pp. C-59 – C-65 *in* Malcolm E. Sumner (ed.-in-chief), Handbook of Soil Science. CRC Press, Boca Raton. 1999.

2.3 Microarthropods

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2.3.1 Introduction

Soil microarthropods are a major fraction of the mesofauna, namely, those arthropods with body widths ranging between approximately 0.1 and 2 mm, and body lengths between 0.2 mm and 10 mm

(Fig. 2.3). This scheme of classification, although imprecise, is practical, defined by the method of sampling. Microarthropods are sampled by collecting a fragment of habitat (e.g., a soil core) and extracting them from it, while macroarthropods (Section C, Chapter 2.4) are collected by hand sorting, pitfall trapping, or other methods dealing with individuals. Microarthropods are dominated by two groups: the mites (Acari) and the springtails (Insect order Collembola). Together, mites and springtails account for about 90% of the microarthropods in most soil systems. Also included in this group, among others, are the Protura, Pauropoda, dipteran larvae, small spiders, pseudoscorpions, some Homoptera and Coleoptera, and thrips. Immature stages of many insect Orders are collected from soil samples, and some may be considered microarthropods for purposes of a particular study. These minor groups typically constitute less than 10% of the total number of microarthropods.

Numbers of microarthropods in soil systems range upwards to 200,000 m^{-2} or more (Table 2.12). Forested systems generally support higher microarthropod population densities than do grasslands, deserts, or agricultural systems, with densities being higher in soils from temperate than tropical forests, and coniferous than deciduous forests. Soils in agroecosystems may have sparse populations, although numbers increase under conservation tillage management. Together with protozoans, nematodes and other small soil fauna, the microarthropods make up a food web of several trophic levels, driven by energy sources from decomposing residues and mobilizing nutrient elements.

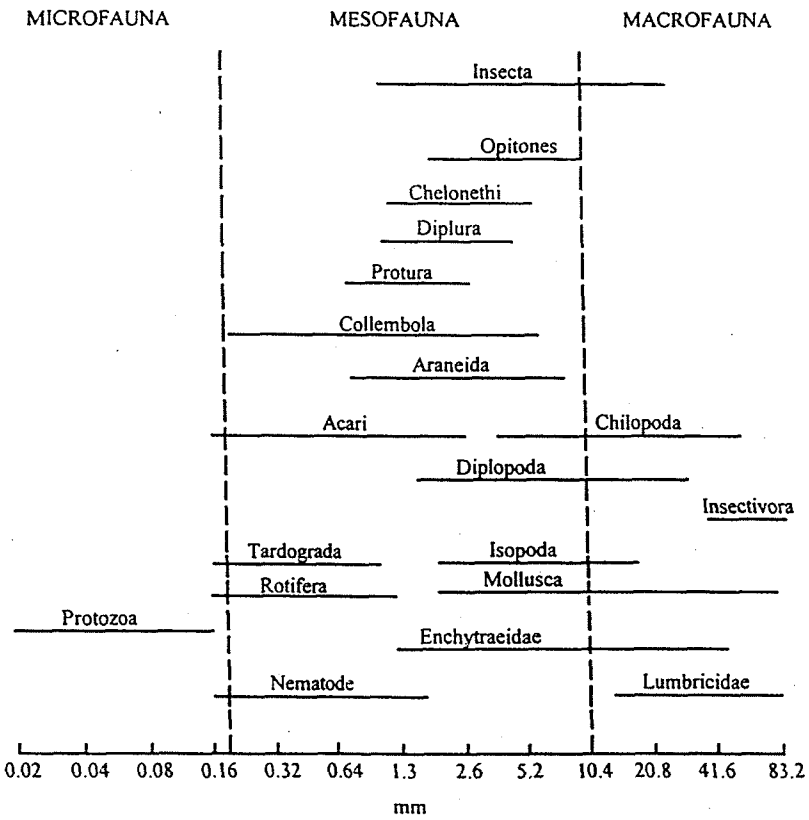

Fig. 2.3 A generalized classification of soil fauna by body length [Reprinted from Wallwork, 1983. Earthworm biology. Camelot Press, Southampton, UK with permission of McGraw-Hill]

2.3.2 Biology and Ecology

2.3.2.1 Collembolans

These minute insects (Fig. 2.4) are commonly called "springtails" in reference to an abdominal appendage, the furcula, which enables them to leap through the air. They possess a characteristic ventral tube with eversible sacs, important in moisture balance. Collembolans are most obvious when they swarm on the soil surface, sometimes on snowbanks, leading to the name "snowfleas." But springtime swarms are common in North American forest, grassland and agricultural soils as well. Eighteen families of Collembola are currently recognized (Hopkin, 1997) but the taxonomy is in a state of flux. General reference works on Collembola are presented in Maynard (1951) and Christiansen and Bellinger (1980).

Collembolan numbers in terrestrial ecosystems range between 10^4 and 10^5 m^{-2} and typically constitute 20–50% of the soil microarthropods. They are opportunistic species and dominate microarthropod communities in springtime during population blooms. Their habitat extends from the litter layers of soil down into deeper substrata. Their morphology reflects their habitat in that surface dwellers are larger, often colored, with well-developed furcula and long antennae, while those inhabiting the soil are white, with reduced furcula and shorter antennae (Fig. 2.4).

Although most collembolans are fungivores or detritivores, a few species are economic pests, and some have proved to be predaceous. Like other microarthropods, collembolans may feed opportunistically upon nematodes or other periodically abundant resources in the soil. Collembolans appear to be attracted to plant roots and may be important in rhizosphere dynamics. In experiments, collembolans grazed selectively on fungal root pathogens, thereby protecting cotton plants (Curl and Truelove, 1986).

2.3.2.2 Soil Mites (Acari or Acarina)

Being members of the Class Arachnida, mites are eight-legged, chelicerate relatives of spiders and phalangids. Conservatively, mites are placed in the Order Acari (or Acarina) and are divided into several suborders. While many species of mites are plant feeders or parasites, only the soil forms will be considered here. For a general treatment of the Acari, see Evans (1961) or Krantz (1978). Most soil

Table 2.12 Representative densities of soil microarthropods from various ecosystems

Region	Ecosystem type	Density (m^{-2})	Reference
North Carolina	Deciduous forest	133,000	Seastedt and Crossley (1981)
North Carolina	Deciduous forest	88,000	Lamoncha and Crossley (1997)
Tennessee	Pine forest	102,000	Bohnsack and Crossley (1960)
Belgium	Oak forest	70,000 - 180,000 (mites only)	Lebrun (1965)
Canada	Aspen forest	123,000 (mites only)	Mitchell (1977)
Australia	Tropical rain forest	33,000 - 49,000	Holt (1985)
Africa	Tropical rain forest	22,000 (dry season) 65,000 (wet season)	Madge (1969)
Georgia	Agroecosystem (Sorghum)	119,000 (no-tillage) 49,000 (conventional)	House and Parmelee (1985)
South Carolina	Pine plantation	166,000	Johnston (1996)
Colorado	Short-grass prairie	102,000	Walter et al. (1987)

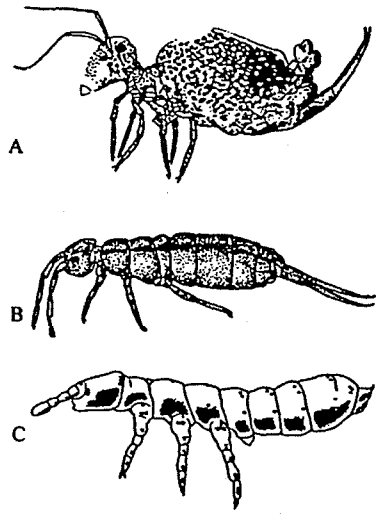

Fig. 2.4 Collembolan life forms: (A). Family Sminthuridae, typically found at the soil surface. (B). Family Isotomidae, from forest leaf litter. (C). Family Onychuridae, from mineral soil layers [Reprinted from Coleman and Crossley, 1996. Fundamentals of soil ecology with permission of Academic Press, Inc, Orlando, FL]

mites fit into one of four suborders, separation of which is easily performed using a dissecting microscope at 20x. Each suborder is considered below.

2.3.2.3 Acari: Prostigmata

Representatives of this very diverse suborder are often among the most numerous of the soil mites. In general, they are delicate, white to colorless, and subject to desiccation. While most species are predaceous, some are fungivorous and these species may become abundant in decomposing organic litter. Many Prostigmata are opportunistic species, able to reproduce rapidly when food resources become abundant. Large populations may build in disturbed situations, such as forest clearings, drained marshes, and so forth. Larger Prostigmata are predators, including the bright red "velvet mites" seen walking on the soil surface in the spring, or following rains in desert systems. Smaller species with piercing stylet chelicerae are generally fungal feeders in soil and litter layers, but some are effective predators on other mites or nematodes. Some species may switch between fungal hyphae and nematodes, or perhaps supplement a fungal diet with occasional protein.

Recent comprehensive treatments of the Prostigmata are those of Kethley (1990). He gives extensive tables of abundance and biomass for the Prostigmata in a range of habitats, as well as a key to families from edaphic habitats.

2.3.2.4 Acari: Mesostigmata

This suborder consists of generally flattened, tick-like mites. Although not as numerous as other mite groups, mesostigmatic mites are important predators in soil systems, particularly on nematodes and other arthropods. The smaller species are mainly nematophagous. Larger ones are active predators of collembolans, other small arthropods and arthropod eggs. One species in the family Macrochelidae has been used successfully to control housefly populations in manure (Krantz, 1978). In forest floors, litter species tend to be larger, and mineral soil inhabitants are generally smaller and colorless. In agricultural soils, Mesostigmata are attracted to decomposing roots. Members of the family Uropodidae feed upon fungal hyphae and associated organic debris.

A large and comprehensive literature discusses the soil mesostigmatic mites of North America, but the group is in need of a comprehensive revision (Evans and Till, 1979; Krantz and Ainscough, 1990).

2.3.2.5 Acari: Oribatei

Next to collembolans, oribatid mites (Fig. 2.5) are the most numerous of microarthropods (Balogh and Balogh, 1992; Marshall et al., 1987; Moldenke and Fichter, 1988). They are usually brown and beetle-like in form and, like other mites, are octopod with the body essentially unsegmented except for some secondary sutures. Their rate of reproduction is slower than that of collembolans, but they maintain high populations by longer survivorship. Adult oribatids have a heavily sclerotized exoskeleton containing deposits of $CaCO_3$ evidently accumulated from calcium oxalate crystals in their fungal food sources. Together with snails, millipedes and isopods, oribatids may play a significant role in Ca metabolism in soil systems. The immature stages of oribatid mites often do not resemble the adults, to the extent that recognition of species based on immatures is difficult.

Densities of oribatid mites in soils, as with Collembola, range from 10^4 to 10^5 m^{-2}. In deciduous forests, peaks of abundance occur in autumn and again in spring, with numbers remaining high during summer months. Year-to-year variation may be large, but fluctuations are not as wide as with Collembola. Coniferous forest floors typically support the largest populations of oribatids, followed by deciduous hardwood forest, grassland, and tundra (Coleman and Crossley, 1996). Cultivation of agricultural soils reduces oribatid population sizes.

Oribatids are primarily fungivorous, but will eat a variety of foods. Those species with stout chelate chelicerae can fragment and ingest decomposing leaf litter and wood, but many species can be reared on algae or lichens. Although oribatids have been observed to ingest nematodes, it seems clear that fungi are the major resource base. The major importance of oribatids in soils is their effect on the decomposition process; they are able to break down organic litter by fragmenting in or tunneling within materials such as woody residues. Their activities may stimulate microbial immobilization of nutrient elements, but at the same time, ingestion of fungal hyphae may destroy hyphal bridges (Lussenhop, 1992).

There are over 1,000 genera of oribatid mites, with newly discovered ones being published annually. Perhaps as few as 20% of the world fauna of oribatid species have been named (Behan-Pelletier and Bissett, 1993). The identification of oribatids to genus has been greatly facilitated by the

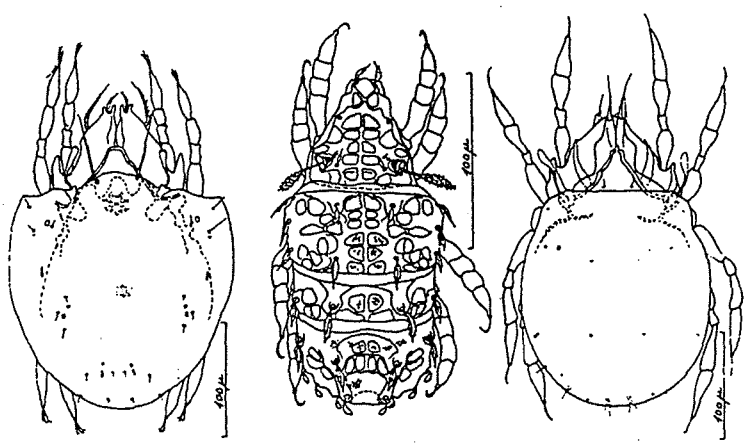

Fig. 2.5 Illustrations of oribatid mites. Left, Family Achipteriidae. Center, Family Brachychthoniidae. Right, Family Astegistidae [After D. L. Dindal, State University of New York, Syracuse with permission]

herculean efforts of Janos Balogh, who has authored a series of well-illustrated works during the past two decades (Balogh and Balogh, 1992). Recent publications, especially those which include scanning electron micrographs of oribatids, will aid in identification, but validation by an expert taxonomist is essential (Marshall et al., 1987; Moldenke and Fichter, 1988).

2.3.2.6 Acari: Astigmata

This suborder is occasionally found in soil samples. These mites, commonly called cheese mites, seem to be associated with highly organic, decomposing materials such as manure. Buried agricultural residues may support Astigmata, and they may become pests of root crops on occasion.

2.3.3 Sampling and analysis

Microarthropods are not sampled directly. Rather, samples of habitat are collected and microarthropods extracted from them. Soil cores (5 cm dia x 5 cm deep) are extracted on micro-Tullgren apparati (Fig. 2.6) or by flotation methods (Walter et al., 1986). An alternate sampling method employs litterbags containing leaf litter, which are placed in the field at the beginning of the season and then retrieved through time (Crossley and Hoglund, 1962). Microarthropods are extracted from them using Tullgren funnels ("Berlese funnels") (Evans, 1961). Using this technique, it is possible to identify microarthropod groups associated with various stages of litter decay. With either Tullgren or micro-Tullgren funnels, animals are collected in containers of 70% ethyl alcohol.

Samples of microarthropods may be sorted into major taxa with the use of a dissecting microscope at 20 times magnification. Suborders of mites and many families of Collembolans are readily identified, once their basic morphology and characteristics are learned. Further identification requires slide mounted material. Slide mounts can be made directly from alcohol (Table 2.13), although heavily sclerotized specimens may require preliminary clearing. Identification of North American microarthropod species is problematic because of the large number of poorly described or unnamed species (Behan-Pelletier and Bissett, 1993). While it is essential that preliminary identifications be

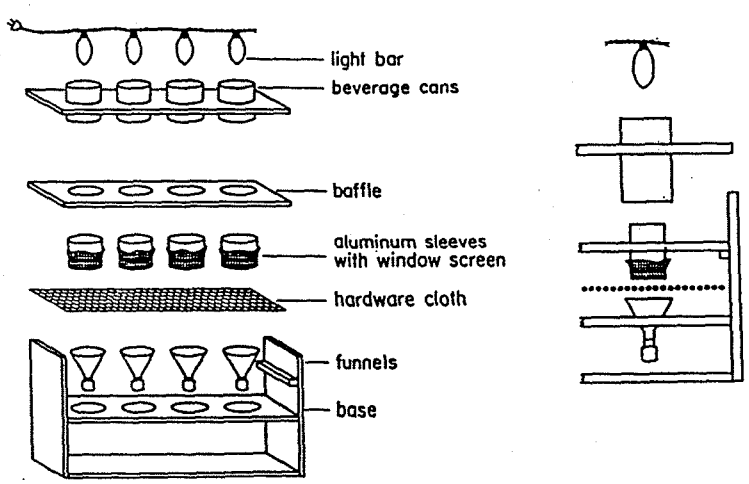

Fig. 2.6 A high-efficiency extractor for core samples of soil microarthropods. Soil cores contained in aluminum sleeves are inverted and heated from above with 5-watt lights. Fauna are collected in funnels below [Reprinted from Crossley and Blair, 1991. Agric. Ecosys. Environ. 34:187. Copyright with kind permission of Elsevier Science, Amsterdam, Netherlands].

Table 2.13 Procedures for preparation of slide mounts of microarthropods (Krantz, 1978)

Storage media:	70% ethyl alcohol
	95% ethyl alcohol
	Oudeman's fluid:
	Glycerin.....5 parts 70% alcohol.....87 parts Glacial acetic acid.....8 parts
Clearing agents:	Lactophenol:
	Lactic acid.....50 parts Phenol crystals.....25 parts Distilled water.....25 parts
Mounting media:	Hoyer's medium:
	Distilled water.....50 mL Gum Arabic.....30 g Chloral hydrate.....200 g Glycerin.....20 mL
	CMC-10 medium*

*available from Masters Chemical Company, 200 Wilson Court, Bensenville, Il 60106