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Ecomorphological Groups of Earthworms Found in a Beech Wood in the Bieszczady National Park (South-Eastern Poland)

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ABSTRACT

Earthworms play an important role in the soil quality, including forest soils. Their presence in zooedaphone, as well as their abundance and species diversity, indicate the state of the soil profile. The species diversity of the representatives of this group of macrofauna in a beech forest in the Bieszczady Mountains is recounted in this article. Earthworms were investigated in the soil of four sites selected near Ustrzyki Górne in Carpathian Dentario glandulosae – Fagetum beech woods within the Bieszczady National Park (sites in D. g. *Fagetum festucetosum*, – typicum, – lunarietosum and – allietosum), every month during the annual cycle during two periods: a/ in 1986–1987 and b/ in 2009–2010. It was done according to the Zicsi's recommendations, using the Zajonc combinated method, on each site, six 25×25×20 cm samples were extracted. The soil was divided into two layers (0–10 cm and 10–20 cm) and the earthworms were selected manually from them. From deeper layers, they were driven out with a weak (0.4%) formalin solution. In the 1980s, thirteen earthworm species were found (total of 1805 specimens) in the soil of four sites investigated. In a decreasing order of numbers there were: *Dendrobaena alpina alpina* (Rosa 1984), *Allolobophora cernosvitoviana* (Zicsi 1967), *Aporectodea rosea rosea* (Sav.,1826), *Aporectodea caliginosa* (Sav., 1826), *Lumbricus terrestris L*., 1758, *Octolasium lacteum* (Orley,1881), *Allolobophora carpathica* (Cog., 1927), *Fitzingeria platyura montana* (Cer., 1932), *Octodrilus transpadanus* (Rosa, 1884), *Dendrobaena octaedra* (Sav., 1826), *Eisenia lucens* (Waga, 1857), *Lumbricus rubellus* (Hoffm., 1843), *Dendrodrilus rubidus tenuis* (Eisen, 1874). Twenty years later, in the years 2009–2010, eleven earthworm species were found in the soil of the same four sites investigated (total of 660 specimens). There was no occurrence of *L. rubellus*, and *O. transpadanus*. For all the cited species, the vertical distribution dynamics in an annual cycle was investigated as well as the preferred soil layer in terms of soil profile. The features of the afore-mentioned earthworm species and the soil levels they prefer allowed their affiliation with the ecological groups defined by Bouche to be considered or determined. The knowledge on the association of earthworms to ecomorphological groups in natural or a slightly changed ecosystem is becoming very useful, for example at the time of the reclamation of degraded soils with *Lumbricidae* as bioindicators.

Keywords: earthworms, beech wood, forest, ecomorphological groups

INTRODUCTION

The *Lumbricidae* family includes about 3000 species [Sims and Gerard 1999], most commonly occurring in Europe and North America. In Poland, nearly 40 species have been observed [Kasprzak 1986, Kostecka and Rożen 1988].

The earthworms are the macrofauna of the soil, comprising 70% of its biomass. They are decisive to many processes occurring in this ecosystem. They are mainly detritivores; their food is the detritus occurring in various forms at different soil levels.

They can belong to one of two ecomorphological categories (Perel, 1977):

- *detritivores*, feeding on the soil surface or near-surface – mainly on vegetation detritus, dead roots or e.g. animal feces.
- *geophages*, feeding at deeper levels, eating large amounts of soil, usually choosing the fragments containing the highest amounts of organic matter.

The detritivores can be defined as the group that generates humus and the geophages as humus consumers.

Earthworms inhabit the soil at different levels. These aspects were observed in French earthworms by Bouche (1972, 1977), and in Australian earthworms by Lee (1985). Bouche differentiates three main ecomorphological groups:

a. *Epigees* – litter dwellers

They live above the mineral layer of the soil, spending their life in the litter. They are very poor diggers; therefore, when they have to move to deeper soil layers (e.g. because of hostile environmental conditions) they rather use the existing spaces left by roots or other earthworm tunnels.

Within this group, Bouche qualifies the earthworms that feed exclusively on litter as *stramini-coles*. The species living under tree bark and feeding on decomposing phloem were qualified as *corticoles*. *Pholeophiles* – a group of earthworms found in the cracks and crevices of trees above the soil level. *Detritiphages* are found in seasonal accumulations of organic matter (animal feces or waste piles). *Coprophages* are the earthworms living in animal feces.

b. *Endogees* – the earthworms digging horizontally

They dig rather shallow corridors in the mineral soil. The corridors are ramified and earthworm excrements can be found on their walls. The earthworms belonging to this group feed on organic matter mixed with the soil.

c. *Aneciques* – deep diggers

These species can live very deep and feed on soil more or less rich in organic compounds. They deposit their excrements on the soil surface in nodular piles. They are very sensitive to vibration (e.g. caused by digging) and hide very quickly in their corridors. One of the methods to investigate them is to drive them out by using a weak formalin solution, which is a skin irritant for earthworms.

Bouche delineates: *hypoendogees*, typical deep-digging earthworms, and *epiendogees*, living closer to the surface and competing with the *epigees*. This especially applies to the ones feeding on dead plant roots. In the terminology proposed by Lee (1985) the three above-listed Bouche groups correspond to the following division: a. litter dwellers, b. topsoil species, c. subsoil species. The investigators of earthworms in Europe accepted the terminology proposed by Bouche, and this same terminology is used in the present paper.

MATERIAL AND METHODS

Earthworms were investigated in the soil of four sites selected near Ustrzyki Górne in the West Bieszczady Mountains, according to the Zicsi's recommendations (1962), using the Zajonc combined method (1970). On each site, six 25×25×20 cm samples were extracted. The soil was divided into two layers, 0–10 cm and 10–20 cm. The earthworms were selected manually. The earthworms from the deeper layers were driven out with a weak (0.4%) formalin solution. The sites were selected within the fertile beech woods dominating the forest communities of the Bieszczady Mts (Zarzycki, 1963). The sites have been described in Kostecka and Skoczeñ (1993). The sites differed in their phytosociological features, in strict association with habitat factors: humidity, pH and the degree of soil decay as well as the microclimatic conditions.

Site I was selected in *Dentario glandulosae -Fagetum festucetosum drymejae* community, site II in *D.g. Fagetum typicum*, site III in *D. g Fagetum lunarietosum*, and site IV in *D. g*. *Fagetum allietosum* .

The samples from each site were taken each month in the July-November 1986 and May-November 1987 and by four times (spring, summer and autumn) in 2009 and 2010. The earthworms were identified by the Kasprzak key (1986); the updated species names were taken from Easton (1983).

RESULTS AND DISCUSION

In total, 13 earthworms species were found at the investigated sites (a total of 1,805 specimens in 1986-1987, and 660 specimens in years 2009 and 2010). In a decreasing order of numbers, there were *Dendrobaena alpina alpina (Rosa, 1984), Allolobophora cernosvitoviana (Zicsi, 1967), Aporectodea rosea rosea (Sav., 1826), Aporectodea caliginosa (Sav., 1826), Lumbricus terrestris L., 1758, Octolasium lacteum (Orley, 1881), Allolobophora carpathica Cog., 1927, Fitzingeria platyuira montana (Cer., 1932), Octodrillus transpadanus (Rosa, 1884), Dendrobaena octaedra (Savigny, 1826), Eisenia lucens (Waga, 1857), Lumbricus rubellus Hoffm., 1843, Dendrodilus rubidus tenuis* and *(Eisen, 1874)*.

The preferred soil layer for the cited species in terms of the soil profile was investigated, by determining the presence in a characteris-

tic part of the soil profile throughout the entire study period (in %).

Affiliation of the observed earthworm species with ecological groups

The features of the delineated earthworm species and the soil levels they prefer allowed their affiliation with the ecological groups defined by Bouche (1972) to be confirmed or determined.

Epigees (litter dwellers) in *Fagetum carpaticum*:
Dendrodrilus rubidus tenuis
Dendrobaena octaedra

D. rubidus tenuis was found in the 0-10 cm layer in 100% of the specimens found throughout the study cycle. A similarly high percentage of occurrence in this layer was found in *D. octaedra* (96.6% of the numbers of specimens and 95.5% of their biomass). Both of the above-mentioned species occur in the litter layer all year long, regardless of the environmental conditions, never moving deeper down in the soil (Fig. 1).

Lumbricus rubellus
Eisenia lucens

The studies confirmed other authors' results concerning *L. rubellus* (Römbke, 1987; Rożen, 1980; Rundgren, 1975). According to their data, this earthworm species lives in the humus layer at a depth of about 8 cm, but in stress situations, e.g. low temperature or humidity, it can even be found at 50 cm under the soil surface. Out of the specimens observed in *F. carpaticum*, 76.5% (71.5% biomass) lived in the 0–10 cm layer. 17.6% of the specimens (17.7% of biomass) were found in the 10-20 cm layer. 5.9% (10.8% of biomass) were driven out from the layer below 20 cm (Fig. 2).

The endemic *E. lucens* is similarly a transitory species. It lives under tree bark and in decaying fallen trunks. This is confirmed by the observations of Plisko (1973), Kasprzak (1986) and Zajonc (1986), and also by the observations of the authors. *E. lucens* can be found under bark during the warm months. The studies also allow the structure of the vertical distribution of this species in the soil to be completed. It was found there mainly in autumn, when 85% of the specimens were observed in the 0–10 cm layer. However, it also occurred in the 10–20 cm layer and below. It can be stated that stress situations make this species move deeper down in the soil (preparation for the winter) (Fig. 2).

Endogees (upper soil dwellers)
Aporectodea caliginosa
Aporectodea rosea
Octolasium lacteum
Dendrobaena alpina
Allolobophora cernosvitoviana

The observations confirmed other authors' data concerning the first four species (Bouche, 1972; Rożen, 1980; Rundgren, 1975; Zajonc, 1970); 70% of the specimens were observed in the shallow, 0-10 cm soil layer (*A. rosea* 84.3%,

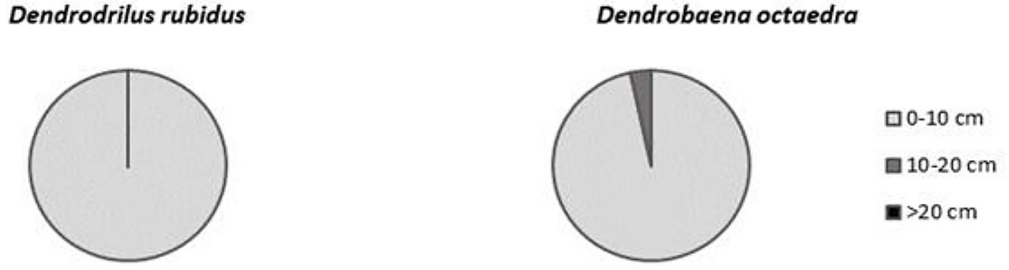

Fig. 1. Percentage of specimens found in different soil layers – *Epigees* (by species)

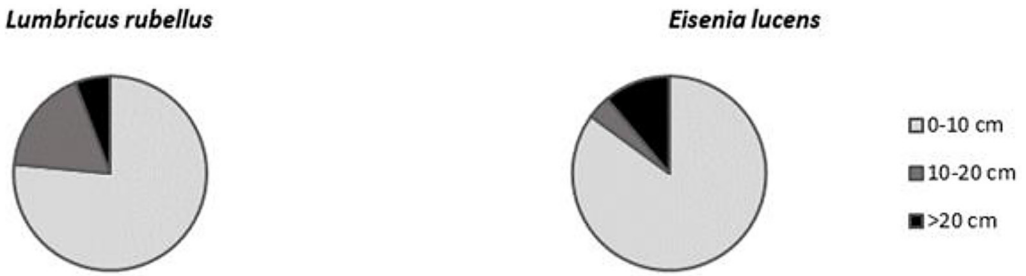

Fig. 2. Percentage of specimens found in different soil layers – *intermediate species* (by species)

D. alpina 76.9%, *O. lacteum* 75.5% and *A. caliginosa* 71.8%). These species also occurred during the study period in the other soil layers.

D. alpina present at all the sites, is a very mobile species, with an efficient muscular system. Large specimens are able to escape by jumping to a height of a few centimeters, as often observed. The Polish earthworm identification keys (Plisko, 1973; Kasprzak, 1986) assume that this species occurs in litter and under the bark of decaying trees; the results of the present study suggest that this view is not accurate. This earthworm was observed all year, also in deeper soil layers. It was found in the 0-10 cm layer (68.7% of the specimen numbers). It also occurred rather frequently (28.3%) in the 10–20 cm layer, but below 20 cm it reached only 3% of the specimens at all the studied sites.

The faunistic and morphological data concerning *Allolobophora cernosvitoviana* are available in the literature (Zicsi, 1967 and 1968; Perel, 1979). The size of this earthworm, the general features of the genus *Allolobophora* genus and the observations made warrant the classification of this species in the above-mentioned ecomorphological group. This earthworm was observed in the 0–10 cm layer (68.7% specimens, 63.1% biomass). It also occurred in the 10–20 cm layer (28.3%), but in all the subgroups of *F. carpaticum* only 3% of the specimens were found in the layer below 20 cm (Fig. 3).

Aneciques (deep diggers):
Allolobophora carpathica
Octodrilus transpadanus
Lumbricus terrestris
Fitzingeria platyura montana

A. carpathica was most commonly observed in the 0-10 cm soil layer (60.5% specimens, 54.2% biomass). It was less numerous in the 10-20 cm layer (19.3%). This earthworm dug deeper corridors; 20.2% of the specimens (35.4% biomass) were found in the layer below 20 cm. The description of this species in the Polish identification keys (Plisko, 1973; Kasprzak, 1986) states that this earthworm lives in the surface layers of the soil, in litter, under stones and tree trunks. The author rather suggests that this large species is able to dig deeper corridors. The high percentage of specimens driven from the soil layers below 20 cm during the whole vegetation period, and especially their high biomass, suggests classification of *A. carpathica* in this ecological group.

O. transpadanus is a medium-sized earthworm. According to Plisko (1973) and Kasprzak (1986), it lives in the upper soil layers, in the organic detritus deposited by stream waters. This fact was confirmed by the present studies. *O. transpadanus* occurred only at site IV. Each spring, the streams that flow from Rozsypaniec, carrying the snowmelt water and large amounts of organic matter, cross this area. However, the studies showed that this species inhabits deeper soil levels, which confirms the observations of Zajonc (1970); 57.8% of the specimens (39.8% biomass) of *O. transpadanus* were observed in the 0–10 cm layer in the D. g. *Fagetum* beech wood, but 31.1% of the specimens (49.45% biomass) were driven from the layer below 20 cm.

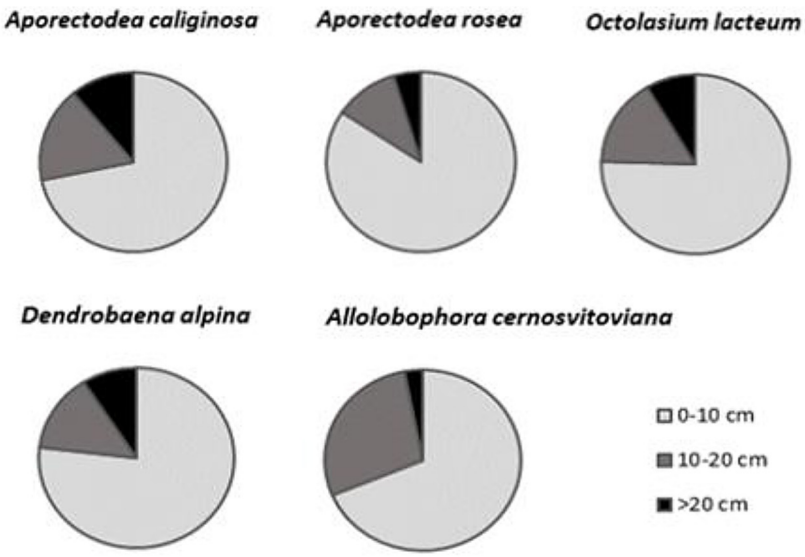

Fig. 3. Percentage of specimens found in different soil layers – *Endogees* (by species)

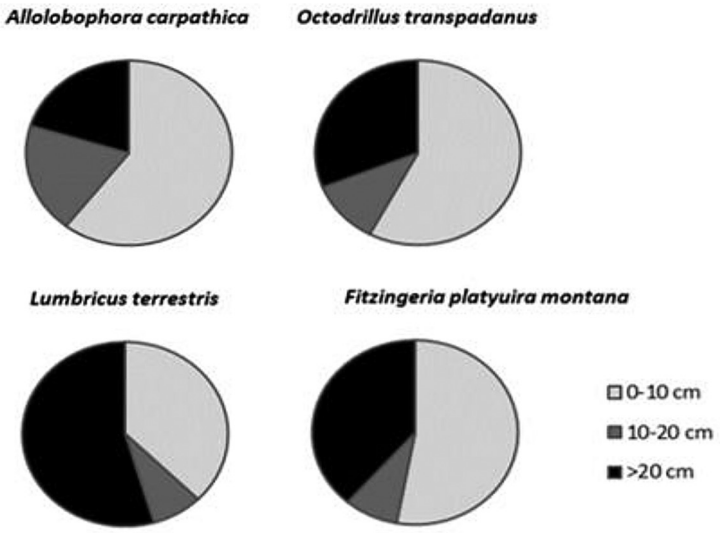

Fig. 4. Percentage of specimens found in different soil layers – *Aneciques* (by species)

L. terrestris and *F. platyura montana* are very large earthworms. According to many authors they are able to dig deep corridors. In both species, the highest percents of specimens were driven from the layer below 20 cm (*L. terrestris* – 54.5% specimens, 74.8% biomass; *F. platyura* – 38.6% specimens, 48.8% biomass).

Very small numbers of specimens were observed in the 10-20 cm layer. 37.5% of the *L. terrestris* specimens (16.2% biomass) and 52.9% of the *F. platyura* specimens (36.2% biomass) were found in the 0–10 cm layer. This can stand as a confirmation of the data on their soil surface feeding (Fig. 4).

Earthworms play an important role in the soil quality, including forest soils. Their presence in zooedaphone, as well as their abundance and species diversity, indicate the state of the soil profile. The knowledge on the association of earthworms to ecomorphological groups in natural or slightly changed ecosystems is becoming very useful, for example at the time of the reclamation of degraded soils with Lumbricidae as bioindicators.

In the European Union countries, mainly in Germany and the Netherlands, long-term biomonitoring of soil quality is used based on the number and species composition of earthworms [Rutgers et al. 2009]. Römbke et al. [2005] prepared soil parameters lists to which one can assign "real" or "probable" occurrence of the most popular species from particular morphological groups of earthworms in Central Europe.

The analysis of the earthworm populations in degraded areas allows to assay the progress of the reclamation processes. The state of reclamation involving Lumbricidae analysis was, among others, taken into consideration in the degraded areas of the Machów S.A sulfur mine in Jeziórko (Podkarpackie province, Grębów commune) [Kostecka et al. 2004, Mazur-Pączka et al. 2017].

In the area of the longest reclaimed field II (reclamation in the forest direction, completed in 1992) earthworms represented three morpho-ecological categories: epigees, endogees and deeply digging earthworms were found. This shows the full soil profile of this position. At site X (reclamation in the years 1995–1997, in the forest direction of the forest) on the successful succession of species from the group of deep diggers was still too early, so only the representatives of epigees and endogees occurred.

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