SOIL ORGANISMS 96 (3) · December 2024 pp. 195–207

Methods for the extraction of microarthropods from soil: A bibliography and guide to the literature

Alexander Bruckner

Institute of Zoology, Department of Integrative Biology and Biodiversity Research, Boku University, Gregor-Mendel-Strasse 33, 1180 Vienna, Austria
https://orcid.org/0000-0002-2453-4352
E-mail: alexander.bruckner@boku.ac.at

Received 6 August 2024 | **Accepted** 11 November 2024
Published online at www.soil-organisms.org 1 December 2024 | **Printed version** 15 December 2024
DOI https://doi.org/10.25674/432

Abstract

This paper accompanies a bibliography of the literature on methods for the extraction of microarthropods that have been published between 1905 and the end of 2023. The bibliography comprises 378 publications. 311 address the extraction of microarthropods, while the other 67 describe the extraction of other animal groups, or are general methodological textbooks that include the soil habitat. The bibliography is intended to serve as a gateway to all published studies on the topic, with the aim of promoting future methodological development. The materials collected in this paper and its supplements consist of a commented list of publications on microarthropod extraction, including bibliometric, technical and ecological specifications; reference manager files with full bibliographic data; a thematic guide to the key publications in the bibliography; and a glossary of technical terms.

Keywords Acari | Collembola | sampling | biodiversity | scientific | literature

1. Introduction

More than 100 years ago, the Italian zoologist Antonio Berlese first described an automated device for the extraction of microarthropods. For reasons unknown, and confusing to later authors, he submitted two almost identical manuscript versions, but to different journals (Berlese 1905a, 1905b). He found that the use of the apparatus greatly accelerated the tedious work of picking animals out of soil, litter, dung and moss, and also enhanced the yield. Impressive descriptions of zoologists manually digging through murky substrates for days and weeks (e.g. Beebe 1916, McAtee 1907, Trägårdh 1910) help to understand the revolutionary nature of Berlese‘s invention, and the enthusiastic reactions of contemporary zoologists.

Antonio Berlese disseminated the development in his native language, Italian. Nevertheless, the news spread amazingly fast - likely because comments and translations were published quickly after the original description (Banks 1909, Howard 1906, Jarvis 1908, Trägårdh 1910, Williams 1913). First modifications were soon proposed that increased the efficiency of the devices and facilitated their handling, and the principle was further disseminated in other languages (Jarvis, 1908, Krausse 1915, Tullgren 1917, 1918). The first significant methodological evaluation of the funnel method (temperature and moisture development, but no genuine efficiency test) was then carried out by Trägårdh & Forsslund (1932).

As far as can be inferred from their scientific work, these early authors merely used the new development to obtain animals quickly and easily for their taxonomic and

ISSN 1864-6417 · **eISSN** 2509-9523

biological work. Nevertheless, they opened a door, as the devices were soon adopted for quantitative ecological research, for instance by Bornebusch 1930, Dogiel & Efremoff 1925, Pfetten 1925, Pillai 1922, Soudek 1928. And for these ecological questions, the devices had to meet a requirement that Berlese and his contemporaries did not ask, namely efficiency: How is it possible to extract all individuals of a taxon from a sample, rather than just a fraction?

Since then, soil zoologists have been tinkering with new or modified versions of extraction techniques to maximize their efficiency and ease of use. A substantial body of literature has been published on the subject, including empirical papers, reviews, manuals, books, and even an international standard (European Committee for Standardization, 2006).

Nevertheless, the efficacy of recovering individuals and species from soil remains poorly evaluated. In the most recent comprehensive review on the subject, it has been suggested to be devastatingly low (André et al. 2002, but see Bruckner et al. 2023). And despite considerable technical developments over more than a century, and interesting out-of-the-box approaches in the last 25 years, many laboratories continue to use equipment that is largely similar to Albert Tullgren's 1917 apparatus. For example, in a recent large-scale biodiversity project, the simple funnel appears to be the preferred choice many participants can agree on (Potapov et al. 2022, https://soilbonfoodweb.org/protocols-and-manuals/). It is my personal impression that modern soil zoology is sometimes unaware of the wealth of technical solutions that its predecessors have developed over the decades.

One potential explanation for this limited awareness is that many valuable contributions from the past are difficult to know about, find, and obtain. Uncovering potential methodological treasures that are not referenced in online literature databases, and may be written in languages other than English, is a daunting task for the busy scientist. Without dedicated research, it is highly unlikely that historical solutions to current extraction problems will be found. For example, it was Arthur Paul Jacot in 1936 who first proposed a remedy for the costly debris contamination in dynamic extractors, which is still a problem today, especially in large-scale projects where many samples must be processed in a short time (Jacot 1936), see Section 3.1.

It is evident that contemporary microarthropod research needs new access to the substantial corpus of literature on the inadequately understood question of soil extraction. The materials assembled in this contribution are thus intended to serve as an accessible yet comprehensive guide to all sources published since 1905, with the objective of supporting the informed development of extraction methods. The literature on this subject is indeed rich and often intricate, but it can be managed. Using the materials and guides provided here, all publications on any methodological approach published to date can be identified quickly.

In particular, the work presented consists of

(a) A commented list of publications on microarthropod extraction, from 1905 to the end of 2023, including bibliometric, technical and ecological specifications for each paper (online Table S1 in Excel format (.xlsx),
(b) as (1), but in machine-readable format (.csv), with all diacritics in author names removed (including the German umlauts), for convenient upload to statistical software (online Table S2),
(c) reference manager files with bibliographic data of the publications, including full abstracts where available (online File S3 (.rdf, the Zotero data format) and online File S4 (.ris, a more universal reference format)),
(d) a thematic guide to the key publications in the bibliography, to facilitate access to individual topics (Section 3.1 of this paper),
(e) a glossary of technical jargon that may be intimidating especially for those new to the field (Section 3.2 of this paper).

2. Materials and methods

2.1 Scope of papers

The search for literature focused on the extraction of microarthropods. It must be acknowledged that the term 'microarthropod' is somewhat vague. In accordance with the size classification of edaphic animals by Drift (1951), they are usually understood as arthropods with a body length between 0.1 and 2 mm. Mites, springtails, and proturans are included in the literature database as they fit well into this category. In contrast, pseudoscorpions, symphylans and diplurans are borderline cases, as many of their species exceed the 2 mm threshold. Notwithstanding, contributions on these groups have been included, as they have been treated in the extraction literature since the days of Berlese (1905) and are often extracted with the same methods as true microarthropods. Other taxa with a fraction of small-bodied species below 2 mm (e.g. spiders and beetles) are not considered.

I have searched for all scientific publications where extraction methods are a significant, but not necessarily large, aspect of the text. 'Extraction' was used in a very broad sense, so that literature on pitfall traps (when dealing with microarthropods) and soil sectioning (mostly dealing with the spatial distribution of animals) were also included. Sources addressing extraction only marginally (as many identification books, e.g. Dindal 1990) have been omitted. Also omitted was the occasional conference poster retrieved from the Internet, but Master's and Ph.D. theses and reports (e.g. Umble et al. 2006) have been included.

The focus was on edaphic animals, but all contributions that provided potentially valuable content for microarthropod research were accepted. Since common soil extraction methods are sometimes also employed for non-microarthropod groups (e.g., macroarthropods, insect eggs, bird ectoparasites; Blank & Bell 1988, Espinaze et al. 2019) and other substrates as well (e.g., tree leaves, grass hay, stream sediment, bird nests, house dust; Espinaze et al. 2019, Hill 1998, Klen & Leskinen 1989, Proctor 2001, Yoshida & Hijii 2008), these papers were also included in the database, if found during the search. An illustrative example of a valuable non-microarthropod paper is Rousseau (2011), which sought to recover insect parts from archaeological excavations, but is the only contribution that empirically tested the influence of operator experience on the efficiency of a flotation procedure. I excluded publications that did not sample arthropods from a substrate, but for example from the tree canopy (Koponen et al. 1997) or from air (Santos et al. 2022).

In addition, I have included publications on techniques for sampling epedaphic microarthropods (pitfall traps, suction traps, etc.), as well as general handbooks on sampling and census methods, in which soils are only one aspect among many (e.g., Henderson & Southwood 2016, Zou et al. 2012). It should be noted, however, that no attempt was made to be exhaustive in the search for these non-soil, non-microarthropod contributions, so it is possible that some sources may have been missed.

Included in the bibliography were publications on sampling techniques that addressed circumstances related to extraction efficiency (e.g., optimal core size to maximize efficiency, core handling prior to extraction: Brand 1979, Bruckner 2022, Cancela da Fonseca et al. 1967), but contributions specifically on sampling devices, spatial placement of cores, numbers of samples, etc., were excluded.

Publications describing technical add-ons, such as methods for removing contaminating debris, were incorporated, even if they did not describe extraction processes per se. Conversely, contributions describing other post-extraction procedures (enumeration, mounting, identification, etc.) were not included.

2.2 Searching procedure

The search was conducted from early 2023 to March 2024. A preliminary keyword search in an online database (Web of Science Core Collection, https://clarivate.com/) failed to identify numerous papers that were already included in my literature collection, so I decided to employ a less rigorous search strategy. Since my primary objective was not a systematic meta-analysis of published information, but rather a comprehensive compilation of the literature corpus, a minor potential bias resulting from a more piecemeal search was deemed an acceptable compromise. Accordingly, I proceeded to collect references (in roughly chronological order):

(1) from the literature I already had in my collection, including many old (~ pre-1980) papers from the collection of the Viennese oribatidologist Eduard Piffl (1921-1998),
(2) from the online 'Comprehensive literature list' in the Checklist of the Collembola of the World by Frans Janssens (https://www.collembola.org), using a single keyword search ('extract*', 'efficien*', 'method*', 'sampl*', 'trap*'),
(3) from an unpublished list of oribatid mite literature by Heinrich Schatz (Innsbruck, Austria), using the same keywords as for (2),
(4) from a private digital library of oribatid mite literature maintained by Roy Norton (Syracuse, USA) and Valerie Behan-Pelletier (Ottawa, Canada), using the same keywords as for (2),
(5) by tracking papers on the Internet (especially using Google Scholar and Research Gate) and screening the first pages of results that appeared,
(6) by screening the References section in all acquired literature,
(7) from a final formal search of the Web of Science Core Collection in March 22, 2024, using a broad search string (ALL=((collembol* OR oribatid* OR protura*) AND (Berlese OR Tullgren OR Macfadyen OR flotation OR trap* OR grease OR elutriation OR funnel* OR canister* OR sieve* OR extraction))).

It is quite possible that I have missed publications from countries with a recognized tradition in soil zoology, but whose language I do not understand and/or whose libraries I had only limited access to (especially France, Japan, and the former USSR). I assume that this is especially true for older papers, for journals with predominantly national coverage, and, given the comprehensive nature of the consulted lists and libraries (2 - 4 above), for contributions on non-oribatid and non-collembolan taxa. However, since the majority of publications on microarthropod extraction refer to these two major groups, it seems likely that the number of missing publications is negligible.

2.3 Bibliometric, technical and ecological specifications

Each collected publication was examined and a number of parameters were extracted for convenient identification of entries and future bibliometric analysis. In assessing these parameters, I may have misinterpreted important details of publications in languages with which I am not fluent (i.e., everything except German and English). I employed the use of Google Translate (www.translate.google.com) extensively, and, in instances where the content was particularly challenging to translate, consulted native speakers. However, errors may still occur, particularly in the case of complicated technical descriptions and in the evaluation of experimental designs. Nevertheless, a reliable understanding of the content of the papers was possible in all cases. I would like to express my gratitude to native readers who may report any remaining errors, and thus help to improve future versions of the bibliography!

The following information was extracted from each contribution:

(-) the name(s) of the author(s);

(-) the year of publication;

(-) whether the publication had at least one substantial focus on extraction, or on related aspects;

(-) how often the publication was cited, as reported by Google Scholar, as of the end of March 2024;

(-) if the publication dealt with soil (including hypogeal = subsoil layers), or other materials;

(-) if the focus was on microarthropods (although not necessarily mentioned as such, e.g. in purely technical descriptions), or other animal groups (mostly soil macrofauna and pests of crop and foodstuff);

(-) whether extraction efficiency was quantified (or, for example, if methods were qualitatively described, discussed, or reviewed);

(-) the type of the research. Particularly for summarizing works, the distinctions were sometimes subjective, but for convenience I distinguished between reviews (evaluating, often comparing methods), overviews (simply presenting methods), and manuals (in how-to style);

(-) whether current empirical standards were met. In order to assess this, the following criteria were used: (1) the experimental treatment levels were replicated ($n \geq 3$), (2) measures of data variability (confidence intervals, standard deviations, etc.) were reported alongside averages, or the original data were presented (e.g., Faraji et al. 2004), and (3) statistical methods were used to test for significance (if applicable), and the results were adequately reported. I did not, however, evaluate whether the statistical methods were appropriate for the research and properly executed. While there were instances where not all criteria were met (e.g., Nsengimana et al. 2017, Pande & Berthet 1973, Shaw & Ozanne 2011) or the experimental or statistical approach was questionable (e.g., Shaw 1970), the criteria were applied leniently, allowing for clear decisions to be made for all papers;

(-) what type of extraction was used or described (see online Graph S5). Unfortunately, there is no generally accepted classification of extraction methods and each review on the subject groups them a little differently. A natural classification is hindered by the varying emphasis on methodological details (for instance, Hale's (1964) 'vacuum and bubbles' method can legitimately be considered elutriation or flotation), and by the multiple combinations of individual techniques that have been developed over time (e.g. Salt & Hollick's 1944 procedure includes sieving, density and hydrocarbon flotation; see also Dritsoulas & Duncan 2020). However, the primary purpose of the classification used here is to provide quick access to relevant information, and, more importantly, to ensure that all papers dealing with a particular group of methods are actually found by the interested reader. Therefore, subtle differences between closely related methods are ignored, even though they may make a big difference in extraction efficiency, effort, and cost.

Combinations of methods have been listed with more than one term. For example, several authors sieved their substrates and then used kerosene flotation to separate the animals from the debris in the sieves. This was indexed as 'sieve+flotation', and additionally as 'hydrocarbon flotation'. Using this classification, all of the procedures in the literature could be reasonably well categorized. A notable exception was the extractor of Farrar & Crossley (1983) which was specifically designed to analyze the spatial distribution of microarthropods in soil. This device was classified as 'high-gradient canister';

(-) the microarthropod groups considered. A very old-fashioned classification had to be followed here, and some groups had to be merged into larger ones, because (1) the bibliography covers a long period full of changes in the biological system, and (2) authors have identified their material to very different levels. This was especially true for mites, where the outdated Oribatida / Astigmata / Mesostigmata / Prostigmata classification had to be used. Gamasina and Uropodina were treated separately by some authors, while others combined them into 'Mesostigmata'. In these cases, both levels of resolution have been maintained in the bibliography, so that all three terms are represented. Given the small number of publications on non-oribatid mites however, all this should not be a problem for the interested reader, and relevant papers can be navigated quickly;

(-) if the animals were identified to species level (including morphospecies; as opposed to taxa of higher systematic rank);

(-) whether all extracted individuals of a taxocoenosis have been identified and counted at the species level (as opposed to only a selection of species, or to taxa of higher systematic rank);

(-) what aspect of the investigated fauna was quantified (e.g., abundance, body size, functional group);

(-) the language of the paper;

(-) the country of the sampling site(s), using its current name. This was not clearly stated in every paper, but could be inferred from the affiliation or contemporary papers of the author(s). One particular sampling site on the Antarctic continent (Usher & Booth 1984) was categorized as 'Antarctica' because the various national claims to this area have not been fully resolved;

(-) the biogeographic realm of the sampling site(s) according to Olson et al. (2001).

3. Results

A total of 378 publications met the search parameters. Of these, 311 addressed the extraction of microarthropods, while the other 67 described the extraction of other animal groups (primarily edaphic macroarthropods and pest animals), or were general methodological textbooks that included the soil habitat. 31 publications dealt with the extraction of non-edaphic substrates (stored food, aboveground vegetation, house dust, ...) and used the same or similar methods as utilized for soil arthropods.

Thirteen references seemed potentially relevant, but they could not be obtained (online Table S6). Readers who provide copies will be gratefully acknowledged, thank you!

The final formal search in Web of Science yielded a total of 916 references and added eight (2.1 %) publications that were not retrieved by methods (1) to (6) (Chan & Trott 1972, Fioratti Junod et al. 2023, Joseph & Bettiga 2016, Kozel et al. 2017, Pang et al. 2023; Sanders & Entling 2011, Spafford & Lortie 2013, Therrien et al. 1999). The Web of Science database alone performed poorly with respect to microarthropod extraction articles. Only 34 of the 916 references met the scope of the literature search, representing 9.0 % of the bibliography. Furthermore, these 34 references exhibited a pronounced bias towards recent papers (> 1990, Figure 1).

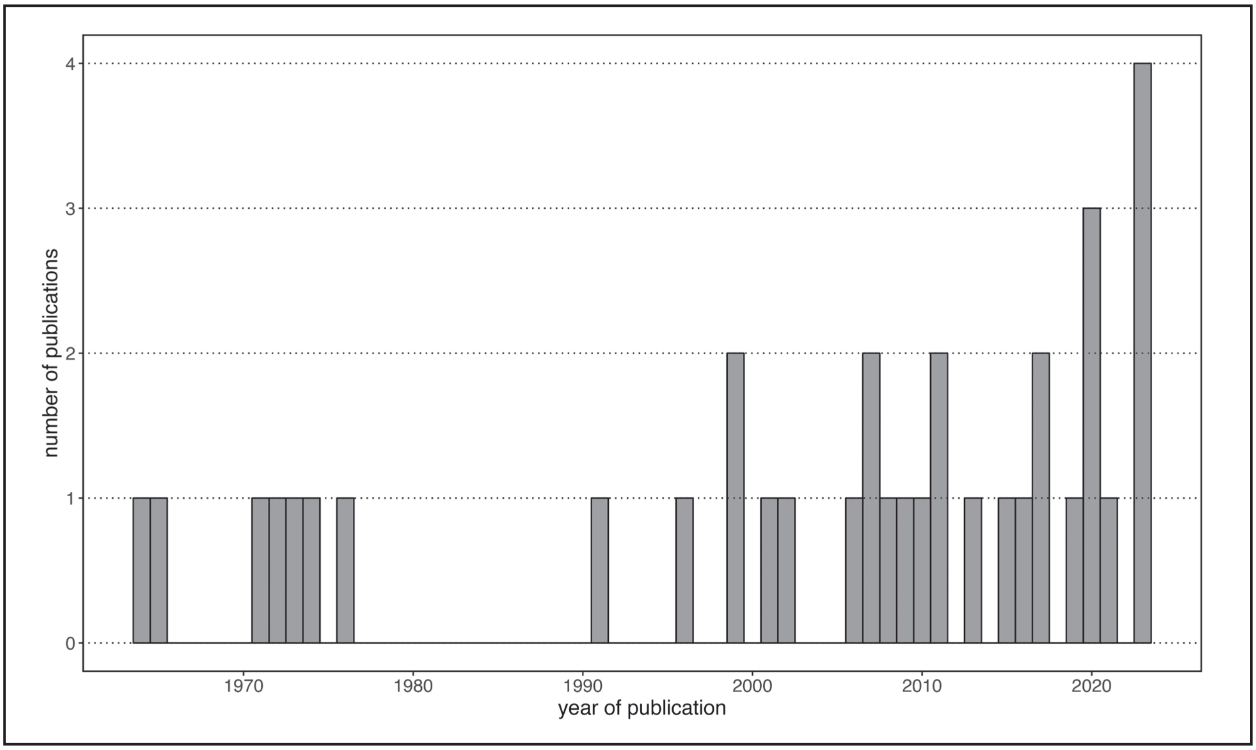

Figure 1. Temporal distribution of 34 publications found by searching for methods of microarthropod extraction in the Web of Science Core Collection in March 2024.

3.1 Thematic guide to the publications in the bibliography

The entries in this bibliography form a list of formidable length. For a more detailed search, it is recommended to use Boolean combinations of the parameters describing each publication (columns E to R of Table S1), and/or to perform a full-text search in column S, which summarizes the contents of the papers in a nutshell.

Nevertheless, in order to facilitate access, the following guide is intended to provide a quick introductory tour, primarily on various technical aspects of microarthropod extraction. It is especially useful for topics that are not immediately obvious from the paper titles or the nutshell descriptions. Only those papers are listed that I subjectively consider to be the most relevant. The entries are not exclusive, and the same paper may be listed more than once. For the sake of brevity, the following citations are available in full length in online Files S3 and S4, but not necessarily in the references section of this paper.

Comprehensive overviews and reviews of extraction devices and procedures
Andre et al. (2002), Balogh (1958), Dunger & Fiedler (1997), Edwards (1991), Edwards & Fletcher (1971), Gorny & Grüm (1993), Kevan (1962), Macfadyen (1962), Murphy (1962a, b), Vannier (1970)

Technical descriptions of simple funnel and canister extractors (see also *Simple, collapsible, ...* below)
Haarløv (1955), Kikuzawa (1967), Macfadyen (1953), Murphy (1958), Norton (1988), Vannier (1964), Winter & Behan-Pelletier (2008)

Technical descriptions of high-gradient (funnels and canisters) extractors
Bieri et al. (1978), Dobrowolski 1976, Hassall et al. (1988), Kempson et al. (1963), Merchant & Crossley (1970), Usher & Booth (1984), Niedbała & Rohloff (1971), Winter & Behan-Pelletier (2008)

Various sample and device details affecting the efficiency of dynamic extractors
Sample treatment before extraction (disturbance, storage, warming, etc.): Bruckner (2022), Edwards & Fletcher (1971), Lakly & Crossley (2000), Leinaas (1978), Murphy (1958), Valpas (1969)
Sample size, subdivision, thickness, orientation, preservation fluids, etc. in extractors: Berthet (1954), Bieri et al. (1986), Bruckner (2022), Cancela da Fonseca (1967), Edwards and Fletcher (1971), Fletcher (1976), Hammer (1944), Jacot (1936), Kikuzawa et al. (1967), Lasebikan (1975), Moreau (1965), Murphy (1958), Rapoport & Oros (1969), Subbotina (1965)
Mesh size of the net that supports the sample: Reca & Rapoport (1975)
Condensation inside funnels: Kempson et al. (1963), Murphy (1958), Seastedt & Crossley (1978), Törne (1962)

Temperature and humidity in dynamic extractors
Adis (1987), Block (1966), Brady (1969), Goddard (1979), Lasebikan (1975), Kempson et al. (1963), Macfadyen (1953, 1968), (Takeda 1979), Vannier (1969)

Simple, collapsible, easily transported, and/or inexpensive extractors, particularly for field use in remote areas
Belfield (1976), Jacot (1932), Kamczyc et al. (2020), Norton (1985, 1988), Salmon (1946), Tuf & Tvardík (2005)

Add-ons and accessories for dynamic extractors
Reduction of debris contamination in dynamic extractors: Aoki (1984), Crossley & Blair (1991), Jacot (1936), Johnson (1984), Kempson et al. (1963), Murphy (1958), Newell (1955), Törne (1962), Ulrich (1933), Valle (1951), Watanabe (1985)
Separation of animals and debris after dynamic extraction: Balogh (1938), Berlese (1921), Dondale et al. (1971), Hart & Fain (1987), Jeanson (1964), Lefors et al. (2018), Rohita (1992)

Elaborate descriptions of elutriation, flotation, and centrifugation procedures
Aguilar (1957), Bieri & Delucchi (1980), Block (1967), Ducarme et al. (1998), Fraser (1964), Hale (1964), Heath (1965), Kenward et al. (1978), Kethley (1991), Kraan (1973), Kuenen et al. (2009), Ladell (1936), Raw (1955), Salt & Hollick (1944), Strickland (1945), Thind (2000), Törne (1962b), Wilcocks & Oliver (1971), Winter & Behan-Pelletier (2008)

Out-of-the-box approaches to extraction
These papers present interesting approaches that work on different principles than the usual extraction methods. Some of them seem unlikely to work in practice, others promise fascinating new directions for methodological research.
Arthropods are concentrated in litter bags and then expelled in dynamic extractors: Prasifka et al. (2007), Ruiz-Lupión et al.(2019),
Arthropods leave thin-layer samples in a horizontal (instead of vertical) direction: Johnson (1984),
Baits attract epedaphic pest microarthropods: Joseph &

Bettiga (2016), Soler et al. (2011)
Grease film/belt extractors: Aucamp & Ryke (1964), Aucamp (1969), Belfield (1976), Shaw (1970), Speight (1973),
Trap-like sensor and camera setups for counting microarthropods and measuring their body size: Balla et al. (2020), Dombos et al. (2017), Florian (2020), Gedeon et al. (2017),
Repellent vapors drive microarthropods out of samples: Adamska et al. (1978), Brown (1973), Espinaze et al. (2019), McClure (1935), Muchmore (1966), Sortwell (1984), Niedbala & Trawińska (1980),
Arthropods are counted in soil sections: Anderson & Healey (1970), Haarløv & Weish-Fogh (1953), Pande & Berthet (1973), Seastedt et al. (1980), Takakuwa (1979),
Soil soundscapes quantify animal abundance and diversity: Maeder et al. (2022),
Sticky traps capture epedaphic Collembola: Mellanby (1962), Taverner (1996),
Sweep netting epedaphic Collembola: Spafford & Lortie (2013),
Use of light in pitfall traps: Therrien et al. (1999), Tsurikov (2006),
Use of thermography to enumerate springtails in toxicological studies: Pang et al. (2023).

Hidden (and not-so-hidden) gems
These publications are particularly well presented, comprehensive, ingenious, or otherwise noteworthy. They definitely deserve more attention, as some of them are rarely cited.

Brand (1979) reported a significant influence of the time of day of sampling on extraction efficiency. Similarly, El-Kifl (1968) presented evidence indicating that the color of light bulbs can affect extraction efficiency.
Farrar & Crossley (1983) designed a modified dynamic extractor to investigate the spatial distributions of microarthropods in thin (2 cm) sections of soil.
Jacot (1936) & Ulrich (1933) may serve as exemplars of early authors who addressed extraction problems that many soil zoologists of subsequent decades continued to grapple with (e.g., water condensation inside funnels).
Kempson et al. (1963) presented a novel type of high-gradient extractor and examined a number of technical details pertinent to dynamic devices. These included the physical gradients in and under the samples, the convenient loading of the samples into the extractor units, the covering of the units to reduce evaporation from the samples, and efficiency tests.
Kenward et al. (1980) provided a most detailed description of a hydrocarbon floatation procedure, including many practical hints and suggestions.
Kikuzawa et al. (1967) presented the only round-robin test of extracting devices and sample processing that has been conducted to date.
Lasebikan et al. (1978) conducted a comprehensive study including many microarthropod groups, each analyzed at the level of species.

The publications of Macfadyen and Murphy from the 1950s and 1960s offered exemplary analyses and reviews of the existing literature and proposed unparalleled new developments. Moreover, their papers are a pleasure to read.

Nef (1970, 1971) demonstrated that the downward movement of arthropods during dynamic extraction is not an effect of the animals escaping from a desiccation front. Instead, it is the result of a behavioral shift (positive geotaxis) induced by increasing sample dryness.

Norton (1988) provided a most detailed description of a simple funnel extractor and Bieri et al. (1978) and Dobrowolski (1976) of high-gradient canister extractors.

Pang et al. (2023) employed a range of techniques to immobilize springtails following their elutriation from soil in toxicological studies. They then utilized thermography to enumerate the individuals.

Petersen (1978) provided a comprehensive and in-depth analysis of two types of high-gradient extractors, including emergence patterns, extraction efficiency estimates, the description of physical gradients in the extractors, marking techniques, and many technical details. Along with the work of Kempson, Macfadyen, and Murphy, I consider this paper to be one of the highlights of the methodological literature.

Rousseau (2011) reported a significant influence of operator experience on the efficiency of the extraction of insect remains in archaeological materials. This factor has yet to be quantified for soil microarthropod methods.

Skellam (1962) gave a mathematical treatment of dynamic extraction.

Tamura (1976) elegantly showed that a simple funnel extractor is biased against small body sizes of microarthropods, and proposed correction equations to address the bias.

Vannier (1969) described the process of water evaporation from samples in a funnel extractor, and paralleled it to the emergence patterns of microarthropods.

3.2 Glossary of technical terms

This section clarifies terms that have become established as ‘laboratory jargon’, but for which clear definitions are difficult to find, or for which a terminological Babel has been created over time. Some are still commonly used, others are outdated and only appear in older sources.

The glossary does not cover clearly described extraction principles, such as mechanical/dynamic, density/hydrocarbon flotation, etc. For these, refer to the many summary works available (see Section 3.1).

Berlese - A funnel-type extractor that uses light and heat to expel microarthropods from samples of soil, litter, leaves, moss, etc. Some terminological confusion arises from the fact that, historically, Antonio Berlese was indeed the first to describe a device for automatically extracting arthropods from soil samples. However, his apparatus clumsily heated the collected material from the sides using hot water. It was Albert Tullgren in 1917 who first proposed an extractor that heated samples from above with electric light bulbs, as we still have today. It is therefore questionable whose name deserves the honor of addressing the modern devices. Confusingly, all three possible combinations are found in the literature: 'Berlese', 'Tullgren', and 'Berlese-Tullgren'. Choose the one you prefer.

Berlese-Tullgren - see Berlese

high-gradient canister - see Macfadyen

high-gradient funnel - see Macfadyen

Kempson - A variation of a high-gradient extractor (specifically, Macfadyen's 1961 'small canister extractor') that avoids low humidity under the sample that may discourage animals from moving out of the material. This is achieved by the use of wide-mouthed bowl under the net (instead of tapered funnel), and a collecting fluid that neither dries out the air volume above it nor produces toxic fumes (aqueous picric acid solution, in the original description by Kempson et al. (1963).

Ladell can - Part of a mechanical extraction setup proposed by W.R.S. Ladell of Rothamsted, England, in 1936. In a specially designed vessel (the 'Ladell can'), soil is floated in a high-density aqueous solution (originally $MgSO_4$). Air bubbles are injected into the vessel from below to break up aggregates. In a subsequent sedimentation step, inorganic material sinks, while organic material (including arthropods) floats to the surface and can be sampled from the buoyant froth.

Macfadyen - The Englishman Amyan Macfadyen was probably the most ingenious and consistent developer of extraction methods for microarthropods. It is my contention that his thoughts and insights into the processes occurring in dynamic devices remain unparalleled. However, the sheer quantity and intricacy of the results presented by Macfadyen can easily overwhelm the reader. From 1953 to 1968, he proposed five different types of dynamic extractors, studied their properties, and tinkered with details. To add to the confusion, he varied the convoluted names of his devices even within a single paper, and was somewhat opaque regarding the devices' most crucial identifying characteristics. Because of the importance of Macfadyen's work, an overview of the devices is given in Table 1.

Three of Macfadyen's apparatuses employ the so-called 'high-gradient' principle, at least to some extent (whether the 'normal laboratory use' funnel of 1953 is a true high-gradient apparatus in the modern sense is open to debate - in the paper, Macfadyen did utilize this term). In short, high-gradient devices are constructed to create a steep gradient of temperature and humidity within the sample. For microarthropods, two of Macfadyen's apparatuses are particularly important and have been widely adopted and modified by later authors. Both are best described in detail in Macfadyen (1961).

Table 1. Overview of extraction devices developed by Amyan Macfadyen. The author has varied the names of his devices, sometimes in the same paper. 'Gradient' refers to the temperature and humidity gradients within the extraction units.

name(s) of device	short description	described in
expedition funnel apparatus	Extraction of microarthropods from small (50 ml) samples. Funnel shaped extraction units. For field use, heating with a paraffin burner. No steep gradient.	Macfadyen 1953
'high-gradient' funnel apparatus	Forerunner of later high gradient devices. Operates the same way as large funnel extractor, but for small (50 ml) samples.	Macfadyen 1953
large funnel extractor controlled-draught funnel extractor	Extraction of macroarthropods from large (1250 cm^2) samples. Funnel shaped extraction units. Steep gradient created 'passively' by passing ambient air through the extractor.	Macfadyen 1955, 1961
small(er) funnel extractor with air conditioning air-conditioned funnel extractor	Extraction of microarthropods from medium-sized (100 cm^2), loose or stony samples. Funnel shaped extraction units. Steep gradient created by actively cooling (car radiator) funnels with moistened air from below.	Macfadyen 1961, 1962
cylinder extractor small cylinder extractor high-gradient cylinder extractor small canister apparatus	Extraction of microarthropods from small (25 cm^2) samples, left intact in a cylindrical corer during extraction. Cylindrical extraction units (canisters). Steep gradient actively created by immersing the bottom of canisters in a cold water bath.	Macfadyen 1961, 1968

(1) In the 'small funnel extractor with air conditioning', a stream of cool and humid air is circulated around the samples while simultaneously heating them from above. In this way, water vapor is actively supplied to maintain the sample bottom cool and moist. Macfadyen designed this extractor specifically for cores that could not be placed in the unit in an intact form because the soil was too loose, rough, or stony to retain moisture. (2) In the 'small canister extractor', the funnels under the samples are replaced by containers and their bases are cooled in a bath of cold water. Once more, the objective is to create a steep gradient within the samples. However, the 'small canister' lacks air conditioning, so the cores are positioned intact in tightly fitting sample holders. Since the air volume within the containers is closed to the atmosphere and constantly cooled, it remains saturated until the very end of the extraction.

It should be noted that the last name is 'Macfadyen', not 'MacFadyen', as is sometimes misspelled (e.g., European Committee for Standardization 2006). In addition, since five different types of extractors have been proposed by this author, it is not sufficient to simply write 'Macfadyen extractor' to refer to a specific design (e.g. European Committee for Standardization 2006).

Merchant-Crossley - A high-gradient funnel extractor built into a domestic refrigerator, using cheap components (e.g. Christmas tree lights). It was introduced by Virginia Merchant and David Crossley of Athens, Georgia, in 1970. The idea was to create temperature gradients at low cost, i.e. without water bath, cold air circulation, hoses, etc. The concept is outdated as the expensive components of that time are now quite affordable.

Rothamsted funnel - This appears to be a (modified?) example of a Macfadyen high-gradient funnel apparatus used at the Rothamsted Experimental Station in England in the 1970s. I was not able to find a detailed description of the apparatus, only Bater (1996) provided a superficial sketch. Bieri et al. (1978) referred to the Rothamsted funnel as the basis for their own developments, but did not indicate whether it had any relevant modifications beyond Macfadyen's (1961) description. Edwards & Fletcher (1971) mentioned two types of Rothamsted funnels, one with and one without light and heat source. From their description, the devices were simple funnels that did not implement the high-gradient principle.

Salt-Hollick flotation - A sequential mechanical extraction method, proposed by George Salt and F.S.J. Hollick of Rothamsted in 1944. Originally described for the recovery of wireworms, it has also been used for microarthropods by other authors. It works by (1) breaking up soil aggregates by freezing or dispersing soil with a chemical, (2) washing the resulting slurry through a series of sieves of decreasing mesh size to remove larger particles, (3) subjecting the remaining material to density flotation to separate organic from inorganic particles, and (4) separating arthropods from the remaining organic material by hydrocarbon flotation.

Split-funnel - A modified version of the Berlese-Tullgren extractor, introduced by Paul W. Murphy of Rothamsted in the late 1950s. The heating element above the sample and the funnel below the sample are separated ('split') by a small gap, and the collection tube is closely attached to the base of the funnel. These details have the advantage that the circulating air ventilates and dehydrates the sample from above (instead of from below through the funnel), and that the interior of the funnel remains unventilated and its internal atmosphere moist.

Tullgren - see Berlese

Winkler-Moczarski eclector - A simple device for separating arthropods from soil, leaves, etc. The sample is placed in a series of thin, permeable mesh bags that are suspended freely in a closed casing (usually a sack of cloth). Arthropods migrate out of the sample, fall off the meshes, and can be collected from the bottom of the enclosure. The working principle is sometimes confused with that of dynamic extractors, but in the Winkler-Moczarski the animals are not driven out of the material by external heat, but by their random movement through the contents of the mesh bag. It was invented in the early 20th century by the Austrian coleopterist Emil Moczarski, and the entomological supply company Winkler & Wagner, which marketed (and still markets) the eclectors.

4. Discussion

This bibliography is intended to promote the efficiency of future methodological research. Trawling through over one hundred years of research on the subject, it is frustrating to see that numerous intelligent thoughts and canny inventions largely have been overlooked by subsequent work, simply because they were published in an unfamiliar language or printed outside the mainstream media of Soil Zoology.

A case in point is a contribution by A.T. Ulrich (1933), who compared the edaphic fauna of forests with fast and slow litter breakdown in Central Germany. In his paper, the topic of extraction took up only two pages

(285 f) in the Materials section, but in the description of his funnel-type device, Ulrich proposed solutions to methodological issues that were much discussed in later decades: a ventilation system that avoided condensation inside the funnel that could trap minute arthropods (cf. Haarløv 1947, Seastedt & Crossley 1978, Törne 1962), and a device to minimize contaminating debris in the extract (cf. Aoki 1984, Crossley & Blair 1991, Newell 1955). However, this technical aspect of Ulrich's paper was ignored by subsequent authors, probably because it was written in articulate German (thus, difficult for the non-native to understand), published in a silvicultural journal (thus, difficult for the contemporary soil zoologist to find), and extraction was only a secondary aspect (thus, not mentioned in the title, or abstract of the paper).

It is my hope that the materials presented here will be viewed as a valuable resource of information by contemporary method tinkerers, and will be used extensively. The relevant literature is now readily accessible, and, with the advent of online character recognition and translation tools, the notorious problem of reading foreign languages has been overcome. I have deliberately broadened the scope of the literature search beyond sources that focus exclusively on edaphic microarthropods, and have instead extended the search to a wider range of organisms, substrates, and habitats. Knowledge from neighboring fields is now accessible also. To illustrate, the Salt-Hollick flotation (Salt & Hollick 1944) was originally developed for wireworms, and only later adapted for the extraction of microarthropods. In addition, other papers that do not focus on microarthropods may highlight previously neglected aspects of the scientific field, such as the influence of operator experience on extraction efficiency (Rousseau 2011), a factor that has not yet been considered by soil zoologists.

An alarming finding of this research is the poor performance of Web of Science in locating the vast majority of the papers collected in this bibliography. Modern scientists searching the literature are likely to miss the majority of the relevant publications if they rely solely on online reference databases. In contrast, Google scholar referenced 97 % of the publications in the bibliography, namely all entries without 'NA' in the citation column of Table S1. This is consistent with recent reviews of literature search engines, which also found Google Scholar as the currently most comprehensive database (Gusenbauer 2019, Martín-Martín et al. 2021, Singh et al. 2022). However, to efficiently identify literature on microarthropod extraction methods, global terms (e.g., 'extract*', 'sampl*') must be combined with specific terms (e.g. 'collembol*', 'Macfadyen') in a search string. Here, Google Scholar is limited in its capabilities, particularly given the lack of full Boolean functionality (Gusenbauer 2019). This makes advanced searches challenging, if not impossible. Therefore, it is advantageous for microarthropod researchers to first consult this bibliography for methodological questions, especially for older (< 1990) literature, and then turn to online databases.

5. Acknowledgements

Lucie Bruckner clarified translational issues with Czech, and Karolina Taczanowska with Polish texts. Neville Winchester and Anna Seniczak helped with some questionable references and sent papers. Most of all, Thomas Müllner helped immensely by tracking down many references in the bibliography, and by typing in references and abstracts of poorly printed literature for which automatic text recognition did not work. Without him, this research would not have been possible. All are gratefully acknowledged.

6. References

André, H.M., Ducarme, X. & Lebrun, P. (2002): Soil biodiversity: myth, reality or conning? Oikos 96: 3–24.

Aoki, J. (1984): A modified Tullgren funnel with double porous discs for preventing soil particles from dropping into collection tube. Bulletin of the Institute of Environmental Science and Technology, Yokohama National University 11: 103–105.

Banks, N. (1909): Directions for collecting and preserving insects. United States National Museum Bulletin 67: 258 pp. + 30 plates.

Bater, J. (1996): Micro- and macro-arthropods. In: Hall, G.S. (ed): Methods for the Examination of Organismal Diversity in Soils and Sediments. CAB International, Wallingford, Oxon, pp. 163–174.

Beebe, W. (1916) Fauna of four square feet of jungle debris. Zoologica 2, 107–119.

Berlese, A. (1905a): Apparecchio per raccogliere presto ed in gran numero piccoli arthropodi. Redia 2: 85–89.

Berlese, A. (1905b): Apparecchio per raccogliere presto ed in gran numero piccoli artropodi. Bulletino della Societá Entomologica Italiana 35–36: 227–232.

Bieri, M., Delucchi, V. & Lienhard, C. (1978): Ein abgeänderter Macfadyen-Apparat für die dynamische Extraktion von Bodenarthropoden. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 51: 119–132.

Blank, R. & D. Bell (1988): Apparatus for extraction of arthropods from soil using differential water flows. Journal of Economic Entomology 81: 1241–1245.

Bornebusch, C.H. (1930): The Fauna of Forest Soil. Det forstlige Forsøgsvæsen i Danmark, Copenhagen: 254 pp.

Brand, R. (1979): Effect of sampling time on estimates of soil arthropod populations. Revue d'Écologie et de Biologie du Sol 16: 499–515.

Bruckner, A. (2022): Effects of soil core handling, transport and storage on numbers and body sizes of edaphic predatory mites (Gamasina). Soil Organisms 94: 163–169.

Bruckner, A., Querner, P. & Scholz, C. (2023): No indication of methodological biases in tullgren and macfadyen extraction of edaphic microarthropods. European Journal of Soil Biology 115: 9 pp.

Cancela da Fonseca, J.-P., Poinsot, N. & Vannier, G. (1967): Essai comparatif sur les microarthropodes et la taille des échantillons de sol. Revue d'Écologie et de Biologie du Sol 4: 331–355.

Chan, T. & Trott, L. (1972): The Collembolan, Oudemansia Esakii, an intertidal marine insect in Hong Kong, with emphasis on the floatation method of collection. Hydrobiologia 40: 335–343.

Crossley, D. jr. & Blair, J.M. (1991): A high-efficiency,"low-technology" Tullgren-type extractor for soil microarthropods. Agriculture, Ecosystems and Environment 34: 187–192.

Dindal, D.L. (199): Soil biology guide. John Wiley & Sons, New York.

Dogiel, V. & Efremoff, G. (1925): Versuch einer quantitativen Untersuchung der Bodenbevölkerung im Fichtenwalde [in Russian]. Trudy Leningradskogo Obshchestva Estestvoispytatelei (= Travaux de la Société des Naturalistes de Leningrad) 55: 97–110.

Drift, J. van der (1951): Analysis of the animal community in a beech forest floor. Tijdschrift voor Entomologie 94: 1–168.

Dritsoulas, A. & Duncan, L.W. (2020): Optimizing for taxonomic coverage: a comparison of methods to recover mesofauna from soil. Journal of Nematology 52: 1–9.

Edwards, C. & Fletcher, K. (1971): A comparison of extraction methods for terrestrial arthropods. –In: Phillipson, J. (ed.): Methods of Study in Quantitative Soil Ecology: Population, Production and Energy Flow, IBP Handbook. Blackwell Scientific Publications, Oxford, UK, pp. 150–185.

Espinaze, M.P., Hui, C., Waller, L. & Matthee, S. (2019): The efficacy of a modified Berlese funnel method for the extraction of ectoparasites and their life stages from the nests of the African Penguin Spheniscus demersus. Ostrich - Journal of African Ornithology 90: 271–277.

European Committee for Standardization (2006): Soil quality - Sampling of soil invertebrates - Part 2: Sampling and extraction of micro-arthropods (Collembola and Acarina) (ISO 23611-2:2006).

Faraji, F., Bruin, J. & Bakker, F. (2004): A new method for mite extraction from leaf samples. Experimental and Applied Acarology 32: 31–39.

Farrar, F. & Crossley, D. (1983): Detection of soil microarthropod aggregations in soybean fields, using a modified Tullgren extractor. Environmental Entomology 12: 1303–1309.

Fioratti Junod, M., Reid, B.J., Sims, I. & Miller, A.J. (2023): Below-ground pitfall traps for standardised monitoring of soil mesofauna: Design and comparison to Berlese/Tullgren funnels. Pedobiologia 101: 150911.

Gusenbauer, M. (2019): Google Scholar to overshadow them all? Comparing the sizes of 12 academic search engines and bibliographic databases. Scientometrics 118: 177–214.

Haarløv, N. (1947): A new modification of the Tullgren apparatus. Journal of Animal Ecology 16: 115–121.

Hale, W. (196): A flotation method for extracting Collembola from organic soils. Journal of Animal Ecology 33: 363–369.

Henderson, P. & T. Southwood (2016): Ecological Methods, 4th ed. John Wiley & Sons.

Hill, M. (1998): Quantification of house-dust-mite populations. Allergy 53: 18–23.

Howard, L. (1906): Professor Berlese´s apparatus for collecting small arthropods rapidly and in great quantities. Entomological News 17: 49–53.

Jacot, A.P. (1936): Soil structure and soil biology. Ecology 17: 359–379.

Jarvis, T.D. (1908): Apparatus for collecting small arthropods terrestrial and aquatic. Annual Report of the Ontaria Entomological Society 19: 66–69.

Joseph, S.V. & Bettiga, C. (2016): Captures of Protaphorura fimata (Collembola: Poduromorpha: Onychiuridae) on beet and potato baits in the Salinas Valley of California. Journal of Entomological Science 51: 79–86.

Kempson, D., Lloyd, M. & Ghelardi, R. (1963): A new extractor for woodland litter. Pedobiologia 3: 1–21.

Klen, T. & Leskinen, L. (1989): The effect of temperature on the efficiency of extracting astigmatic mites from hay - a trial with a heat extractor. Acarologia 30: 255–260.

Koponen, S., Rinne, V. & Clayhills, T. (1997): Arthropods on oak branches in SW Finland, collected by a new trap type. Entomologica Fennica 8: 177–183.

Kozel, P., Pipan, T., Šajna, N., Polak, S. & Novak, T. (2017): Mitigating the conflict between pitfall-trap sampling and conservation of terrestrial subterranean communities in caves. International Journal of Speleology 46: 359–368.

Krausse, A. (1915): Hexapodologische Notizen. Archiv für Naturgeschichte 81: 160–167.

Macfadyen, A. (1953): Notes on methods for the extraction of small soil arthropods. Journal of Animal Ecology 22: 65–77.

Macfadyen, A. (1955): A comparison of methods for extracting soil arthropods. In: Kevan, D.K. (ed): Soil Zoology, Proceedings of the University of Nottingham Second Easter School in Agricultural Science. Academic Press and Butterworth Scientific Publications, New York and London, pp. 315–332.

Macfadyen, A. (1961): Improved funnel-type extractors for soil arthropods. Journal of Animal Ecology 30: 171–184.

Macfadyen, A. (1962): Control of humidity in three funnel-type extractors for soiol arthropods. In: Murphy, P.W. (ed): Progress in Soil Zoology. Butterworths, London, UK, pp. 158–168.

Macfadyen, A. (1968): Notes on methods for the extraction of small soil arthropods by the high gradient apparatus. Pedobiologia 8: 401–406.

Martín-Martín, A., Thelwall, M., Orduna-Malea, E. & Delgado López-Cózar, E. (2021): Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. Scientometrics 126: 871–906.

McAtee, W.L. (1907): Census of four square feet. Science 26: 447–449.

Newell, I.M. (1955): An autosegregator for use in collecting soil-inhabiting arthropods. Transactions of the American Microscopical Society 74: 389–392.

Nsengimana, V., Kaplin, A.B., Francis, F. & Nsabimana, D. (2017): A comparative study between sampling methods for soil litter arthropods in conserved tree plots and banana crop plantations in Rwanda. International Journal of Development and Sustainability 6: 900–913.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C. & et al. (2001): Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience 51: 933–938.

Pande, Y. & P. Berthet (1973): Comparison of the Tullgren funnel and soil section methods for surveying Oribatid populations. Oikos 24: 273–277.

Pang, A., Nicol, A.M., Rutter, A. & B. Zeeb (2023): Improved methods for quantifying soil invertebrates during ecotoxicological tests: Chill comas and anesthetics. Heliyon 9: 1–7.

Pfetten, J. (1925): Beiträge zur Kenntnis der Fauna der Waldstreu: Fichtenstreu-Untersuchungen [in German]. Zeitschrift für Angewandte Entomologie 11: 35–54.

Pillai, S.K. (1922): Beiträge zur Kenntnis der Fauna der Waldstreu. Kiefernstreu-Untersuchungen [in German]. Zeitschrift für Angewandte Entomologie 8: 1–30.

Potapov, A.M., Sun, X., Barnes, A.D., Briones, M., Cameron, E.K., Tang, C.-H.A., Eisenhauer, N., Franco, A.L., Fujii, S. & S. Geisen (2022): Global monitoring of soil animal communities using a common methodology. Soil Organisms 94: 55–68.

Proctor, H.C. (2001): Extracting aquatic mites from stream substrates: a comparison of three methods. Experimental and Applied Acarology 25: 1–11.

Rousseau, M. (2011): Paraffin flotation for archaeoentomological research: is it really efficient? Environmental Archaeology 16: 58–64.

Salt, G. & F. Hollick (1944): Studies of wireworm populations: I. A census of wireworms in pasture. Annals of Applied Biology 31: 52–64.

Sanders, D. & M.H. Entling (2011): Large variation of suction sampling efficiency depending on arthropod groups, species traits, and habitat properties. Entomologia Experimentalis et Applicata 138: 234–243.

Santos, A.C., Leite, T.R., Cunha, M.S., Gondim Jr, M.G., Lofego, A.C., Ferla, N.J., Bizarro, G.L. & A.R. Oliveira (2022): A rotatory funnel-shaped collector for trapping airborne mites in a glycerin-based adhesive surface. Experimental and Applied Acarology 86: 189–200.

Seastedt, T. & D. Crossley (1978): Further investigations of microarthropod populations using the Merchant-Crossley high-gradient extractor. Journal of the Georgia Entomological Society 13: 338–344.

Shaw, G.G. (1970): Grease-film extraction of an arthropod: A modification for organic soils. Journal of Economic Entomology 63: 1323–1324.

Shaw, P. & C. Ozanne (2011): A calibration of the efficiency of Winkler eclectors for extracting Collembola at different humidities. Soil Organisms 83: 515–520.

Singh, V.K., Srichandan, S.S. & H.H. Lathabai (2022): ResearchGate and Google Scholar: How much do they differ in publications, citations and different metrics and why? Scientometrics 127: 1515–1542.

Soudek, Š. (1928): Fauna lesní hrabanky [in Czech]. Sborník Vysoké Školy Zemědělské v Brně, Fakulta Lesnická D8: 1–24.

Spafford, R.D. & C.J. Lortie (2013): Sweeping beauty: Is grassland arthropod community composition effectively estimated by sweep netting? Ecology and Evolution 3: 3347–3358.

Therrien, F., Chagnon, M. & C. Hébert (1999): Biodiversity of Collembola in sugar maple (Aceraceae) forests. The Canadian Entomologist 131: 613–628.

Törne, E. von (1962): A Tullgren-Funnel modification to prevent contamination of the collecting tube with sample debris, in: Murphy, P. (Ed.), Progress in Soil Zoology. Butterworths, London, pp. 179–181.

Trägårdh, I. (1910): Om Berlese´s apparat för snabb och effektiv insamling af små leddjur [in Swedish]. Entomologisk Tidskrift 31: 35–38.

Trägårdh, I. & Forsslund, K.-H. (1932): Studier över insamlingstekniken vid undersökningar över markens djurliv. Medföljer Skogsvårdsföreningens Tidskrift 1–2: 21–45.

Tullgren, A. (1918): Ein sehr einfacher Ausleseapparat für terricole Tierformen. Zeitschrift für Angewandte Entomologie 4: 149–150.

Tullgren, A. (1917): En enkel apparat för automatiskt vittjande av sållgods [in Swedish]. Entomologisk Tidskrift 38: 97–100.

Ulrich, A.T. (1933): Die Makrofauna der Waldstreu. Quantitative Untersuchungen in Beständen mit guter und schlechter Zersetzung des Bestandesabfalles. Mitteilungen aus Forstwirtschaft und Forstwissenschaft 2: 283–323.

Umble, J., Dufour, R., Fisher, G., Fisher, J., Leap, J. & Van Horn, M. (2006): Symphylans: soil pest management options. NCAT ATTRA Publications, 16 pp.

Williams, C. (1913): The Berlese funnel. The Entomologist 46: 273–274.

Yoshida, T. & Hijii, N. (2008): Efficiency of extracting microarthropods from the canopy litter in a Japanese cedar (Cryptomeria japonica D. Don) plantation: a comparison between the washing and Tullgren methods. Journal of Forest Research 13: 68–72.

Zou, Y., Feng, J., Xue, X., Sang, W. & Axmacher, J.C. (2012): A comparison of terrestrial arthropod sampling methods. Journal of Resources and Ecology 3: 174–182.