Soil Biology Manual

Sampling and characteristics of soil macro- and mesofauna

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1st edition

MADREPÉROLA

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FRB Fondation pour la Recherche sur la Biodiversité

CESAB Centre de Synthèse et d'Analyse sur la Biodiversité

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

MACSA Programa de Pós-Graduação em Manejo e Conservação do Solo e da Água

FAPESP Fundação de Amparo à Pesquisa do Estado de São Paulo

ESALQ Escola Superior de Agricultura Luiz de Queiroz Universidade de São Paulo

Universidade Federal de Pelotas RS-Brasil

iDiv German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

Sorbonne Université

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1290 Universidade de Coimbra

EEG Environmental Ecology & Ecotoxicology Group

Centre d'Ecologie Fonctionnelle & Evolutive

Embrapa

SPD Soil Diagnostic Diagnóstico preciso do solo

SBCS Sociedade Brasileira de Ciência do Solo Núcleo Estadual Paraná

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Chapter 1

Introduction

Recent estimates suggest that soils harbor approximately 60% of the planet's total biodiversity (Anthony et al., 2023). Soil invertebrates, display high diversity in this habitat and participate both directly and indirectly in several soil functions, have only recently begun to receive greater attention in scientific, social, and political spheres (Orgiazzi et al., 2016; Eisenhauer et al., 2019; Guerra et al., 2020; 2021). Today, there is no doubt of the importance of these invertebrates as providers and regulators of various ecosystem services in both native and managed ecosystems, including nutrient cycling, primary production, climate regulation, and pedogenesis, among others (Brown et al., 2025).

In addition to their functional relevance, soil fauna are also sensitive to biotic and abiotic changes and have therefore been widely used as indicators of soil quality in agricultural systems around the world (Lavelle et al., 2022). Given the immense species richness and the wide range of body sizes among soil fauna, they are commonly divided into micro-, meso-, and macrofauna according to size of the taxa (Figure 1). Although this classification is quite old (Drift, 1951; Dunger, 1964; Wallwork, 1970; Swift et al., 1979), it remains useful for distinguishing between groups of organisms and offers an intuitive understanding of their ability to influence organic matter dynamics and modify their environment.

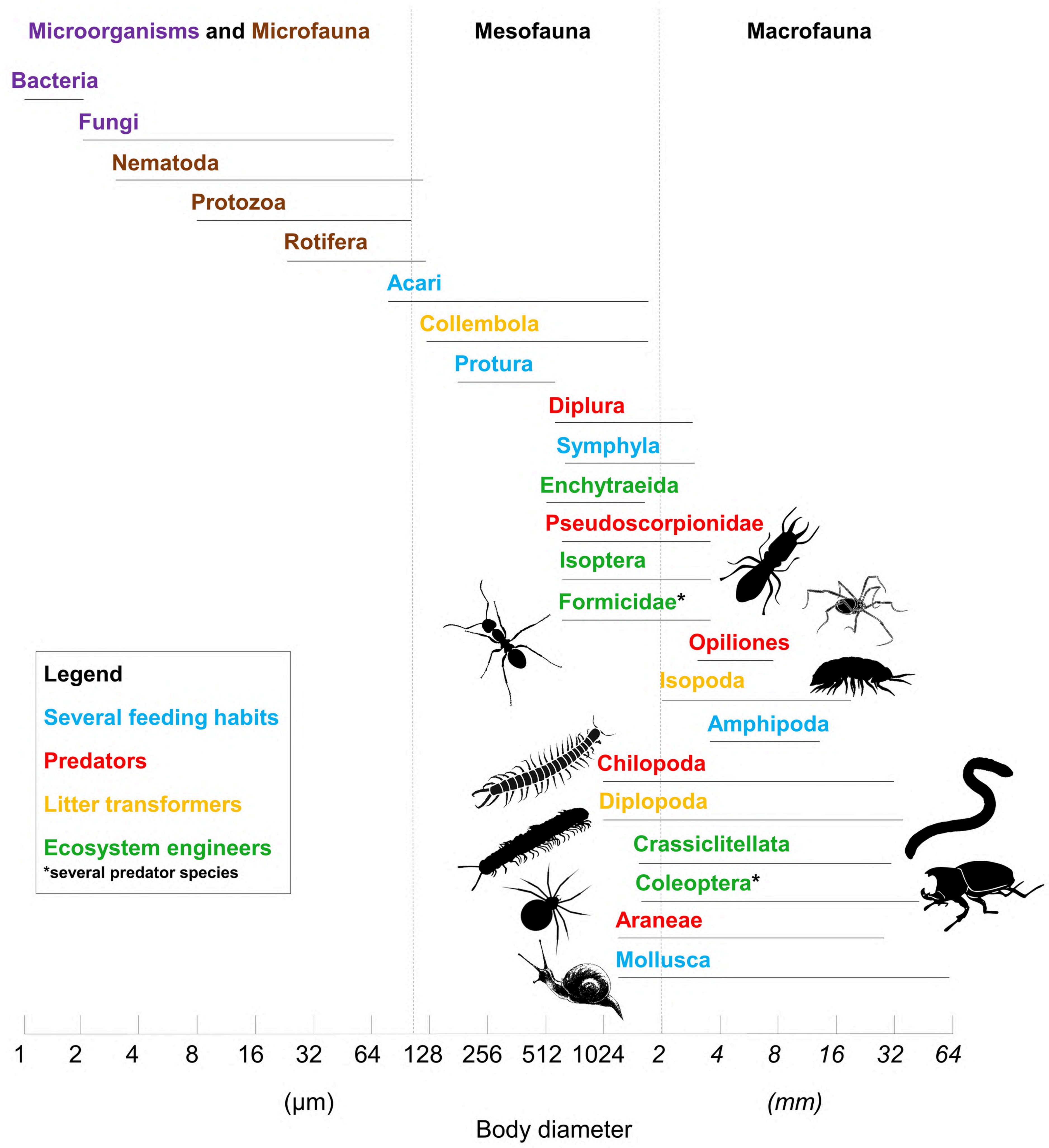


Figure 1. Classification of the main groups of soil invertebrate fauna based on body size and feeding habits. Source: Brown et al. (2025).

Several methodologies can be used to assess these organisms; however, care must be taken when choosing the method, as it may complicate the comparison of results with other studies. Furthermore, it is important to consider variables such as soil chemical and physical properties, land-use history, and the time of year when sampling period to facilitate the interpretation of the observed results. A more in-depth discussion of key considerations for studies on soil macrofauna can be found in Demetrio et al. (2025), although these recommendations are also useful for research involving meso- and microfauna.

Among the main methods used for sampling the soil fauna are: handsorting of soil monoliths, commonly referred to as the TSBF* method (Anderson & Ingram, 1993) used for macrofauna; pitfall traps, applied to assess epigeic macro- and mesofauna; and soil sampling using cylinders or cores followed by Berlese-Tullgren heat extraction for the mesofauna. Although several published studies describe these methods (Anderson & Ingram, 1993; Aquino, 2001; Dionísio & Signor, 2016; Signor & Dionísio, 2016; Moreira et al., 2010; among others), the objective of this manual is not only to describe these three sampling methods but also to provide relevant information to support identification of the collected organisms, especially for scientists who are beginning their studies in this field.

Recommended supplementary reading:

For a better understanding of the ecology of these organisms, the roles of soil fauna in the environment, and key decisions during sampling, we recommend the following publications: “Macrofauna do solo e sua importância nos processos edáficos e na provisão de serviços ecossistêmicos” (Brown et al., 2025), “Macrofauna nos solos Brasileiros: Estado da arte e recomendações de coleta” (Demetrio et al., 2025), “Fundamentals of Soil Ecology” (Coleman et al., 2017), and “Global monitoring of soil animal communities using a common methodology” (Potapov et al., 2022).

*TSBF stands for the Tropical Soil Biology and Fertility Programme, a UNESCO initiative originally based in Nairobi, Kenya, which began in the 1980s and continued until the mid-2000s, aimed at promoting the study and assessment of soil biology and fertility in tropical regions.

Chapter 2

Soil macro- and mesofauna sampling methods: general issues and the use of TSBF, pitfall traps, and Berlese-Tullgren funnels

Introduction

The experimental design is one of the most important stages of a study. The spatial distribution of samples, the depth evaluated, and the choice of sampling method are critical steps in soil fauna research, and are largely responsible for the success or failure of the study. Thus, in soil biodiversity studies focusing on invertebrates, the answers to five key questions must be clear to the researchers involved before sampling begins. These questions are:

I) What is the objective of assessing the soil fauna, i.e., what is your main research question?
II) Which group(s) will be assessed, and why?
III) What is the best method (or combination of methods) for the target groups/taxa, and do we have the resources to carry it out?
IV) How many samples will be collected, and how will they be spatially and temporally distributed across the different treatments?
V) What environmental variables are crucial to measure in order to achieve the study's objective?

Although the answers to these questions may seem clear, the simple exercise of addressing them will allow researchers to identify methodological gaps that are often only noticed during the analysis and interpretation of results. Unfortunately, in most cases, one cannot return to the experimental areas/fields to collect additional samples and information.

Here are some examples of answers to the above questions:

I) What is the relationship between soil structure, water infiltration, greenhouse gas emissions, and soil fauna communities, under different agricultural management conditions?. Soil structure is related to water infiltration and greenhouse gas emissions. Since soil fauna positively impacts soil structure (see Brown et al., 2025), understanding the land management practices that favor these organisms is important in the context of climate change. This justifies sampling soil fauna.
II) The soil macrofauna will be assessed since several taxa in this group are bioturbators. Here, we define why we chose this group rather than mesofauna or the specific collection of a single taxon.

The answers to questions III and IV often require field experience and/or preliminary assessments in the field since it is not easy to balance sampling feasibility and data quality.
III) The chosen method will be monolith collection and hand sorting, since it can efficiently collect most macrofauna taxa. Although it requires considerable labor, we currently have enough resources (human and financial) to carry it out.
IV) In each evaluated system, 9 monoliths will be collected, each measuring 25x25 cm to a depth of 0-10 cm, distributed across three transects with 20 m distance between each transect and 20 m between samples.

The answer to question V is complex and also depends on the resources available for the study. To better understand the importance of environmental variables, the impact of land history, and soil properties on soil fauna, we recommend reading Demetrio et al. (2025). However, for practical purposes, a possible answer to this question could be:

V) The chemical properties to be evaluated include pH, exchangeable nutrients, and soil carbon content, as these factors impact various macrofauna taxa as well as greenhouse gas emissions. Physical properties such as soil bulk density, macro- and microporosity, and water infiltration capacity will also be assessed, as they are affected by land management practices and, in turn, influenced by soil organisms. Furthermore, they affect gas emissions from soils.

Even in a simplified form, the previous answers draw attention to some important steps between the objective of the study and the sampling needed to achieve it. A more in-depth discussion of questions I to V can be found in Brown et al. (2025) and Demetrio et al. (2025). Assuming these questions have been addressed, this chapter will provide a detailed description of how to sample soil fauna using the three of most commonly used methods in the field.

Number and distribution of samples

The number of samples to be collected, as well as their spatial (and temporal) distribution, often need to be adjusted depending on the environment studied. Sampling should always prioritize inclusion of true replicates, meaning multiple sites with the same land use system (and similar history, if possible), preferably in areas that are spatially independent from one another. Ideally, these should be different areas (Figure 1), or, if the area is very large (large scale or commercial production), the sampling grids should be spaced at least 500 m apart (Figure 2). Each grid should have at least 3 sampling points for large-scale land use systems (Figures 1 and 2), while for experimental plots, at least 2 or 3 points per plot (Figure 3), depending on the number of treatment replicates and/or blocks. For both (large scale or experimental plots), the desired total number of points should be at least 9 for representativeness in statistical analysis. It is important to note that the greater the number of sampling points, the better the representativeness of the evaluated system and the more reliable the results obtained.

Figure 1. Example of the spatial distribution and number of samples to be collected in spatially independent areas. Image: Google Earth.

Figure 2. Example of the distribution and number of samples to be collected in large-scale areas. Image: Google Earth.

Figure 3. Example of the distribution and number of samples to be collected in experimental plots. Image: Google Earth.

In sloping areas, it is important that the sampling points be distributed across different positions of the watershed (e.g., upper third, middle third, lower third), due to possible variations in soil type, organic matter, and moisture along the slope position.

Macrofauna sampling using the TSBF method

List of materials required for soil macrofauna sampling using the TSBF method:

- Flat shovel (square point shovel) x 2
- Ruler or measuring tape
- Metal template (25x25 cm x 10 cm, not mandatory) x 2
- Trays (minimum 30 x 50 cm)
- Durable plastic bags (50 L) (minimum thickness 0.10 microns) for sample storage
- Small plastic bags (1000 mL) for collecting soil samples
- Metal volumetric rings with metal or plastic lids for collecting undisturbed samples; if lids are not available, plastic wrap (PVC) can be used to cover the rings
- Plastic PET vials with screw caps (80 mL)
- Ethanol (96%, but >80% can also be used)
- Tweezers for collecting invertebrates
- Sample identification labels; these can be pre-printed using laser printer on self-adhesive paper for external labeling of bags and jars, and on vellum paper (>90 g/m²) or heavy paper (>130 g/m²) for internal labels in bags and jars
- Pencils or pens with ink that does not dissolve in alcohol
- Pens
- Buckets to help transport soil samples
- Plastic box for transporting undisturbed samples

Collection of soil monoliths and hand-sorting

At each sampling point, the area for monolith collection should be marked using a metal or wooden template (25 x 25 cm), avoiding areas that have been trampled, tire tracks from agricultural machinery, or animal trails.

The litter within the area should be removed and hand sorted, collecting any animals found. These animals should be immediately placed in containers with ethanol (≥80%), and labeled with the sample number and layer designation (L) for the litter layer or straw layer in agricultural fields. In pasture areas or areas dominated by grasses, it may not be possible to separate the litter layer, so it should be considered as the first layer, L+0-10 cm. After removing the litter, the remaining sampling can be performed in two ways:

1. By digging an "L"-shaped trench to the desired depth (10, 20, or 30 cm deep) around the monolith (to assist with removal of the monolith layers of 10 cm thickness; Figures 4 and 5). In this case, the monolith should be preferably isolated with the straight spade to a depth of 20 cm, to prevent animals from escaping to the soil matrix. The soil from each depth should be sorted immediately on-site (at the location), or temporarily stored in plastic bags until it can be sorted.

The highest abundance and diversity of soil macrofauna are found in the litter and the surface soil layer (0-10 cm in depth). Therefore, depending on the study's objective, it is more interesting to collect up to 10 cm in depth and invest the sampling effort in collecting and sorting a larger number of monoliths at each study site.

Figure 4. Collection of soil macrofauna using the mini-trench method. Photo: George Brown.

Figure 5. Removal of 10 cm soil layers using the mini-trench method. Photo: George Brown.

2. The soil monolith can also be collected without the need for trench excavation, using a metal template (Figure 6) or by using only the spade (Figure 7). However, the latter is recommended for individuals who already have experience in macrofauna sampling due to the increased difficulty in collecting deeper layers. After marking the surface of the monolith with or without the use of a metal template (25 x 25 cm), the spade should be inserted into the soil to a depth of 10 cm, slightly tilted forward to maintain a 90° angle in the soil cut. This should be repeated for the four sides of the square, in order to isolate the monolith from the surrounding soil, and reduce the escape of the organisms from within the sample. After this procedure, slowly lift the spade, removing the top 10 cm of soil, and store it in plastic bags (Figure 8).

Figure 6. Metal template for collecting soil macrofauna up to 10 cm depth using the TSBF method. Photo: George Brown.

Figure 7. Collection of the monolith without trench excavation. Photo: Marie Bartz.

Figure 8. Completed sample stored in a plastic bag. Photo: Marie Bartz.

It is important to always check if the hole is the correct size (25 x 25 cm) and that the removed layer has exactly 10 cm thickness (Figure 9).

Figure 9 Checking the dimensions of the monolith. Photo: Wilian Demetrio.

In studies focused on earthworms, soil layers can be placed in trays to be immediately sorted in the field. However, in macrofauna studies, due to the high mobility of some invertebrates and the possibility of animals entering the sample, plastic bags can be used to store the layers if they are not sorted immediately. It is essential to keep the plastic bags with the samples in the shade, in a cool environment, away from heat and sunlight.

Hand-sorting, a slow and labor-intensive process, should be performed in a comfortable location with good lighting, usually outdoors (Figure 10), and preferably on a table, as it requires a lot of patience (on average, it takes 1 to 2 hours per sample/layer).

Figure 10. Hand sorting of samples in situ outdoors in the Amazon. Photo: George Brown.

A small amount of soil should be placed on one side of a large white tray, and the soil should be broken up in the middle of the tray, removing all visible animals. As the soil is sorted, it should be moved to the other side of the tray. Do not place a large amount of soil in the tray, as this will mix what has already been sorted with what has not yet been looked at (Figure 11).

Figure 11. Amount of soil to be placed for hand-sorting in the plastic tray. Photo: Wilian Demetrio.

Plastic vials should be properly labeled. Abbreviations are often used: for instance, A for 0-10 cm, B for 10-20 cm, and C for 20-30 cm. Earthworms can be placed in formalin (4-10%) or ethanol (>80% or 96% for DNA analysis purposes), and the rest of the fauna in alcohol >80% or 96% if DNA analysis is planned. Labels made of thicker paper (>90 g or >130 g) should be placed inside the vial, as it is common for the label written on the outside with a pen to smudge due to alcohol leakage from the vial. The use of vials with a good seal and a tight-fitting lid is important, as they may leak during transport, and when they reach their destination, the fauna in the sample may be compromised.

Important: If genetic analysis of the collected animals is planned, formalin should be avoided as it destroys DNA. Instead, use alcohol with a concentration >96%.

In the laboratory, using a stereoscopic microscope, the fauna from each vial should be identified and separated into the different taxa (see the characteristics of each taxon in Chapter 3 of this manual). The animals belonging to each taxon are counted and, whenever possible, weighed on an analytical balance with a precision of 0.0001 g. The fauna is left to air-dry for a minute on top of a paper towel, and then weighed. The weight is recorded per group/taxon. For example, if 10 earthworms are found in layer A, all 10 should be weighed together (this information is relevant for studies related to energy flow; for more information, see Buchkowski et al., 2023).

Recording data and other information

Whenever possible, macrofauna should be identified at the family, genus, or species level, especially for taxa with different feeding habits (e.g., beetles and ants, among others). All data should be entered into an Excel spreadsheet, with columns for: project name, municipality, sampling date, sample data (acronyms, block or replication numbers, sampled layer, etc., for each monolith), and the taxa found. A standard spreadsheet template can be downloaded using this link: https://zenodo.org/records/10956013.

Table 1. Example of a spreadsheet for data entry.

Land use	Nº monolith	Top depth (cm)	Bottom depth (cm)	Crassiclitellata	Isoptera	Formicidae	...	Total
Forest	1	Litter	0					
Forest	1	0	10					
Forest	1	10	20					
Forest	1	20	30					
Forest	2	Litter	0					
...								

Table 2. A list of some of the main taxonomic groups of soil macrofauna, their common names, and functional groups. For a more complete list, see Brown et al. (2025).

Taxon	Common name	Functional groups
Araneae	Spiders	Predators
Blattaria	Cockroaches	Detritivores, plant feeders, omnivores
Chilopoda	Centipedes	Predators
Coleoptera	Beetles, and beetle grubs	Plant feeders, predators, detritivores
Crassiclitellata	Earthworms	Geophages, detritivores, omnivores
Dermaptera	Earwigs	Omnivores, predators
Diplopoda	Millipedes	Detritivores, plant feeders (some species)
Diptera larvae	Fly larvae, maggots	Detritivores, predators, parasites
Formicidae	Ants	Geophages, detritivores, plant feeders
Gastropoda	Snails and slugs	Phytophagous, detritivores
Heteroptera	True bugs	Plant feeders, plant feeders, predators
Homoptera	Cicadas	Plant feeders
Isopoda	Woodlice	Detritivores
Isoptera	Termites	Geophages, detritivores, plant feeders
Lepidoptera larvae	Caterpillars	Plant feeders, predators, symbionts
Symphyla	Symphylans or garden centipedes	Detritivores, predators
Orthoptera	Crickets, grasshoppers, mole crickets	Plant feeders, predators (mole crickets)
Pseudoscorpionidae	Pseudoscorpions	Detritivores, predators

Table 3 includes a list of important variables that, whenever possible, should be included in studies of soil fauna.

Table 3. List of methodological, biological, soil, and environmental variables that should be included, when possible, in macrofauna studies.

Attributes	Variables	Units description
Methodological	Sample size	Dimensions of the monolith (e.g., 20x20, 25x25, 30x30 cm), diameter and volume of the cylinder, and size of the pitfall trap used
	Number of samples	Number of samples and sampling design used in each evaluated system
	Sampling depth	Litter, 0-10, 0-20 cm. Iron rings (litter - 5 cm depth).
	Collecting and preserving solution(s)	Alcohol or formol (specify concentration) for preserving fluid, and the liquid and concentrations used for pitfall traps
Biological	Identification of each taxon	Provide the name of each taxon identified, and when not encountered, specify 0 for the taxon; when not able to identify the taxon, provide identification at higher resolution, e.g., insect larvae
	Density of each taxon	Individuals per m^2
	Biomass of each taxon (only for macrofauna)	Grams per m^2
Soil	Routine chemical analysis	pH, Ca, Mg, K, total organic matter and in sand, silt and clay fractions
	Particle size distribution analysis	Percentage of sand, silt and clay, or grams per kg
	Soil bulk density	Grams per cm^3
Environmental	Location	Geographic coordinates (preferably in decimal degrees)
	Climate	Köppen climate type
	Sampling season	Dry or wet
	Sampling	Precipitation in the sampling month and in the three previous months
	Vegetation	Native (forest or pasture) or agricultural (annual crop, perennial crop, orchard, etc.), specifying the crop(s) planted at sampling
	Soil management and management history	Crop rotation (specify the crops used and the sequence), soil tillage system, fertilization and use of pesticides (specify amounts, frequency and types applied, when possible)

Sampling of soil macro- and mesofauna using pitfall traps and Berlese-Tullgren funnels

To demonstrate sampling using pitfall traps and Berlese-Tullgren funnels, different sites on the Capão do Leão campus of the Federal University of Pelotas - UFPel are shown in Figure 12. Areas with different land uses were selected and identified as: forest (site A), grass lawn (site B), vegetable cultivation (site C), and spontaneous vegetation (site D).

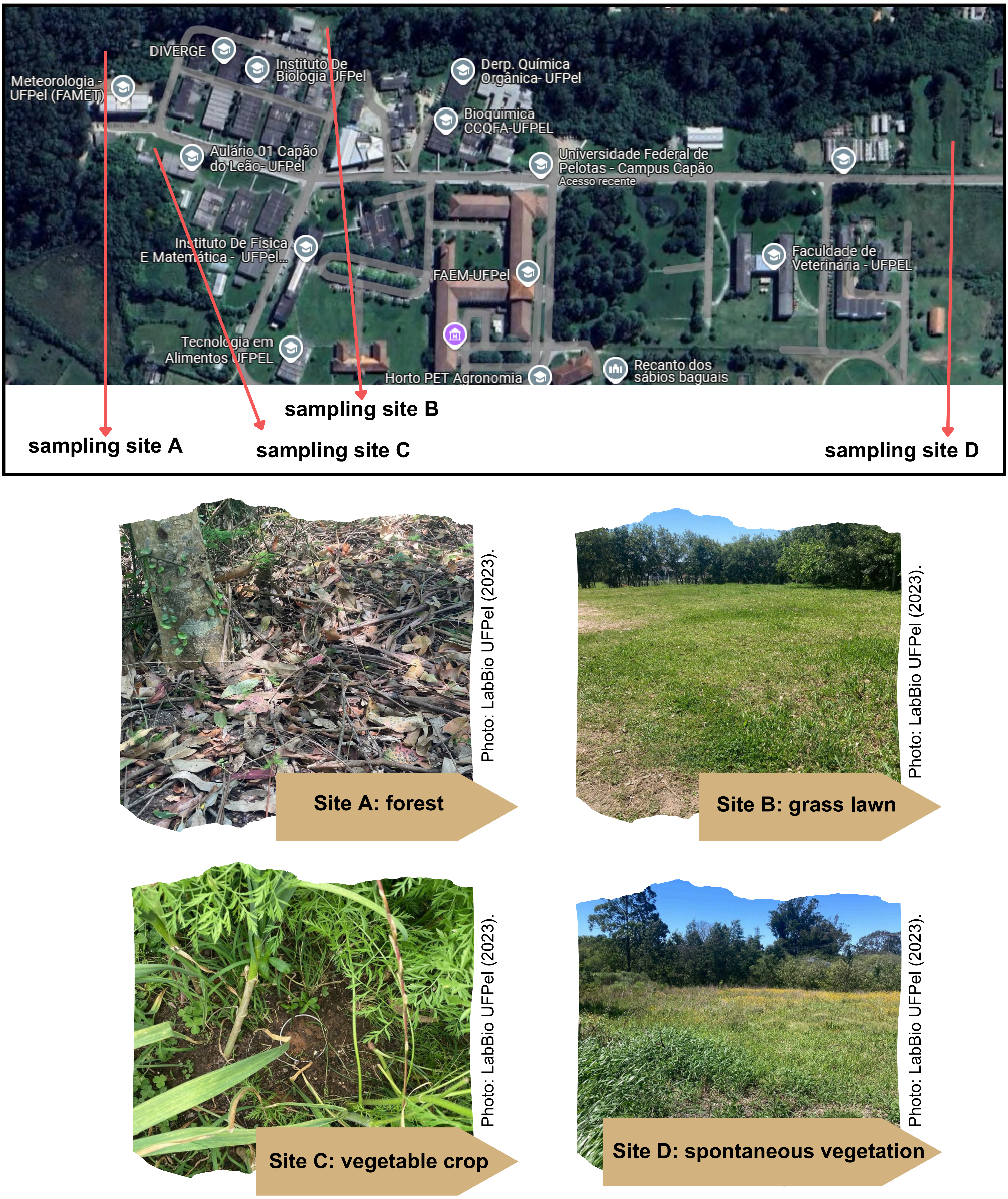


Figure 12. Map of the Capão do Leão Campus of UFPel and its sampling units. Image: Google Earth.

The soil sampling and installation of pitfall traps for capturing soil fauna organisms should be carried out as follows:

Photo: LabBio UFPel (2023).

Using a sledgehammer and a wooden base, a metal cylinder is driven into the 0 -10 cm soil layer, capturing the organisms that inhabit the soil. Litter should not be removed during the sampling.

Photo: LabBio UFPel (2023).

In the spot where the cylinder was removed, a pitfall trap is installed, typically using 500 mL plastic screw-top jars (commonly used for honey), filled with 200 mL of a 4% formalin solution (prepared by diluting 20 mL of formalin in 180 mL of water), to capture organisms that inhabit the litter/soil interface. The traps remain in the field for 7 days.

Photo: Lilianne Bruz.

At 10 cm from the trap, a stake is fixed to support a tile that serves as protection against rain and sunlight while the trap is open in the field.

To collect the fauna that lives within the soil, steel cylinders with a known volume are used (e.g., height = 10 cm; Ø = 8.5 cm). After sampling, the cores should be kept refrigerated at 4 °C until they are taken to the extractors.

Photo: LabBio UFPel (2023).

Photo: LabBio UFPel (2023).

In the laboratory, soil organisms are extracted using the Tullgren funnel method, in which each sample is placed in the upper part of the funnel on a 2 mm mesh sieve. Then, 40-watt lamps are turned on for a period of 48 hours. The light and heat causes the organisms to move downward, where they are collected in a jar containing either 80% alcohol or 4% formalin, placed at the base of the funnel.

Subsequently, the organisms collected from both the funnels and the pitfall traps are counted. For this, a syringe is used to transfer the sample from the jars into an appropriate container.

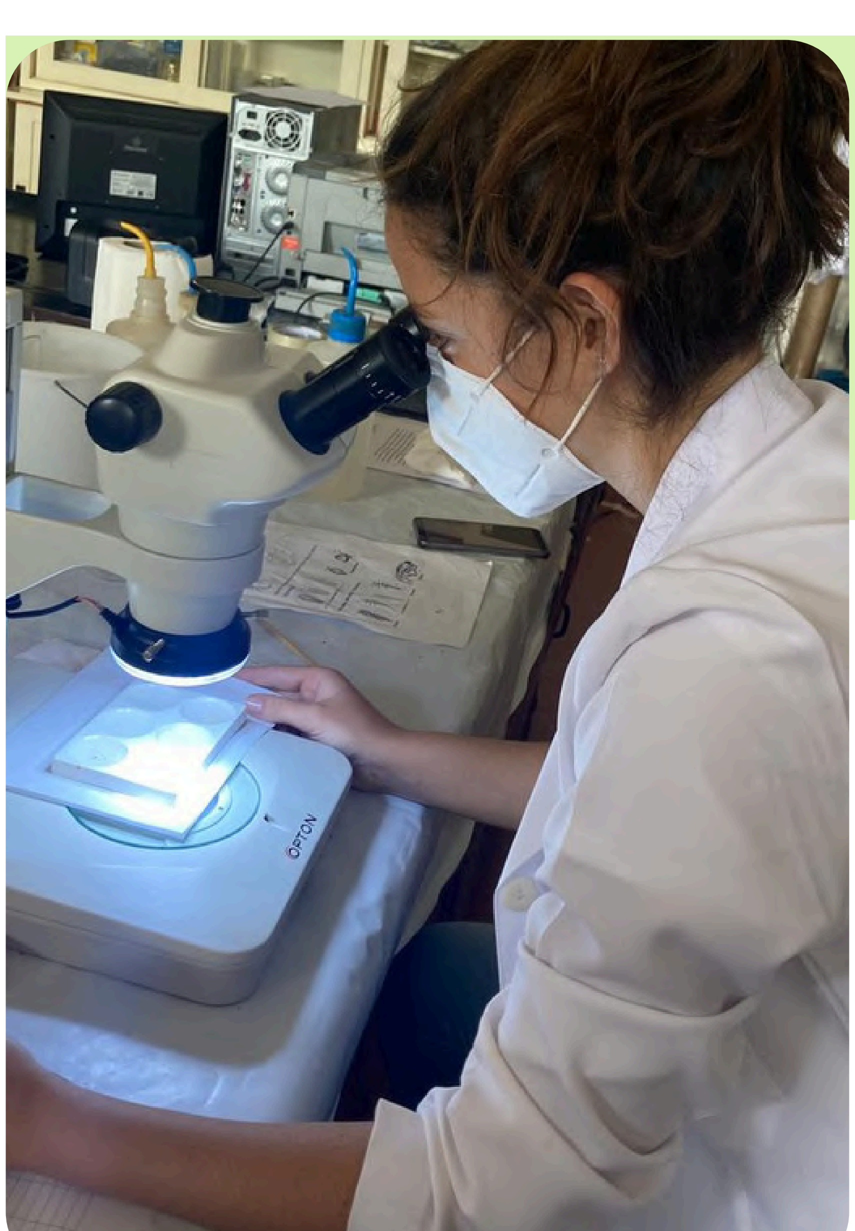


Photo: LabBio UFPel (2023).

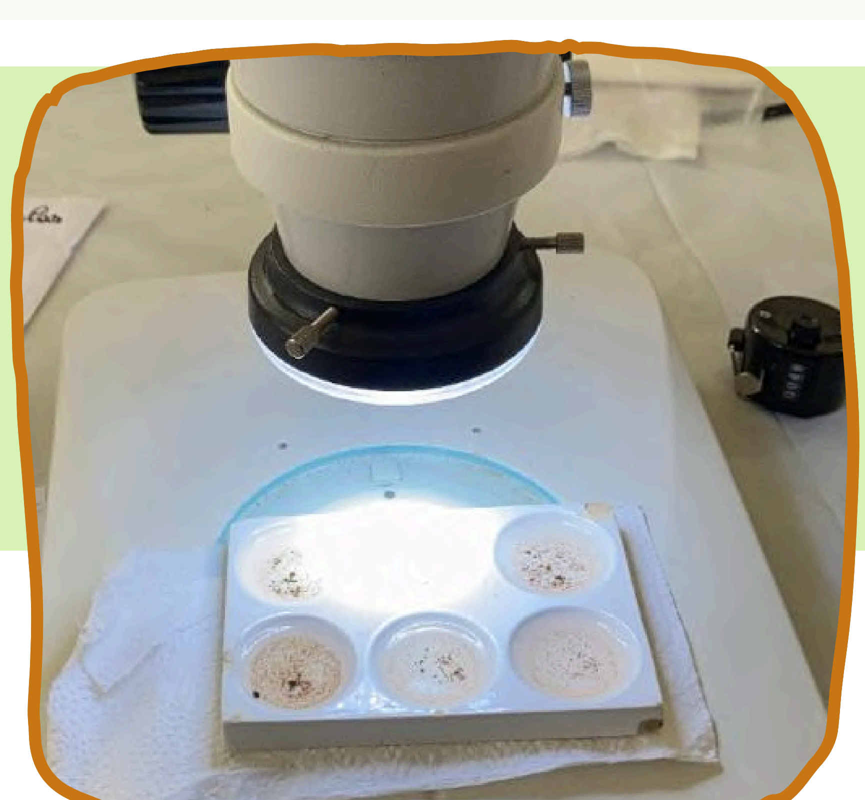


Photo: LabBio UFPel (2023).

Finally, the organisms are identified, counted, and photographed under a stereomicroscope.

Petri dishes with grid markings further facilitate the counting of the organisms.

Many variations of both the Berlese-Tullgren and the pitfall trap methods have been proposed. Some examples of published methods for Berlese-Tullgren sampling are available in Aquino et al. (2006) and Bruckner (2024). Pitfall standardization was proposed by Dueli et al. (1999), although other proposals are also available (see Brown & Matthews, 2016).

Here we illustrate a method that has been used extensively and for many years in the UFPel campus.

The size of the sample core used needs special consideration in terms of the dimension of the heat extractors. Larger cores will require wider heat extractors. The extraction time and temperature control are also important. Stronger lamps should not be used as they dry the soil too quickly. Lamps should also be far enough from the sample to not dry out the soil too quickly. Dimmers may also be used to control light and heat intensity. LED lamps should not be used, as they must provide heat.

Extraction times may last up to one week, depending on the moisture of the sample and the intensity of the heat. Ideally, the soil should be dry when the extraction is finalized.

For the pitfall traps, various size vials can be used. We have illustrated a screw-cap vial as this facilitates insertion into the soil and reduces dirtying of the preservative fluid with soil particles and litter. Various preservative fluids can be used, and consideration of the amount of time in the field is important in deciding which one to use. A surface-tension breaking liquid such as drops of detergent should also be used, to help animals drop to the bottom of the liquid.

Chapter 3

Characteristics and identification of taxonomic groups of soil macro- and mesofauna

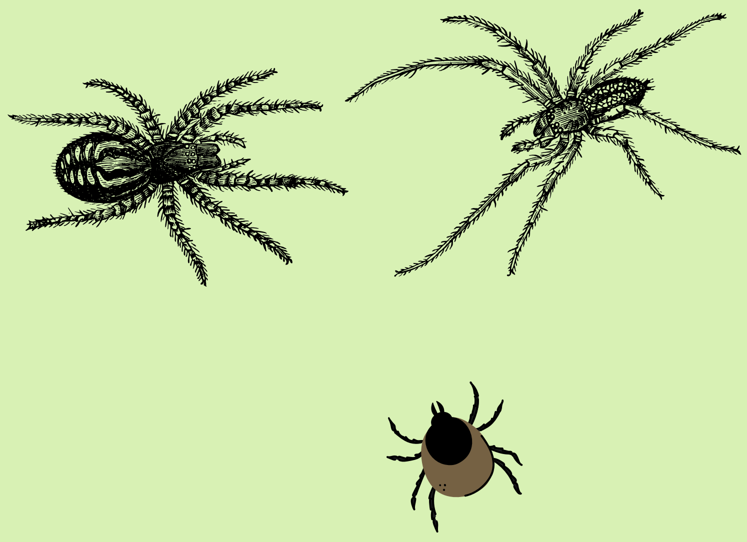
Introduction

Soil fauna is extremely diverse, and, as previously discussed, one of the most commonly used classifications of soil fauna is based on the size of the organisms, dividing them into micro-, meso-, and macrofauna. These groups are all related to various soil functions, including the decomposition of organic matter, nutrient cycling, soil structuring and plant production, among others. Due to these functions, these organisms can also be grouped into other subgroups. For example, some macrofauna organisms are considered ecosystem engineers (Lavelle et al., 1997), as they are bioturbators and/or geophages, affecting physical soil attributes such as structure, porosity, and water infiltration. This group includes mainly earthworms, termites, some species of ants, beetles, and millipedes. Meanwhile, mesofauna organisms are mainly considered biological regulators, preying on or stimulating the soil microfauna and microorganisms through the fragmentation and redistribution of plant residues (Coleman et al., 2017), although enchytraeids can also be considered ecosystem engineers at a smaller scale (Conti & Mulder, 2022).

Soil invertebrates, in general, are found in the first few centimeters of soil, mainly living in the soil-litter interface. This is where the highest concentration of organic matter, roots, and microorganisms are typically found, resulting in a higher amount of food available to these animals (Brown et al., 2018). As soil depth increases, the number of organisms decreases, with only species more adapted to living in the deeper soil layers remaining (Brown et al., 2025). These different adaptations to life in the soil can also be used to categorize soil fauna into three categories based on their adaptation to living at different soil depths: epigeic, hemiedaphic (including anecic and epi-endogeic organisms), and edaphic or endogeic.

Epigeic fauna consists of litter transformers, which can be saprophytic, detritivorous, or predatory, and do not ingest soil. Hemiedaphic populations live in the soil and usually move to the surface occasionally through permanent or temporary galleries. Edaphic or endogeic organisms, the euedaphic, spend most of their lives in the soil and rarely go to the surface (Brown et al., 2025). All of these classifications help us better understand the role of different soil fauna taxa. However, while some organisms, such as earthworms, ants, and beetles, are abundant and easily identifiable, it is common to encounter difficulties identifying some invertebrates, even at the class or order level. This happens due to the high morphological diversity within these large taxonomic groups, often leading to confusion, especially for researchers who are new to the field. Thus, this chapter aims to assist in the identification of the main taxa occurring in the soil, usually at the class, order, or family level. It is important to note that for some groups, especially those with various feeding habits, such as beetles, identification at the family or genus level is recommended. This allows for correct identification of the organisms' feeding habits and the generation of important information about the communities, the functions they perform, and the ecosystem services they provide.

ARACHNIDS



Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Chelicerata
Class: Arachnida

Characteristics:

- Lack of antennae;
- 4 pairs of legs;
- 1 pair of chelicerae ("fangs").

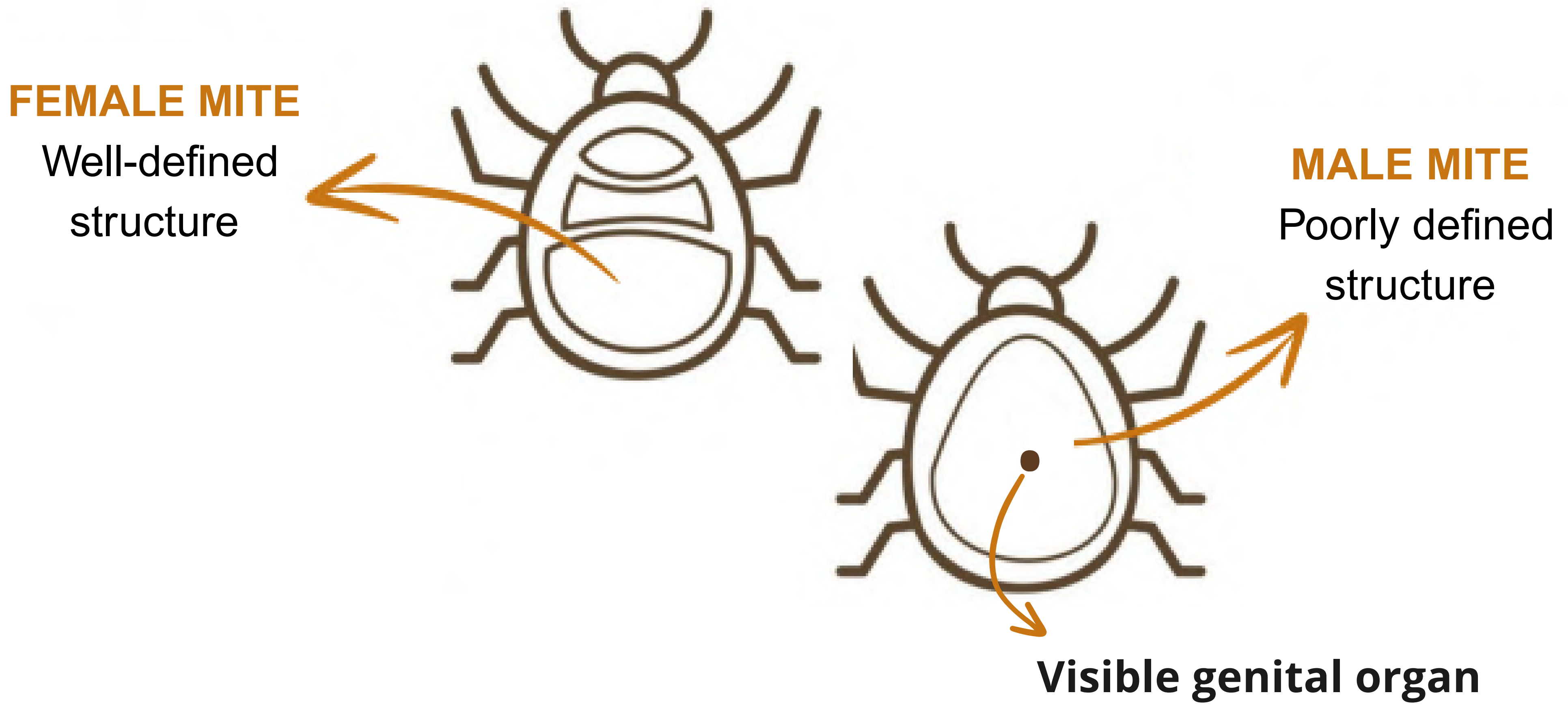
Mites

Sub-Class: Acari

Characteristics:

- Belong to the soil mesofauna;
- 4 pairs of legs (adults);
- Rounded or elongated body;
- Chitinous exoskeleton (rigid structure);
- No body segmentation;
- Various feeding habits, including decomposers, predators, or phytophagous.

Mite observed under a stereomicroscope (Photo: LabBio UFPel, 2023).



Mites can be classified as **decomposers**, **predators**, and **phytophages**

Detritivores

- Detritivores and microbivores;
- Oribatid mites feed on fungi, bacteria, algae, lichens, and decomposing plant debris;
- They are the most abundant mites in the soil, especially in soils rich in organic matter;
- Relatively large and covered by a hard exoskeleton;
- Sensitive to soil disturbance and structural degradation, making them good indicators of soil quality;
- Do not create pores in the soil;
- Possess trichobothria, a sensory organ that distinguishes them from other mites.

Phytophages

- Agricultural pests
- Chelicerae modified into stylets used to pierce plant tissues;
- The chelicerae are used for feeding.

Predators

- The most important predators of the soil micro- and mesofauna;
- Feed on nematodes, enchytraeids, springtails, other mites, and small insects and their larvae;
- Serve as prey for larger arthropods, providing an important link between the soil microfauna and macrofauna.

Predator mite (Photo: LabBio UFPel, 2024).

Oribatid mite (Photo: Miguel Macedo, https://www.inaturalist.org/photos/428408037).

Mesostigmata mite (Photo: Gustavo Schiedeck).

Observations and functional importance:

They disperse in various ways**:** by hitchhiking on mammals, birds, and insects, as well as with the wind or water. Most mites live within the soil and their ecological function varies depending on the family. Identification is typically carried out using female specimens.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/52788-Acari

Spiders

Order: Araneae

Characteristics:

- Part of the soil macrofauna;
- Body segmented into cephalothorax and abdomen;
- 1 pair of pedipalps (located in front of the first pair of legs).

Oxyopes aglossus
(Photo: Mattheu Lindsey, https://www.inaturalist.org/photos/390330397).

Stenochilus scutulatus
(Photo: Naveen Iyer, https://www.inaturalist.org/photos/149577338).

Hasarius adansoni
(Photo: Lucas Vasconcellos, https://www.inaturalist.org/photos/368185855).

Observations and functional importance:
Quite abundant in the litter layer, they can also be found in the 0 - 10 cm soil layer. Spiders are active predators of many other soil and litter-dwelling animals.

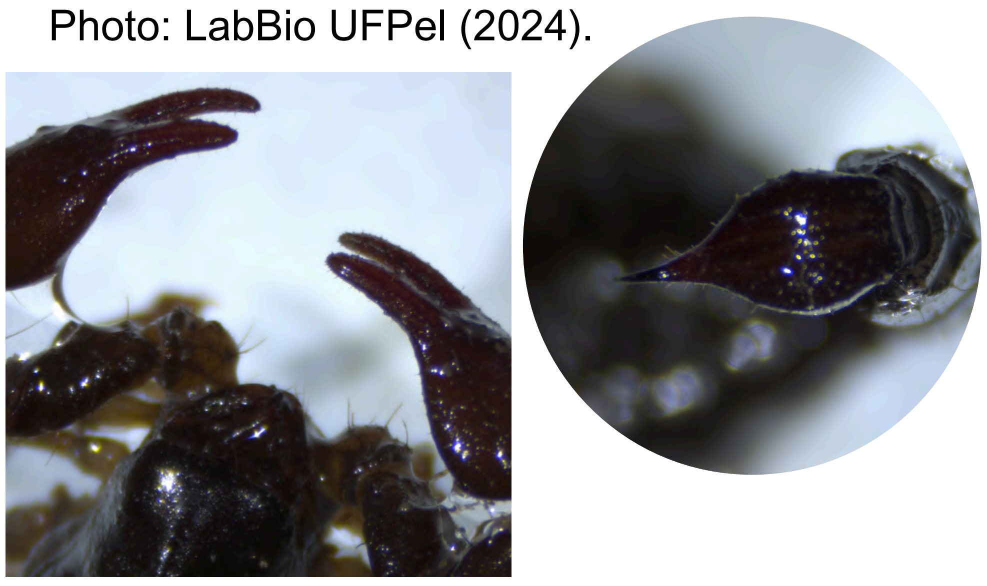
For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/47118-Araneae

Scorpions

Order: Scorpiones

Characteristics:
- Belong to the soil macrofauna;
- Have pedipalps modified into pincers and a stinger (telson) at the end of the abdomen used to inject venom.

Photo: LabBio UFPel (2024).



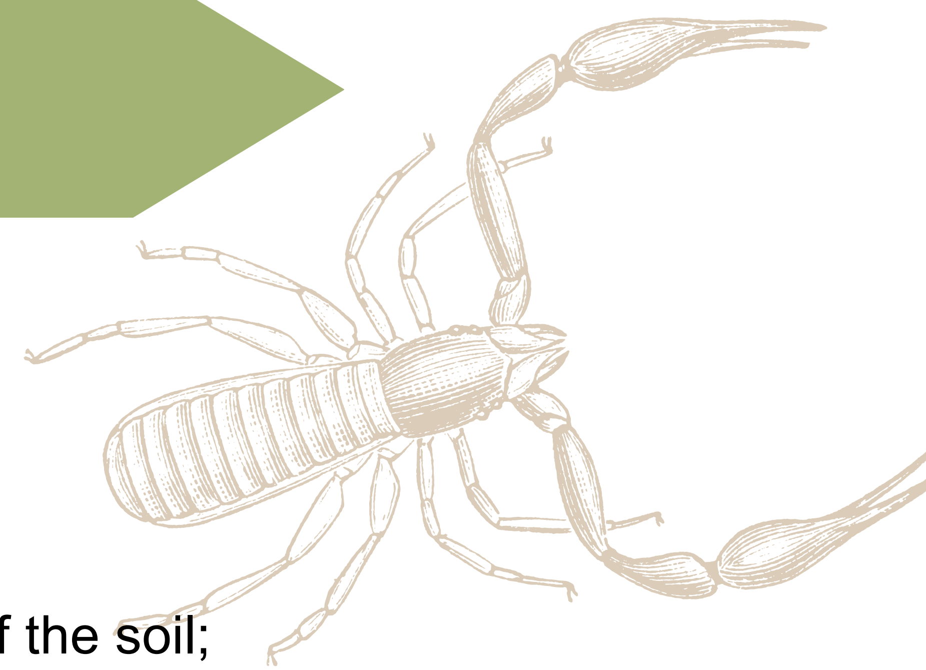
Brazilian yellow scorpion - *Tityus serrulatus*
(Photo: Ísis Medri, https://www.inaturalist.org/photos/269833630).

Opistophthalmus macer (Photo: Klaus Wehrlin, https://www.inaturalist.org/photos/348507765).

Observations and functional importance:
Some species have elaborate mating rituals similar to "dancing". Scorpions are active predators of many soil and litter dwelling animals.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/48894-Scorpiones

Pseudoscorpions



Order: Pseudoscorpiones

Characteristics:

- Belong to both the meso- and macrofauna of the soil;
- Have pedipalps modified into pincers like scorpions, but they do not have a telson (stinger).

Hysterochelifer tuberculatus
(Photo: Julien Tchilinguirian, https://www.inaturalist.org/photos/287532869).

Hysterochelifer tuberculatus
(Photo: Julien Tchilinguirian, https://www.inaturalist.org/photos/287542374).

Observations and functional importance:
Pseudoscorpions are rare, usually observed in well-preserved areas. Some larger specimens can be collected using the TSBF method. They are active predators of the smaller members of soil and litter fauna.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/172373-Pseudoscorpiones

Harvestmen

Order: Opiliones

- Belong to the soil macrofauna;
- Unlike spiders, they have a fused cephalothorax and abdomen;
- Possess a pair of elongated legs used for sensory functions.

Licornus atroluteus
(Photo: Philipp Hoenle, https://www.inaturalist.org/photos/166002312).

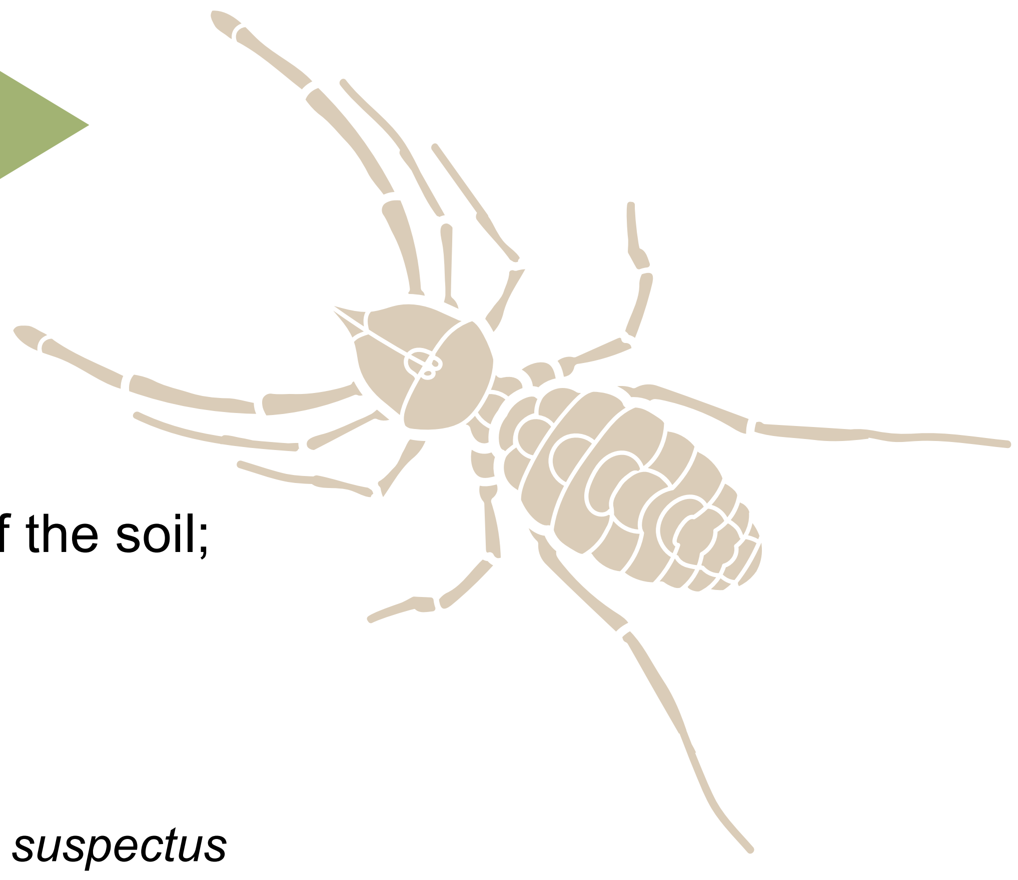
Mischonyx squalidus
(Photo: Tsssss, https://www.inaturalist.org/photos/90475033).

Harvestman (Photo: Ana Cristina Almeida, https://www.inaturalist.org/photos/407854868)

Observations and functional importance:
Found in the litter layer, they are rare, usually observed in well-preserved areas. Opilionids feed on a variety of substrates (plant and animal), acting as both predators and scavengers.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47367-Opiliones

Camel spiders



Order: Solifugae

- Belong to both the meso- and macrofauna of the soil;
- The abdomen is usually elongated;
- Have well-developed chelicerae.

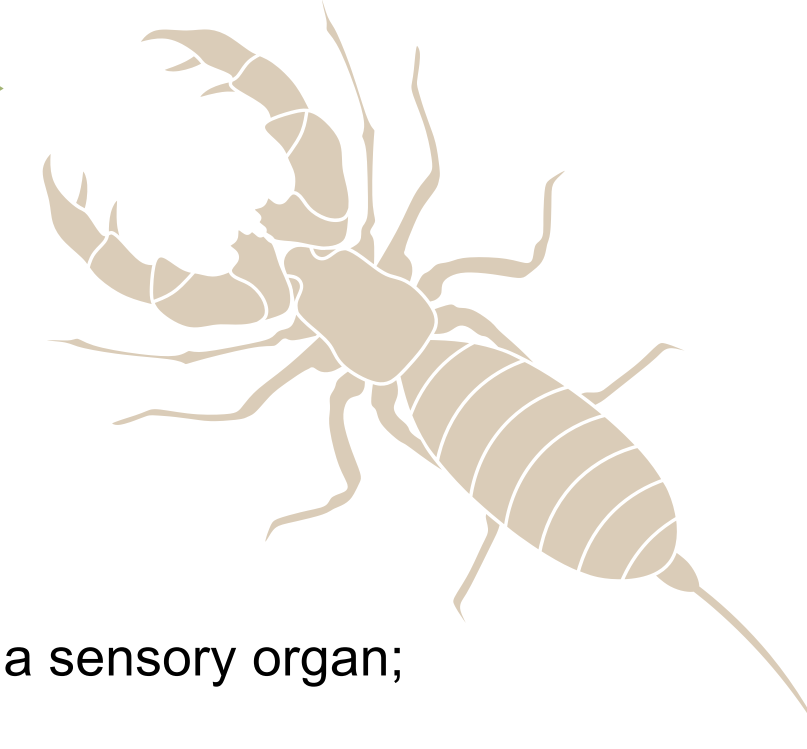
Eremobates suspectus
(Photo: Raymond Wyatt Mendez, https://www.inaturalist.org/photos/166002312).

Gylippus caucasicus
(Photo: Armen Seropian, https://www.inaturalist.org/photos/90475033).

Observations and functional importance:
This important predator is quite rare, usually found in drier environments.

For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/47824-Solifugae

Whip scorpions



Order: Uropygi

- Belong to the soil macrofauna;
- Have large, spiny pedipalps;
- The first pair of legs is elongated and serves as a sensory organ;
- Possess a thin, segmented tail flagellum.

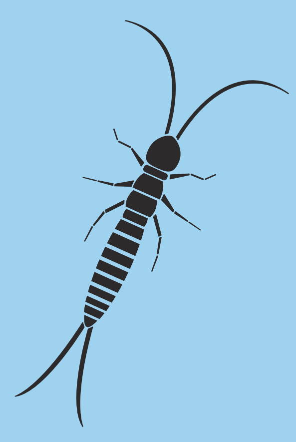
Mastigoproctus floridanus
(Photo: John Serrao,
https://www.inaturalist.org/photos/166002312).

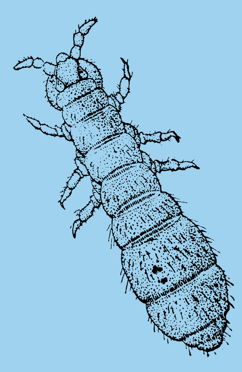
Amauromastigon maximus
(Photo: flavioubaid,
https://www.inaturalist.org/photos/174680593).

Observations and functional importance:
Rare in soil or litter samples, whip scorpions, also known as vinegaroons are important predators of above and below-ground prey

For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/48900-Uropygi

ENTOGNATHA



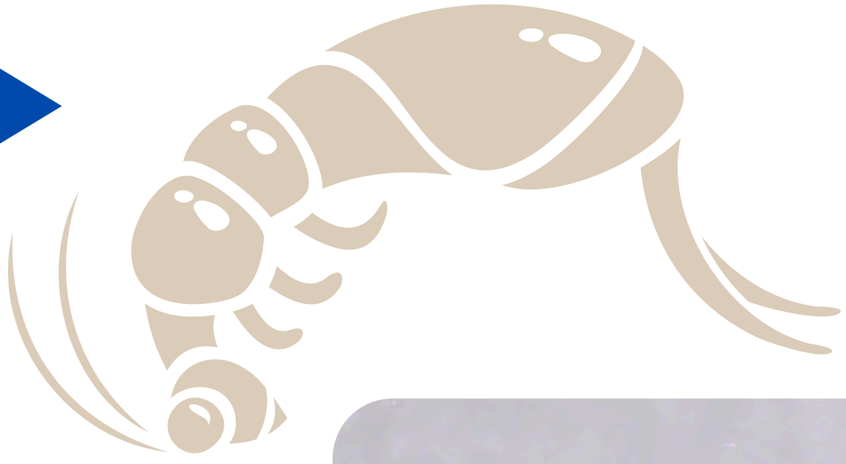


Kingdom: Animalia
Phylum: Arthropoda
SubPhylum: Hexapoda
Class: Entognatha

Characteristics:

- Body divided into head, thorax, and abdomen;
- Have 1 pair of antennae;
- Have 3 pairs of legs;
- Possess a furca, a structure used for jumping;
- Do not have wings.

Springtails



Sub-Class: Collembola

Characteristics:

- Part of the soil mesofauna;
- Possess a furca (sometimes hidden);
- Three pairs of legs;
- Body more elongated or spherical;
- Do not have wings;
- One pair of antennae;
- May have body hair.

Photo: LabBio UFPel (2022).

Order SYMPHYPLEONA

- Rounded body;
- Long antennae;
- Live in the litter (epigeic), and move quickly (good jumpers).

Order PODUROMORPHA

- Elongated body;
- Short antennae;
- Primarily live in the soil (endogeic) and are slower.

Order ENTOMOBRYOMORPHA

- Elongated body;
- Long antennae;
- Furca clearly visible;
- Body with pilosity (hair);
- Live in the litter (epigeic), and move quickly (good jumpers).

Springtail from the order Entomobryomorpha
(Photo: LabBio UFPel, 2022).

Springtail from the family Dicyrtomidae
(Photo: Damien Brouste,
https://www.inaturalist.org/photos/45740181).

Springtail from the family Entomobryidae (Photo: William G. Borges, https://www.inaturalist.org/photos/410405419).

Observations and functional importance:

The furca is a bifurcated appendage, and when released, it acts like a spring, allowing them to propel themselves several times the length of their body. Some springtail species are predators of nematodes or other springtails and their eggs, but most of them feed on fungal hyphae and spores, bacteria, and decomposing plant material, thus accelerating the decomposition of organic matter by ingesting litter and producing excrement and altering the carbon cycle by helping microorganisms decompose material, increasing the surface area of dead plant material, making it more accessible to microbial attack. Springtails do not create tunnels or actively dig the soil, but they play a role in altering soil structure by releasing millions of fecal pellets per m², which, in addition to structural effects, is beneficial to plants, as it provides slow release of nutrients.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/49470-Collembola

Proturans

Order: Protura

Characteristics:

- Order of great importance within the mesofauna group;
- Similar to springtails, they are wingless arthropods with entognathous mouthparts, meaning the mouthparts are retracted within the head capsule;
- Cylindrical body, pointed at both ends;
- Unpigmented, pale, or yellowish;
- Wingless, eyeless, and lacking antennae;
- Adults have 12 abdominal segments.

Proturan observed under a stereomicroscope (Photo: Michael Caterino, https://www.inaturalist.org/photos/222062964).

Example of a proturan (Photo: Zachary Dankowicz, https://www.inaturalist.org/photos/276453688).

Observations and functional importance:
Typically, they are part of the community of organic matter decomposers in the soil and litter. They also feed on fungal hyphae and serve as important prey for small predators such as spiders and mites. When disturbed, proturans raise the tip of their abdomen in a defensive posture similar to that of scorpions.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/83242-Protura

Diplurans

Order: Diplura

Characteristics:

- Belong to the soil macro- and mesofauna;
- Possess a cerci at the end of the abdomen, shaped like pincers or filaments.

Dipluran with pincer-shaped cerci (Photo: Elliott Smeds, https://www.inaturalist.org/photos/111070657).

Dipluran with pincer-shaped cerci (Photo: César Favacho, https://www.inaturalist.org/photos/44352401).

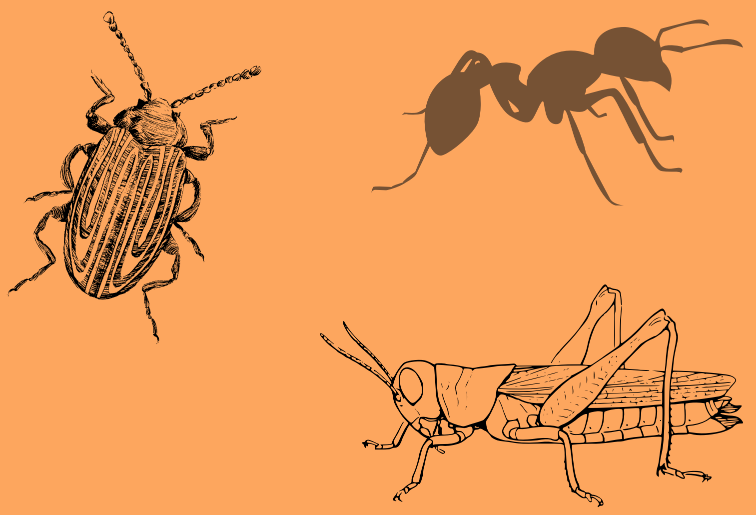
Observations and functional importance: Quite similar to earwigs (Order Dermaptera), Diplura have very little or no pigmentation and retracted mouthparts, characteristic of the class Entognatha. Important predatory organisms. Species with shaped like pincers are predators, while filament-shaped cerci species are detritivores, omnivores or fungivores

Dipluran of the genus *Campodea* (Photo: Tobias Gratzer, https://www.inaturalist.org/photos/254477812).

For more information and photos, please scan the QR code or visit the link (https://www.inaturalist.org/taxa/56215-Diplura)

INSECTS

Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta



Characteristics:
- Have a body divided into head, thorax, and abdomen;
- Possess 3 pairs of jointed legs and 1 pair of antennae.

Bees and bumblebees

Subclass: Pterygota
Order: Hymenoptera
Family: Apidae

Characteristics:
- 2 pairs of wings;
- Chewing-type mouthparts;
- May possess a stinger.

Xylocopa virginica (Photo: Glenn Berry, https://www.inaturalist.org/photos/155262792).

Observations and functional importance:
Rarely encountered in soil fauna sampling, many species nest in the soil. Essential pollinators of many kinds of plants.

Bombus melanopygus (Photo: Tony Ernst, https://www.inaturalist.org/photos/145652517).

For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/47221-Apidae

Ants

Subclass: Pterygota
Order: Hymenoptera
Family: Formicidae

Characteristics:

- Part of the soil macrofauna, although there are also many small sized-species;
- Chewing-type mouthparts;
- Have geniculate (elbowed) antennae;
- Possess a knot-like structure at their waist (junction between thorax and abdomen).

Genus *Solenopsis* (Photo: Jake Nitta, https://www.inaturalist.org/photos/31318826).

Leafcutter ant - *Atta laevigata*
(Photo: Tsssss, https://www.inaturalist.org/photos/90915216).

Genus *Pachycondyla* (Photo: Guillherme Martinello, https://www.inaturalist.org/photos/371257935).

Observations and functional importance:
Collected abundantly in soil monoliths, Berlese-Tullgren funnels, and pitfall traps, ants are important for many soil functions. They can create very large mounds in the soil, and are some species are agricultural or urban pests.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47336-Formicidae

Wasps

Subclass: Pterygota
Order: Hymenoptera
Family: Vespidae

Characteristics:

- Chewing-type mouthparts;
- Social insects, but unlike the ants, do not have a knot-like structure between the thorax and abdomen;
- Generally have two pairs of wings of different sizes, although some species are wingless.

Polistes exclamans (Photo: Dan Horowitz, https://www.inaturalist.org/photos/57455961).

Polybia sericea (Photo: Andre Lima, https://www.inaturalist.org/photos/118833011).

Observations and functional importance:
Rarely found in the soil, these insects are important plant pollinators, as well as predators often used for biological control. The pupae of some species can be found in the litter and the first few centimeters of the soil.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/52747-Vespidae

Cockroaches

Subclass: Pterygota
Order: Blattodea
Suborder: Blattaria

Characteristics:

- Part of the soil macrofauna;
- Chewing-type mouthparts;
- Oval and flattened body shape, generally dark-colored, but specimens can also have in lighter colors, including white.

Ectobius balcani (Photo: Kostas Zontanos, https://www.inaturalist.org/photos/17744567).

Allacta bipunctata (Photo: Philipp Hoenle, https://www.inaturalist.org/photos/199237655).

Cockroach - lateral view (Photo: Gustavo Schiedeck).

Ventral view of a cockroach under stereomicroscope (Photo: Luan Gabriel, https://www.inaturalist.org/photos/322765191).

Observations and functional importance:
Quite abundant in the litter, cockroaches can also be found in the surface layers of the soil. They are important decomposers of fresh organic debris.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/81769-Blattodea

Termites

Subclass: Pterygota
Order: Blattodea
SubOrder: Isoptera

Characteristics:

- Belong to the soil macrofauna;
- Chewing-type mouthparts;
- Social insects;
- Generally, species that live in the soil are white in color;
- Unlike ants, they have straight antennae and the separation between the thorax and abdomen is not as distinct.

Syntermes molestus (Photo: César Favacho, https://www.inaturalist.org/photos/39360720).

Subterranean termites (Photo: Marie Bartz).

Observations and functional importance:
Can create very large mounds in the soil, and are very important plant litter decomposers; some species are agricultural or urban/household pests.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/118903-Termitoidae

Cicadas (nymphs)

Subclass: Pterygota
Order: Hemiptera
Superfamily: Cicadoidea

Characteristics:

- Part of the soil macrofauna;
- Generally collected in the soil during the nymph stage of cicadas;
- In the nymphs, the first pair of legs is modified for digging.

Cicada nymph (Photo: Ken Rosenthal, https://www.inaturalist.org/photos/135005676).

Cicada nymph (Photo: Gustavo Schiedeck).

Observations and functional importance:
Although not difficult to find, they are not very abundant. Some species can create soil towers on the surface, and some species can spend many years in the soil before they emerge and molt into adults. Feed on the sap of plant roots.

For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/50190-Cicadoidea

True bugs

Subclass: Pterygota
Order: Hemiptera
Suborder: Heteroptera

Characteristics:

- Part of the soil macrofauna;
- Sucking-type mouthparts;
- Have two pairs of wings, the front pair is leathery at the base and membranous at the tip;
- Nymphs are similar to the adults, but lack wings.

True bug nymph
família Cydnidae (Photo: Gustavo Schiedeck).

True bug adult, dorsal view
(Photo: Botswanabugs,
https://www.inaturalist.org/photos/44177060).

True bug adult, ventral view
(Photo: Botswanabugs,
https://www.inaturalist.org/photos/44179151).

Observations and functional importance:
Some species are important agricultural pests in various crops. Many species have scent glands that emit strong smells.

For more information and photos, please scan the QR code or visit the link:
https://www.inaturalist.org/taxa/61267-Heteroptera

Aphids, scale insects and mealybugs

Subclass: Pterygota
Order: Hemiptera
Suborder: Sternorrhyncha

Characteristics:

- Sucking-type mouthparts;
- Aphids are generally wingless, but some species have wings.

Freysuila dugesii (Photo: Jesse Rorabaugh, https://www.inaturalist.org/photos/17851322).

Ground pearl - *Eurhizococcus brasiliensis* (Photo: Vinicius Domingues, https://www.inaturalist.org/photos/257514636).

Observations and functional importance:

Rarely found in the soil. many species of aphids, scale insects, ground pearls and mealybugs are considered to be agricultural, tree or lawn pests.

For more information and photos, please scan the QR code or visit t link: https://www.inaturalist.org/taxa/334037-Sternorrhyncha

Beetles and ladybugs

Subclass: Pterygota
Order: Coleoptera

Characteristics:

- Part of the soil macrofauna;
- Highly varied in shape and color, species found in soils tend to be darker colored;
- Adults have two pairs of wings, with the anterior pair highly sclerotized and hard (elytra), protecting the second pair of membranous wings used for flight;
- One pair of antennae, can be filiform, serrated, or clavate, among others.

Dung beetles feed on animal manure, accelerating its decomposition and stimulating nutrient cycling in the soil.

Dung beetle from the family Scarabaeidae (Photo: Christian Kropf, https://www.inaturalist.org/photos/112695463).

Observations and functional importance:
Beetles represent about 40% if all insect species described. Their present several feeding habits, being plant feeders, predators, detritivores or parasites. Many species are found in soil in their larval stage.

Life cycle

Insects are animals that undergo two types of development cycles: direct (ametabolous - no body changes) or indirect (hemimetabolous - gradual growth, characterized by a juvenile stage as a nymph; holometabolous - complete metamorphosis, with a larval stage). Beetles are holometabolous, having four distinct life stages:

EGG | **LARVA** | **PUPA** | **ADULT**

Larvae commonly observed in the soil

Family Scarabaeidae

- Milky-white coloration;
- C-shaped body with a dark-colored head

Beetle larva of the family Scarabaeidae
(Photo: Wilian Demetrio).

Scarabaeidae larva
(Photo: Gustavo Schiedeck).

Family Curculionidae

- Generally vermiform body, curved in a 'C' shape, similar to Scarabaeidae; however, most lack legs (apodous) or have rudimentary legs.

Curculionidae larva
(Photo: the_knower,
https://www.inaturalist.org/photos/445095244).

Curculionidae larvae
(Photo: Gustavo Schiedeck).

Family Ptilodactylidae

- Elongated and cylindrical body, with well-defined segments;
- Frequent lateral projections or setae on abdominal segments;
- Well-developed thoracic legs, adapted for locomotion;
- Leg segments usually short and end with claws that assist adhesion.

Ptilodactylidae larva
(Photo: Adam Kohl,
https://www.inaturalist.org/photos/338109636).

Family Staphylinidae

- Elongated and generally flattened body, with well-defined segments;
- Frequent setae or rigid projections on the body, that help in locomotion and defense;
- Color from shades of white or yellow to brown;
- Well-developed thoracic legs;
- Typically 10 visible segments;
- Some species have appendages at the end of the abdomen, such as pseudopods or specialized structures to assist in movement or defense.

Staphylinidae larva of the subfamily Staphylininae (Photo: Gustavo Schiedeck).

Staphylinidae larva - Genus *Ocypus*
(Photo: Iridescence, https://www.inaturalist.org/photos/386588393).

Family Elateridae

- Elongated, cylindrical, and rigid body, with appearance similar to metallic threads, hence the common name 'wireworms';
- Color usually brown or yellowish, with little variation.

Elateridae larva (Photo: Adriano Corte Real, https://www.inaturalist.org/photos/432373084).

Elateridae larva - Genus *Heteroderes* (Photo: Gustavo Schiedeck).

Family Lampyridae

Lampyridae larva - subfamily Lampyrinae
(Photo: Gustavo Schiedeck).

- Larvae of fireflies and lightning bugs that are often bioluminescent;
- Color from brown to black;
- Segmented appearance.

Lampyridae larva (Photo: Whaldener Endo, https://www.inaturalist.org/photos/243545914).

Family Tenebrionidae

- Elongated and cylindrical body, with well-defined segments;
- Soft and shiny appearance, but slightly hardened in some parts, mainly the thorax;
- Last segment may have small projections or spines in some species.

Tenebrionidae larva
(Photo: David Akers, https://www.inaturalist.org/photos/448577872).

Tenebrionidae larva -
subfamily Lagriinae
(Photo: Gustavo Schiedeck).

Tenebrionidae larva -
subfamily Alleculinae
(Photo: Gustavo Schiedeck).

Family Dryopidae

- Elongated shape with a cylindrical body;
- Small head, usually darker than the body.

Dryopidae larva (Photo: Gustavo Schiedeck).

Carabidae larva - subfamily Harpalinae (Photo: Gustavo Schiedeck).

Family Carabidae

- Shape similar to Elateridae, but with more developed legs.

Carabidae larva (Photo: Célio Moura Neto, https://www.inaturalist.org/photos/282199932).

Family Chrysomelidae

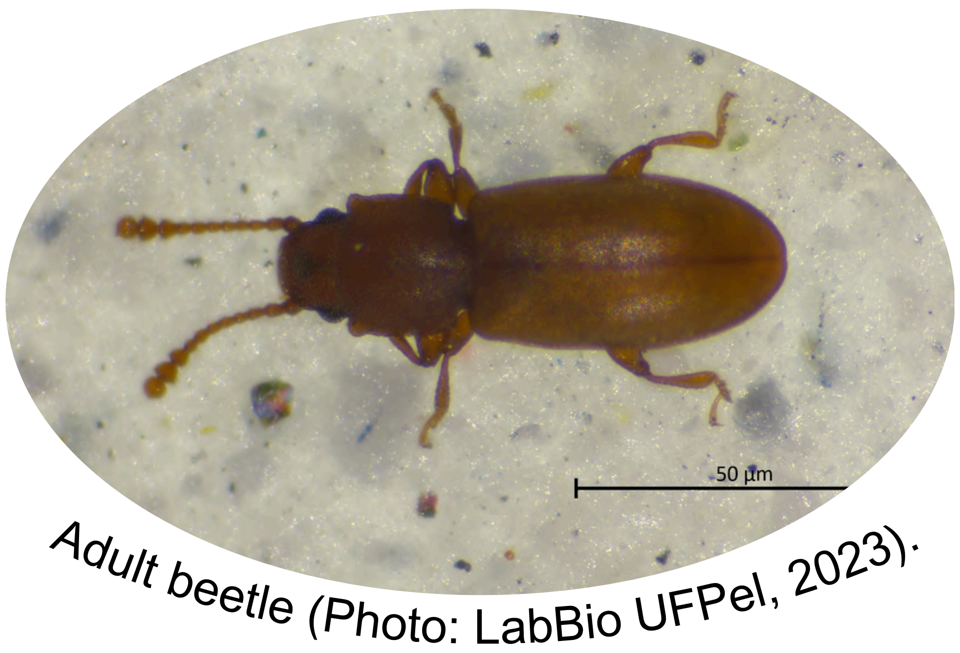
- Schlerotized and visible cephalic capsule;
- Well-developed mandibles, adapted for chewing plant tissues;
- Three pairs of well-developed and functional thoracic legs;
- No abdominal legs or pseudopods.

Chrysomelidae larva (Photo: Per Hoffmann Olsen, https://www.inaturalist.org/photos/427241857).

Chrysomelidae larva (Photo: Gustavo Schiedeck).

Adults

- Body with three pairs of legs; one pair of antennae; and hardened front wings;
- Found in the soil, humus, leaf litter, and manure, contributing to organic matter decomposition;
- Some species are predators of other soil animals like earthworms, springtails, and nematodes.



Adult beetle (Photo: LabBio UFPel, 2023).

Predatory beetle (*Carabus prodigus* - family Carabidae) feeding on an earthworm (Photo: Spark, https://www.inaturalist.org/photos/291775926)

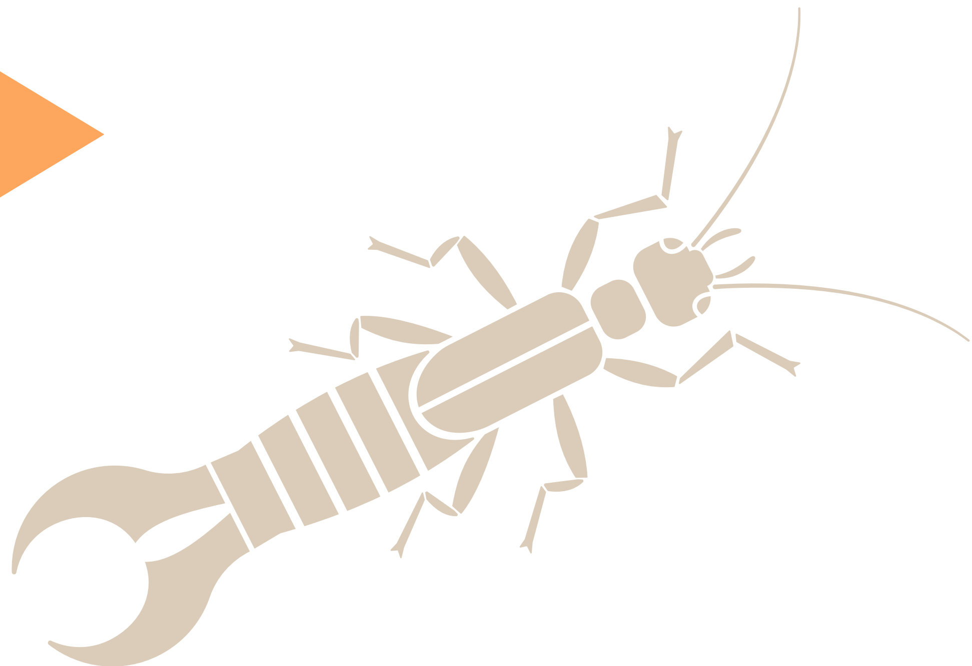
Protaetia judith
family Scarabaeidae
(Photo: Andrii Churilov,
https://www.inaturalist.org/photos/58998982).

Japanese tiger beetle
Cicindela chinensis ssp. *japonica*
(Photo: Ryosuke Kuwahara,
https://www.inaturalist.org/photos/92982013).

Due to the high diversity of feeding habits of beetles, identification at the family, genus, or species level should performed whenever possible.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47208-Coleoptera

Earwigs



Subclass: Pterygota
Order: Dermaptera

Characteristics:

- Belong to the soil macrofauna;
- Elongated and narrow body;
- May be winged (one or two pairs) or not;
- One pair of antennae;
- Possess cerci at the end of the abdomen, usually in the form of pincers.

Earwig - *Euborellia annulipes* (Photo: Kyle C. Elshoff, https://www.inaturalist.org/photos/29006737).

Earwig (Photo: Douglas Oliveira, https://www.inaturalist.org/photos/102491680).

Observations and functional importance:
Earwigs are often confused with diplurans or beetles of the Staphylinidae family. Widely known in the agricultural sector for their activity as natural enemies (predators of many smaller prey), and usefulness in biological control of pests.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47793-Dermaptera

Flies

Subclass: Pterygota
Order: Diptera

Characteristics:
Adults:
- Body divided into head, thorax, and abdomen;
- 3 pairs of legs;
- Pair of membranous wings and a modified pair similar to halteres (balancers).

Larvae

- Part of the soil macrofauna;
- Lack of legs;
- Tubular and long body;
- Generally, lacking distinct heads, they have a clearly tapered cephalic cap and a rounded posterior portion.

Sciaridae larva (Photo: Gustavo Schiedeck).

Stratiomyidae larva - genus *Chiromyza* (Photo: Gustavo Schiedeck).

Asilidae larva (Photo: Gustavo Schiedeck).

Thereva unica larva (Photo: Alberto J. Narro Martín, https://www.inaturalist.org/photos/95349560).

Cheilosia fasciata larva (Photo: Mareks Ievins, https://www.inaturalist.org/photos/174823892).

Observations and functional importance:
Adults are rarely collected using the TSBF method; however, larvae can be abundant in some land-use systems. Caution should be taken to avoid confusing fly larvae with beetle larvae or vice versa. Most of the fly larvae feed on organic matter contributing to nutrient cycling.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47822-Diptera

Webspinners

Subclass: Pterygota
Order: Embioptera

Characteristics:

- Belong to the soil macrofauna;
- Elongated body, usually brownish or darker;
- Have silk-producing spinnerets on their forelegs;
- Males usually have 2 pairs of well-developed wings, similar to winged termites, while females are always wingless.

Haploembia palaui
(Photo: Savvas Zafeiriou, https://www.inaturalist.org/photos/128646252).

Haploembia solieri
(Photo: George Manavopoulos, https://www.inaturalist.org/photos/114303375).

Observations and functional importance:
Webspinners are usually found in the leaf litter, where they feed on various materials including decaying plant matter, moss, lichens and algae.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/56834-Embioptera

Crickets and mole crickets

Subclass: Pterygota
Order: Orthoptera
Infraorder: Gryllidea

Characteristics:

- Part of the soil macrofauna;
- Chewing mouthparts;
- Crickets, like grasshoppers, have highly developed hind legs, but they have long antennae compared to grasshoppers;
- Mole crickets are easily identified by the first pair of legs modified for digging.

Crickets (Photo: Helio Lourencini, https://www.inaturalist.org/photos/111560745).

Mole cricket (Photo: Simão Mateus, https://www.inaturalist.org/photos/62802902).

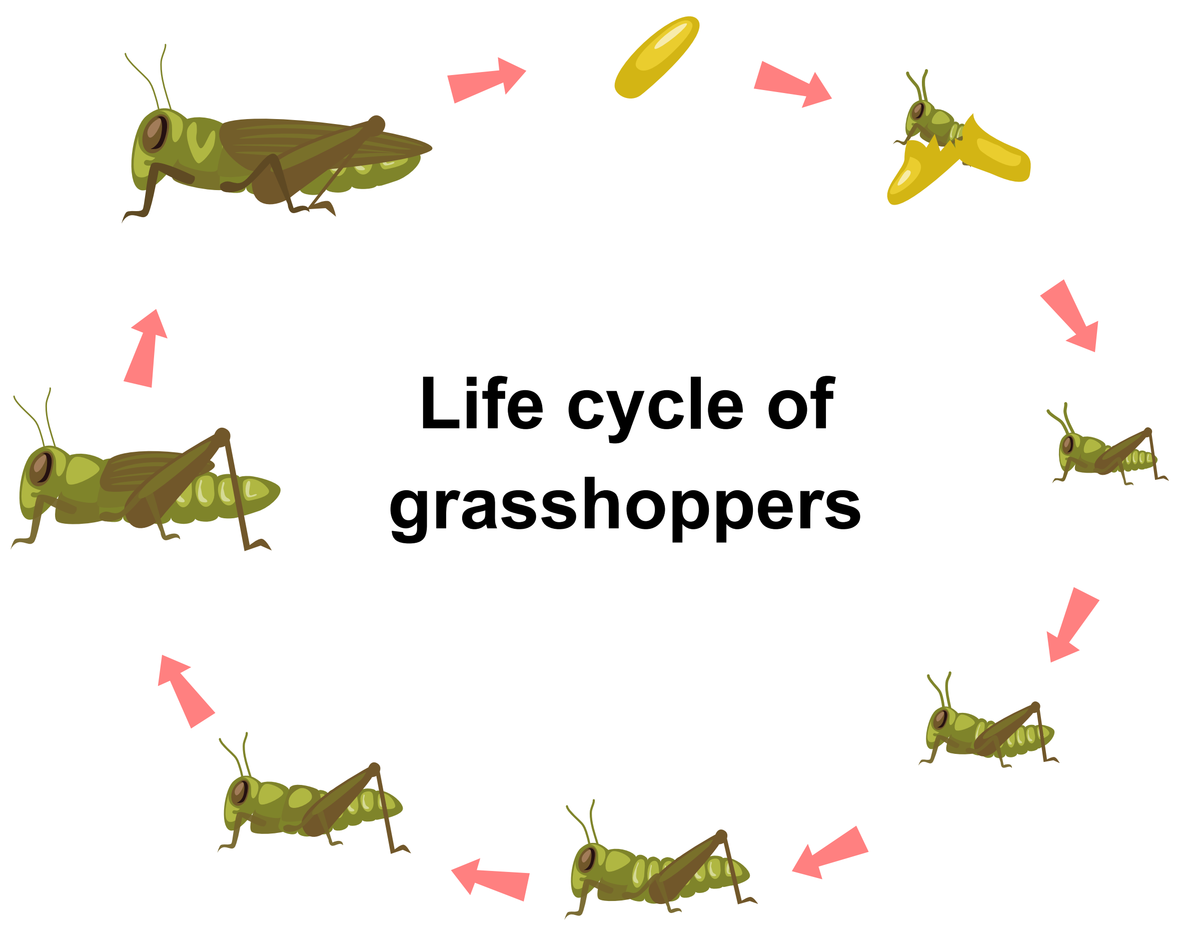
Observations and functional importance:
Crickets and mole crickets usually consume plant materials including roots, stems, and foliage, and therefore can be important pests in lawns and gardens. However, mole crickets can also consume insects, other small animals, and even their own kind.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/50158-Grylloidea

Grasshoppers

Subclass: Pterygota
Order: Orthoptera

- **Characteristics:**
- Part of the soil macrofauna;
- Chewing mouthparts;
- Possess a well-developed last pair of legs;
- **Hemimetabolous**, i.e., no larval or pupal stage.

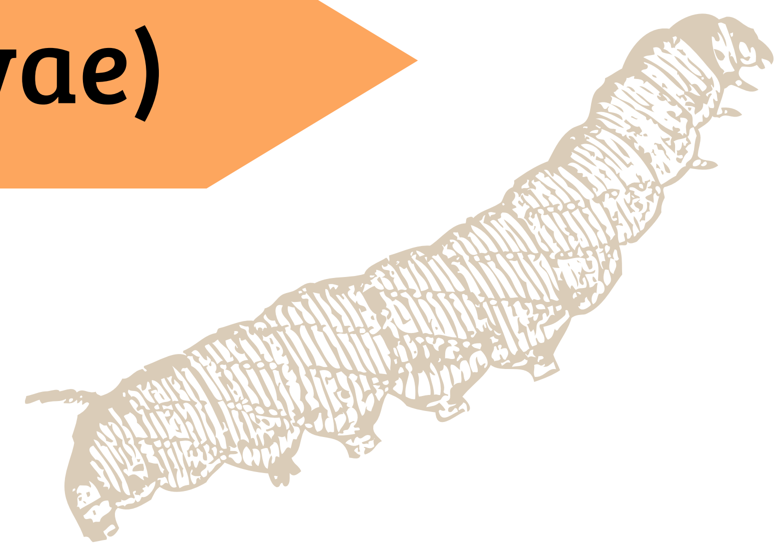


Dactylotum bicolor (Photo: Felix Fleck, https://www.inaturalist.org/photos/49657086).

Observations and functional importance:
When it is not possible to separate grasshoppers from crickets and mole crickets, all can be grouped in the Order Orthoptera. In general, crickets are much more common in samples than grasshoppers. Some species are important pests in agricultural crops.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47651-Orthoptera

Butterflies and moths (larvae)



Subclass: Pterygota
Order: Lepidoptera

Characteristics:

- In larvae, in addition to the 3 pairs of legs common to insects, several abdominal legs are also present.

Leto venus larva (Photo: Colin Ralston, https://www.inaturalist.org/photos/21452923).

Rothschildia prionia larva (Photo: Alenilson Rodrigues, https://www.inaturalist.org/photos/166099738).

Observations and functional importance:
Adults and caterpillars are rarely found in soil, but sometimes chrysalis can be found in the leaf litter or top few centimeters of the soil. Many species of Lycaenidae and Riodinidae larvae have developed a special relationships with ants (myrmecophyly). Lepidoptera larvae are generally phytaphagous and some species can be important agricultural pests, while adults of many species can be important plant pollinators.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47157-Lepidoptera

Antlions

Subclass: Pterygota
Order: Neuroptera

Characteristics:
- Belong to the soil meso and macrofauna;
- In the larval stage, they usually have a rounded body and a prominent pair of mandibles;
- The adults have 2 pairs of membranous wings, usually transparent with well-defined venation (resembling a net).

Antlion larva
(Photo: jbio, https://www.inaturalist.org/photos/145122237).

Antlion adult (Photo: kamedaphor, https://www.inaturalist.org/photos/18544819).

Observations and functional importance:
Antlions are rarely found in soils samples. The larvae are important predators of other macro and mesofauna taxa.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/48763-Neuroptera

Stick insects

Subclass: Pterygota
Order: Phasmida

Characteristics:

- Mimic branches, twigs or leaves;
- Generally wingless and green or brown in color.

Genus *Prisopus* (Photo: Onildo João Marini Filho, https://www.inaturalist.org/photos/254389068).

Stick insect found in Rolândia-PR (Photo: Marie Bartz).

Observations and functional importance:
Rarely found in the soil, stick insects are usually observed in leaf litter or above ground vegetation. They are important herbivores, feeding on fresh leaves of various plant species.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47198-Phasmida

Thrips

Subclass: Pterygota
Order: Thysanoptera

Characteristics:
- Adults have an elongated and slender body;
- Can have two pairs of wings with fringe-like setae, but wingless individuals also exist.

Genus *Franklinothrips* (Photo: Ben Jobson, https://www.inaturalist.org/photos/321130719).

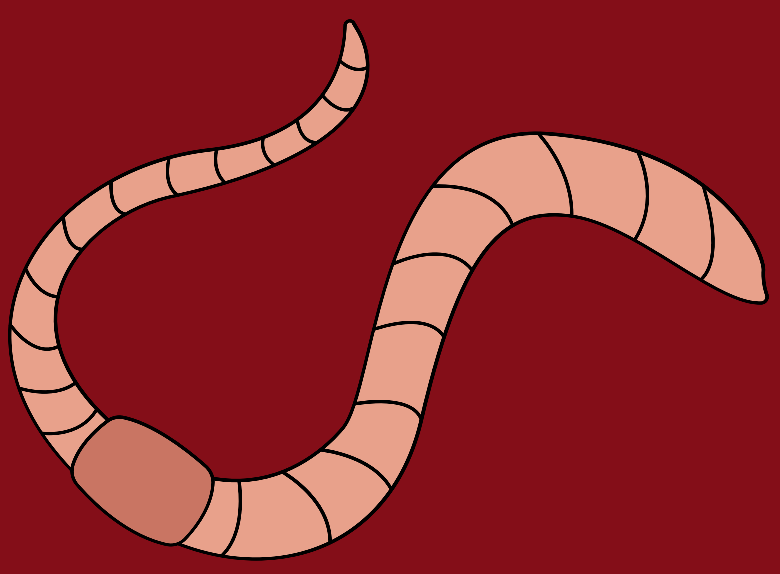
Dendrothrips howei observed under a stereomicroscope (Photo: Alex Bairstow, https://www.inaturalist.org/photos/19774950).

Observations and functional importance:
Rarely found in the soil, many species of thrips can be important agricultural crop pests.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/83201-Thysanoptera

CLITELLATES

Kingdom: Animalia
Phylum: Annelida
Class: Clitellata



Characteristics:

- Soft, cylindrical body divided into segments;
- No legs or antennae;
- Bilateral symmetry.

Earthworms

Subclass: Oligochaeta
Order: Crassiclitellata

Characteristics:

- Belong to the soil macrofauna;
- Have setae, small hair-like structures on the rings that assist in locomotion;
- In the adult stage, most species have a well-developed clitellum, a structure usually ring-shaped and often a different color from the rest of the body, located near the anterior part of the animal.

THREE MAIN ECOLOGICAL GROUPS KNOWN, WITH INTERMEDIATE CLASSES

EPIGEIC:

- Live in the leaf litter layer;
- Small, with uniform color, ranging from green to blue, or reddish depending on their habitat.

ANECIC:

- Feed on surface leaf litter;
- Large with dark dorsal or antero-dorsal pigmentation;
- Live in vertical burrows.

ENDOGEIC:

- Little to no pigmentation;
- Geophagous and live entirely in the soil.

Earthworm cast deposited on the soil surface (Photo: Wilian Demetrio).

Giant earthworm - *Andiorrhinus duseni* (Photo: Wilian Demetrio).

Developed clitellum indicating an adult individual

Earthworm in the genus *Dichogaster* (Photo: Marie Bartz).

Observations and functional importance:

Earthworms can be found in the litter and soil; species found in the litter are pigmented, while those found in the soil have little to no pigmentation. Earthworm burrowing (soil ingestion) and casts excretion modifies soil structure. Organic matter digestion in the earthworm's digestive tract is stimulated by a mutualistic interaction with gut microbes. Earthworms also incorporate organic matter into the soil profile, they can ingest up to 20-30 times their own body weight in soil every day, and about 10 tons of soil per hectare per year.

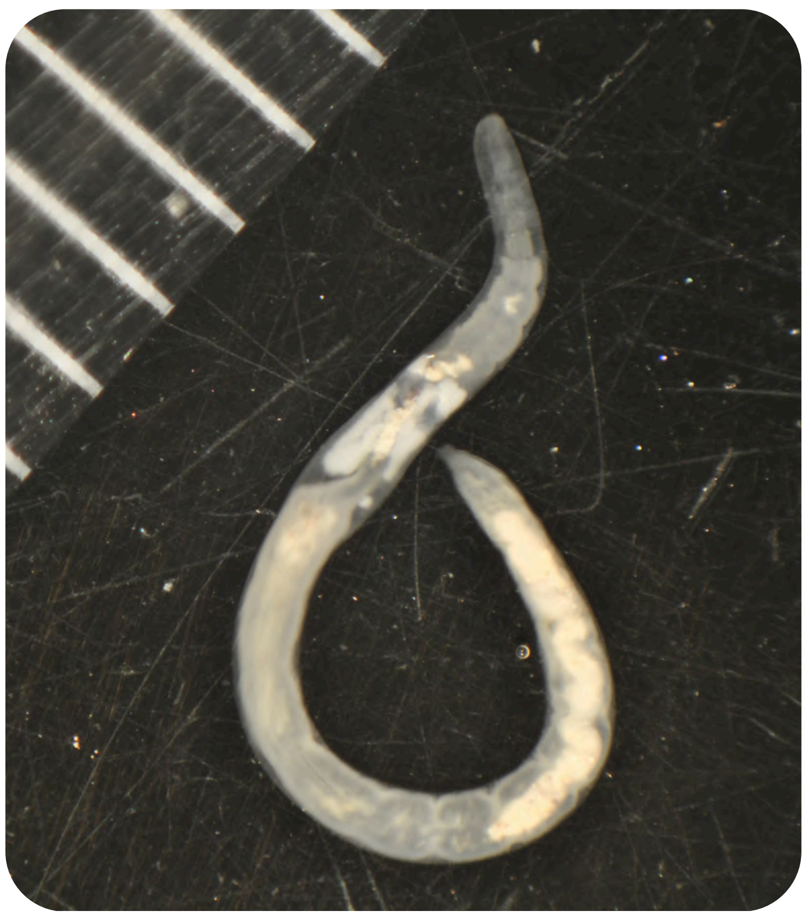
For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/152943-Crassiclitellata

Potworms

Subclass: Oligochaeta
Order: Enchytraeida

Characteristics:

- Part of the soil mesofauna;
- Similar to earthworms, but much smaller (most species only a few millimeters long, and invisible to the naked eye) and lacking pigmentation.



Enchytraeid observed under a microscope (Photo: Cintia Niva).

Enchytraeid (Photo: Adam Kranz, https://www.inaturalist.org/photos/64768157).

Photo: LabBio UFPEL (2023).

Due to their translucent whitish coloration, the internal organs of enchytraeids can be observed, as well as the food being digested and subsequently excreted.

Observations and functional importance:

Specimens of larger potworm species may be collected by hand sorting using the TSBF method. Rarely collected with Berlese-Tullgren funnels, potworms requires a specific extraction method. Potworms concentrat in the upper soil lauers (0-5 cm), where the organic matter accumulates, and where they feed on bacteria and fungal mycelia, as well as dead organic matter.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/180684-Enchytraeidae

Leeches or bloodworms

Subclass: Hirudinea

Characteristics:

- Part of the soil macrofauna;
- Have an anterior (smaller) and a posterior sucker (larger).

Example of leech commonly observed in the soil (Photo: dilsonvp, https://www.inaturalist.org/photos/366189400).

Haemadipsa ornata (https://www.inaturalist.org/photos/58241709).

Observations and functional importance:
Most species found in the soil have a reddish coloration. Leeches are important predators of other organisms such as earthworms.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/63081-Hirudinea

VELVET WORMS

Kingdom: Animalia
Phylum: Onychophora

Characteristics:

- Have a body, including legs, with a texture similar to velvet.

Ooperipatellus viridimaculatus (Photo: Carey Knox, https://www.inaturalist.org/photos/164281898).

Diemenipatus taiti (Photo: Gonzalo Giribet, https://www.inaturalist.org/photos/253001994).

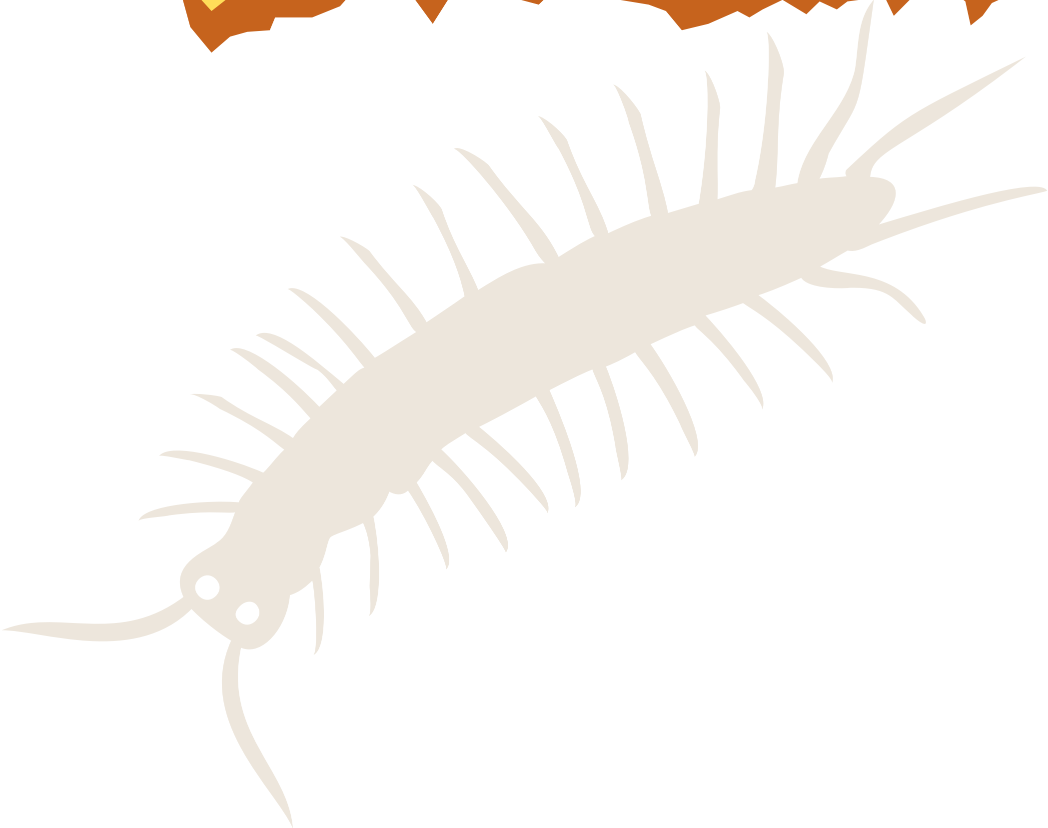
Observations and functional importance:
Extremely rare, this group is one of the most difficult to observe in the field. Velvet worms are important predators of other taxa of the soil meso and macrofauna.

For more information and photos, please scan the QR code or visit the link **(https://www.inaturalist.org/taxa/51836-Onychophora)**

MYRIAPODS

Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Uniramia
Superclass: Myriapoda

Pauropods

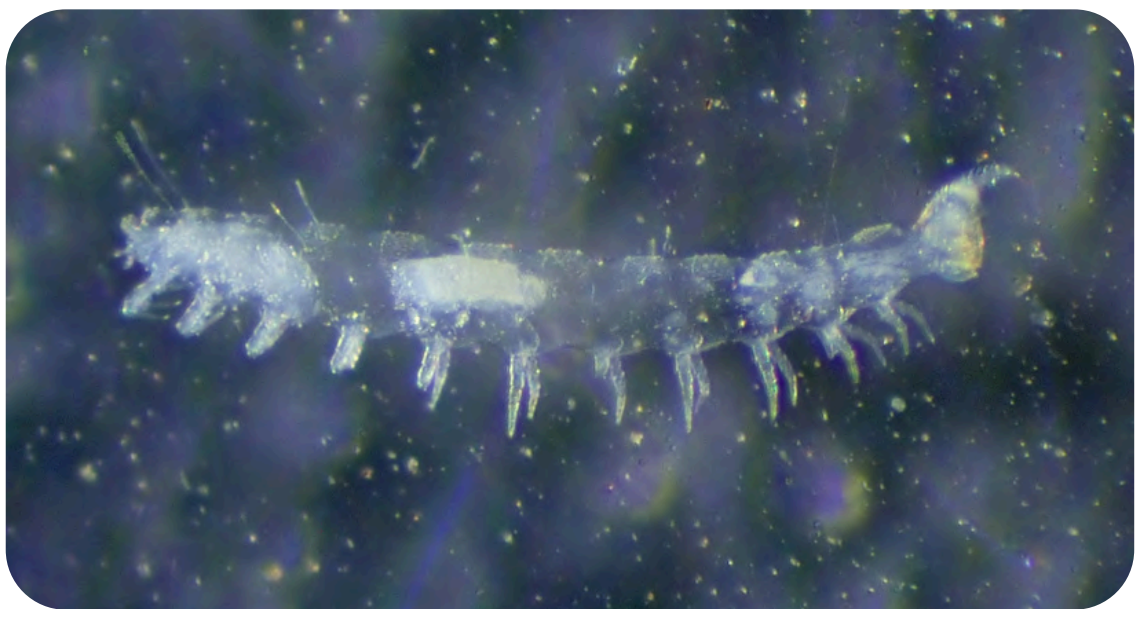


Class: Pauropoda

Characteristics:

- Belong to the soil mesofauna;
- Elongated and segmented body;
- Adults have 9 to 11 pairs of legs;
- Have a pair of bifurcated antennae.

Genus *Stylopauropus* (Photo: Frank Ashwood, https://www.inaturalist.org/photos/394340483).



Order Hexamerocerata observed under a stereomicroscope (Photo: Hubert Szczygiel, https://www.inaturalist.org/photos/394146194).

Observations and functional importance:
Pauropods are frequently observed in fauna samples obtained using Berlese-Tullgren funnels. These animals are important detritivores, feeding on fungi, decaying organic matter, and mold.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/83243-Pauropoda

Millipedes

Class: Diplopoda

Characteristics:

- Part of the soil macrofauna;
- Elongated and segmented body;
- Two pairs of legs per segment;
- One pair of antennae;
- Typically rounded head.

Millipede (Photo: Marie Bartz).

Millipede observed under a stereomicroscope (Photo: LabBio UFPEL, 2023).

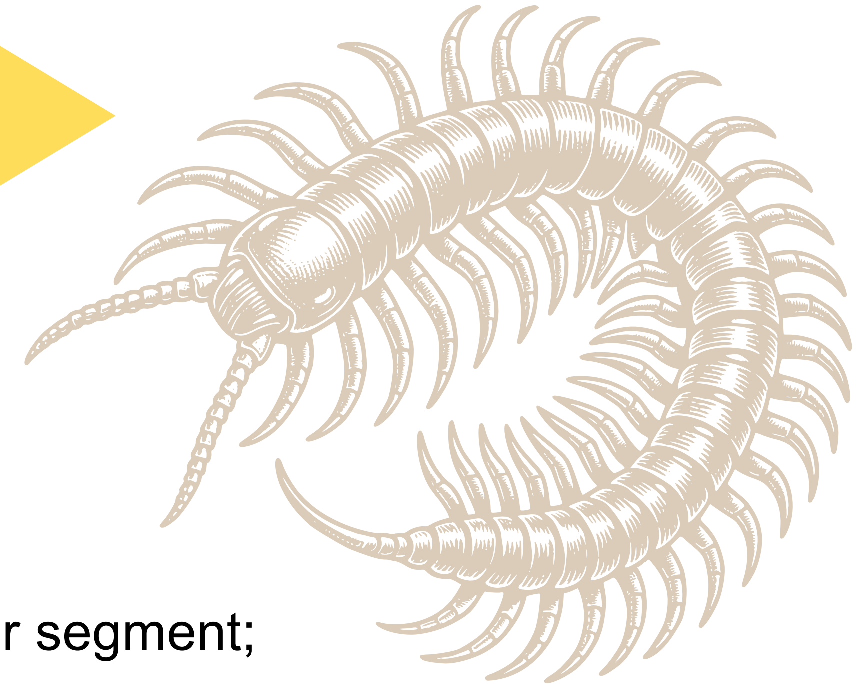
Millipede (Photo: Lucas Kaminski, https://www.inaturalist.org/photos/215834848).

Amplaria staceyi (Photo: BJ Stacey, https://www.inaturalist.org/photos/6289322).

Observations and functional importance:
Millipedes are important detritivores, fragmenting litter, accelerating organic matter decomposition and stimulating nutrient mineralization. Some species are active soil burrowers, producing tunnels in the soil and organo-mineral pellets.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47735-Diplopoda

Centipedes



Class: Chilopoda

Characteristics:

- Part of the soil macrofauna;
- Body with multiple segments, and one pair of legs per segment;
- One pair of antennae;
- Pair of forceps or maxillipeds with venomous claws;
- Last pair of legs is usually longer and modified.

Order Scolopendromorpha (Photos: Marie Bartz).

Geophilus flavus - order Geophilomorpha (Photo: Feliz Riegel, https://www.inaturalist.org/photos/112036456).

Observations and functional importance:
Quite abundant in the leaf litter centipedes are also found within the soil, mainly without pigmentation (order Geophilomorpha). These animals are important predators of other soil meso and macrofauna taxa.

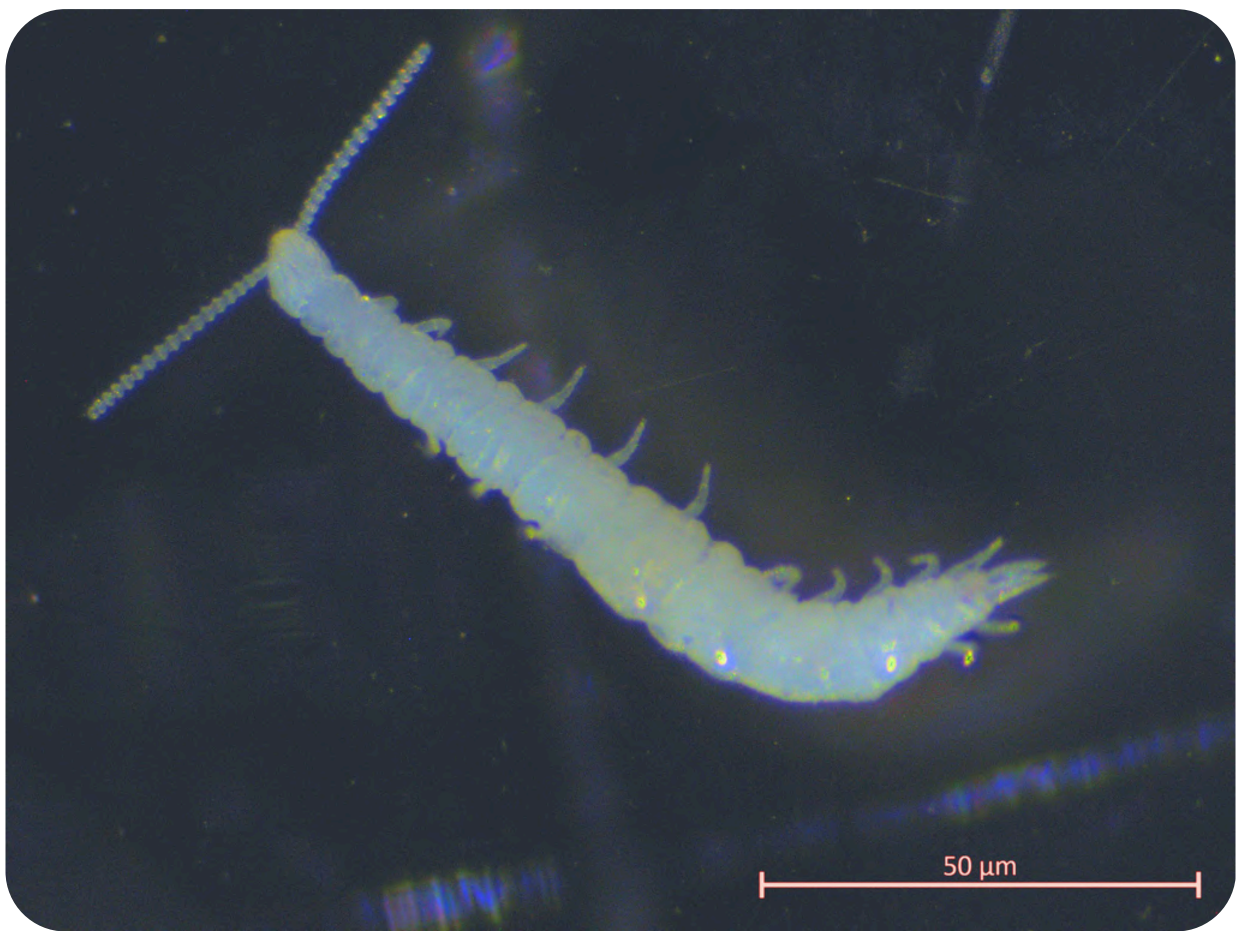
For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/49556-Chilopoda

Symphylans or garden centipedes

Class: Symphyla

Characteristics:

- Part of the soil mesofauna;
- Small body, usually measuring from 2 to 10 mm length;
- Elongated body and thin, resembling small centipedes;
- 12 well-defined body segments, of which 10 have locomotor appendages;
- Long, thread-like antennae, segmented and used for sensory perception.



Symphylan (Photo: LabBio UFPEL, 2024).

Symphylan - família Scutigerellidae
(Photo: Gustavo Schiedeck).

Symphylan (Photo: arielopezpics, https://www.inaturalist.org/photos/451229140).

Observations and functional importance:
Symphylans are primarily detritivores, feeding on decaying plant and organic materials, and fungi. Some species can also be pests, eating seeds and roots.

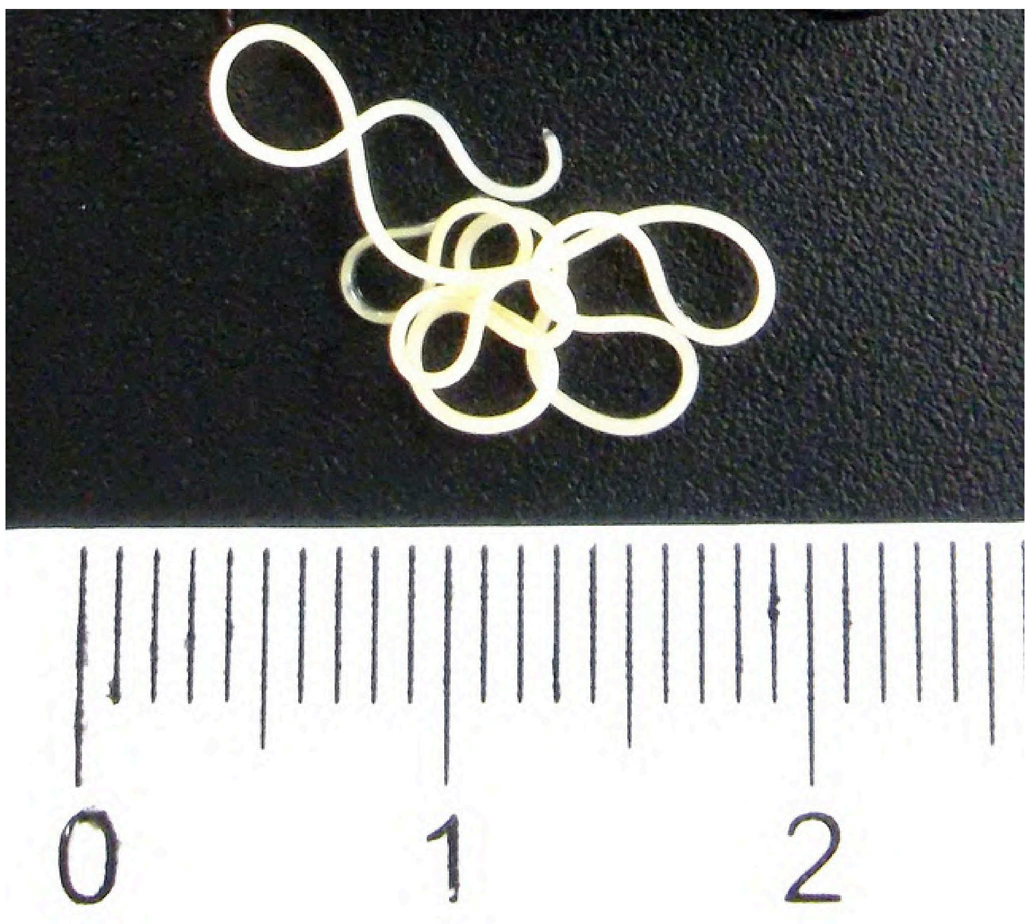
For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/84638-Symphyla

ENTOMOPATHOGENIC NEMATODES

Kingdom: Animalia
Phylum: Nematoda
Class: Enoplea
Order: Mermithida
Family: Mermithidae

Characteristics:

- Cylindrical body quite long, usually white in color, often found coiled up.



Mermis nigrescens (Photo: Steven Evans, https://www.inaturalist.org/photos/1947864).

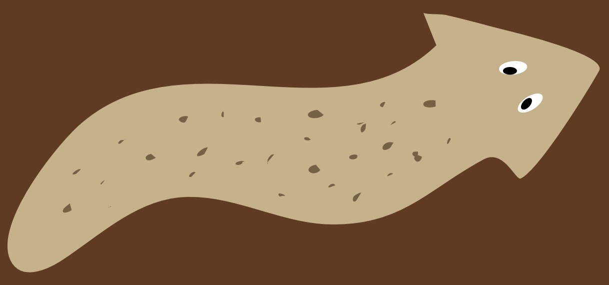
Observations and functional importance:

Mermithids are important parasites of arthropods and often found in the soil after the death of the host.

For more information and photos, please scan the QR code or visit the link: **https://www.inaturalist.org/taxa/345882-Mermithidae**

FLATWORMS

Kingdom: Animalia
Phylum: Platyhelminthes
Class: Rhabditophora
Order: Tricladida
Family: Geoplanidae



Characteristics:

- Dorsoventrally flattened body.

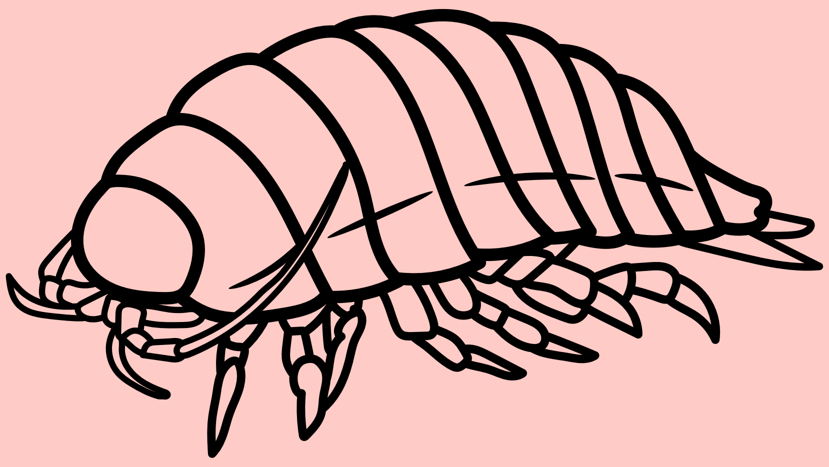
Geoplana arkalabamensis (Photo: John M. Faggard, https://www.inaturalist.org/photos/31443939).

Australopacifica leichhardtiana (Photo: Damien Brouste, https://www.inaturalist.org/photos/98621289).

Observations and functional importance:
Flatworms are rarely found in soil samples, but these animals are important predators of other members of the soil meso and macrofauna, including earthworms.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/52319-Platyhelminthes

CRUSTACEANS



Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostraca

Characteristics:

- Body composed of head and abdomen;
- 2 pairs of antennae;
- Variable number of legs.

Crabs

Order: Decapoda

Characteristics:

- 5 pairs of legs, with the first pair modified for food capture.

Ucides cordatus
(Photo: Gustavo Sandres, https://www.inaturalist.org/photos/269931828).

Observations and functional importance:
Crabs are rarely found in soil samples, but can be collected in sites near rivers or mangroves. Feeds on leaf litter, detritus, and sometimes living plant tissue

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47186-Decapoda

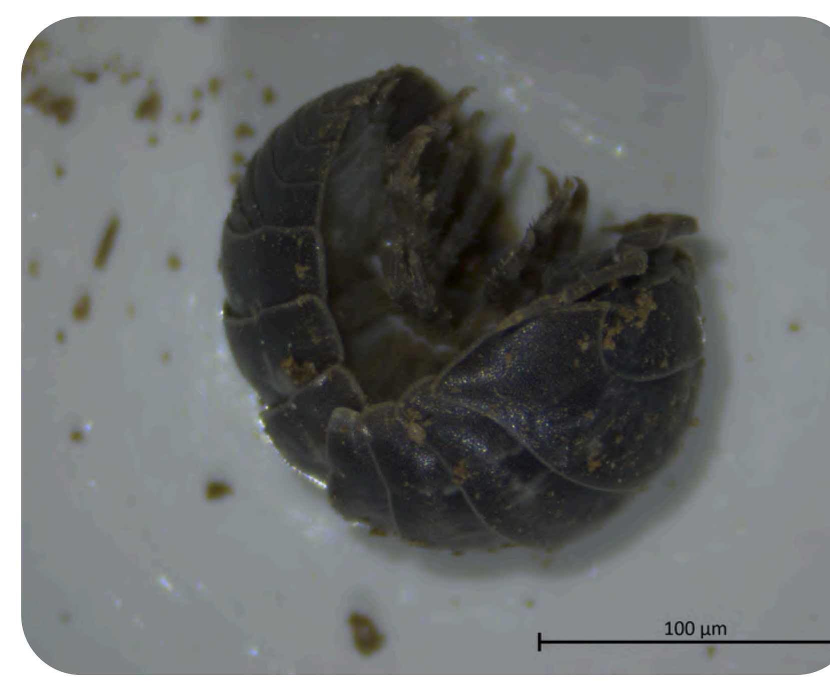
Woodlice

Order: Isopoda

Characteristics:

- Part of the soil macrofauna;
- Flattened body divided into head, thorax, and abdomen;
- Thorax divided into 7 segments;
- Two pairs of antennae, with the first pair called antennules, as it is vestigial and underdeveloped;
- Generally dark-colored.

Woodlouse under stereomicroscopy (Photo: LabBio UFPEL, 2023).



Woodlouse under stereomicroscopy (Photo: LabBio UFPEL, 2023).

Porcellio scaber (Photo: Guerric Haché, https://www.inaturalist.org/photos/277612426).

Woodlice in the Philosciidae family (Photo: Gustavo Schiedeck).

Cubaroides pilosus (Photo: Jesse Rorabaugh, https://www.inaturalist.org/photos/44028395).

Observations and functional importance:
Woodlice are quite abundant in litter and the surface soil. These detritivores are important promoters of leaf litter fragmentation, accelerating its decomposition and nutrient release.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/48147-Isopoda

Sand fleas

Subclass: Eumalacostraca
Superorder: Peracarida
Order: Amphipoda

Characteristics:

- Part of the soil meso- and macrofauna;
- Although mostly aquatic, some species inhabit damp soils;
- Body includes segmented head and thorax;
- 10 pairs of legs, divided into the thorax (maxillipeds used for feeding and pereopods used for locomotion) and abdomen (pleopods used for swimming).

Capeorchestia capensis
(Photo: Gareth Yearsley, https://www.inaturalist.org/photos/115740984).

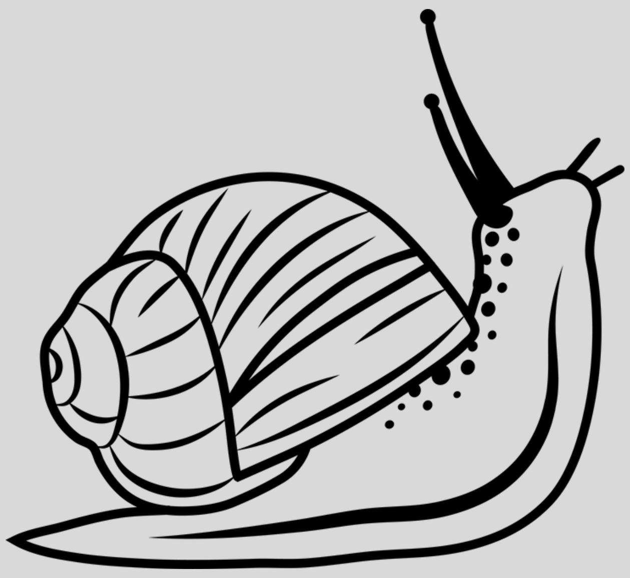
Bulychevia enigmatica
(Photo: Richard Hasegawa, https://www.inaturalist.org/photos/268928727).

Sand flea
(Photo: LabBio UFPEL, 2023).

Observations and functional importance:
Sand fleas are rarely collected using the TSBF method, but can be abundant in pitfall traps. Also known as beach hoppers, these animals are vigorous jumpers common in sandy beaches. In soils, they are avid litter consumers facilitating its degradation and nutrient release.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47628-Amphipoda

SLUGS AND SNAILS



Class: Gastropoda

Characteristics:

- Part of the soil macrofauna;
- No legs;
- Two tentacles (resembling antennae), with eyes at the tips;
- Can have shells (snails) or not (slugs).

Example of a snail (Photo: Marie Bartz).

Example of a slug (Photo: Marie Bartz).

Observations and functional importance:
Some species are pests of agricultural crops.

For more information and photos, please scan the QR code or visit the link: https://www.inaturalist.org/taxa/47114-Gastropoda

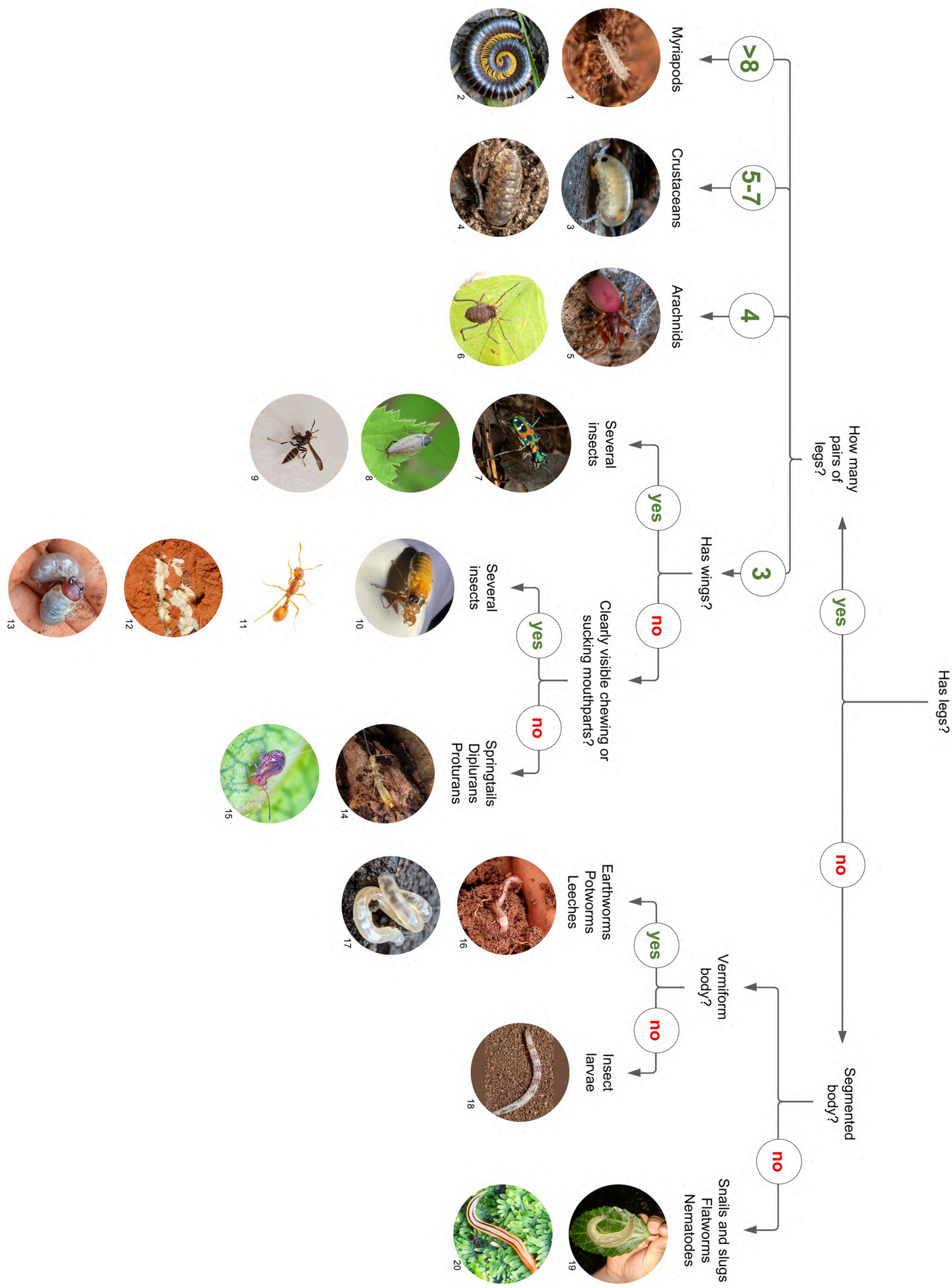


Figure 14. Simplified identification key for some soil fauna groups. Source: Modified from Eglin et al. (2010).

Photos: 1) Pauropod - genus *Stylopauropus* (Photo: Frank Ashwood, https://www.inaturalist.org/photos/394340483); 2) Millipede (Photo: Lucas Kaminski, https://www.inaturalist.org/photos/215834848); 3) Sand flea - *Capeorchestia capensis* (Photo: Gareth Yearsley, https://www.inaturalist.org/photos/115740984); 4) Woodlouse - *Cubaroides pilosus* (Photo: Jesse Rorabaugh, https://www.inaturalist.org/photos/44028395); 5) Spider - *Stenochilus scutulatus* (Photo: Naveen Iyer,https://www.inaturalist.org/photos/149577338); 6) Harvestman - *Mischonyx squalidus* (Photo: Tsssss, https://www.inaturalist.org/photos/90475033); 7) Beetle - *Cicindela chinensis* ssp. *japonica* (Photo: Ryosuke Kuwahara, https://www.inaturalist.org/photos/92982013); 8) Cockroach - *Ectobius balcani* (Photo: Kostas Zontanos, https://www.inaturalist.org/photos/17744567); 9) Wasp - *Polistes exclamans* (Photo: Dan Horowitz, https://www.inaturalist.org/photos/57455961); 10) Cicada nymph (Photo: Ken Rosenthal, https://www.inaturalist.org/photos/135005676); 11) Ant - genus *Solenopsis* (Photo: Jake Nitta, https://www.inaturalist.org/photos/313181826); 12) Cupins subterrâneos (Photo: Marie Bartz); 13) Larva de besouro (coró) - família Scarabaeidae (Photo: Wilian Demetrio); 14) Diplura (Photo: Elliott Smeds,https://www.inaturalist.org/photos/111070657); 15) Springtail from the family Dicyrtomidae (Photo: Damien Brouste, https://www.inaturalist.org/photos/45740181); Earthworm from the genus *Dichogaster* (Photo: Marie Bartz); 17) Potworm (Photo: Adam Kranz, https://www.inaturalist.org/photos/64768157); 18) Fly larva (Photo: Alberto J. Narro Martín,https://www.inaturalist.org/photos/95349560); 19) Slug (Photo: Marie Bartz); 20) Planária - *Australopacifica leichhardtiana* (Photo: Damien Brouste, https://www.inaturalist.org/photos/98621289).

Chapter 4

Presentation and interpretation of macro- and mesofauna results

Presenting the data obtained is one of the final stages of any study and, should be properly done to allow for optimal visualization and interpretation of the results. How data is presented goes beyond the individual importance of the study and should be done in a way that allows for their reuse in future syntheses and meta-analyses. This practice increases the "lifespan" of the data, enhancing its sustainability and accumulation. Furthermore, raw data should be deposited in free repositories such as Zenodo (www.zenodo.org).

Interpreting the response of soil fauna communities to different environmental and anthropogenic variables is not a straightforward task, and sometimes yield results that contradict those in the literature. For this reason, it is crucial to record all observed information, including the specifics of each site and variable evaluated, as this will assist in the interpretation of the results obtained. As mentioned earlier, environmental variables, such as data on management practices and the chemical and physical properties of the soil, are important in understanding macro and mesofauna ecology. This chapter provide guidance on the presentation and interpretation of results on soil macro and mesofauna communities.

Presenting and interpreting results

There are several ways to show collected data, which can be presented in the form of tables, for example, Table 1. The tables should be clear, showing the average number of organisms collected, which can be the average number per sample or the number of individuals per m^2, when resulting from quantitative samples using TSBF and Berlese-Tullgren funnels. The numbers should be presented by taxon, representing the abundance, and/or total density (sum of the number of individuals in each class) and the relative frequency (percentage of each group in relation to total abundance).

Example of description:

"In Table 4, we can observe that in area under the vegetable cultivation had 540 individuals in the leaf litter-soil interface (pitfall traps), distributed across 5 taxonomic groups. The highest relative frequency was of springtails (Collembola), comprising 63% of the individuals collected, followed by Isopoda with 15.4%. Meanwhile, in the soil we recovered 496 individuals distributed across 4 taxonomic groups, with mites (Acari) representing 78% of the individuals, followed by springtails (19.8%)."

Data can also be presented in the form of figures such as boxplots or bar charts (Figure 13). It is always important to include measures that indicate dispersion, like standard deviation or standard error, as these indicate variability in the replicates in relation to the mean.

Table 4. Abundance (number of individuals) and relative frequency (%) of organisms collected using pitfall traps and Berlese-Tullgren funnels in different land use systems at UFPel - Campus.

Taxon	Vegetables	Spontaneous vegetation	Grass lawn	Forest
	mean number of individuals sampled in pitfall traps			
Acari	44 (8.1%)	21 (6.8%)	164 (41.4%)	43 (23.6%)
Collembola	340 (63%)	163 (53.3%)	238 (45.5%)	50 (27.5%)
Diplura	44 (8.1%)	35 (11.5%)	0	1 (0.5 %)
Amphiphoda	18 (3.3%)	8 (2.6%)	104 (19.8%)	2 (1.1%)
Isopoda	94 (17.4%)	75 (24.5%)	17 (3.3%)	23 (12.6%)
Symphyla	0	0	0	57 (31.3%)
Enchytraeidae	0	4 (1.3%)	0	6 (3.4)
Total	540	306	523	182
	mean number of individuals sampled in Berlese-Tullgren funnels			
Acari	387 (78%)	356 (67.4%)	381 (71.6%)	1919 (69.7%)
Collembola	98 (19.8 %)	163 (30.9%)	118 (22.2%)	786 (28.6%)
Diplura	0	0	19 (3.6%)	0
Amphiphoda	0	0	0	6 (0.2%)
Isopoda	9 (1.8%)	9 (1.7%)	1 (0.2%)	0
Symphyla	2 (0.4%)	0	12 (2.2%)	35 (1.3%)
Enchytraeidae	0	0	1 (0.2%)	5 (0.2%)
Total	496	528	532	2751

It is important to emphasize that, for data comparison, statistical analyses are necessary.

Another example of description of results in text could be:

"Ant density ranged from 486 to 1,560 ind. m^{-2}, with no significant differences between the evaluated systems; a similar result was observed for termites, with abundance varying from 21 to 1,200 ind. m^{-2} (Figure 15A). The young regeneration forest exhibited the highest earthworm density (912), followed by the intermediate secondary forest (296) and old native forest (13 ind. m^{-2}). Centipedes were more abundant in the old forest (107; Figure 15B) compared to the intermediate secondary forest (56) and the young regeneration area (3 ind. m^{-2}). Beetles showed higher density values in the old native forest (300) and intermediate secondary forest (220) compared to the young regeneration one (16 ind. m^{-2}). For spiders, significant differences were only observed between the old (67) and young forest (5 ind. m^{-2})."

In the figure, we can observe how a measure of dispersion is important in helping to understand the absence of significant differences between the means. For ants, although the mean is three times higher in the regenerating forest, the standard deviation bars show large variation between replicates, which explains the lack of significant differences. Additionally, we can see how the TSBF method is limited in sampling social insects, as high variability was also presented in the termites data.

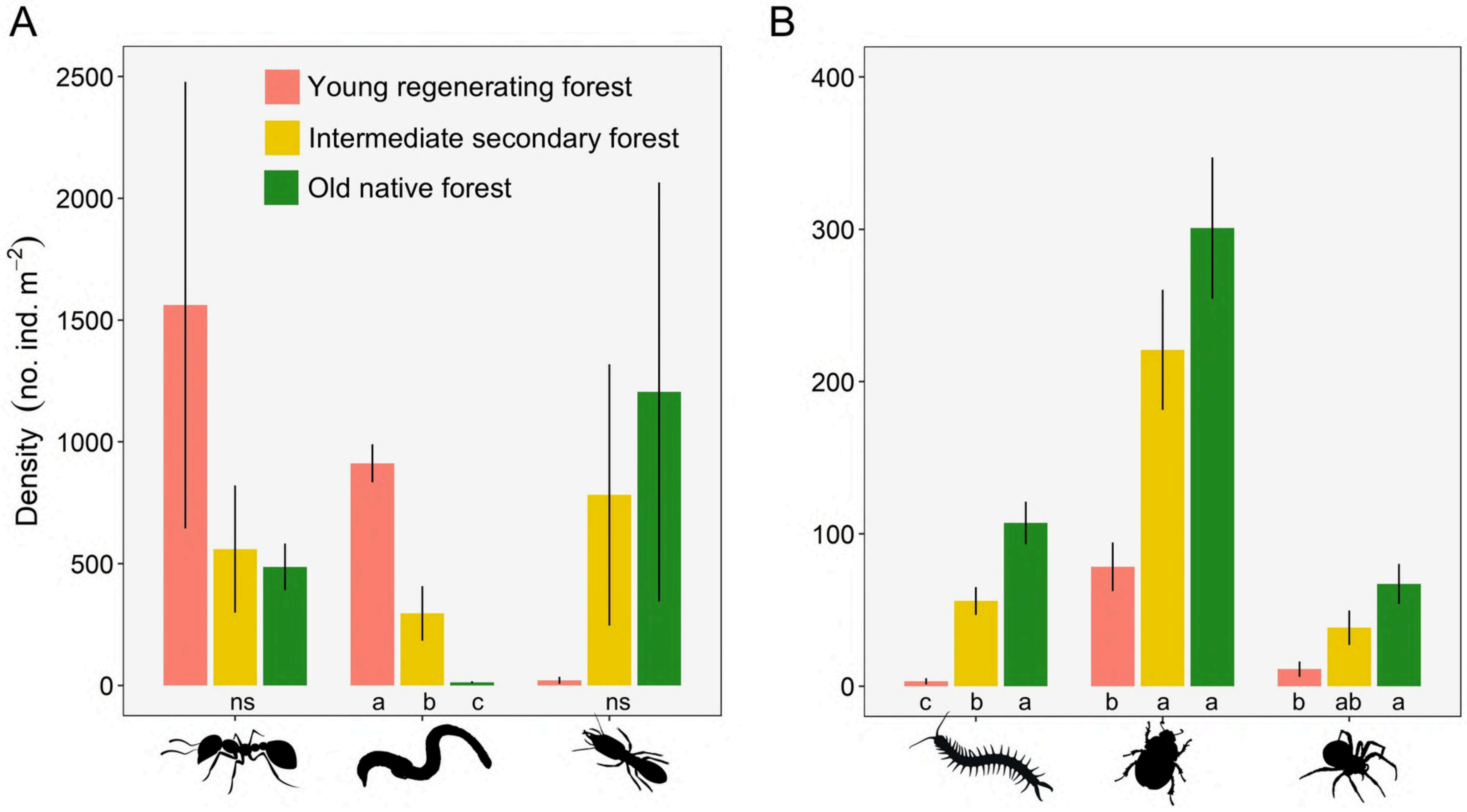


Figure 13. Average density (number of individuals per m²) up to 30 cm depth of the soil macrofauna collected using the TSBF method in forests at different regeneration stages: early regenerating forest, intermediate secondary forest and old native forest. A) Average density of ants, earthworms, and termites; B) Average density of centipedes, beetles, and spiders. Black bars indicate standard deviation (n=10) and letters indicate significant differences between the evaluated areas for each macrofauna taxon. Source: Adapted from Demetrio et al. (2024).

Recommendations for what **NOT** to do in a publication with data on soil meso or macrofauna:

- Show soil fauna community data using only multivariate analyses;
- Show only ecological indices, and no abundance data;
- Show only means by functional groups;
- Show overall general means by region, municipality, or location without showing average values for each studied system;
- Show fauna data by soil volume instead of per square meter;
- Show results without including the unit of measurement;
- Not include measures of dispersion for means, such as standard deviation or standard error.

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