

Lumbricidae Biodiversity at the Sites in Bieszczady Mountains (Poland) After 25 Years

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ABSTRACT

Soil degradation is caused by geological, climatic and biological factors, as well as human activities. One kind of degradation involves loss of soil biodiversity as a result of global environmental changes. A study on earthworms was carried out near Ustrzyki Górne in the Bieszczady Mts (Poland), on a monthly basis, in 1986–1987 and 2009–2010 at various sites within the Carpathian beech forests (*Fagetum carpaticum*). During the years 1986–1987, a total of 13 species of earthworms were found: 6 species on site I, 8 species on site II, and 9 species were recorded within the site III. The highest abundance, i.e. 11 species was found on site IV. The study, which revisited the same locations in 2009–2010, identified only 10 species. In sites I, II and III, 7 earthworm species were found in each, and in site IV – 10 species. The authors also investigated the factors endangering the fauna of earthworms in the Bieszczady Mountains, and following the example set by other countries which had made attempts to introduce earthworms into the red lists of the threatened species, it was proposed that such a procedure should be adopted for the endemic species *O. transpadanus*. It was also observed that specimens of *L. terrestris* had penetrated the natural areas of the National Park.

Keywords: earthworms, biodiversity, Carpathian beech forest (*Fagetum carpaticum*)

INTRODUCTION

Biological diversity is the foundation of ecosystem services. Despite various conservation oriented efforts, biological diversity is decreasing both at the level of species and habitats [Benayas, Bullock 2012]. Because of their specific lifestyle, Lumbricidae play a key role in the soil environment as “the ecosystem engineers”. They participate in all the categories of services provided by ecosystems. They are involved in developing soil structure, in circulation of nutrients, primary production, climate regulation, reduction of pollution, and culture-related services; they are a source of nutritious food for animals and, in some cultures, for people [Blouin et al. 2013]. The factors linked with geology, climate and biology, as well as human operations based on excessive exploitation lead to soil environment degradation. In recent years, it has also been pointed

out that due to a decreased biological diversity of soil fauna, these resources are also at risk.

The study was designed to compare the biological diversity of Lumbricidae within the subunits of Carpathian beech forests (*Fagetum carpaticum*), varied in terms of phytosociology, and located in the Western Bieszczady (Poland) after 25 years.

MATERIAL AND METHODS

The study was carried out in the Western Bieszczady (Poland) near the village of Ustrzyki Górne in 1986–1987 and 2009–2010 in four phytosociologically varied locations within the Carpathian forest (*Fagetum carpaticum*): I – *F. c. festucetosum drymejae*, II – *F. c. typicum*, III – *F. c. lunarietosum*, IV – *F. c. allietosum* (Fig. 1).

On each occasion, soil temperature and moisture were also measured in the examined locations

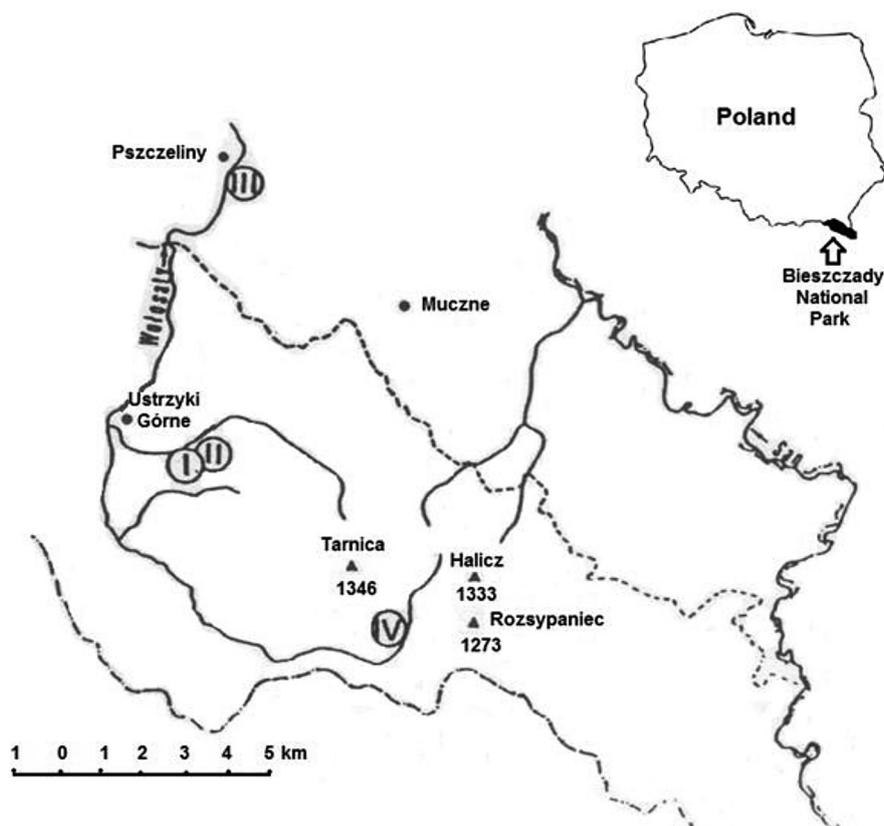


Figure 1. The examined sites within *F. carpaticum* near Ustrzyki Górne, Poland

at the depth of 0–10 cm and below this level. Soil moisture was determined with drying method at 105°C [Mocek et al. 2000]. For this purpose, three soil samples were collected at the relevant sites, from the layer up to 10 cm and below 10 cm.

Moreover, at each location, soil samples were collected once in order to examine the pH at 1 mol · dm⁻³ KCl (potentiometer method), organic carbon (using Tiurin's method), contents of available forms of phosphorus and potassium (Egner-Riehm method) and magnesium (Schachtschabel method) [Mocek et al. 2000] (Table 1).

At each investigated site, eight samples of soil (0.25×0.25 m, 0.25 m depth) were taken and examined by hand sorting. From the deeper layers, earthworms were expelled using weak formalin solution (0.4%) [Zajonc 1970, EN ISO 23611-1:2006]. The extracted specimens were purified from soil and mucus residues and bathed in water for 15 minutes. They were put down by submerging in 30% ethyl alcohol, and then transferred to preservation solution (4% formalin). After 24 hours, formalin was replaced with new solution. The collected specimens stored this way were identified and weighed in the course of a few days.

The obtained data are presented as means ± standard deviation (SD). The findings were subjected to statistical analyses using STATISTICA ver. 10 software, with Student's t-test.

RESULTS

During the study of Lumbricidae in 1986–1987 and after 25 years in 2009–2010, the identified earthworms belonging to 3 eco-morphological groups were found (Table 2).

During the years 1986–1987, the total of 13 species of earthworms were found: 6 species at Site I, 8 species at Site II, and 9 species were recorded within Site III. The highest abundance, i.e. 11 species was found on site IV. The study, which revisited the same locations in 2009–2010, identified only 11 species (Table 2). Sites I, II and III, each, were found with 7 earthworm species were found in each, and in site IV – with 10 species.

In 1986–1987 the number of earthworms identified at Site I amounted to 19 ± 9 ind. · m⁻², at Site II there were 147 ± 52 ind. · m⁻², Site III was found with 140 ± 63 ind. · m⁻² and Site IV with 110

Table 1. Characteristics of Lumbricidae sampling sites, in subunits of *Fagetum carpathicum* near the village of Ustrzyki Górne

Site	Location	Altitude m.a.s.l. [m]	Soil type	Soil properties	
				1986–1987	2009–2010
<i>F. c. festucetosum drymejae</i>	N 49°05'52,5" E 022°40'17,3"	740	podzolic typical, slightly sandy clay, skeletal	mean soil temperature: (0–10 cm) 8.9 ± 3.6 °C (10–20 cm) 8.7 ± 3.4 °C mean soil moisture: (0–0.10 cm) 36.9 ± 7.8 % (10–20 cm) 31.3 ± 4.4 % pH (KCl) 3.3 C org. 2.55% P/100 g d.m. 0.96 mg K/100 g d.m. 2.6 mg Mg/100 g d.m. 4.1 mg	mean soil temperature: (0–10 cm) 11.9 ± 2.8 °C (10–20 cm) 11.8 ± 2.7 °C mean soil moisture: (0–0.10 cm) 38.8 ± 5.4 % (10–20 cm) 38.9 ± 5.5 % pH (KCl) 3.1 C org. 2.43% P/100 g d.m. 0.86 mg K/100 g d.m. 2.7 mg Mg/100 g d.m. 3.8 mg
<i>F. c. typicum</i>	N 49°05'50,2" E 022°40'15,4"	750	brown eutrophic, medium loam, silty	mean soil temperature: (0–10 cm) 8.9 ± 3.5 °C, (10–20 cm) 8.7 ± 3.4 °C; mean soil moisture: (0–10 cm) 35.1 ± 3.9 %, (10–20 cm) 27.4 ± 3.3 %; pH (KCl) 4,1; C org. 1.86% P/100 g d.m. 0.7 mg; K/100 g d.m. 1.7 mg; Mg/100 g d.m. 8.0 mg	mean soil temperature: (0–10 cm) 11.7 ± 2.7 °C, (10–20 cm) 11.5 ± 2.4 °C; mean soil moisture: (0–10 cm) 40.6 ± 7.9 %, (10–20 cm) 39.4 ± 6.6 %; pH (KCl) 4,0; C org. 2.00% P/100 g d.m. 0.61 mg; K/100 g d.m. 1.7 mg; Mg/100 g d.m. 7.6 mg
<i>F. c. lunarietosum</i>	N 49°08'54" E 022°41'11"	650	brown eutrophic, heavy loam and ordinary loam, silty, skeletal	mean soil temperature: (0–10 cm) 9.7 ± 4.4 °C (10–20 cm) 9.5 ± 4.3 °C mean soil moisture: (0–10 cm) 34.3 ± 5.3 % (10–20 cm) 32.2 ± 8.8 % pH (KCl) 5.0 C org. 2.72% P/100 g d.m. 0.92 mg K/100 g d.m. 16.3 mg Mg/100 g d.m. 12.9 mg	mean soil temperature: (0–10 cm) 12.0 ± 2.8 °C (10–20 cm) 11.9 ± 3.2 °C mean soil moisture: (0–10 cm) 36.3 ± 4.9 % (10–20 cm) 36.6 ± 4.6 % pH (KCl) 5.0 C org. 2.43% P/100 g d.m. 0.92 mg K/100 g d.m. 16.4 mg Mg/100 g d.m. 12.6 mg
<i>F. c. allietosum</i>	N 49°03'24,5" E 022°45'44,3"	960	alluvial chernozem, silty loam, highly skeletal	mean soil temperature: (0–10 cm) 8.3 ± 3.6 °C (10–20 cm) 8.2 ± 3.6 °C mean soil moisture: (0–10 cm) 39.8 ± 6.7 % (10–20 cm) 33.6 ± 16.5 % pH (KCl) 4.8; C org. 4.53% P/100 g d.m. 1.61 mg K/100 g d.m. 13.3 mg Mg/100 g d.m. 13.9 mg	mean soil temperature: (0–10 cm) 11.1 ± 3.4 °C (10–20 cm) 11.1 ± 3.7 °C mean soil moisture: (0–10 cm) 37.8 ± 4.9 % (10–20 cm) 38.3 ± 6.0 % pH (KCl) 4.8 C org. 4.52% P/100 g d.m. 1.48 mg K/100 g d.m. 13.4 mg Mg/100 g d.m. 13.4 mg

± 59 ind.·m⁻². The study carried out at the same locations in 2009–2010 enabled to identify lower numbers of earthworms: I – 33 ± 9 ind.·m⁻²; II – 48 ± 11 ind.·m⁻²; at Site III – 42 ± 9 ind.·m⁻², and at the most fertile site 66 ± 12 ind.·m⁻² (Figure 2).

In the 1980s, the total earthworm biomass measured at Site I amounted to 11.49 ± 4.24 g·m⁻², Site II was found with 55.56 ± 25.20 g·m⁻², the total biomass observed at Site III was 88.95 ± 54.36 g·m⁻², and Site IV presented with 105.84 ± 45.76 g·m⁻² (Fig. 3). The study carried out 25 years later identified the following amounts: at Site I – 17.18 ± 4.55 g·m⁻²; II – total biomass of 25.88 ± 6.17 g·m⁻²; at Site III – 56 ± 4.74 g·m⁻², and at Site IV – 112.55 ± 28.34 g·m⁻² (Fig. 3).

DISCUSSION

The research carried out within natural Carpathian beech forests shows that there is a growing anthropogenic impact negatively affecting the biological diversity, including earthworms. A comparison of research findings acquired at present and in the 1980s may suggest a decrease in the diversity of earthworm communities in the course of twenty five years. The reasons for this, despite the statutory operations conducted in that period (the investigated sites I, II and IV are located within the Bieszczady National Park), may include the direct and/or indirect impacts caused by human activity in this area. Due to these, the

Table 2. Earthworm species identified in 1986–1987 and in 2009–2010 at the sites within *F. carpaticum* near Ustrzyki Górne, Poland

Species of earthworm		1986–1987	2009–2010
<i>Dendrodrilus rubidus tenuis</i> (Savigny 1826)	a	+	+
<i>Dendrobaena octaedra</i> (Savigny 1826)	a	+	+
<i>Lumbricus rubellus</i> (Hoffmeister 1843)	a	+	–
<i>Eisenia lucens</i> (Waga 1885)		+	+
<i>Octolasion lacteum</i> (Oerley 1881)	b	+	+
<i>Aporrectodea rosea rosea</i> (Savigny 1826)	b	+	+
<i>Aporrectodea caliginosa</i> (Savigny 1826)	b	+	+
<i>Dendrobaena alpina alpina</i> (Rosa 1884)	b	+	+
<i>Allolobophora cernovitoviana</i> (Zicsi 1967)	b	+	+
<i>Allolobophora carpatica</i> (Cognetti 1927)	c	+	+
<i>Octolasion transpadanus</i> (Rosa 1884)	c	+	–
<i>Lumbricus terrestris</i> (L. 1758)	c	+	+
<i>Fitzingeria platyura montana</i> (Fitzinger 1833)	c	+	+
Number of species		13	10

a – epigeic earthworms; b – endogeic earthworms, c – anecic earthworms

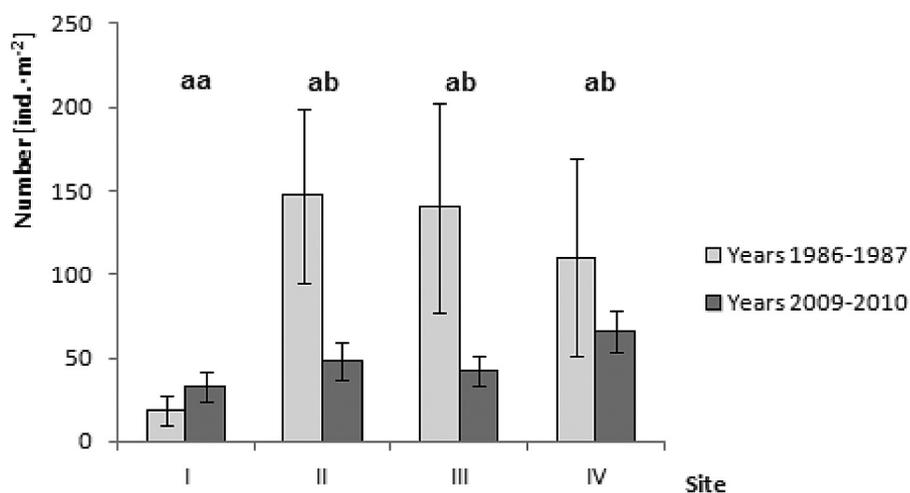


Figure 2. Number [ind.·m⁻²] of earthworms identified in 1986–1987 and in 2009–2010 at the sites within *F. carpaticum* near Ustrzyki Górne, Poland
aa – statistically insignificant differences $p > 0.05$; **ab** – statistically significant differences $p < 0.05$

most vulnerable species are directly in danger of extinction. It seems that one of such species is the large earthworm *O. transpadanus* (in 1986–1987 the mean number of 2.56 ± 0.4 ind.·m⁻², the mean biomass 3.12 ± 0.5 g·m⁻², the mean biomass individual 2.494 ± 0.529 g) which was not found during the study 25 years later.

The presence of *L. terrestris* in Ustrzyki Górne in *F. c. allietosum* is of particular notice, as the species was not found in the same location in the 1980s [Kostecka, Skoczeń 1993, Kostecka 1998]. It is considered to be a synanthropic species; hence, its presence may be an evidence of anthropogenization of the relevant location. Their increased distribution could be caused by birds

or mammals. Yet, it is also rather likely that they could have been spread by the transfer of cocoons e.g. caused by mountain tourism or conservation works carried out in this area by employees of the national park. (e.g. on wheels of machines).

The transformations of the natural environment into anthropogenic areas contribute to a decrease and loss of the original habitats of Lumbricidae. The loss of their natural living grounds as well as pollution of environment, including soil, results in decreased populations and eventually their extinction.

The differences in the number and biomass of earthworm species in the 1980s and at present are presumably linked with the different condi-

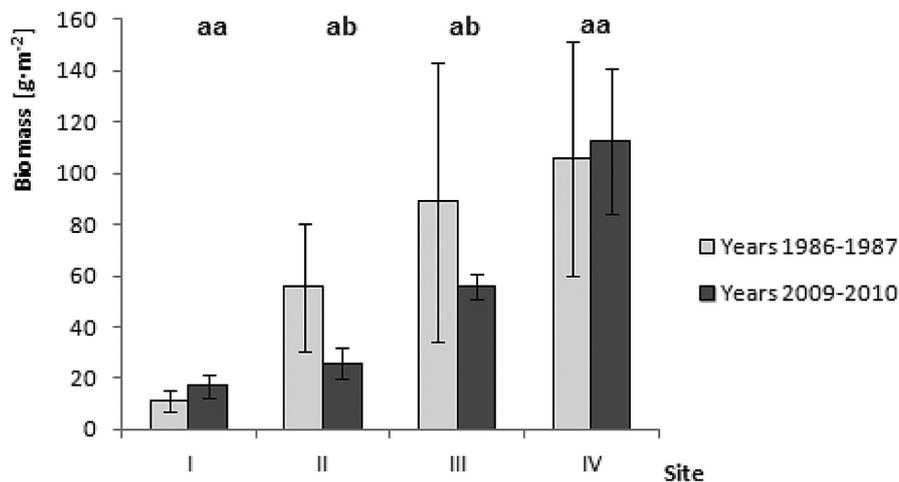


Figure 3. Biomass [$\text{g}\cdot\text{m}^{-2}$] of earthworms identified in 1986–1987 and in 2009–2010 at the sites within *F. carpaticum* near Ustrzyki Górne, Poland
aa –statistically insignificant differences $p > 0.05$; **ab** –statistically significant differences $p < 0.05$

tions, e.g. availability of nutrients in soil, as well as soil temperature and moisture, as these factors largely determine the distribution of earthworms. However, the condition of Lumbricidae colonies living in the relevant areas may also be of importance.

Anthropogenic impacts contribute to increased rates of earthworm species with a wide range of habitats and high adaptation capacities, at the expense of the species with narrow range of distribution. Stenotopic species have lower chances for colonizing new areas. Certain countries conduct monitoring of foreign species which may endanger and drive out the native earthworm species [Gonzalez et al. 2006, Hendrix 2006, Nuttinen, Butt 2009, Plisko 2010].

Increasing attention is paid worldwide to the earthworms protection, e.g. in the Balkan Peninsula a special Red List of endangered species was created for them, defining hazard categories according to International Union for Conservation of Nature and its Resources [Stojanović et al. 2008]. There have also been attempts to develop and update the maps showing their zoogeographical distribution [Carpenter et al. 2012].

In Poland, the classification of Lumbricidae species in compliance with European hazard categories is currently difficult or indeed impossible due to the lack of comprehensive information regarding the status of the specific species. Therefore, it seems that the acquisition of data related to the Lumbricidae populations in the areas which have not been investigated yet, and updating the existing data, is an urgent task.

It also seems that the red list created for the area of the Bieszczady should include the stenotopic species *O. transpadanus* which was not found during the study carried out in 2009–2010.

CONCLUSIONS

1. The studies described here contribute a lot of significant information. They may provide the basis for comparing the condition of Lumbricidae in the same locations over a long period of time.
2. The decade of biodiversity (announced for the period of 2011–2020) emphasizes mainly the organisms living above ground; therefore, it is necessary to educate the public about the importance of soil animals in maintaining soil fertility.

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