Applied Soil Ecology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Short communication

Enchytraeids as bioindicators of land use and management

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ARTICLE INFO

Keywords:
Potworm
Forest
Grassland
Arable land
Agricultural practices
Biological indicator

ABSTRACT:

Enchytraeids, also called potworms, are Annelida Oligochaeta. They are present in many different soils worldwide and were found to be dominant in biomass or abundance in many habitats. These organisms are involved in key soil functions such as the dynamics of soil structure and organic matter. Based on an exhaustive literature review, we summarized the ecology and main roles of enchytraeids in soils. We also showed that enchytraeids are sensitive to changes in land use and management, both in terms of total abundance and community composition. The knowledge gaps were highlighted, as well as the needs for further research allowing to better understand the functional importance of these organisms in a context of global changes and anthropic pressures.

1. Introduction

Over the past half century, anthropogenic activities such as land use and management of production systems contributed massively to biodiversity loss, ecosystem pollution and soil degradation (Tilman et al., 2001). Among soil organisms, earthworms have often been used as soil bioindicators of anthropogenic activities (Daugbjerg et al., 1988; Paoletti, 1999) but the use of enchytraeids has been far less documented. Yet, these organisms have been proposed for the monitoring of soil biological quality (e.g. Bispo et al., 2009). Moreover, they are recognized as bioindicators of chemical stress and agricultural practices (Didden and Römbke, 2001; Pelosi and Römbke, 2016). After summarizing their ecology and their main roles in soils, we reviewed the literature to assess whether enchytraeids can be used to indicate changes in land use and management.

2. Ecology and functional roles of enchytraeids

Commonly known as potworms, enchytraeids belong to the family *Enchytraeidae*, phylum *Annelida*, and class *Oligochaeta.* Their diversity is rarely studied or often underestimated due to difficulties in distinguishing the species. Individuals must be identified alive using external and internal characteristics such as the body length and the number of segments (visible on Fig. 1), the number and shape of setae (i.e., sense organs, see Fig. 2), or the shape of the esophageal appendage (Fig. 3). Meanwhile, it is possible to fix and stain the individuals for an easier visualization of internal structures (Figs. 4 and 5). Moreover, although data sets combining genetic and morphological information are still missing, the ongoing developments of genetic methods such as DNA barcoding are promising (Orgiazzi et al., 2015; Epp et al., 2012).

Enchytraeids are present and abundant in many ecosystems across the world. Numerous studies dealing with enchytraeids focused on forests but these small organisms are also abundant in agricultural sites such as grasslands and arable fields. Enchytraeids are patchily distributed in soils and their occurrence depends mainly on soil moisture, organic matter content and pH (Graefe and Schmelz, 1999; Brussaard et al., 2012). Belonging to soil mesofauna, they are smaller than earthworms but tolerant to a wider range of conditions and far more numerous in many soils (Didden, 1993). For instance, they dominate the soil fauna in abundance under conventional tillage (Hendrix et al., 1986; Pelosi and Römbke, 2016). Their abundance generally ranges from 10^2 to 10^5 individuals m^{-2} in the organic horizons (Didden, 1993). Enchytraeids are also dominant in biomass in many habitats (Orgiazzi et al., 2016; Cragg, 1961).

Enchytraeids play key roles in the functioning of soils. Despite their difference in size, earthworms and enchytraeids have similar functional roles but at different scales (Van Vliet et al., 1993). Enchytraeids are involved in soil food webs since they ingest bacteria, fungi, protists, hyphae and decomposing organic matter (Didden, 1993; Briones and Ineson, 2002). They are themselves ingested by different soil organisms such as nematodes, carabid beetles or centipedes (Didden, 1993). Living in the first five to ten centimeters of soil, they are strongly involved in the decomposition of plant residues, the fate of organic matter and thus the nutrient cycling which are key processes for the functioning of ecosystems (Hendrix et al., 1986; van Vliet et al., 1995). These litter transformers (Lavelle, 1996) can modify microbial activity

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http://dx.doi.org/10.1016/j.apsoil.2017.05.014
Received 19 November 2016; Received in revised form 28 April 2017; Accepted 12 May 2017

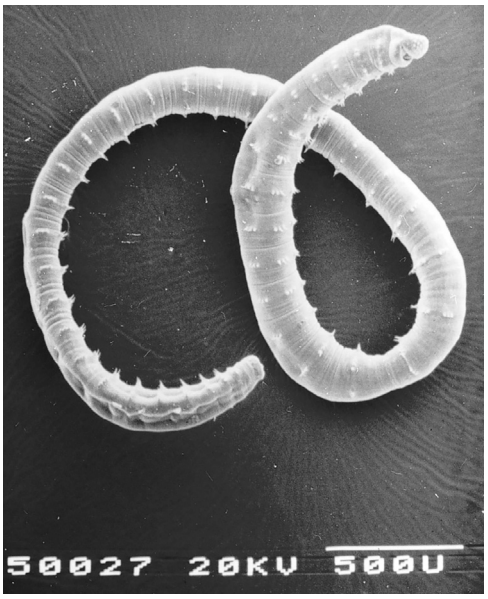

Fig. 1. Whole individual of *Cognettia sphagnetorum* (©J. Römbke, ECT).

Fig. 2. Head of *Cognettia sphagnetorum;* note the high number of sense organs (©J. Römbke, ECT).

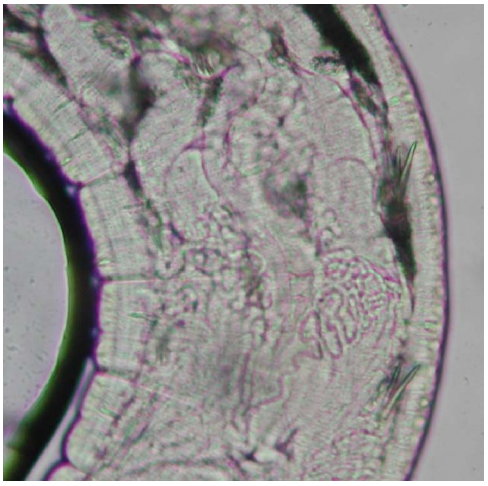

Fig. 3. Oesophageal appendage of *Enchytraeus* sp. (©C. Pelosi, INRA).

Fig. 4. Lateral view of the head of *Enchytraeus albidus*, with coloured internal structures (©J. Römbke, ECT).

and processes that influence the fate of soil organic matter and pollutants (Förster et al., 1995). In temperate grasslands, 90% of the soil organic matter is processed by a few species of earthworms and enchytraeids (Davidson et al., 2002). Based on estimates of their feeding activity, it is known that enchytraeids ingest more than 2 kg m^{-2} $year^{-1}$ of mineral soil in agricultural fields (Van Vliet et al., 1995). These authors assumed that enchytraeids had "*a larger influence on soil structure in agricultural fields than in forested areas, in spite of lower population densities*".

Moreover, enchytraeids influence soil structure due to their burrowing activity, fecal pellet production and the mixing of mineral and organic soil particles. Thus, their feeding and burrowing behavior can improve air permeability, hydraulic conductivity, pore volume, and aggregate stability (Didden, 1990; van Vliet et al., 1993; Linden et al., 1994). In Brussaard et al. (2012), enchytraeids are cited among the major soil invertebrate engineer groups, along with termites, ants, and earthworms. These authors also explained that "*enchytraeids could be considered as ecosystem engineers of the organic layers, whereas earthworms play an essential role in structuring the organo-mineral layers*".

Finally, Oldenburg et al. (2008) highlighted that detritivorous earthworm species promote the disappearance of both *Fusarium* plant pathogens and the mycotoxin deoxynivalenol from plant residues, thus reducing the risk for cultivated crops being infected by *Fusarium* and preventing the soil system from being contaminated by the mycotoxin deoxynivalenol. This biological form of control has not been thoroughly studied yet for enchytraeids, but being microbivores (Dash and Cragg, 1972), they were found to influence soil-borne pathogens affecting plants and humans. Indeed, Friberg et al. (2009) highlighted that enchytraeids modified microorganism communities and in particular the development of pathogens. The physical (i.e., incorporation of surface residues into the soil) and chemical (i.e., digestion) actions displayed by soil *Oligochaeta* (enchytraeids and earthworms) might explain this influence. This is especially true in the context of conservation agriculture, i.e., permanent soil cover without tillage, where plant residues remain on the soil surface for soil protection purposes. These residues are reactors of pathogens that may endanger the following crop.

3. Land use and management

The literature review was carried out on the basis of keywords in the ISI Web of Knowledge, using the "All Databases" option, with the following formula: 'enchytr* or potworm* in Topics'. About 1700 references were obtained from which we selected the articles dealing with the effects of anthropic activities and in particular land use and management on enchytraeids.

The authors studying enchytraeids under different land use and management often assessed several bioindicators in the same study and were mainly interested in forest areas, grasslands and arable fields (in