaprus et al. (2017), Khanahmadi et al. (2018), Bakhshi et al. (2022), Vahedi Moghadam et al. (2022), Shayanmehr et al. (2023).
Heteraphorura kaprusi Arbea, Yahyapour & Shayanmehr, 2020, MAZ: Yahyapour et al. (2020b), Vahedi Moghadam et al. (2022).
Hymenaphorura prox. sibirica (Tullberg, 1876), GI, MAZ: Cox (1982).
Onychiuroides cf. granulatus (Stach, 1930), GI, MAZ: Cox (1982).
Onychiuroides cf. pseudogranulosus (Gisin, 1951), GI, MAZ: Cox (1982).
Onychiuroides mazandaranensis Arbea, Yahyapour & Shayanmehr, 2020, MAZ: Yahyapour et al. (2020b).
Orthonychiurus cf. rectopapillatus (Stach, 1933), GI, MAZ: Cox (1982).
Orthonychiurus folsomi (Schäffer, 1900), MAZ: Yahyapour & Shayanmehr (2011), Shayanmehr et al. (2023).
Protaphorura cf. quadriocellata (Gisin, 1947), GI, MAZ: Cox (1982); GO: Khanahmadi et al. (2018).
Protaphorura cf. salsa Kaprus' et al. 2014, GO: Hosseini et al. (2016).
Protaphorura fimata (Gisin, 1952), GI: Cox (1982); MAZ: Cox (1982), Balvasi et al. (2015), Alijani-Ardeshtir et al. (2017).
Protaphorura hyrcanica Arbea, Yahyapour & Shayanmehr, 2020, MAZ: Yahyapour et al. (2020b).
Protaphorura iranica Arbea, Yahyapour & Shayanmehr, 2020, MAZ: Yahyapour et al. (2020b), Bakhshi et al. (2022).
Protaphorura ombrophila (Stach, 1960), MAZ: Ghasemi Cherati (2017), Ghasemi Cherati et al. (2022).
Protaphorura sakatoi (Yosii, 1966), MAZ: Yahyapour et al. (2020b), Zamani Khormandichali et al. (2024).
Sensillonychiurus sp, GO: Khanahmadi et al. (2018).
Thalassaphorura encarpata (Denis, 1931), GO: Hosseini et al. (2016); MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015a), Alijani-Ardeshtir et al. (2017).

Tullbergiidae

- Mesaphorura krausbaueri* Börner, 1901, GI, MAZ: Cox (1982).
Metaphorura affinis (Börner, 1902), GI: Cox (1982), Daghighi (2012), Daghighi et al. (2013b).
Tullbergia simplex (Gisin, 1958), MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014).

Symphyleona

Arrhopalitidae

- Arrhopalites caecus* (Tullberg, 1871), GI: Cox (1982); MAZ: Yahyapour et al. (2019).
Pygmarrhopalites principalis (Stach, 1945), MAZ: Yahyapour et al. (2019).

Dicyrtomidae

- Dicyrtoma fusca* (Lubbock, 1873), MAZ: Yahyapour & Shayanmehr (2011), Yahyapour (2012), Vahedi Moghadam et al. (2022).
Dicyrtoma ghilarovi Bretfeld, 1996, MAZ: Mehrafrooz Mayvan et al. (2015), Zamani Khormandichali et al. (2024); Yahyapour et al. (2022b).
Dicyrtomina minuta (Fabricius, 1783), GI, MAZ: Cox (1982).
Dicyrtomina ornata (Nicolet, 1842), MAZ: Yahyapour & Shayanmehr (2011), Yahyapour (2012).

Katiannidae

- Sminthurinus aureus* (Lubbock, 1862), GI: Daghighi (2012), Daghighi et al. (2013a); MAZ: Yahyapour & Shayanmehr (2011), Yahyapour (2012), Vahedi Moghadam et al. (2022).
Sminthurinus bimaculatus Axelson, 1902, GI: Cox (1982).
Sminthurinus gisini da Gama, 1965, MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015b).

Sminthurididae

- Sminthurides inaequalis* Börner, 1903, MAZ: Vahedi Moghadam et al. (2022).
Sminthurides malmgreni (Tullberg, 1876), GI: Cox (1982).

Sphaeridia pumilis (Krausbauer, 1898), GI: Cox (1982), Daghighi (2012); GO: Moradi et al. (2019); MAZ: Yoosefi Lafooraki (2014), Yoosefi Lafooraki & Shayanmehr (2015b).
Stenacidia violacea (Reuter, 1881), GI: Daghighi (2012).

Sminthuridae

Allacma fusca (Linnaeus, 1758), MAZ: Bakhshi et al. (2022).
Capraínea marginata (Schött, 1893), MAZ: Yahyapour & Shayanmehr (2011), Mehrafrooz Mayvan et al. (2015).
Sminthurus ghilarovi Stebaeva, 1966, MAZ: Mehrafrooz Mayvan et al. (2015), Vahedi Moghadam et al. (2022).
Sminthurus nigromaculatus (Tullberg, 1871), MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014).
Sminthurus viridis (Linnaeus, 1758), MAZ: Yoosefi Lafooraki & Shayanmehr (2013), Yoosefi Lafooraki (2014).
Lipothrix lubbocki (Tullberg, 1872), MAZ: Mehrafrooz Mayvan et al. (2015), Yahyapour et al. (2019); Yahyapour et al. (2022b).
Neosminthurus sp., GO: Khanahmadi et al. (2018).
Paralipothrix natalicius (Ellis, 1974), MAZ: Mehrafrooz Mayvan et al. (2015).
Sphyrrotheca sp., MAZ: Ghasemi Cherati (2017).

Discussion

A remarkable species diversity.

In the three sites sampled in the Bula Forest, we inventoried a total of 73 Collembola species, 49 of which were identified with precision. These species represent 39 genera and 12 families (Table 1). While some species could not be identified due to poor slide quality, several others appear to be strong candidates for new species. For example, *Ceratophysella* sp.01, *Friesea* sp.01, *Micranurida* sp.01, and *Paranura* sp.01 may be new to science and warrant formal description.

The specific diversity highlighted in this study is remarkable for several reasons. Firstly, the number of species identified exceeds that observed in most similar studies conducted in temperate broadleaved forests. On average, temperate forests are reported to host around 38 species of Collembola (Potapov et al. 2023). For example, Collembola diversity in French natural forests ranges between 29 and 54 species (Prat & Massoud 1980, Ponge & Prat 1982, Deharveng 1996,

Cassagne et al. 2006, Lek-Ang et al. 2007, Luque et al. 2011). However, the diversity observed in certain Pyrenean forests, such as the 66 species documented by de Izarra (1980) approaches the levels observed in the Bula Forest. On the other hand, some studies have found higher counts in the Caucasus with 79 species (Kuznetsova et al. 2019) and in the Polish Carpathians, ranging from 93 to 120 species (Smolis & Skarżyński 2003, Skarżyński & Smolis 2006), on the basis of extensive sampling.

Study limitations

It is important to note that our study is based on fieldwork with several limitations: only two sampling dates (both in spring), no autumn sampling, a relatively small geographic area (compared to the studies cited above), and the use of a single sampling method (Berlese funnel), without complementary techniques such as mouth aspirator. Consequently, the number of species is likely to be underestimated. A forthcoming publication will provide a more detailed analysis of the quantification of this species diversity.

A biodiversity reservoir.

Placing our findings in a broader biogeographical context underscores the importance of the Bula Forest as a biodiversity reservoir. To better appreciate this, we conducted an extensive literature review, compiling a list of all Collembola species recorded in the Hyrcanian Forest massif and across Iran (see Table S2, Supplementary Material).

A total of 323 species have been documented throughout the country, including 18 identified only to the genus (e.g., *Vitronura* sp. Yahyapour et al. 2022a). Of these, 215 species have been reported from the Hyrcanian Forests (excluding those found in artificial environments), with 8 species only partially identified and labelled as “sp.” (e.g., *Spatulosminthurus* sp., Shayanmehr et al. 2024).

Our work increases these totals to 354 species for Iran and 250 species for the Hyrcanian Forests. However, these numbers must be interpreted with caution, as they include unidentified morpho-species (e.g. sp.01, sp.02 etc). Some morphospecies likely correspond to already known species from the Hyrcanian region (e.g., *Isotomurus* sp.01–03 or *Lepidocyrtus* sp.01–03), while others represent new regional records, such as *Spatulosminthurus* sp.01, or potentially species new to science, such as *Paranura* sp.01.

Table 1. Summary table of species data

Number of Collembola species in Iran (→ including this study)	323 (→ 354)
Number of Collembola species in the Hyrcanian forest (→ including this study)	215 (→ 250)
Number of morphospecies identified in this study	73
Number of species identified in this study	49
Number of genera in this study	39
Number of families in this study	12
Number of new species for the Hyrcanian forests	35
Number of new species for Iran	31
Potential number of new species for science	~2-4

Our inventory from the Bula Forest alone accounts for approximately 30% of all Hyrcanian Collembola species documented to date. Notably, the Hyrcanian region harbours around 70% of Iran's total known Collembola species.

The diversity observed in the Bula Forest is striking not only at the species level but also across higher taxonomic levels. Sampling just three sites within the forest, we recorded 12 families and 39 genera. These figures represent a substantial portion of the 18 families and 91 genera recorded in the Hyrcanian Forests and the 20 families and 114 genera documented across Iran.

These numbers confirm that Bula Forest, part of the Caucasus and Irano-Anatolian Biodiversity Hotspots already well-recognised for their richness in other taxa (Zachos & Habel 2011, Tohidifar et al. 2016, Noroozi et al. 2019, Noroozi et al. 2022), is also an exceptional reservoir of Collembola diversity. This undoubtedly reinforces the critical need for conservation programs to preserve these unique ecosystems (Katouzian et al. 2016, Noroozi et al. 2022).

Future studies should explore Hyrcanian Collembola communities on a broader biogeographical scale, comparing the proportions of cosmopolitan, regional, and endemic species with those in other regions of Iran, such as the Zagros Forests, and in temperate forests globally. Such comparisons could further highlight the distinctive nature of the Hyrcanian Collembola communities. For instance, only 39 Collembola species have been recorded in Kurdistan, home to the Zagros Forests (Ahmadi et al. 2023), a number significantly lower than the diversity documented in the Bula Forest.

Exploring the Composition and Structure of Collembola Communities

While this initial inventory provides an important overview of the species composition of springtail

communities in the Bula Forest, more detailed analyses are needed to estimate the total species diversity and to examine whether, and how, diversity and evenness vary across sites and habitats. A finer-scale analysis of Collembola community composition could also help identify the most abundant or widespread species and uncover potential ecological specializations among the inventoried taxa.

These questions related to community composition and structure will be thoroughly addressed in a follow-up article. This upcoming research will focus on refined diversity estimates, species distribution and co-occurrence patterns, and the identification of species affiliated to specific microhabitats.

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