



Original Article

An annotated catalog of Iranian Symphypleona and Neelipleona (Hexapoda: Collembola): new records and key to species

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ABSTRACT

This article provides an annotated catalog of the Symphypleona and Neelipleona (Hexapoda: Collembola) of Iran based on published literature and specimens recently collected from three different ecosystems in North Khorasan province (Forest, Rangeland, and Agricultural) of the years 2018 and 2019. Thirty-five species in seven families and 17 genera are listed. Among them, *Megalothorax minimus* and *Bourletiella* sp. are recorded for the first time from Iran. An updated key to the Iranian species and information on the biology and geographical distribution of each species is provided.

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Introduction

Iran is located in a semiarid region of the Middle East in the southwestern corner of Asia. Most authors, for example, Darlington (1957) and Dasmann (1974), consider Iran as part of the Palearctic region except for some areas in southern Iran (considered Ethiopian). It is a large country with 31 provinces.

Springtails (Hexapoda, Collembola) are small arthropods commonly found in soil, litter, and other habitats worldwide (Ospina-Sánchez et al. 2020). So far, most studies on Collembola have been conducted in northern Iran, and a total of 19 provinces have been surveyed (Shayanmeh et al. 2020b). The first Iranian records of Collembola were collected from wheat and alfalfa fields in Khuzestan province (Farrahbakhsh 1961). The first Collembola references to Iran were by Gardenehire (1959) and Cox (1982). Later, Shayanmeh et al. (2013) published a catalog of Iranian Collembola and reported 112 species belonging to 18 families and 78

genera. Since 2013–2020, there has been more research on Collembola faunas in different parts of Iran (Mohammadi Nodehki and Shayanmeh 2020; Ramezani et al. 2020; Yoosefi Lafooraki et al. 2020).

There are four Orders of Collembola: Entomobryomorpha, Poduromorpha, Symphypleona, and Neelipleona (Fjellberg 2007). Symphypleona accounts for more than 1200 species worldwide. Earlier, they were grouped with Neelipleona because of the shared spherical body shape (Nardi et al. 2020). This order remains little known in Iran because of the lack of experts in this field. Here, we document the globular springtails belonging to the order Symphypleona and Neelipleona. The present study has two aims: to increase knowledge of the Symphypleona and Neelipleona of Iran by presenting an updated checklist and also a new key for identified symphypleonan springtails. Here, they are cataloged and updated for future researchers. In addition, distributional data, some biological notes, and bibliographical references for each species are provided.

Material and methods

This checklist is based on the literature published between the years 2013 and 2020 and includes new records of species collected

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by the senior author from different ecosystems in North Khorasan province (Figure 1) in 2018 and 2019. The new records were found in soil samples collected from three different ecosystems (forest, agricultural, and pasture land) monthly over 12 months. In this survey, samples were transported to the laboratory, and Collembola were extracted using modified Berlese/Tullgren funnels under light and preserved in 75% alcohol. Samples were cleared with Nesbitt's fluid and lactic acid. Permanent microscopic slides were prepared using Hoyer's medium. Specimens were identified using Bretfeld (1999) and Fjellberg (2007). Voucher specimens are deposited at Systematic Entomology Laboratory, Ferdowsi University of Mashhad, Iran. For each species, bibliographical data, habitat, ecology, and distribution are provided here. New reports are denoted by an asterisk (*).

The following abbreviations are used: Abd., abdominal segment; Ant., antennal segments; Cl., claw; Th., thorax; Tib., Tibiotarsi.

Results

Thirty-five species in seven families and 17 genera of Symphypleona and Neelipleona are listed (Table 1). Neelipleona (Neelidae) is five species in two genera, whereas Symphypleona has 30 species in 15 genera and six families. In addition, two newly recorded species *Megalothorax minimus* Willem 1900 and *Bourletiella* sp., are reported for the first time from the country, and for more information, micrographs of their important features are presented.

Systematic accounts

Subclass Collembola Lubbock, 1871

Order Neelipleona Massoud, 1971

Family Neelidae Folsom, 1896

Genus *Megalothorax* Willem, 1900

1. *Megalothorax incertus* Börner, 1903

Megalothorax incertus Börner, 1903: 160.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Mazandaran (Savadkooh) and Kermanshah by Yoosefi Lafooraki (2014), Yoosefi Lafooraki and Shayanmehr (2014), Kahrarian (2015), Shayanmehr and Yahyapour (2019), and Shayanmehr et al. (2020b).

General distribution and ecology. Cosmopolitan (Smolis and Skarżyński 2006).

2. *Megalothorax minimus** Willem, 1900

Megalothorax minimus Willem, 1900: 9.

Habitat and distribution in Iran. This species is reported here for the first time in Iran, collected from soil of alfalfa fields in North Khorasan (Shirvan; Figure 2).

General distribution and ecology. Cosmopolitan. A common soil form being present in a variety of habitats (Fjellberg 2007; Papáč and Kováč 2013; Babenko et al. 2019).

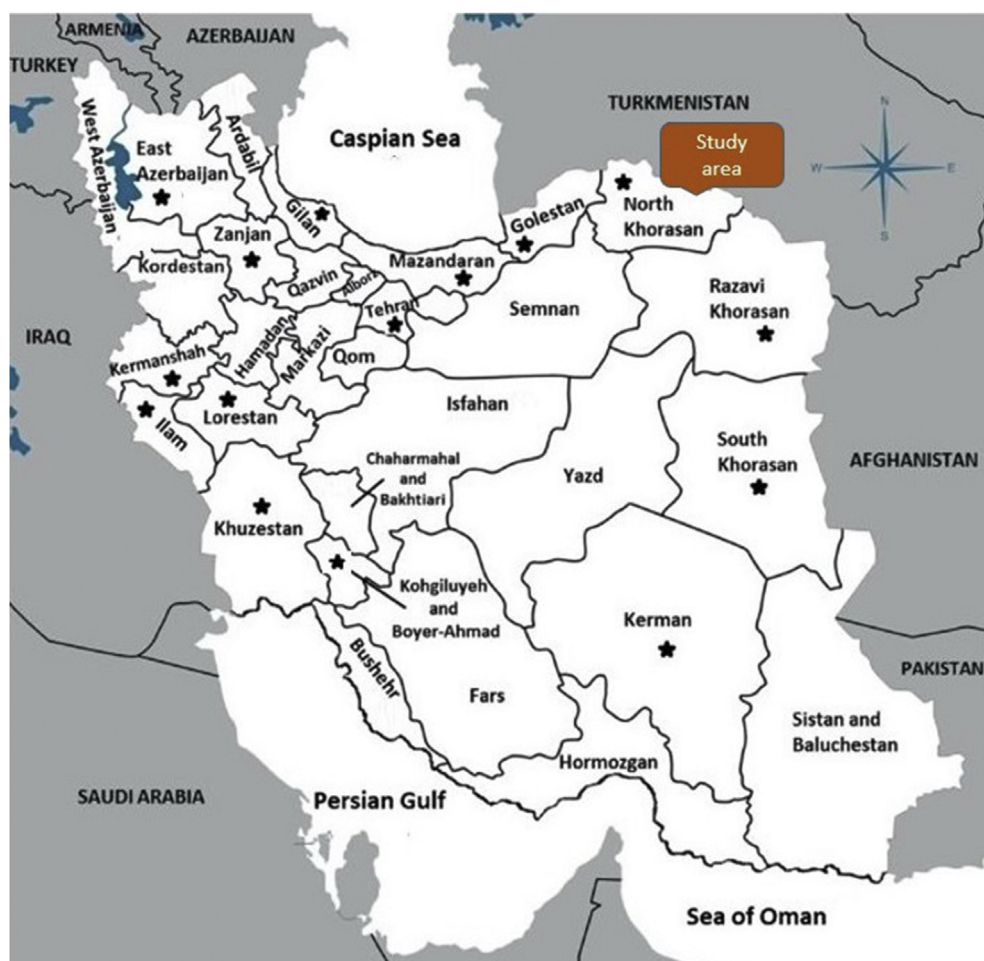


Figure 1. Map of Iranian provinces. *Localities from which Symphypleona and Neelipleona have been reported.

Table 1. Species, family, habitat, and distribution of Symphypleona recorded in Iran. Species marked with (*) recorded for the first time from Iran.

No.	Order	Species	Family	Habitat	Reference	Sampling area
1	Neelipleona	<i>Megalothorax incertus</i> Börner 1903	Neelidae	Soil and leaf litter	Yoosefi Lafooraki (2014) Yoosefi and Shayanmehr (2014) Kahrarian (2015) Shayanmehr and Yahyapour (2019) Shayanmehr et al (2020b)	Kermanshah Mazandaran
2		<i>Megalothorax minimus</i> Willem 1900*	Neelidae	Soil of alfalfa fields	Present study	North Khorasan
3		<i>Megalothorax perspicillum</i> Schneider and D'Haese 2013	Neelidae	Soil, leaf litter and dead wood	Yoosefi Lafooraki (2014) Yoosefi Lafooraki and Shayanmehr (2014) Kahrarian (2015) Shayanmehr and Yahyapour (2019) Shayanmehr et al (2020b)	Kermanshah Mazandaran
4		<i>Megalothorax willemi</i> Schneider and D'Haese 2013	Neelidae	Soil, leaf litter under <i>Parrotia persica</i> , <i>Quercus</i> sp. and <i>Pinus</i> sp. trees and from dead wood	Yoosefi Lafooraki (2014) Kahrarian (2015) Ghasemi Cherati (2017) Kahrarian (2019)	Mazandaran
5		<i>Neelus murinus</i> Folsom 1896	Neelidae	Soil and leaf litter	Cox (1982) Ghasemi Cherati (2017)	East Aerbaijan Mazandaran Tehran
6	Symphypleona	<i>Arrhopalites caecus</i> (Tullberg 1871)	Arrhopalitidae	Soil and leaf litter	Cox (1982) Ghahramaninezhad et al (2013) Kahrarian (2015) Present study	East Aerbaijan Kermanshah North Khorasan Razavi Khorasan
7		<i>Arrhopalites persicus</i> Vargovitsh and Kahrarian 2020	Arrhopalitidae	Surface layer of soil and leaf litter	Vargovitsh and Kahrarian (2020)	Kermanshah
8		<i>Arrhopalites principalis</i> Stach 1945	Arrhopalitidae	Soil and leaf litter	Yahyapour et al 2019	Mazandaran
9		<i>Bourletiella</i> sp.*	Bourletiellidae	Soil of alfalfa fields	Present study	North Khorasan
10		<i>Dicyrtoma fusca</i> (Lubbock 1873)	Dicyrtomidae	Leaf litter	Yahyapour and Shayanmehr (2011) Yahyapour (2012)	Mazandaran
11		<i>Dicyrtoma ghilarovi</i> Bretfeld 1996	Dicyrtomidae	Leaf litter	Mehrafrooz Mayvan (2014) Mehrafrooz Mayvan et al (2015) Moradi et al (2018) Kahrarian (2019) Moradi et al (2018)	Lorestan Mazandaran
12		<i>Dicyrtoma grinbergi</i> Stebaeva 1966	Dicyrtomidae	Surface layer of soil and leaf litter under Oak forest		Lorestan
13		<i>Dicyrtomina minuta</i> (Fabricius 1783)	Dicyrtomidae	Soil and leaf litter	Cox (1982)	Gilan Mazandaran
14		<i>Dicyrtomina ornata</i> Nicolet 1842	Dicyrtomidae	Leaf litter	Yahyapour and Shayanmehr (2011) Yahyapour (2012)	Mazandaran
15		<i>Sminthurinus aureus</i> (Lubbock 1862)	Katiannidae	Leaf litter and soil (<i>Ulmus</i> sp., <i>Prunus</i> sp., <i>Acer</i> sp., <i>Cupressus</i> sp., <i>Robinia</i> sp., <i>Populus</i> sp.)	Yahyapour and Shayanmehr (2011) Yahyapour (2012) Daghighi et al (2013) Present study.	Gilan Mazandaran North Khorasan
16		<i>Sminthurinus bimaculatus</i> Axelson 1902	Katiannidae	Soil and leaf litter	Cox (1982)	Gilan
17		<i>Sminthurinus elegans</i> (Fitch 1863)	Katiannidae	Soil, leaf litter and moss on tree	Cox (1982) Moravvej (2003) Yahyapour and Shayanmehr (2011) Yahyapour (2012) Mehrafrooz Mayvan et al (2015) Qazi and Shayanmehr (2014) Ghasemi Cherati (2017) Abdolzadeh (2018) Moradi et al (2018)	Golestan Kerman Kermanshah Lorestan Mazandaran North Khorasan Tehran
18		<i>Sminthurinus gisini</i> da Gama 1956	Katiannidae	Split of tree and moss on tree	Yoosefi Lafooraki (2014) Yoosefi Lafooraki and Shayanmehr (2013a, 2015).	Mazandaran

(continued on next page)

Table 1 (continued)

No.	Order	Species	Family	Habitat	Reference	Sampling area
19		<i>Sminthurinus reticulatus</i> Cassagnau 1964	Katiannidae	Soil and moss in garden	Falahati Hossein Abad et al (2013)	Kohgiluyeh
20		<i>Sminthurinus signatus</i> (Krausbauer 1898)	Katiannidae	Soil in garden	Falahati Hossein Abad et al (2013)	Kohgiluyeh
21		<i>Sminthurinus transversalis</i> Axelson 1905	Katiannidae	Soil and moss	Falahati Hossein Abad et al (2013)	Kohgiluyeh
22		<i>Sminthurides aquaticus</i> (Bourlet 1842)	Sminthurididae	Soil	Falahati Hossein Abad et al (2013)	Kohgiluyeh
23		<i>Sminthurides malmgreni</i> (Tullberg 1877)	Sminthurididae	Soil and leaf litter	Cox (1982)	East Aerbaijan Gilan Tehran
24		<i>Sphaeridia pumilis</i> (Krausbauer 1898)	Sminthurididae	Soil and leaf litter	Cox (1982) Kahrarian et al (2012) Yoosefi (2014) Kahrarian (2015) Yoosefi and Shayanmehr (2015) Zamani (2016) Moradi et al (2018) Present study	Gilan Kermanshah Lorestan Mazandaran North Khorasan Tehran
25		<i>Stenacidia violacea</i> (Reuter 1881)	Sminthurididae	Soil under cedar and pulm tree	Daghighi (2012)	Gilan
26		<i>Allacma fusca</i> (Linnaeus 1758)	Sminthuridae	Pitfall trap in forest	Bakhshi et al (2014)	Mazandaran
27		<i>Caprainea marginata</i> (Schött 1893)	Sminthuridae	Soil in forest	Yahyapour and Shayanmehr (2011) Kahrarian et al (2012) Mehrafrroz Mayvan et al (2015) Present study	Kermanshah Mazandaran North Khorasan
28		<i>Lipothrix lubbocki</i> (Tullberg 1872)	Sminthuridae	Leaf litter	Mehrafrroz Mayvan et al (2015) Yahyapour et al 2019	Mazandaran
29		<i>Neosminthurus</i> sp.	Sminthuridae	Leaf litter and soil of forest	Khanahmadi (2018)	Golestan
30		<i>Paralipothrix natalicius</i> (Ellis 1974)	Sminthuridae	Leaf litter in Forest	Mehrafrroz Mayvan et al (2015)	Mazandaran
31		<i>Sminthurus ghilarovi</i> Stebaeva 1966	Sminthuridae	Leaf litter in Forest	Mehrafrroz Mayvan et al (2015)	Mazandaran
32		<i>Sminthurus muscicolus</i> Betsch 1977	Sminthuridae	Soil and leaf litter under Cypress trees (Cupressaceae)	Shayanmehr et al (2020a and b)	Ilam
33		<i>Sminthurus viridis</i> Linnaeus 1758	Sminthuridae	Soil of wheat and alfalfa fields	Farahbakhsh (1961) Yoosefi and Shayanmehr (2013a, b) Ghahramaninezhad et al 2013 Yoosefi (2014) Kahrarian (2015) Moradi et al (2018) Present study	Kermanshah Khuzestan Lorestan Mazandaran North Khorasan
34		<i>Sminthurus wahlgreni</i> Stach 1920	Sminthuridae	Soil of wheat fields and date-palm orchards	Ramezani and Mossadegh (2016) Ramezani et al (2020)	Khuzestan
35		<i>Sphyrotheca</i> sp.	Sminthuridae	Leaf litter and soil of forest	Ghasemi Cherati (2017)	Mazandaran

Species marked with (*) recorded for the first time from Iran.

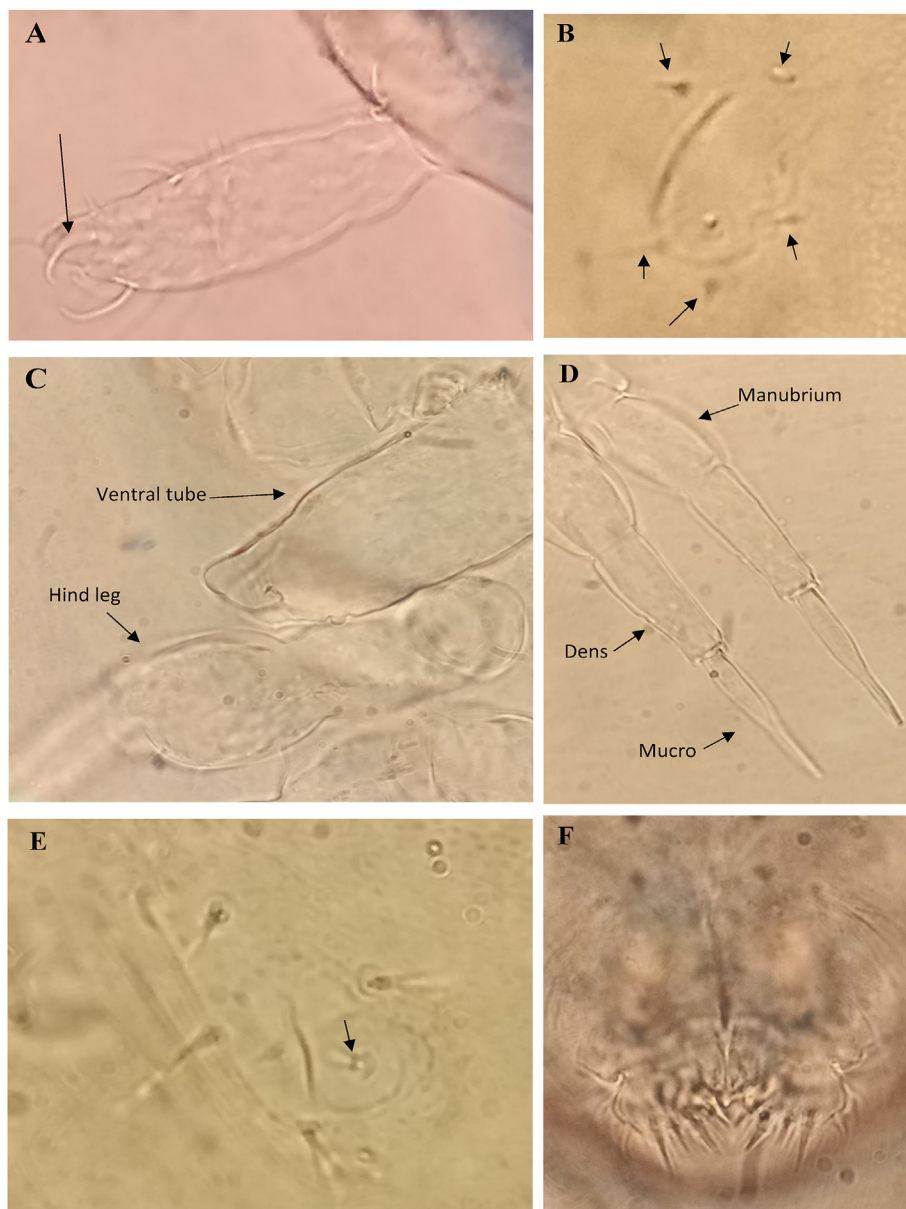


Figure 2. *Megalothorax minimus* from Iran. A, Ant.4 with particularly strong subapical sensillum indicate with arrow (100×); B, Sensory field of abdomen surrounded by five setae indicate with arrow (100×); C, Ventral tube without posterior lobe (100×); D, Mucro with smooth edges (40×); E, sensilla at base of hind leg (100×); F, head, anterior side of labrum (100×).

3. *Megalothorax perspicillum* Schneider and D'Haese, 2013
Megalothorax perspicillum Schneider and D'Haese, 2013: 340.

Habitat and distribution in Iran. This species was collected from soil, leaf litter, and dead wood in Mazandaran (Neka and Behshahr) and Kermanshah by Yoosefi Lafooraki (2014), Yoosefi Lafooraki and Shayanmehr (2014), Kahrarian (2015), Shayanmehr and Yahyapour (2019), and Shayanmehr et al. (2020b).

General Distribution. The species might be widespread (Bendjaballah et al. 2018).

4. *Megalothorax willemi* Schneider and D'Haese, 2013
Megalothorax willemi Schneider and D'Haese, 2013: 347.

Habitat and distribution in Iran. This species found in soil, leaf litter under *Parrotia persica*, *Quercus* sp., and *Pinus* sp. trees and from dead wood in Mazandaran (Neka, Behshahr, Noor, and Sari) by Yoosefi Lafooraki (2014), Yoosefi Lafooraki and Shayanmehr (2014), Kahrarian (2015), Ghasemi Cherati (2017), and Kahrarian (2019).

General distribution. Belgium and Iran. Represent edaphic species with occurrence in different habitats such as forest litter, moss, and caves. It was discovered in a park near the type locality of *M. minimus* (Schneider & Haese, 2013).

Genus *Neelus* Folsom, 1896

5. *Neelus murinus* Folsom, 1896
Neelus murinus Folsom, 1896: 391.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Mazandaran (Sari), Tehran, and East Azarbaijan by Cox (1982), Qazi and Shayanmehr (2016), and Ghasemi Cherati (2017).

General distribution. Cosmopolitan (Fjellberg 2007; Bendjballah et al. 2018).

Order Symphypleona Börner, 1901

Family Arrhopalitidae Stach, 1956

Genus Arrhopalites Börner, 1906

6. *Arrhopalites caecus* (Tullberg, 1871)

Sminthurus caecus Tullberg, 1871: 146.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Guilan, East Azarbaijan, Kermanshah, and

Razavi Khorasan by Cox (1982), Ghahramaninezhad et al. (2013), Kahrarian (2015), and the present study.

General distribution and ecology. Palearctic. Widely distributed, but uncommon. In various litter, both in forests and outside. Sometimes under bark and in rotten wood (Fjellberg 2007).

7. *Arrhopalites persicus* Vargovitsh and Kahrarian, 2020

Habitat and distribution in Iran. The species was collected from the surface layer of soil and leaf litter in oak forest in Kermanshah by Vargovitsh & Kahrarian (2020).

General Distribution. Iran (Vargovitsh and Kahrarian 2020).

8. *Arrhopalites principalis* Stach, 1945

Arrhopalites principalis Stach, 1945: 47.

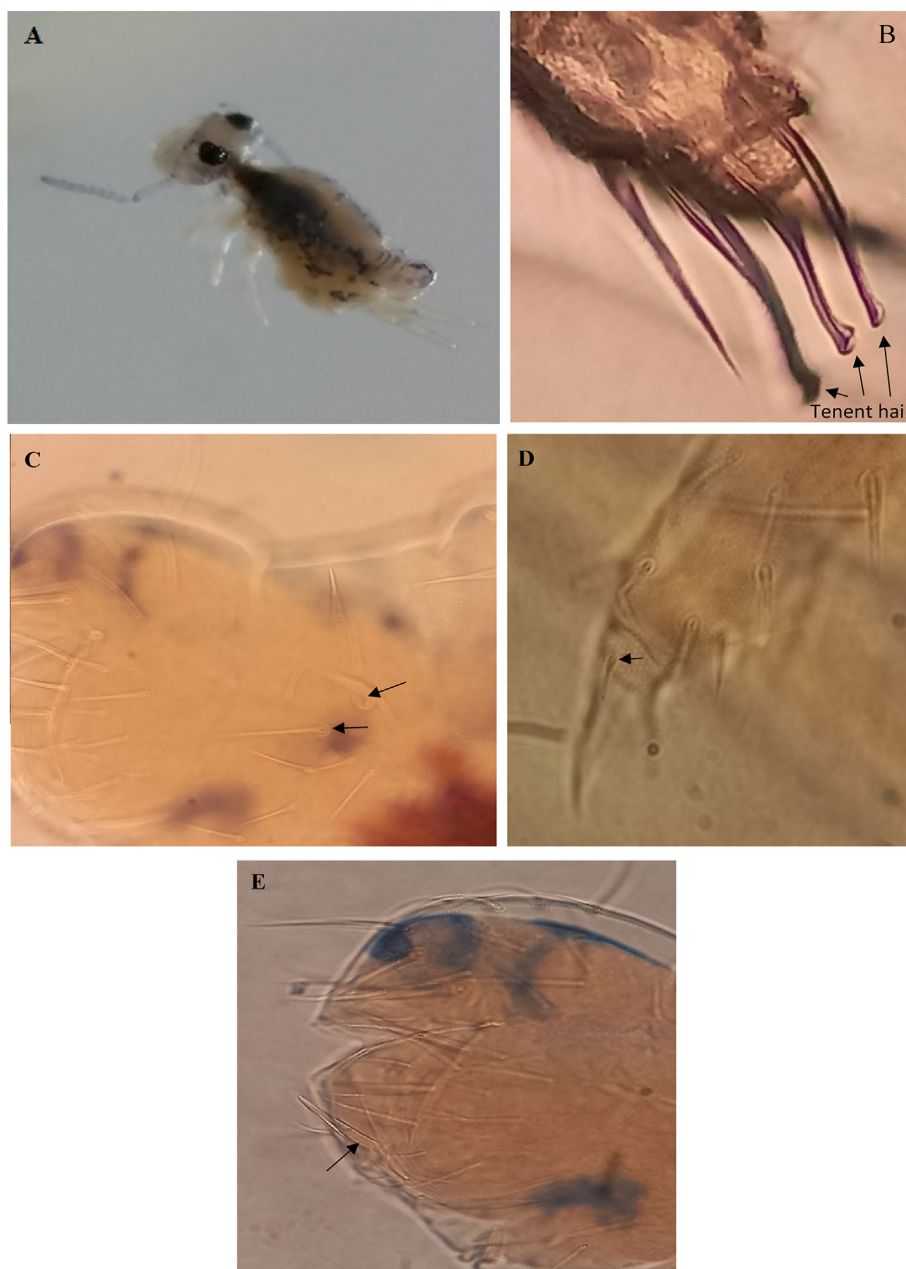


Figure 3. *Bourletiella* sp. from Iran. A, Habitus of specimen fixed in alcohol (10×); B, clavate apical setae on Tibiotarsi (100×); C, pairs of trichobothria on abd.5 indicated by arrows (100×); D, one anterior setae on pretarsus (100×); E, subanal setae indicated by arrow (40×).

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Mazandaran (Sari, Chahardangeh, and Langar village) by [Yahyapour et al. 2019](#).

General distribution and ecology. Holarctic. Probably most common *Arrhopalites*, recorded even in high mountains and in the Arctic. Present in moss and forest litter but also in bogs and alpine meadows and *Salix* thickets ([Fjellberg 2007](#)).

Family Bourletiellidae [Börner, 1913](#)

Genus *Bourletiella* Banks, 1899

9. *Bourletiella* sp.*

Habitat and distribution in Iran. This species is reported here for the first time in Iran, collected from the soil of alfalfa fields in North Khorasan (Shirvan; [Figure 3](#)).

Family Dicyrtomidae [Börner, 1906](#)

Genus *Dicyrtoma* Bourlet, 1842

10. *Dicyrtoma fusca* ([Lubbock, 1873](#))

Papirius fuscus [Lubbock, 1873](#): 120.

Habitat and distribution in Iran. This species was collected from leaf litter in Mazandaran (Sari) by [Yahyapour and Shayanmehr \(2011\)](#), and [Yahyapour \(2012\)](#).

General distribution and ecology. Holarctic. Common and widely distributed in forest vegetation but also in bogs and other wet habitats ([Fjellberg 2007](#); [Buşmachıu et al. 2014](#)).

11. *Dicyrtoma ghilarovi* [Bretfeld, 1996](#)

Habitat and distribution in Iran. This species was collected from leaf litter in Mazandaran (Sari) and Lorestan by [Mehrafröoz Mayvan \(2014\)](#), [Mehrafröoz Mayvan et al. \(2015\)](#), [Moradi et al. \(2018\)](#), and [Kahrarian \(2019\)](#).

General Distribution. Palearctic ([Bretfeld 1999](#)).

12. *Dicyrtoma grinbergi* [Stebaeva, 1966](#)

Dicyrtoma grinbergi [Stebaeva, 1966](#): 10.

Habitat and distribution in Iran. The species was collected from the surface layer of soil and leaf litter under Oak forest in Lorestan province (Khoramabad) by [Moradi et al. \(2018\)](#).

General distribution and ecology. Palearctic. This species was reported in a few countries such as Russia and Taiwan ([Bretfeld 1999](#)) and Iran ([Moradi et al. 2018](#)).

Genus *Dicyrtomina* Börner, 1903

13. *Dicyrtomina minuta* ([Fabricius, 1783](#))

Podura minuta O. [Fabricius, 1783](#): 307.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Mazandaran and Guilan by [Cox \(1982\)](#).

General distribution and ecology. Holarctic. A common species which is usually found in the litter layer of humid meadows and forests but also in bogs ([Fjellberg 2007](#)).

14. *Dicyrtomina ornata* [Nicolet, 1842](#)

Smythurus ornatus [Nicolet, 1842](#): 83.

Habitat and distribution in Iran. This species was collected from leaf litter in Mazandaran (Sari) by [Yahyapour and Shayanmehr \(2011\)](#) and [Yahyapour \(2012\)](#).

General distribution and ecology. Palearctic. Probably less common than *D. minuta*, with few records apart from in Finland. In Norway, common around Bergen in moist habitats ([Fjellberg 2007](#); [Bendjaballah et al. 2018](#)).

Family Katiannidae [Börner, 1913](#)

Genus *Sminthurinus* Börner, 1901

15. *Sminthurinus aureus* ([Lubbock, 1862](#))

Smythurus aureus [Lubbock, 1862](#): 589.

Habitat and distribution in Iran. This species was collected from leaf litter and soil (*Ulmus* sp., *Prunus* sp., *Acer* sp., *Cupressus* sp., *Robinia* sp., and *Populus* sp.) in Mazandaran (Sari) and Guilan (Rasht) by [Yahyapour and Shayanmehr \(2011\)](#), [Yahyapour \(2012\)](#), [Daghighi et al. \(2013\)](#), and the present study.

General distribution and ecology. Palearctic. Probably widely distributed but mostly scattered records from dry meadows and moss/litter in forests ([Fjellberg 2007](#)).

16. *Sminthurinus bimaculatus* [Axelson, 1902](#)

Sminthurinus igniceps var. *bimaculata* [Axelson](#): 110.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Guilan by [Cox \(1982\)](#).

General distribution and ecology. Palearctic. Originally described from forest habitats in Northern Finland. No records from other Nordic countries ([Fjellberg 2007](#)).

17. *Sminthurinus elegans* ([Fitch, 1863](#))

Sminthurus elegans [Fitch, 1863](#): 657.

Habitat and distribution in Iran. This species was collected from soil, leaf litter, and moss on tree in Mazandaran (Sari, Noor, Royan, Neka, Hezar jrib forest, Royan, and Behshahr), Golestan (Gorgan), Tehran, Kermanshah, Kerman, and Lorestan by [Cox \(1982\)](#), [Moravvej \(2003\)](#), [Yahyapour and Shayanmehr \(2011\)](#), [Yahyapour \(2012\)](#), [Falahati Hossein Abad et al. \(2013\)](#), [Ghahramaninezhad et al. \(2013\)](#), [Yoosefi Lafooraki \(2014\)](#), [Kahrarian \(2015\)](#), [Mehrafröoz Mayvan et al. \(2015\)](#), [Yoosefi Lafooraki and Shayanmehr \(2015\)](#), [Qazi and Shayanmehr \(2014\)](#), [Qazi and Shayanmehr \(2016\)](#), [Ghasemi Cherati \(2017\)](#), [Abdolalizadeh \(2018\)](#), [Moradi et al. \(2018\)](#), and the present study.

General Distribution and ecology. Probably widely distributed (Cosmopolitan) but mostly scattered records from dry meadows and moss/litter in forests ([Fjellberg 2007](#)).

18. *Sminthurinus gisini* [da Gama, 1956](#)

Sminthurinus carpathicus [Baquero et al., 2021](#): 7.

Habitat and distribution in Iran. This species was collected from the trunk of tree and moss on tree in Mazandaran (Neka, Hezar jrib forest, Savadkooh, and Alasht) by [Yoosefi Lafooraki \(2014\)](#) and [Yoosefi Lafooraki and Shayanmehr \(2013a, 2015\)](#).

General Distribution. Europe and Iran ([Ramel et al. 2008](#); [Busmachıu et al. 2014](#)).

19. *Sminthurinus reticulatus* [Cassagnau, 1964](#)

Sminthurinus reticulatus [Cassagnau, 1964](#): 481.

Habitat and distribution in Iran. This species was collected from soil and moss in garden Kohgiluyeh and Boyer-Ahmad (Choram) by [Falahati Hossein Abad et al. \(2013\)](#).

General distribution. Palearctic ([Fjellberg 2007](#)).

20. *Sminthurinus signatus* (Krausbauer, 1898)

Sminthurus aureus var. *signatus* Krausbauer, 1898: 496.

Habitat and distribution in Iran. This species was collected from soil in garden Kohgiluyeh and Boyer-Ahmad (Elghechin village) by Falahati Hossein Abad et al. (2013).

General distribution and ecology. Palaearctic. According to Linnaniemi (1912), this characteristic species is widely distributed in Finland, mainly in moss and litter of the forest floor but also in damp ground. Few records from other Nordic countries (Fjellberg 2007; Bendjaballah et al. 2018).

21. *Sminthurinus transversalis* Axelson, 1905

Sminthurinus aureus var. *transversalis* Axelson, 1905: 794.

Habitat and distribution in Iran. This species was collected from soil and moss in Kohgiluyeh and Boyer-Ahmad (Forest- Elghechin village) by Falahati Hossein Abad et al. (2013).

General Distribution. Palaearctic (Fjellberg 2007).

Family Sminthuridae Börner, 1906

Genus *Sminthurides* Börner, 1900**22. *Sminthurides aquaticus* (Bourlet, 1842)**

Sminthurus apicalis Reuter, 1880: 146.

Habitat and distribution in Iran. This species was collected from soil in Kohgiluyeh and Boyer-Ahmad (Forest-choram) by Falahati Hossein Abad et al. (2013).

General distribution and ecology. Holarctic (Fjellberg 2007). *Sminthurides aquaticus* (Bourlet, 1842) is common and widely distributed in ponds and along the shores of atrophic lakes (Fjellberg 2007).

23. *Sminthurides malmgreni* (Tullberg, 1876)

Sminthurus malmgreni Tullberg, 1876: 30.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Tehran, Guilan, East Azarbaijan by Cox (1982) and Qazi and Shayanmehr (2016).

General distribution and ecology. Holarctic. This is our most common *Sminthurides*, being recorded both in lowlands, mountains, and the Arctic. May be found in different kinds of water bodies and wetlands (Fjellberg 2007).

Genus *Sphaeridia* Linnaniemi, 1912**24. *Sphaeridia pumilis* (Krausbauer, 1898)**

Sminthurus pumilis Krausbauer, 1898: 495.

Habitat and distribution in Iran. This species was collected from soil and leaf litter in Central, Guilan, Kermanshah (Sahneh and Harsin), Mazandaran (Neka, Hezar jarib forest, Sari, Beh-shahr, Noor, and Royan), Tehran and Lorestan by Cox (1982), Kahrarian et al. (2012), Yoosefi Lafooraki (2014), Kahrarian (2015), Yoosefi Lafooraki and Shayanmehr (2015), Zamani (2016), Qazi and Shayanmehr (2016), Moradi et al. (2018), and the present study.

General distribution and ecology. Cosmopolitan. Unlike members of the next genus, which are mostly present in aquatic or very wet habitats, *Sphaeridia pumilis* is frequently found in terrestrial habitats both in forest and outside. Widely distributed, also in the Arctic (Fjellberg 2007; Ramel et al. 2008).

Genus *Stenacidia* Reuter, 1881**25. *Stenacidia violacea* (Reuter, 1881)**

Sminthurus violaceus Reuter, 1881: 203.

Habitat and distribution in Iran. This species was collected from soil under Cedar (*Cedrus*) and Pulm (*Prunus*) tree in Guilan (Sangar) by Daghighi (2012).

General distribution and ecology. Cosmopolitan. Linnaniemi (1912) gives several records from Finland, from various wet habitats (Fjellberg 2007).

Family Sminthuridae Lubbock, 1862

Genus *Allacma* (Börner, 1906)**26. *Allacma fusca* (Linnaeus, 1758)**

Podura fusca Linnaeus, 1758: 608.

Habitat and distribution in Iran. This species was collected from pitfall traps in forest in Mazandaran (Sari) by Bakhshi et al. (2014).

General distribution and ecology. Holarctic. This large species, reaching sizes not matched by any other Symphyplona in our area, is commonly found in moist forests where it is easily spotted on damp logs and stumps of wood. Widely distributed (Fjellberg 2007; Busmachiu et al. 2014).

Genus *Caprainea* Dallai, 1970**27. *Caprainea marginata* (Schott, 1893)**

Sminthurus marginatus Schött, 1893: 25.

Habitat and distribution in Iran. This species was collected from soil in forest in Mazandaran and Kermanshah (Sahneh and Harsin) by Yahyapour and Shayanmehr (2011), Kahrarian et al. (2012), Mehrafrooz Mayvan et al. (2015), and the present study.

General distribution and ecology. Palaearctic. The only Nordic records are Schött's (1893), Wahlgren (1906) who reported a record from Scania. In Denmark, the researcher found the species at Lolland (Fuglsang Storskov). All records from forest habitats (Fjellberg 2007).

Genus *Lipothrix* Börner 1906**28. *Lipothrix lubbocki* (Tullberg, 1872)**

Sminthurus lubbocki Tullberg, 1872: 33.

Habitat and distribution in Iran. This species was collected from leaf litter in Mazandaran (Sari and Tonekabon) by Mehrafrooz Mayvan et al. (2015) and Yahyapour et al. 2019.

General distribution and ecology. Palaearctic. Widely distributed in the forested zone, in moss and litter of the forest floor (Fjellberg 2007; Bendjaballah et al. 2018).

Genus *Neosminthurus* Mills, 1834**29. *Neosminthurus* sp.**

Habitat and distribution in Iran. Another genus belonging to this family, *Neosminthurus* Mills, 1834, was reported from Iran with unknown species. Some dispersed reports of the genus have been published from Golestan collected from leaf litter and soil of forest by Khanahmadi (2018).

Genus *Paralipothrix* Bretfeld, 1999**30. *Paralipothrix natalicus* (Ellis, 1974)***Paralipothrix natalicus* Ellis, 1974: 131.

Habitat and distribution in Iran. This species was collected from leaf litter in the Forest of Mazandaran (Sari) by Mehrafrooz Mayvan et al. (2015).

General distribution and ecology. Palearctic. Ecomorphological life form of this species is Hemiedaphic and found in the Mediterranean basin (Bretfeld 1999).

Genus *Sminthurus* Latreille, 1804**31. *Sminthurus ghilarovi* Stebaeva, 1966***Sminthurus ghilarovi* Stebaeva, 1966: 9.

Habitat and distribution in Iran. This species was collected from leaf litter in Mazandaran (Sari) by Mehrafrooz Mayvan et al. (2015).

General distribution and ecology. Palearctic. Ecomorphological life form of this species is Hemiedaphic (Bretfeld 1999; Kováč et al. 2001).

32. *Sminthurus muscicolus* Betsch, 1977*Sminthurus muscicolus* Betsch, 1977: 66.

Habitat and distribution in Iran. This species was collected from soil and leaf litter under Cypress trees (Cupressaceae) in Ilam (Choqa-Sabz Forest Park) by Shayanmehr et al. (2020a and b).

General distribution. Mongolia, Russia, and Iran (Bretfeld 2010; Shayanmehr et al. 2020a, b).

33. *Sminthurus viridis* Linnaeus, 1758*Sminthurus viridis* var. *nigromaculatus* Tullberg, 1872: 145.

Habitat and distribution in Iran. This species was collected from wheat and alfalfa fields in Khuzestan, Kermanshah, Lorestan, and Mazandaran (Savadkooh) by Farahbakhsh (1961), Yoosefi Lafooraki and Shayanmehr (2013a, b), Ghahramaninezhad et al. 2013, Yoosefi Lafooraki (2014), Kahrarian (2015), Moradi et al. (2018), and the present study.

Distribution and ecology. Cosmopolitan. Usually in grassy meadow habitats, mostly dry. Distribution is incompletely known because older records may have included both *S. viridis* and *S. nigromaculata* (Fjellberg 2007; Ramel et al. 2008).

34. *Sminthurus wahlgreni* Stach, 1920*Sminthurus Wahlgreni* Stach, 1930: 310.

Habitat and distribution in Iran. This species was collected from wheat fields and date-palm orchard in Khuzestan province by Ramezani and Mossadegh (2016) and Ramezani et al. (2020).

Distribution and ecology. Eastern and Central Europe and Iran. Also *S. wahlgreni* is a litter-dwelling species (Bretfeld 1999).

Genus *Sphyrotheca* Börner, 1906**35. *Sphyrotheca* sp.**

Habitat and distribution in Iran. Specimens of the genus *Sphyrotheca* Börner 1906 have been reported from Iran with unknown species. Some reports of the genus have been published from Mazandaran collected from leaf litter and soil of forest by Ghasemi Cherati (2017).

Key to the Iranian species of *Neelipleona* and *Symphyleona* (adapted from Richards 1968, Bretfeld 1999, and Fjellberg 2007).

1. Antennae shorter than head, body strongly globular, pigment absent or poorly developed, small species (<0.5 mm), eyes absent (*Neelidae*) 2
- Antennae longer than head, body more or less globular, larger species, mostly with dark pigmentation 6
2. Posterior of ventral tube with a small lobe. Abdominal sensory field surrounded by two setae. Ant.3–4 separated. Mucro with serrated dorsal edges and a mid-ventral keel. Ventral tube with a blunt posterior lobe and 2+2 distal setae. Retinaculum with 3+3 teeth, no setae *Neelus murinus* Folsom 1896
- Ventral tube without posterior lobe. Sensory field of abdomen surrounded by five setae. Ant.3–4 fused. Mucro in our species with smooth edges (*Megalothorax* Willem) 3
3. Mucro posterior edges perfectly smooth, or rather smooth with irregularities 4
- Mucro posterior edges serrate or crenellate 5
4. Inner sensillum of sensory field 2-6 all candle flame-shaped, pigmentation absent, maxilla outer lobe with a sublobal hair; unguis ordinary *M. willemi* Schneider and D'Haese 2013
- Inner sensillum of sensory field 2-6 some T-shaped, pigmentation often brown or orange; sensilla s2 rather small *M. minimus* Willem 1900 sensu Schneider and D'Haese (2013)
5. Body with weak dots of black pigment hardly visible on field microscope; mucro teeth thin and subtle, retinaculum with 4+4 teeth *M. perspicillum* Schneider and D'Haese 2013
- Body not pigmented or slightly reddish, mucro teeth rather large, Retinaculum with 3+3 teeth *M. incertus* Börner 1903
6. Pigmented eye-spots absent, 1+1 ocelli. Pigmentation absent or very weak. (*Arrhopalitidae*) 7
- Eye-spots pigmented, with 8+8 ocelli. Mostly well-pigmented species 9
7. Anterior side of dens with five rows of setae: 3, 2, 1, 1, 1 setae (*caecus* group), Abd.6 with 4+4 cuticular spines 8
- Anterior side of dens with four rows of setae: 3, 2, 1, 1 (*diversus* group), Abd.6 with 5+5 cuticular spines (upper anal valve with 3+3 spines).....*Arrhopalites persicus* Vargovitsh and Kahrarian 2020
8. Ant. 4 undivided or with tendency to five subsegments, subanal appendages as rod-shaped, apex slightly bent, and serrated *Arrhopalites caecus* (Tullberg 1871)
- Ant.4 have six subsegments, subanal appendages with long apical filaments *Arrhopalites principalis* Stach, 1945
9. Males antennae with clasping organ. Females without modified subanal setae (*Sminthuridae*) 10
- Males with simple antennae. Females with a pair of modified subanal setae 13
10. Tibiotarsal organ present (inner side of tib.3) 11
- Tibiotarsal organ absent *Sphaeridia pumilis* (Krausbauer 1898)
11. Posterior large abdomen dorsally with six to eight pairs of long setae close together, Mucro narrow and pointed, Ant.3 and 4 with 2 two and three long erect setae on ventral side *Stenacidia violacea* (Reuter 1881)
- Posterior large abdomen without such setae, Mucrones with well-developed, often complex, Ant.3 and 4 without such setae on ventral side (*Sminthurides* Börner) 12
12. Mucro narrower and only one-third as wide as long, ventral tube with smooth and conical sacs, retinaculum with 2–3 setae *Sminthurides malmgreni* (Tullberg, 1877)

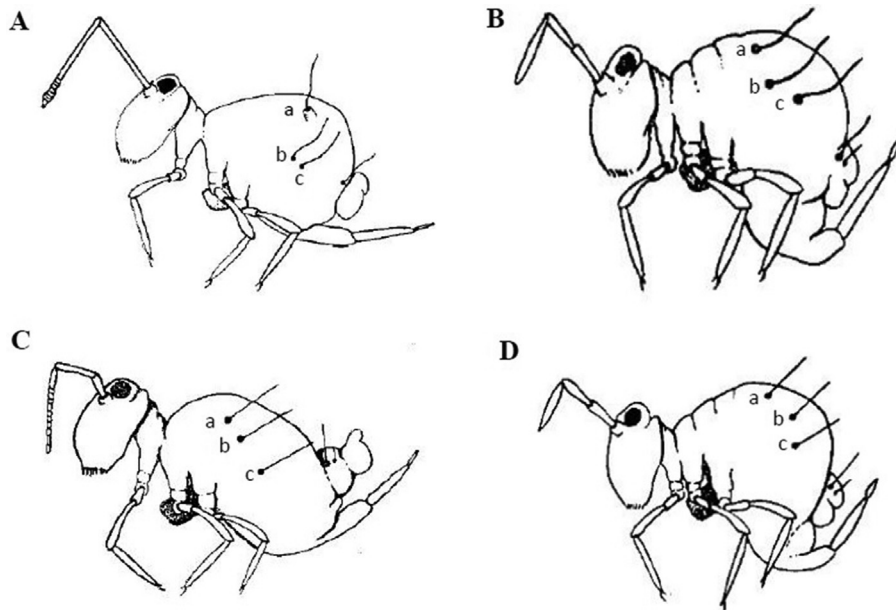


Figure 4. Bothriotrichal patterns: A, dicyrtomoid pattern, a is raised on a conspicuous, whereas b and c are close together almost directly below a; B, inverted pattern, in which b is ventral of a and c; C, linear pattern, in which all of them are arranged in a straight line; D, triangular pattern, in which b is dorsal of a line drawn between a and c (Adapted from Richards 1968).

- Mucro broader and at least half as wide as long, ventral tube with smooth sacs, retinaculum with 3–4 setae *Sminthurides aquaticus* (Bourlet, 1842)
- 13. Antennae elbowed between segments 2 and 3, Ant.4 much shorter than ant.3, Bothriotrichal pattern in fifth segment of abdomen is characteristic of a dicyrtomid (Figure 4A) (Dicyrtomidae) 14
- Antennae elbowed between segments 3 and 4, Ant.4 at least as long as third 18
- 14. Claws with tunica. Backside of head with 2+2 large spine-like macrochaetae and 1+1 normal setae (*Dicyrtomina* Börner) 15
- Claws without tunica. Backside of head with 1+1 long spines, other postocular setae short (*Dicyrtoma* Bourlet) 16
- 15. Large abdomen laterally with dark violet pigmentation and with irregular, bluish-black longitudinal and cross stripes *Dicyrtomina ornata* Nicolet, 1842
- Large abdomen without or with light violet pigmentation *Dicyrtomina minuta* (Fabricius, 1783)
- 16. Setae of dens with large basal teeth and broadened basally 17
- All setae of dens smooth, both edges of mucro serrate *Dicyrtoma grinbergi* Stebaeva, 1966
- 17. Ratio of setae E3:E2 of dens about 1 *Dicyrtoma ghilarovi* Bretfeld, 1996
- Ratio of setae E3:E2 more than or equal to 3 *Dicyrtoma fusca* Lubbock, 1873
- 18. Ant.4 not subdivided. Female subanal setae directed forward/down ventrally, neosminthuroid setae present, Bothriotrichal pattern in the fifth segment of abdomen is triangular (Figure 4D). Tenent hairs rarely absent (Katiannidae (*Sminthurinus*)) 19
- Ant.4 subdivided. Female subanal setae directed backward/up, neosminthuroid setae missing, Bothriotrichal pattern in the fifth segment of abdomen is linear or inverted (Figure 4B and C), tenent hairs not as above 25
- 19. Dens anteriorly without subapical setae, dens posteriorly with one outer subapical and three proximal setae, inner edge of mucro serrate and outer smooth 20
- Dens anteriorly with at least one subapical setae, dens posteriorly with two outer subapical, and four proximal setae, inner and outer edges of mucro serrate ... *S. gisini* da Gama, 1956
- 20. Body with distinct bands or stripes/spots 21
- Body uniformly colored, darker, or paler *S. aureus* (Lubbock, 1862)
- 21. Abdomen with longitudinal bands and/or cross bands 22
- Abdomen dark with a roundish white spot *S. bimaculatus* Axelson, 1902
- 22. Head with 1+1 postlabial setae. Trichobothrium D on abd.5 slender, setaceous, not thicker than surrounding setae 23
- Head with 2+2 postlabial setae. Trichobothrium D thickened, spiniform, thicker than surrounding setae *S. elegans* (Fitch, 1863)
- 23. Abdomen only with a single lateral band present, no dorsal bands *S. signatus* (Krausbauer, 1898)
- Abdomen with anterior dorsal zigzags and posterior mid-dorsal band 24
- 24. Head unpigmented in posterior midsection *S. transversalis* Axelson, 1905
- Midsection of head dark back to posterior *S. reticulatus* Cassagnau, 1964
- 25. Tibiotarsi with 2–3 strongly clavate apical setae, which are adpressed to the claws. Pretarsus with one anterior setae only. Abd.5 with two pairs of trichobothria, Bothriotrichal pattern is linear (Figure 4C; Bourletiellidae) *Bourletiella* Banks
- Tibiotarsi with pointed or weakly clavate apical setae, which are not adpressed to the claws. Pretarsus with two setae (anterior/posterior). Abd.5 with one pair of trichobothria, Bothriotrichal pattern is inverted (Figure 4D; Sminthuridae) 26
- 26. Neosminthuroid setae present. Dens with no more than six ventral setae (Sphyrothecinae) 27

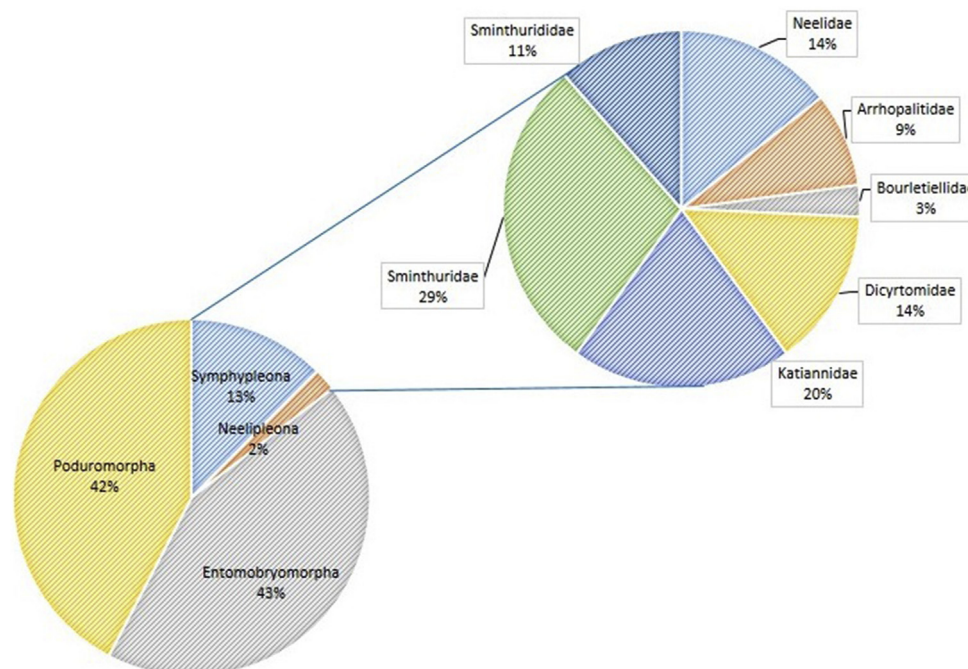


Figure 5. Percentage of families of Symphyleona and Neelipleona springtails recorded until March 2021 in Iran.

- Neosminthuroid setae absent. Dens with at least nine ventral setae (Sminthurinae) 29
- 27. Th.2 with finger-like vesicles. Abd.5 without trichobothrium 28
- Th.2 without vesicles. Abd.5 with trichobothrium *Sphyrotheca* Börner
- 28. Claws with tunica and serrated basolateral edges, Dens with three ventral setae, inner dorsal edge of mucro with seven to eight blunt teeth, outer edge almost smooth, head with thick, blunt-tipped rough macrochaetae *Lipothrix lubbocki* (Tullberg, 1872)
- Claw broad with inner tooth, large tunica, dens with four anterior seta, inner dorsal edge of mucro coarsely serrate, outer smooth, head with short, truncate, almost smooth spine *Paralipothrix natalicus* (Ellis, 1974)
- 29. Trochanter of hind leg with a spine on the backside 30
- Trochanter only with normal setae on the backside (*Sminthurus* Latreille) 31
- 30. Head with a short thick setae between antennal base and eye field (postantennal setae) *Allacma fusca* (Linnaeus, 1758)
- Head without such setae *Caprainea marginata* (Schott, 1893)
- 31. Ant.4 with 17 subsegments, Claws with tunica and cavity *S. ghilarovi* Stebaeva, 1966
- Ant.4 with more than 17 subsegments, Claws without tunica and cavity 32
- 32. Both edges of mucro wavy, notched or denticulate, mucronal setae missing, claws without tunica, with inner and weak, basal outer tooth *S. muscicolus* Betsch, 1977
- Posterior edges of mucro smooth or wavy, mucronal setae present, claws with a long apical filament on unguiculus, passing tip of unguis 33
- 33. Mucro without mucronal setae, Ant.4 with 21 subsegments, trochanter with normal seta on the backside *S. wahlgreni*
- Mucro with lateral setae, Ant.4 with 20 subsegments, trochanter with a small slender microchaeta *S. viridis* Linnaeus, 1758

Discussion

The Symphyleona and Neelipleona springtails of Iran are mostly unknown, and only 35 species, belonging to seven families (Symphyleona with seven families and Neelipleona with one family), and 17 genera were known. The Katiannidae (4 genera and 12 species) with 23% were the family with most species followed by families Sminthuridae with five genera and seven species (20%) and Dicyrtomidae with two genera and five species (18%; Figure 5). From 2013 to 2020, most species were reported from Mazandaran, Kermanshah, and Golestan provinces in Iranian fauna (Daghighi and Hajizadeh 2019; Shayanmehr et al. 2020a, 2020b).

Iran has common borders with many other countries; Iraq and Turkey to the west, Afghanistan and Pakistan to the east, and Azerbaijan, Armenia, and Turkmenistan to the north. Few studies have been conducted on Collembola in Iran's neighboring countries. In Turkey, for example, only 10 species of Symphyleona and three species of Neelipleona have been identified (Sevgili and Özata 2014; Özata et al. 2017). *Megalothorax minimus* has previously been reported in Turkey, although this species is reported for the first time from Iran. With the exception of eight species (*Dicyrtomina minuta* [Fabricius, 1783], *Sminthurinus aureus* [Lubbock, 1862], *Lipothrix lubbocki* [Tullberg, 1872], *Sphaeridia pumilis* [Krausbauer, 1898] and *Sminthurides malmgreni* [Tullberg, 1877], *Neelus murinus* Folsom, 1896, *Megalothorax minimus*, and *Megalothorax incertus* (Börner, 1903) that are common to Turkish specimens, other Iranian species are probably unreported from neighboring countries. In the Iranian Symphyleona, *Arrhopalites persicus* Vargovitsh and Kahrarian, 2020 is the only species that is unique to Iran. Many of the species found in Iran are cosmopolitan. These species include *M. minimus*, *M. incertus*, *N. murinus*, *Arrhopalites caecus* (Tullberg, 1871), *D. minuta*, *S. aureus*, *Sminthurinus elegans* (Fitch, 1863), *Sminthurinus gisini* da Gama, 1956, *Sminthurus viridis* Linnaeus, 1758, *Sminthurides malmgreni* (Tullberg, 1877), *S. pumilis*, and *Stenacidia violacea* (Reuter, 1881). Almost all these species are collected from the soil and leaf litter, except for *S. elegans* and *S. gisini*, which are collected from moss on tree bark. *Megalothorax*

perspicillum Schneider and D'Haese, 2013 and *Megalothorax willemi* Schneider and D'Haese, 2013 are two Palearctic species found in soil as well as wood from dead trees. Also, the Holarctic species identified in Iran so far include *Arrhopalites principalis* Stach, 1945, *Dicyrtoma fusca* (Lubbock, 1873), and *Allacma fusca* (Linnaeus, 1758). Among springtails, the Sminthuridae family is a limited group that lives on plants and grasslands (Resh and Card'e, 2009). So far, *Sminthurus muscicolus* Betsch, 1977, has been reported from Central and West Asia. Because of the vastness of Iran and the diversity of ecosystems in it, it is expected that more studies will identify more species of Symphypleona fauna in the near future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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