

First record of terrestrial Enchytraeidae (Annelida: Clitellata) in Versailles palace's park, France

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Abstract. France can be qualified as *terra incognita* regarding terrestrial enchytraeids because very little data has been recorded so far in this country. In spring and autumn 2016, enchytraeid communities were investigated in a loamy soil in a meadow located in the park of Versailles palace, France. In total, twenty four enchytraeid species were identified, belonging to six different genera i.e. eleven *Fridericia* species, four *Enchytraeus* species, four *Achaeta* species, two *Buchholzia* species, two *Marionina* species and one *Enchytronia* species. According to the published data, this was one of the highest diversity found in a meadow in Europe.

Keywords. Enchytraeids, Potworms, Soil fauna, Annelids, Oligochaeta, Meadow.

INTRODUCTION

Despite their key role in soils (Didden 1993), Enchytraeids (Annelida: Clitellata) are so far poorly studied in many countries worldwide. To our knowledge, and except a few species recorded in Schmelz & Collado (2010), no data have been published on enchytraeid communities in France, *i.e.*, based on a literature search in the ISI Web of Knowledge, using the “All Databases” option, with the formula: ‘(enchytr* or potworm*) and (France or French) in Topics’.

Although some studies assessed enchytraeid community structures in grasslands, meadows and pastures, studying the influence of grazing (Schlaghamerský *et al.* 2007), liming (Davidson *et al.* 2004), fertilization (Sokolowska & Seniczak 2005) or pesticides (Clements *et al.* 1987, Forsters *et al.* 1992, Martin 1975), most of them only reported a total abundance of enchytraeids (*e.g.* Clements *et al.* 1987, Francini *et al.* 2014, Van Vliet *et al.* 2006), without any details on species

diversity. Yet, several authors recommended identifying the individuals at least at the genus level and if possible at the species level (Pelosi & Römbke 2016). Indeed, indicators at the genus or species level appeared to be more sensitive to land use than total abundance. Moreover, taxonomic diversity provides key information on the requirements and sensitivity of the different species to environmental conditions, land use and management.

The objective of this study was to record the diversity of enchytraeids in a meadow in France and to compare it with other data in Europe.

MATERIAL AND METHODS

Study site

Samples were collected in a meadow (about 1 ha, Figure 1.) located in the park of Versailles palace, France (48°48'31''N, 2°05'26''E), which has not been cultivated since 1994. Before that time, it was conventionally cultivated with *e.g.*



Figure 1. Meadow located in the park of Versailles palace.

barley, oats, beans, corn and wheat. The climate is oceanic temperate, with a mean annual temperature of 11 °C and a mean annual rainfall of 660 mm. The soil is a deep Luvisol (FAO soil classification) developed on loess. The homogeneity of the physicochemical characteristics in the experimental site was verified by random sampling a soil core (0–20 cm depth) at seven different locations in the site (Table 1.).

Table 1. Physicochemical characteristics of the soil at the experimental site ($n = 7$, \pm Standard Deviation)

Parameters	Meadow soil
Texture (USDA, 1975)	Loamy soil
Clay (%)	22.9 ± 0.7
Silt (%)	48.0 ± 1.3
Sand (%)	29.1 ± 1.2
pH _{H2O}	7.5 ± 0.2
C _{org} (g kg ⁻¹)	18.9 ± 1.0
N _{tot} (g kg ⁻¹)	1.5 ± 0.1
C _{org} /N _{tot}	12.7 ± 0.3
P ₂ O ₅ (g kg ⁻¹)	0.08 ± 0.01
CaCO ₃ (g kg ⁻¹)	23.3 ± 8.1
Cu _{tot} (mg.kg ⁻¹)	25.2 ± 1.6

Sampling and identification

Ninety-six soil cores were sampled both in April and November 2016, following a regular grid of 60×40 m and using a split soil corer (diameter of 5 cm) at 0–5 cm and 5–10 cm depths. Each sample was transferred separately into a plastic bag and stored at 4°C. Enchytraeids were extracted using wet funnel extractors under a light from incandescent light bulbs. Soil samples were heated up for 3 hours (O'Connor 1959, Kobeticová & Schlaghamerský 2003). All the individuals were kept in Petri dishes in tap water and counted. Adult and sub-adult individuals were identified at the species level under a light microscope (Olympus BX53) up to 400× magnification according to the key of Schmelz and Collado (2010).

RESULTS

In total, twenty four species of enchytraeids were identified, belonging to 6 genera. Species are listed below, with available information on their presence in Europe, habitat and life strategy (based on Graefe & Schmelz 1999 and Schmelz & Collado 2010):

Achaeta bohemica (Vejdovský, 1879): widespread, fresh soils, absent in wet habitats, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Achaeta iberica Graefe, 1989: found in Spain, Italy (Schmelz and Collado 2000), and Switzerland (Amossé et al. 2016), only known from the original description.

Achaeta pannonica Graefe, 1989: widespread, fresh soils, absent in wet habitats, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Achaeta unibulba Graefe, Christensen & Dózsa-Farkas, 2005: widespread.

Buchholzia appendiculata (Buchholz, 1862): common and widespread in neutral to slightly acidic soils, *r/F* (fragmenting)-strategist, litter dweller.

Buchholzia fallax Michaelsen, 1887: widespread.

Enchytraeus buchholzi Vejdovský, 1879: widespread, very common, species complex, not in strongly acidic soils, *r*-strategist, OF (F-horizon dweller) and soil dweller.

Enchytraeus bulbosus Nielsen & Christensen, 1963: widespread, not in strongly acidic soils, *r*-strategist, OF and soil dweller.

Enchytraeus christenseni Dózsa-Farkas, 1992: widespread but not common, wet habitats, not in strongly acidic soils, *r*-strategist, OF and soil dweller.

Enchytraeus lacteus Nielsen & Christensen, 1961: widespread, not in strongly acidic soils, *r*-strategist, OF and soil dweller.

Enchytronia parva Nielsen & Christensen, 1959: common and widespread in neutral to moderately acidic soils, probably a species complex, soil dweller, stress tolerant species adapted to acidity stress.

Fridericia bulboides Nielsen & Christensen, 1959: widespread and common, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller

Fridericia christeri Rota & Healy, 1999: Northern half of Europe, very common in Germany.

Fridericia galba (Hoffmeister, 1843): widespread and very common in Central Europe, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Fridericia isseli Rota, 1994: widespread and common.

Fridericia maculata Issel, 1905: widespread, probably a species complex, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Fridericia nix Rota, 1995: Italy, Germany.

Fridericia paroniana Issel, 1904: widespread and common, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Fridericia tuberosa Rota, 1995: moist soil, widespread.

Fridericia ulrikae Rota & Healy, 1999: Northern and Central Europe.

Fridericia viridula Issel, 1904: found in Ireland, The Netherlands, and Italy.

Fridericia glandifera Friend, 1911: few records in England, Denmark, Germany and France.

Marionina argentea (Michaelsen, 1889): very common and widespread, wet sites also aquatic, slightly salt-tolerant, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, soil dweller.

Marionina communis Nielsen & Christensen, 1959: widespread, fresh soils but not wet, slightly acid to slightly alkaline conditions, never in strongly acid soils, *K*-strategist, OF dweller.

A total of 5 633 and 3 390 individuals were identified in Spring 2016 and in Autumn 2016, respectively. The number of individuals and the percentage of enchytraeid species are presented in Table 2. In Spring, the three most abundant species were *E. buchholzi* (23,6 %), *F. galba* (14,4 %), and *F. isseli* (13,2 %). In autumn, the three most abundant species were *En. parva* (12,7%), *F. christeri* (12,2 %), and *E. buchholzi* (11,8 %).

DISCUSSION

This study, in which twenty four species were found, represents the first record of enchytraeid's community in France. Schmelz & Collado (2010) reported only four to five species identified in France: *Guaranidrilus europaeus* Healy, 1979; *Enchytraeus varithecatus* Bouguenec & Giani, 1987; *Enchytraeus doerjesi* Westheide & Graefe, 1992; *Fridericia glandifera* Friend, 1911 and *Fridericia stephensi* Moszyński, 1933 (need to be confirmed). A bit more than 200 species are listed in the key for terrestrial enchytraeids of Europe (Schmelz & Collado 2010). Among them, 126 have been sampled in Germany (Römbke *et al.* 2013), and 50 of them can be classified as common for Central Europe (Didden *et al.* 1997).

Table 2. Enchytraeid density (ind.m⁻²) per species and per season (Spring and Autumn 2016). Nomenclature follows Schmelz & Collado (2010).

Genus	Species	Spring 2016		Autumn 2016	
		No. of individuals	% abundance	No. of individuals	% abundance
<i>Achaeta</i>	<i>bohemica</i>	0	0.00	20	0.59
<i>Achaeta</i>	<i>iberica</i>	311	5.52	186	5.49
<i>Achaeta</i>	<i>pannonica</i>	12	0.21	34	1.00
<i>Achaeta</i>	<i>unibulba</i>	13	0.23	28	0.83
<i>Buchholzia</i>	<i>appendiculata</i>	238	4.23	120	3.54
<i>Buchholzia</i>	<i>fallax</i>	27	0.48	9	0.27
<i>Enchytraeus</i>	<i>buchholzi</i>	1330	23.61	399	11.77
<i>Enchytraeus</i>	<i>bulbosus</i>	97	1.72	29	0.86
<i>Enchytraeus</i>	<i>christensenii</i>	32	0.57	0	0.00
<i>Enchytraeus</i>	<i>lacteus</i>	2	0.04	0	0.00
<i>Enchytronia</i>	<i>parva</i>	441	7.83	432	12.74
<i>Fridericia</i>	<i>bulboides</i>	0	0.00	31	0.91
<i>Fridericia</i>	<i>christeri</i>	426	7.56	412	12.15
<i>Fridericia</i>	<i>galba</i>	813	14.43	397	11.71
<i>Fridericia</i>	<i>glandifera</i>	0	0.00	2	0.06
<i>Fridericia</i>	<i>isseli</i>	745	13.23	386	11.39
<i>Fridericia</i>	<i>maculata</i>	10	0.18	55	1.62
<i>Fridericia</i>	<i>nix</i>	17	0.30	30	0.88
<i>Fridericia</i>	<i>paroniana</i>	319	5.66	320	9.44
<i>Fridericia</i>	<i>tuberosa</i>	254	4.51	270	7.96
<i>Fridericia</i>	<i>ulrikae</i>	152	2.70	102	3.01
<i>Fridericia</i>	<i>viridula</i>	62	1.1	23	0.68
<i>Marionina</i>	<i>argentea</i>	244	4.33	37	1.09
<i>Marionina</i>	<i>communis</i>	3	0.05	4	0.12
	NI	85	1.51	64	1.89
	Total	5633	100 %	3390	100 %

When looking at the published literature on enchytraeid communities in grasslands, meadows and pastures, only forty publications could be found. Among them, some were performed under tropical climates, in Brazil (e.g. Schmelz *et al.* 2008). Schlaghámerský & Kobetičová (2005) studied Enchytraeidae, Tubificidae, Aeolosomatidae in a field experiment in the Czech Republic during meadow restoration on arable land and in a well-preserved meadow nearby. They found 22 species of Enchytraeidae in the meadow and considered it as a relatively high diversity. The

same authors also studied two sites in the White Carpathians (Czechia) at four dates during one year (Schlagámerský & Kobetičová 2006). Each site consisted of one meadow and one cattle pasture. They found respectively 16 and 17 enchytraeid species in the two meadows. The high percentages of *Fridericia* spp. in all plots were considered to correspond with their rather low soil acidity. In the present study, despite the neutral pH, we also found many *Fridericia* individuals and eleven out of twenty four species belonged to this genus. To our knowledge, the highest

diversity reported in a meadow was 23 species (Schlaghamerský *et al.* 2007) in White Carpathians (Czechia), with twelve *Fridericia* species. The diversity found in our study was close to these results and thirteen species were in common. Some species such as *F. galba*, *E. buchholzi* or *M. argentea* appeared to be relatively well represented in the different meadows of the published studies. Contrarily, some others, such as *F. christeri* are more rarely found.

Regarding enchytraeid species distribution in European countries and soil characteristics (pH, soil water and C_{org} contents), the species found in our study are in accordance with the observations of Schmelz & Collado (2010) and Graefe & Schmelz (1999). We found horizontal heterogeneity in the meadow concerning the occurrence of the different species of enchytraeids. This was probably due to the variations in soil properties in the plot (*e.g.* soil moisture, temperature, vegetation). For example, numerous *M. argentea* were found in few soil cores and absent in others. This could be mainly explained by wetter soil conditions in one part of the plot. By contrast, species such as *F. galba*, *F. isseli*, *F. christeri*, *E. buchholzi* or *En. parva* were observed in most of soil samples. Few species were mainly found in the soil layer at 5–10 cm depth such as *Achaeta spp.* or *F. nix*. Those observations confirm Graefe & Schmelz study (1999) as they indicated that *A. bohemica* and *A. pannonica* are known to be soil dwellers. However, no information was found about *F. nix* habitat requirements.

We found a total of five *r*-strategists (*Enchytraeus spp.* and *B. appendiculata*) including one fragmenting species (*B. appendiculata*) among the sampled species. We also observed numerous specimens of *Buchholzia sp.* with two chaetae, which is unusual except for very young specimens just hatched from cocoons and not “born” by fragmentation (Schmelz pers. observ.). DNA test will confirm if a new species of *Buchholzia* has been found.

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