



Review article

Trophic resources of the edaphic microarthropods: A worldwide review of the empirical evidence

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ARTICLE INFO

Dataset link: [10.5281/zenodo.6508661](https://doi.org/10.5281/zenodo.6508661)

Keywords:

Food web
Trophic ecology
Soil microarthropods
Acari
Collembola

ABSTRACT

Ecosystem sustainable use requires reliable information about its biotic and abiotic structure and functioning. Accurate knowledge of trophic relations is central for the understanding of ecosystem dynamics, which in turn, is essential for food web stability analyzes and the development of sustainable practices. There is a rapid growth in the knowledge on how belowground biodiversity regulates the structure and functioning of terrestrial ecosystems. Although, the available information about trophic relationships is hard to find and fragmented. Most of the information available worldwide about the food resources of soil microarthropods suggested that out of 3105 hits of initial research on this aspect only a total of 196 published works related particular species, genera, and families to particular trophic resources, the majority of them dealing with soils of the Palearctic region. From the 196 publications we extracted 3009 records relating specific taxonomic groups to their trophic resources, 20 percent mention saprophytic fungi as a food resource, 16 percent cite microfauna, 11 percent mention bacteria, 10 percent litter and 8 percent cite Springtails. The available information was highly skewed, the 73.71 percent comes from Acari, and within these, 50.62 percent correspond just to Sarcoptiformes. The literature on Collembola is very scarce and most of the information is on arthropoda. The review also highlights that available research on the use of trophic resources comes from European sites and the information on this aspect from other parts of the soils of the world is still at large but unknown.

1. Introduction

In the last few decades, sustainable use of the soil has come sharply into focus. The report on Global Biodiversity and Ecosystem Services [1], and the recent State of Knowledge of Soil Biodiversity [2] clearly indicate the importance of the soil ecosystem and the central role that soil biodiversity plays on ecosystem services. However, critical information is lacking on edaphic biodiversity and interaction webs for most soils.

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<https://doi.org/10.1016/j.heliyon.2023.e20439>

Received 29 November 2022; Received in revised form 25 September 2023; Accepted 25 September 2023

Available online 28 September 2023

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The view about the edaphic biota has changed in recent years. Most of the work on taxonomic descriptions, richness, biodiversity estimation, and microenvironments [3,4], highlights the fragility and need for the conservation of soils, and soil biodiversity [2,5]. The focus has gradually shifted towards the study of the soil ecosystem's functioning, in which the interactions between the biota and the edaphic environment hierarchically affect its structure and functioning [6–9]. The relationships of species richness with ecosystem dynamics allow establishing causal relationships between the characteristics of the organisms present and the processes and services of the ecosystem [10,11] in natural as well as in controlled environments [12].

The soil microarthropods mainly consists of microarthropods belonging to the Subclasses Acari and Collembola (following [13] and [14]) that inhabit the upper soil horizons [15], where complex communities are developed and maintained. These communities are influenced by a high microhabitat heterogeneity and the number of food resources available [3,16,17], which provide a wide and varied set of ecological niches [18,19]. The microarthropods, through its trophic relationships, contributes to the edaphic functioning through the fragmentation of organic matter, the nutrient cycle dynamics, the transport of microflora propagules, and the regulation of microflora and microfauna populations that affect primary production [2,8,12,20,21].

Determining the food resources used by microarthropod groups is difficult due to their size and cryptic environment. Recognition of their diet must be based on empirical evidence, which constitutes the first step in establishing the interactions between trophic species and resources that describe food webs. [22–24].

The information about trophic relationships of the different microarthropod taxonomic groups is still quite scarce. These data are necessary to build and analyze trophic networks that, in turn, could be used to assess the stability and conservation status of these ecosystems [6,25,26].

This review gathers the information currently available regarding the use of trophic resources by the edaphic microarthropods. This information, together with other characteristic features of the soil microarthropods, will allow building a food web interactions network that could result in a better understanding of the structure and functioning of the edaphic biota [2]. Trophic networks will, in turn, allow for comparing the state of different soils, or the same soils under different intensities of anthropic impact [27].

The empirical characterization of trophic interactions is challenging due to the spatial and temporal complexity of feeding patterns, and the limitations of the methods to identify and quantify the components of the diet [24,28,29].

Thus, the objectives of this review are: 1) to gather all the information currently available regarding the trophic resources used by soil microarthropods, 2) to describe the known trophic relationships and potential diets of these soil microarthropods at different taxonomic levels (from family to species), and 3) to establish the current status of knowledge skews in the available information.

2. Materials and methods

2.1. Empirical evidence

The empirical evidence provided through studies carried out under laboratory conditions (A) can be based on **observations** of the feeding behavior of the animals under study, on studying **food preferences**, or **tests** to study other interactions or biological phenomena related to diet. In general, the tests are made using microcosm [30–33]. The observation of the **intestinal content** (B) is based on considering that what is found in the tract is evidence of what is actually consumed [34–36]. This method requires the preparation of specimens for observation by microscopy techniques. The morphology and functioning of the **mouthparts** (C) are related to the manipulation, acquisition, and processing that microarthropods carry out on food and could be used to determine trophic guilds [37–39]. This evidence also requires microscopy techniques to obtain information.

Molecular tools (D), such as barcoding, could be used to determine the presence of a species or a taxonomic group within the intestinal tract and it allows for establishing trophic relationships or other types of interactions [40–42]. The study of **digestive enzymes** (E) in invertebrates can explain the digested food portions [43,44], and those enzymes that hydrolyze structural polysaccharides are related to the diet [45]. They allow the differentiation of trophic guilds [43,44].

The use of the natural variation of **stable isotopes** (F) as empirical evidence of the use of trophic resources is based on the study of isotopic signatures; the isotopic signature of $\delta^{15}\text{N}$ informs about the trophic level of the invertebrate and that of $\delta^{13}\text{C}$ will indicate the proportion of trophic resources consumed, but the potential trophic resources need to be chosen previously to the isotopic analysis [46–48]. Additionally, this tool has the potential to infer the metabolic pathways of biomolecules [49,50].

Finally, the study of the **lipid profile** (G) is based on using the fatty acids of the tissue of the resources as biological markers through the identification of fatty acids in the animal. This is because the animal either cannot synthesize them (absolute markers) or their synthesis supposes a high metabolic cost (relative markers) [51–55].

2.2. Bibliography search

We conducted a systematic search for empirical evidence relating to the use of at least one trophic resource by soil microarthropods. We relied on publications with keywords related to the taxonomic groups of interest, trophic relationships, and methods that provide evidence of consumption. Using these keywords, we formulated search strings and applied them to scientific bibliographies in both Scopus and Google Scholar database search engines.

We used the following search string in Scopus:

“ALL((microarthropods OR springtails OR mites OR oribatida OR mesostigmata OR prostigmata OR astigmata) AND (trophic OR diet OR feeding) AND soil AND (“gut content” OR “stable isotope” OR “food preference” OR “fatty acid” OR lipids OR metabarcoding) AND (family OR genus OR species)) AND (LIMIT-TO (SUBJAREA, “AGRI”) OR LIMIT-TO (SUBJAREA, “ENVI”) OR LIMIT-TO

Table 1

Basic description of trophic resources. Total records of consumers by trophic resource with absolute values and percentages; and the number of records by taxonomic resolution. ^aBerg & McClaugherty 2008 ^bClark 1971 ^cWarcup 1971 ^dPonge 1991 ^ePersson et al. 1980 ^fKrantz & Walter 2009 ^gChernova et al. 2007 ^hRusek 1998 ⁱSchneider et al. 2005.

Trophic Resource	Description	Total consumer records (%)	Family	Genera	Species
Saprophytic fungi	They are ubiquitous soil fungi that break down organic matter. ^c	599 (19.8)	16	105	478
Microfauna	Soil nematodes and protozoa, tardigrades, rotifers, and other edaphic microfauna. ^e	468 (15.5)	34	140	294
Bacteria	They include bacteria with enormous autotrophic and heterotrophic capacities. ^b	325 (10.7)	7	63	255
Litter	Dead plant tissue accumulated in the soil with different degrees of fragmentation and decomposition. ^a	311 (10.3)	4	30	277
Springtails	Juvenile and adult springtails.	246 (8.1)	50	58	138
Plant tissue	Includes non-vascular plants (mosses, lichens, etc.), live roots, and seedlings.	200 (6.6)	2	25	173
Mites	Juvenile and adults Mites. ^f	193 (6.4)	40	37	116
Mycorrhizal fungi	Symbiotic fungal hyphae with plant roots. ⁱ	156 (5.2)	6	19	131
Humus	Complex and amorphous organic matter with a high degree of decomposition: debris, fecal pellets, etc. ^d	121 (4)	2	8	111
Invertebrate carrion	Animal tissue, molts, invertebrate corpses, etc. ^h	119 (3.9)	10	13	96
Invertebrate eggs	Invertebrate eggs consumed by predators. ^g	103 (3.4)	13	24	66
Enchytraeids	Anatomically homogeneous, soft-bodied oligochaete annelids. ^c	97 (3.2)	11	30	56
Larvae	Soft-bodied invertebrate larvae.	86 (2.9)	15	20	51

(SUBJAREA, “MULT”) OR LIMIT-TO (SUBJAREA, “EART”) AND (LIMIT-TO (EXACTKEYWORD, “Collembola”) OR LIMIT-TO (EXACTKEYWORD, “Acari”) OR LIMIT-TO (EXACTKEYWORD, “Soil Fauna”) AND (LIMIT-TO (LANGUAGE, “English”) OR LIMIT-TO (LANGUAGE, “Spanish”)), which returned 838 titles (September 3, 2021).

For searching in Google Scholar we used:

“(microarthropods OR springtails OR mites) AND (“oribatida” OR “mesostigmata” OR “prostigmata” OR “astigmata”) AND (trophic OR diet OR feeding) AND soil AND (“gut content” OR “stable isotope” OR “food preference” OR “fatty acid” OR metabarcoding)”. This search returned 2170 titles (September 3, 2021).

We also included general review publications and textbooks to provide information on the use of trophic resources from sources that may not be readily available, resulting in 97 more titles. Some further additional publications were suggested by reviewers (4).

The first eligibility criterion to reduce the number of records was to select those papers whose titles or abstracts relate soil microarthropods to trophic resources (425 titles). Out of those, we selected papers that effectively mention families, genera, or species of soil mites and springtails and relate them to at least one trophic resource. This resulted in 200 publications, which can be consulted in Electronic Supplementary Material I (ESM I). All the microarthropods recorded in the 200 publications cited can be found in ESM II, which is cross-referenced with ESM I. A flow diagram of the bibliography search and selection procedure is also provided as ESM III.

2.3. Database construction

The empirical evidence provides information on the trophic relationships of these animals in different ways: some publications relate the taxa to food items and others group them into guilds or trophic categories. To deal with this heterogeneity, it was necessary to define the trophic resources (Table 1) that summarize their trophic and ecological characteristics in the edaphic ecosystem [13,32,56–62].

We associate taxa and those resources so that: a) if the publication indicated a food item, it was assigned to a trophic resource in which it is defined, b) or if the taxa are grouped in some guild or trophic category, then each taxon was assigned the typical resources consumed by that category.

Based on this allocation strategy, we developed a database presented in Supplementary material II. The taxonomic information and the trophic resources were obtained from the different sections of the publications and their appendices [26]. In a complementary way, each taxon found has all the classification levels according to [13] and [14], for mites and springtails respectively. The database is also available in the GitHub repository <https://github.com/EcoComplex/TrophicResources> and Zenodo <https://doi.org/10.5281/zenodo.6508661>.

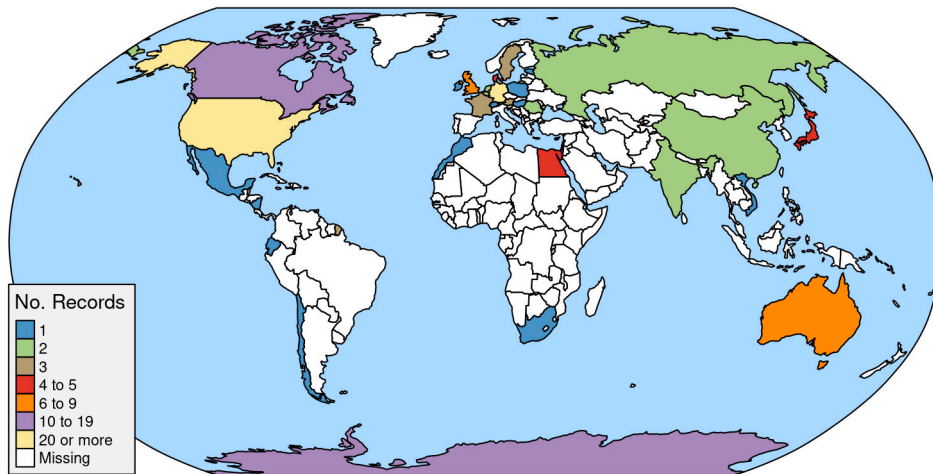


Fig. 1. World map showing the distribution of records assigning trophic resources to soil microarthropods, largely unexplored outside Europe and the United States.

2.4. Data analysis

The records were then analyzed by counting the associations between the taxa, the methods used, and the trophic resources identified. We identified trophic resources, the number of records, and their relationships with the different taxonomic levels. Then, the breakdown of each taxon was carried out within the taxonomic categories and their relationship with trophic resources. We calculated the proportions of the different methods and their relationship with the taxonomic level and trophic resources.

Finally, we estimated the potential importance of resources on the diet for the main orders of mites (Acari) and springtails (Collembola) using the proportion of mentions between trophic resources and taxa included in such orders. For example, if a species has ten records on the consumption of the same trophic resource, the selection of this food item is likely a reflection of the use of the resource. Then, if we gathered the information available from different species of the same genus and the food items consumed by them, we could assign it to the potential diet for the genus. Similarly, the resource use of the genera within a family can be thought of as reflecting the potential diet of the family.

That is, the diet of higher taxonomic hierarchies will be constituted by the sum of the resources used by the lower taxonomic levels.

The calculations, graphs, and tables were prepared using Microsoft Excel and R Statistical software version 4.1.2 [63]. The source code is available at GitHub <https://github.com/EcoComplex/TrophicResources> and Zenodo <https://doi.org/10.5281/zenodo.6508661>.

3. Results

Out of the 3208 research documents initially recovered, 200 were found to meet our criteria (see ESM III). A total of 133 articles from the 200 selected publications (ESM I) mention the countries in which the studies were carried out. Out of those, 1 article belongs to the Ethiopian region, 3 to the Neotropical region, 3 to the Oriental region, 7 to the Australian region, 34 to the Nearctic region, 75 are all located in the Palearctic region, and the remaining 10 are from the Antarctic region. (Fig. 1). This is important to highlight because the species strongly vary depending on the biogeographic region. There are 106 publications mentioning the environments in which the studies were conducted; from these 59 were temperate forests, 3 tropical forests, 21 grasslands, 23 agroecosystems, and 11 deserts.

We obtained a total of 3024 records on trophic relationships (ESM II), with Acari contributing 2218 records (73.34%), and within this number, the majority (50.86%) corresponds to Sarcoptiformes. According to the taxonomic resolution, data of 170 species, 30 genera and 2 families of Collembola and 412 species, 131 genera and 49 families of Acari were obtained.

3.1. Methods used for trophic resources identification

Methods for resource assignment The method of observations in laboratory tests provides the main empirical evidence with 706 records (Fig. 2).

Microarthropods at the family level constitute 9.3 percent of the observations in laboratory tests, with 63.6 percent of the total corresponding to the Prostigmata suborder, within which 10 different families are mentioned. The evidence offered by observations in laboratory tests adds up to 90.7 percent for species and genera. The orders Mesostigmata (62.5%), Sarcoptiformes (23.8%), Trombidiformes (9%) and Arthropleona (4%) are the ones with the higher presence in the literature.

The gut content method reaches 21.3 percent of the records, in which the species taxonomic level corresponds to 89.9 percent of the total records and the genus level to 9.5 percent.

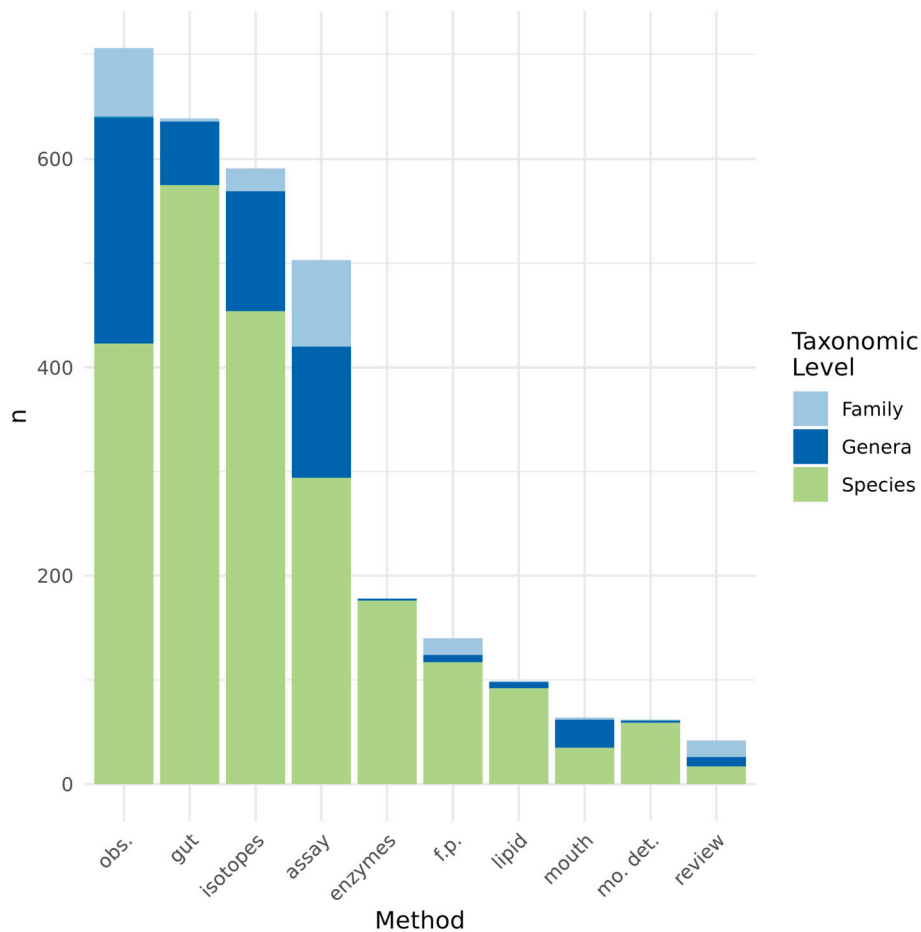


Fig. 2. Methods used in the literature to assign trophic resources to soil microarthropods taxa. Colors within columns refer to the number of different taxonomic levels for which each method assigned at least one resource. Assay: laboratory tests and observations. Isotopes: stable isotopes. Gut: intestinal content. Enzymes: Digestive enzymes. Mouth: mouthparts morphology. Lipid: lipid profile. Mo. det.: molecular detection of intestinal content, f.p.: Food preference assays. Obs.: direct lab observations of feeding activity. Reviews: general reviews by other authors.

Stable isotopes follow in importance. From these, 76.9 percent of the records mention species. Genera and family add up to 23.1 percent of the records.

The activity of digestive enzymes (178 records) in all cases reports down to the species level. For this empirical evidence, the authors worked with the order Sarcoptiforme (Acari) with 38 different species and Arthropleona and Symphypleona (Collembola) with 17 different species.

Other three methods accumulate 9.75 percent of the records, these being food preference tests (131 records), the study of fatty acids (99 records), and the use of mouthpart structures (64 records).

Intestinal contents analyses with molecular techniques for the detection of DNA is a tool of recent development and represent 2 percent of the total records.

Resources identified by empirical evidence The main resource mentioned corresponds to saprophytic fungi (19.8%) followed by microfauna (15.5%), bacteria (10.7%), and litter (10.3%), the records for mites, collembola, enchytraeidae, larvae, and eggs accumulate 725 mentions (24%) (Table 1). It is worth noting that a higher number of records have been taken to the species level. For instance, 592 trophic records are associated with saprophytic fungi consumption, of which 16 were associated with the taxonomic level of the family, 105 to the genus level, and 474 to the species level.

Laboratory observations (the most used method), mention the use of the thirteen trophic resources (Fig. 3) in which the order of importance according to the number of mentions is microfauna > springtails > mites > saprophytic fungi > invertebrate eggs > enchytraeids > larvae of invertebrates that accumulate 82.3 percent. For this empirical method, the main resources correspond to typical resources of predatory animals except for saprophytic fungi, the main taxa mentioned is Mesostigmata. The stacked bars (Fig. 3) show the different proportions in which the methods provide evidence of the use of a resource, if the contribution of each method is considered according to the number of citations in the bibliography, they are counted in decreasing order: direct observations (706 records) > intestinal content (639) > isotopes (591) > laboratory tests (503) > enzymes (178) > food preference tests (140 records).

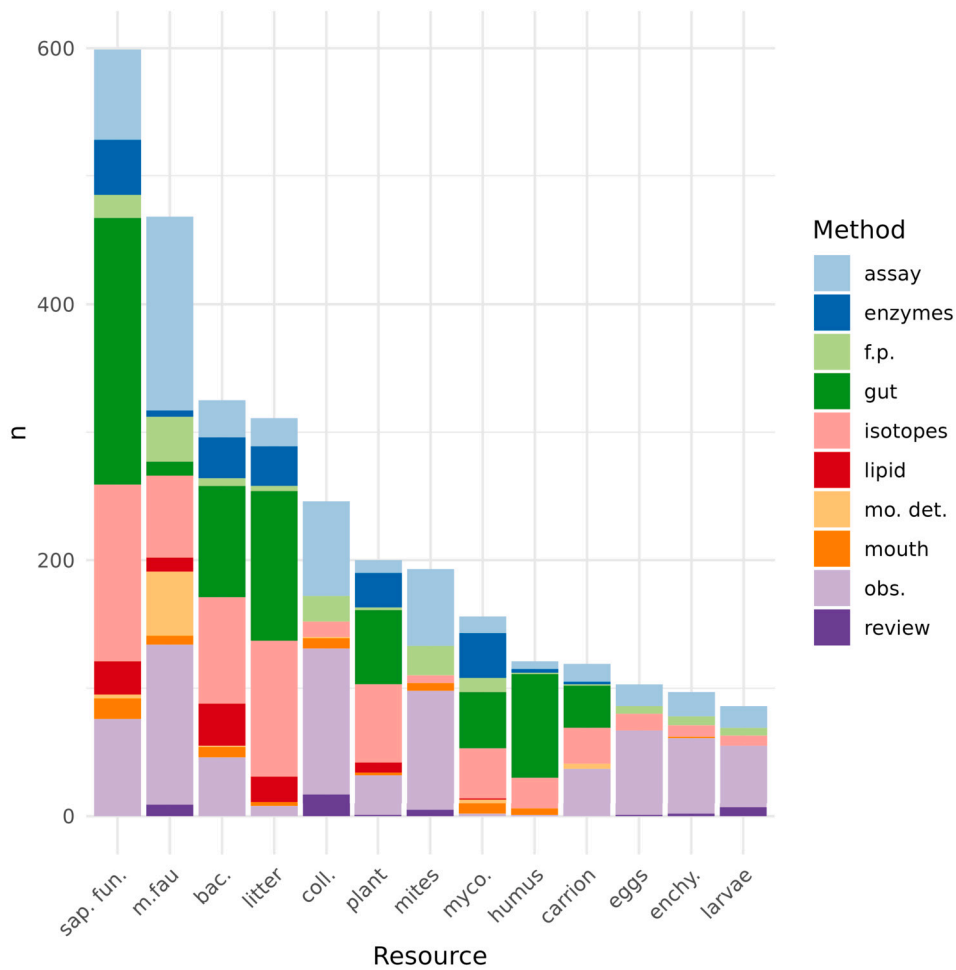


Fig. 3. The number of records in the literature assigning each of the 13 trophic resources to a microarthropod taxon, as shown in Table 1. The colors in the columns refer to the method used to assign those trophic resources to a particular taxon, as shown in Fig. 2. The resource abbreviations are: saprophytic fungi (sap. fun.), microfauna (m. fau), bacteria (bac), litter, springtail (coll), plant tissue (plant), mites, mycorrhizal fungi (myco), humus, invertebrate carrion (carrion), invertebrate eggs (eggs), enchytraeids (enchy), and larvae.

The methodologies that are used in laboratory studies, i.e. laboratory tests, laboratory observations, and food preference tests, provide direct evidence of the use of the trophic resources, constituting together 44.5 percent of the empirical evidence analyzed. (ESM II) These laboratory methods are the ones that most frequently mention the use of animal resources, springtails - mites - invertebrate larvae - invertebrate eggs - enchytraeids, as food resources. These methods rarely mention the consumption of mycorrhizal fungi and rarely the use of humus.

3.2. Use of trophic resources by soil microarthropods

It is interesting to note that at the family level, the most numerous records correspond to trophic resources such as springtail, mites, microfauna, larvae, invertebrate eggs, and enchytraeids, typical resources of predatory microarthropods (Table 2). Similarly, at the genus level, the typical resources of predators represent 54 percent of the records. At the species level, the main resource mentioned is saprophytic fungi.

The use of trophic resources in the seven main orders mentioned in the literature (3 orders of Collembola and 4 orders of Acari) is divided into their families, genera, and species in a nested way (Table 2). For example, for the order Symphypleona (Sy), the empirical evidence studies 13 species included in 10 genera within 3 families. In this way, Table 2 shows also for Symphypleona (Sy), that 8 of the 13 species mentioned, within 7 of the 10 genera, within 2 of the 3 families in the available bibliography, are mentioned consuming Saprophytic fungi. For additional identity and information on families, genera and species see ESM II.

In all the taxonomic hierarchies considered, the order Sarcoptiformes (Acari) consumes mainly saprophytic fungi, bacteria, litter, plant tissues, and Mycorrhizal fungi. The order Trombidiformes (Acari) is presented mainly as predators.

For Collembola, the diversity of species addressed by empirical evidence is grouped into only 13 families, 3 of which belong to Symphypleona and a family of Neelipleona.

Table 2

Number of families, genera and species associated with trophic resources. The letters represent the main orders of Acari and Collembola: M, Mesostigmata; S, Sarcoptiformes; T, Trombidiformes; O, Opilioacarida; A, Arthropleona; N, Neelipleona; Sy, Symphypleona. Because the diet is reported a different taxonomic levels, it could be that in some cases there are more families or genera reported than species. For example there are 10 families of Trombidiformes (T) that consume invertebrate eggs, but there are only 2 genera, and 1 species.

Trophic Resource	FAMILY							GENERA							SPECIES						
	M	S	T	O	A	N	Sy	M	S	T	O	A	N	Sy	M	S	T	O	A	N	Sy
Total	34	82	32	5	9	1	3	89	157	28	1	58	2	10	136	264	22	0	154	1	13
Saprophytic fungi	7	68	10	0	9	1	2	11	120	10	1	54	1	7	7	160	3	0	119	1	8
Microfauna	32	26	23	1	8	0	0	80	40	4	0	33	0	0	106	47	0	0	39	0	0
Bacteria	4	55	6	0	9	1	2	4	91	7	0	38	2	5	3	109	7	0	67	1	5
Litter	0	43	0	0	8	1	3	0	79	0	0	35	1	6	0	124	0	0	59	1	5
Mycorrhizal fungi	2	31	3	0	7	0	1	1	44	0	0	28	0	2	0	54	0	0	46	0	2
Plant tissue	0	42	5	0	7	0	2	0	72	4	0	20	0	7	0	100	3	0	26	0	7
Springtails	24	0	27	3	2	0	0	53	0	13	0	3	0	0	80	0	9	0	4	0	0
Mites	21	0	26	2	0	0	0	54	0	10	0	0	0	0	81	0	7	0	0	0	0
Larvae	12	0	9	2	0	0	0	32	0	0	0	0	0	0	41	0	0	0	0	0	0
Humus	0	24	2	0	8	1	2	0	27	0	0	26	1	3	0	28	0	0	49	1	3
Invertebrate eggs	15	0	10	2	3	0	0	33	0	2	0	5	0	0	52	0	1	0	4	0	0
Enchytraeids	17	0	7	2	4	0	0	41	0	0	0	4	0	0	46	0	0	0	3	0	0
Invertebrate carrion	5	22	2	0	6	1	2	9	30	0	0	28	1	3	11	31	0	0	40	1	4

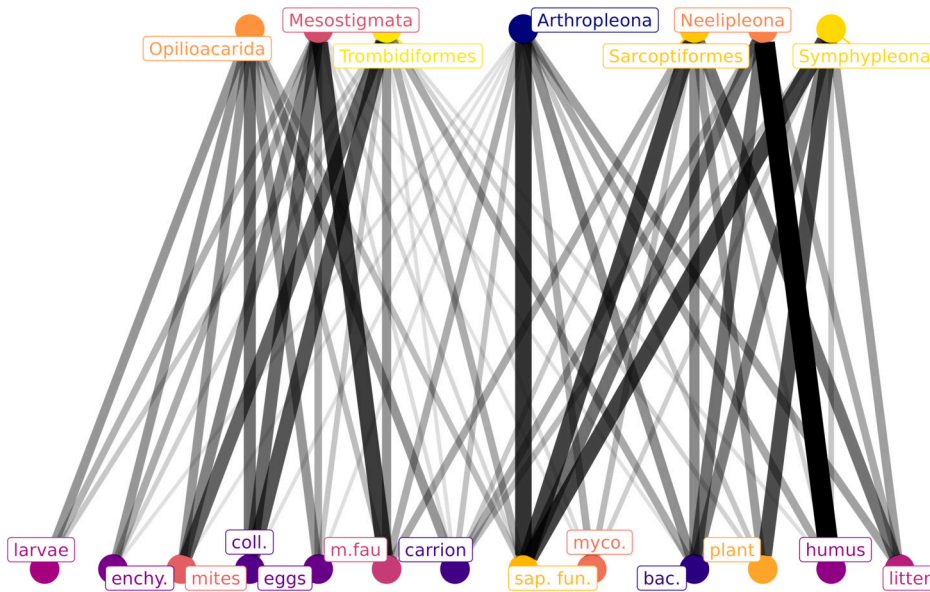


Fig. 4. Bipartite graph showing the use of trophic resources by the main orders of Acari and Collembola. Upper nodes: Acari and Collembola orders as in Table 2. Lower nodes: trophic resources. The thickness and intensity of the lines give an idea of the proportion of mentions in the available literature about their use of trophic resources. The resource abbreviations are: saprophytic fungi (sap. fun.), microfauna (m. fau), bacteria (bac), litter, springtail (coll), plant tissue (plant), mites, mycorrhizal fungi (myco), humus, invertebrate carrion (carrion), invertebrate eggs (eggs), enchytraeids (enchy), and larvae.

The empirical evidence that addresses the trophic study of Arthropleona (Collembola) is represented by 154 different species, these were mainly associated with saprophytic fungi (119 species), followed in importance by bacteria, litter and humus. The microfauna is mentioned as a resource for 39 species.

Fig. 4 presents the proportion of resources used by the main 4 mite orders and 3 Collembola orders, as found in the literature. For instance, the resource of saprophytic fungi is the main constituent of the diet of the Arthropleona, being the bacteria, the litter, the humus, and the microfauna mentioned resources in lesser proportion. Trombidiformes have a diet based mainly on microarthropods and nematodes and to a lesser extent saprophytic fungi and bacteria.

4. Discussion

Until the 1960s, soil fauna was considered mainly earthworms, and terrestrial ecologists considered most of the soil fauna as a “black box” of decomposers and detritivores [25]. The information gradually collected over the following decades regarding edaphic microarthropods has reached the point where there is a need to focus on integrative works [64]. However, the available information

is still scarce and mostly restricted to the most numerous or conspicuous groups of the soil microarthropods, and mainly from European soils.

For soil microarthropods, the evidence provided by laboratory work results in the most straightforward traditional method to know how these animals use trophic resources, their feeding behavior, their food preferences, and their development and growth in controlled environments, but feeding links observed in the laboratory do not necessarily relevant for the field [28,65]. The method used to relate the isotopic signature of organisms and their resources is a recently developed tool that is useful for detecting the importance and the changes in time or space of assumed trophic relationships, which means that we have to know in advance if the trophic relationship exists. The main drawback of the method is that if we erroneously assign a trophic relationship, the proportions of the diets could be greatly distorted from the real trophic relationships. On the other side, this method has several advantages: 1) it can analyze a large number of species and an important variety of resources [48], 2) it can provide field evidence of real interactions, 3) it can provide quantitative data, accounting for interaction strength, 4) it can provide information on assimilation and not only ingestion [28].

The different methods have different sources of errors, so it will be desirable that trophic resources used by soil microarthropods can be determined in a complementary way with several methods [24,66].

The most used resources are saprophytic fungi, microfauna, and bacteria. If we associate them with their nutritional characteristics, these trophic resources are rich in molecules with great nutritional value as determined in the dietary routes labeled by fatty acids, stable isotopes, or the enzymatic methods [45,48,52].

It is also to be noted that the information available for Acari and Collembola is strongly asymmetric, corresponding mainly to the order Sarcoptiformes in Acari and to Arthropleona in Collembola.

Despite the increasing amount of descriptive works and lists of taxonomic groups, the information available worldwide is still largely fragmentary and incomplete, and taxonomic resolution varies considerably between and within published works.

We found that a large proportion of the resources are defined as taxonomic categories of species, genera, and families, which would be important to estimate the diets of higher taxonomic groups. The available information for low taxonomic levels could be used as a reference to address the problem of what the use of soil resources will be alike by higher-level taxonomic groups [66,67].

However, this information must be interpreted with caution, because within a taxonomic category, each species could apply different strategies when exploiting food resources [17,68]. Although the taxa treated here are considered generalist consumers, recently the term “choosy generalist” was suggested as the behavior that characterizes consumers that inhabit soils [65].

The results presented here provide valuable new information about the different feeding strategies of the main groups of the soil microarthropods, and also on the quality and usefulness of the different methods used to assign trophic resource use to different taxa. It also presents the current status of knowledge about soil microarthropods' trophic resources usage. Moreover, it highlights the still meager information available in this regard.

Finally, it is necessary to call attention to the need for more studies on the trophic relationships of the soil microarthropods. Out of a total of approximately 9000 described species of Collembola [69], it was only possible to find trophic information for just 127 soil inhabitant species. In the case of Acari, with more than 58 thousand species described so far [70], but so far only find references of trophic relationships for 307 soil species.

It is clear that big gaps in the available information must be filled to advance our knowledge on the structure and functioning of soil food webs. Not only are there several microarthropods groups hardly explored, but also the geographical coverage is still quite narrow. Almost 52 percent of the published studies about the trophic resources of Acari and Collembola were developed in European countries. Further deepening on the knowledge of functional and trophic relationships of the soil the fauna would allow for a better and more precise evaluation of the functioning of the edaphic ecosystem, the protection of the ecosystem services that the soil microarthropods provide, and the sustainable use of the soil.

Declarations

This work was partially funded by a scholarship to Victor N. Velazco from Consejo Nacional de Ciencia y Tecnología (CONICET). This research did not receive any other specific grant from funding agencies in the public, commercial, or not-for-profit sectors. All the data for this work not shown here are available as Electronic Supplementary Material and referred to in the text when appropriate.

CRedit authorship contribution statement

LF and LS originally formulated the idea, NV, CC developed the methodology, 15 NV, CC, LF, and LS analyzed the data and wrote the manuscript.

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.

Data availability

The data utilized in this study is available in a public repository and can be accessed freely via the following link: <https://doi.org/10.5281/zenodo.6508661>.

Acknowledgements

The authors wish to thank the help of Dr. Fernando Momo for his useful comments to previous versions of this work. To Dr. Mark Breidenbaugh for his help in reviewing the English language usage and grammar.

Appendix A. Supplementary material

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.heliyon.2023.e20439>.

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