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DENSITY AND BIOMASS OF EARTHWORMS (LUMBRICIDAE) ON LEYS AND PERMANENT MEADOWS

ABSTRACT: Research involved three successional sequences on meadows in Suwałki Landscape Park (north-eastern Poland). 2–6 species of Lumbricidae were found on the different sites, with older meadows having a greater abundance and biomass of earthworms. The two dominant species were *Aporrectodea caliginosa* (Sav.) and *Lumbricus rubellus* Hoffm.

KEY WORDS: Lumbricidae, soil, meadows.

1. INTRODUCTION

The role of earthworms in the transformation of the soil habitat in meadow ecosystems is well-known, with several reviews and chapters in handbooks on soil biology having been devoted to the subject (Satchell 1958, 1967, Barley 1961, Edwards and Lofty 1977, Syers and Springett 1983, Lee 1985). The research done has most often concerned fertile natural meadows, pastures or fallow land. Little is however known to date about the communities of Lumbricidae of meadow grasslands used as a normal component of rotation in agriculture. It is therefore interesting to check on the changes to the species composition, abundance and role of earthworms in the course of development of the biocoenosis from the youngest stages through to permanent meadows.

2. STUDY AREA

Selected for study were nine meadows within Suwałki Landscape Park in north-eastern Poland (see Kajak 1997). This is a young glacial area of great geomorphological diversity. Meadows on the extensive plateaus or outwash plains are included in the normal rotation cycle. These are established by the sowing of a single species of grass (*Dactylis glomerata*) or a mixture of grass and clover. After several years of use they are returned to cultivation (Kajak 1997).

All of the meadows studied are included amongst fresh meadows of the order Arrhenatheratalia (Jankowski 1997). The substratum were fertile true brown soils formed from boulder clay sand. Depending on the meadow, the pH of the upper layer of the soil profile ranges from 5.8 to 6.4 (Kusińska and Łakomiec 1997).

The meadows studied are grouped in three successional sequences formed from 3 meadows differing in age: from most simplified ones on which *Dactylis glomerata* or timothy (*Phleum pratense*) are dominant, through 6–8-year-old meadows to multispecies permanent meadows of the *Anthylli-Trifolietum* type. Successive stages were identified by the letters LA – for the youngest, 1–2-year-old meadows; LB – for 3–5-year-old meadows; LC – for 6–8-year-old meadows and P – for permanent meadows. Work in 1989 involved successional sequence I (LA_1, LB_1, LC_1) and work in 1987, sequences II (LB_2, LC_2 and P_2) and III (LB_3, LC_3 and P_3). All the meadows were managed in the manner typical for this region, i.e. mainly with haymaking carried out twice, followed by the grazing of cattle or horses in the second half of the season.

3. METHODS

Samples were taken twice in the course of the season – at June and late September. This allowed for the capture of the spring and autumn maxima important in the dynamics of the occurrence of Lumbricidae.

Ten samples were taken each time at a site, using a metal frame of dimensions 0.3 × 0.3 m. Earthworms were obtained from the soil using the formalin method involving several rinses of the soil surface with a 0.3% formalin solution (Raw 1959). In the very stony soils of Suwałki Landscape Park this is the most effective and efficient method. The animals collected were preserved and then weighed to an accuracy of 1 mg with appropriate corrections made for the leaching effect of the preserving fluids.

4. RESULTS

4.1. SPECIES COMPOSITION

Depending on meadow type, 2–6 species of earthworm were found to occur in the studied sequences of meadows. The lowest species richness – only 2 species – was noted from the youngest meadow in sequence I (LA_1) (Table 1). The species in question were *Aporrectodea caliginosa* (Sav.) and *Dendrobaena octaedra* (Sav.). Older meadows of more diversified vegetation were characterized by the presence of a greater number of species ranging from 3 (on LB_1) to 6 on LB_2 and LC_3 (Table 1). No differences were noted in the lumbricid species composition of permanent mead-

Table 1. Abundance, biomass (mean ± S.D.) and percentage shares of different species of Lumbricidae in the soils of leys and permanent meadows

a. Successional sequence I

Species %	Site*					
	LA_1		LB_1		LC_1	
	indiv. m^{-2}	g m^{-2}	indiv. m^{-2}	g m^{-2}	indiv. m^{-2}	g m^{-2}
Aporrectodea caliginosa (Sav.)	24.1±4.1	10.3±2.4	38.9±7.0	14.9±2.8	59.9±14.6	23.8±6.5
%	98	98	53	55	52	54
Lumbricus rubellus Hoffm.	–	–	33.3±7.2	11.7±2.1	44.4±7.3	16.8±5.2
%			45	44	39	38
Dendrobaena octaedra (Sav.)	0.6±0.6	0.2±0.2	1.8±1.3	0.3±0.2	4.9±1.6	0.5±0.2
%	2	2	2	1	4	1
Octolasion lacteum (Oerley)	–	–	–	–	4.3±1.6	1.8±0.7
%					4	4
Lumbricus terrestris L.	–	–	–	–	0.6±0.6	1.5±1.5
%					1	3
Total	24.7±4.2	10.5±2.4	74.0±4.2	26.9±4.0	114.1±19.2	44.4±8.2
%	100	100	100	100	100	100

b. Successional sequence II

Species %	Site*					
	LB_2		LC_2		P_2	
	indiv. m^{-2}	g m^{-2}	indiv. m^{-2}	g m^{-2}	indiv. m^{-2}	g m^{-2}
Aporrectodea caliginosa (Sav.)	55.5±8.5	13.8±2.6	60.5±10.3	14.2±2.6	105.5±9.5	26.4±3.3
%	56	37	17	13	55	37
Lumbricus rubellus Hoffm.	27.8±8.5	14.9±4.4	224.7±13.8	85.8±6.8	66.6±8.7	35.6±7.2
%	28	40	63	75	35	49
Dendrobaena octaedra (Sav.)	3.7±1.8	0.5±0.2	19.1±4.9	2.1±0.5	2.2±1.3	0.1±0.1
%	4	1	5	2	1	<1
Octolasion lacteum (Oerley)	8.0±3.4	3.0±1.4	17.3±3.5	5.5±1.3	14.4±3.7	9.7±2.9
%	8	8	5	5	8	13
Aporrectodea rosea (Sav.)	2.5±1.4	0.3±0.2	35.2±9.5	6.3±1.7	1.6±1.2	0.3±0.2
%	3	1	10	5	1	<1
Lumbricus terrestris L.	1.2±0.8	5.0±3.5	–	–	–	–
%	1	13				
Total	98.7±15.7	37.5±6.5	356.8±24.3	113.9±9.8	190.3±18.6	72.1±10.5
%	100	100	100	100	100	100

c. Successional sequence III

Species %	Site* LB$_3$ indiv. m^{-2}	LB$_3$ g m^{-2}	LC$_3$ indiv. m^{-2}	LC$_3$ g m^{-2}	P$_3$ indiv. m^{-2}	P$_3$ g m^{-2}
Aporrectodea caliginosa (Sav.)	117.7±22.3	40.3±7.9	22.8±4.2	7.2±1.8	50.0±9.4	16.9±4.24
%	42	46	10	9	20	19
Lumbricus rubellus Hoffm.	121.0±26.5	40.3±8.1	179.6±22.4	64.4±6.1	135.4±19.5	42.2±4.8
%	43	46	75	80	54	47
Dendrobaena octaedra (Sav.)	35.8±8.3	4.2±0.9	21.6±5.5	1.9±0.4	0.7±0.7	0.1±0.1
%	13	5	9	2	<1	<1
Octolasion lacteum (Oerley)	3.7±2.0	2.4±1.8	12.3±3.5	4.6±1.4	64.5±8.0	30.4±5.3
%	1	3	5	6	26	34
Aporrectodea rosea (Sav.)	1.8±1.0	0.3±0.1	3.7±1.2	0.4±0.1	1.3±1.4	0.1±0.1
%	1	<1	1	<1	<1	<1
Lumbricus terrestris L.	–	–	0.6±0.6	2.3±2.3	–	–
%			<1	3		
Total	280.0±23.3	87.5±7.1	240.6±25.6	80.8±9.4	252.0±27.1	89.7±11.9
%	100	100	100	100	100	100

*see Kajak 1997 and the text

ows and many-year-old meadows, or even when comparisons were made with meadows of intermediate successional stages (i.e. those 3–5 years after cultivation). Such a situation applied to successional sequences II and III.

The diversity of earthworm species was thus seen to rise from the early stages of succession and to attain maximal richness on many-year-old meadows.

All meadows except LA$_1$ were characterized by the widespread occurrence of two species: *A. caliginosa* – typical of mineral layers, and *Lumbricus rubellus* Hoffm. inhabiting the surface layer of the soil. It is these species which have the greatest influence on the soil properties of ley meadows.

Octolasion lacteum (Oerley) is a species of the deeper layers of the soil profile which is met with in fertile habitats and those rich in humus. The most abundant occurrence is on permanent meadows and those many years old (Table 1). The remaining species – *Aporrectodea rosea* (Sav.), *D. octaedra* and *Lumbricus terrestris* L. occurred sporadically and did not create great densities. These may be considered typical accessory species.

4.2. THE DENSITY AND BIOMASS OF LUMBRICIDAE

Fig. 1 presents the abundance and biomass of earthworms at the two sampling occasions (June and September). All meadows other than the permanent ones had higher densities at the first time of sampling than in September. In the

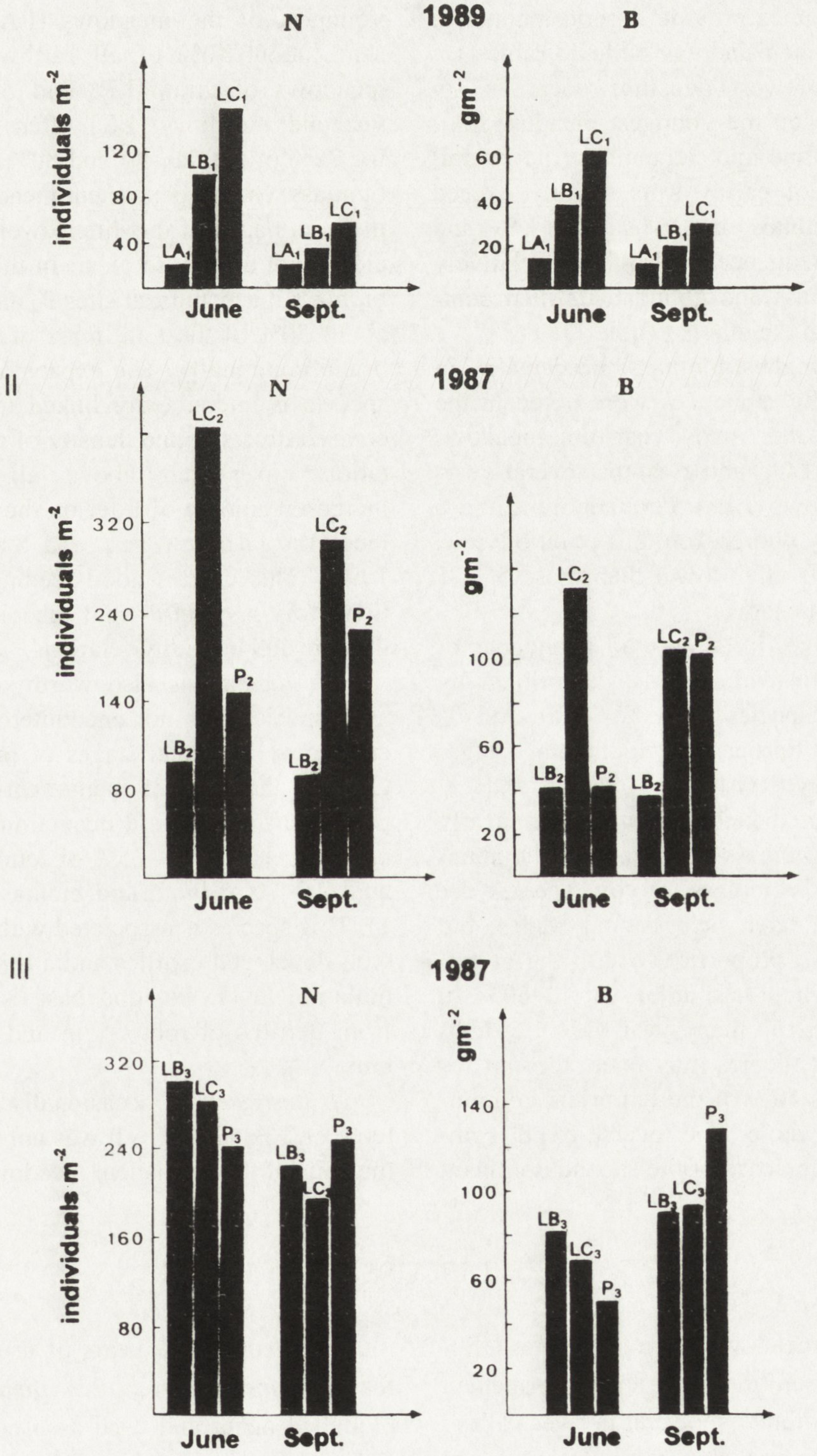

Fig. 1. Numbers (N) and biomass (B) of Lumbricidae in the soils of leys and permanent meadows at the two sampling occasions. I, II, III – successional sequences; LA – 1–2-year-old meadows, LB – 3–5-year-old meadows, LC – 6–5-year-old meadows, P – permanent meadows

face of such a similarity the means from the two times provide a good manner to compare the meadows studied (Table 1).

The lowest densities occur in sequence I, on the youngest meadow LA_1. Both in June and September, the overall numbers of earthworms slightly exceed 20 individuals m^{-2}. Meadows LB_1 and LC_1 of sequence I also have relatively low biomass and abundance when compared with the others (Table 1).

The highest biomass and densities in each of the sequences were noted in the soils of the many–year-old meadows (LC_2 and LC_1) and even the several-year-old meadows (LB_3). Permanent meadows are clearly poorer from this point of view, with levels often lower than those of 3–5 year-old meadows.

Changes in the overall abundance of communities are mainly determined by the two species *A. caliginosa* and *L. rubellus*. Earlier developmental stages (LA_1) have virtually nothing but *A. caliginosa*, which accounts for nearly 100% of biomass and density. The abundance and biomass of this species are greater in later successional stages, but the relative proportion within the grouping as a whole is smaller – at 40–60%. In the soils of many-year-old meadows (LC), this species may even account for as little as 10% of the lumbricid community as a whole. The reverse trend is observed in the case of the second dominant *L. rubellus*. It does not occur on the youngest of the meadows (LA), represents about 40% of all earthworms on meadows of group LB, and on many-year-old meadows (LC) often accounts for 70% of the density and 80% of living biomass. On the permanent meadows (P), the dominance of this litter-dwelling species is not always so clear. In the case of biomass it accounts, at sites P_2 and P_3, for about 50% of the total mass of the lumbricid community. The expansion of this species is undoubtedly linked to the increased diversity and density of the vegetation cover and above all to the increased amount of litter on the soil surface (Bogdanowicz and Szanser 1997). This creates good feeding conditions for *L. rubellus* and also improves thermic and humidity relations.

O. lacteum is also worthy of note. This species was not encountered in the early developmental stages of meadows. Only in the soils of many-year-old and permanent meadows it occurs quite commonly, achieving 5–25% of total density and 6–34% of lumbricid biomass (Table 1). This species is associated with soils of well-developed profiles and a thick accumulation layer. Its food base is formed from detritus of root origin and soil humus.

L. terrestris is occasionally encountered on LB_2 and LC_3. It was not found in the soils of the permanent meadows.

5. DISCUSSION

The meadows of north-eastern Poland are, on the one hand, permanent plant communities located in river valleys or on the steep slopes of moraines and elevations, as well as – on the other hand – ley meadows cyclically established on cultivated land as a normal component of rotation. After 8–10 years of use mainly for hay or pasture, the meadow is ploughed again and used as a cultivated field.

Repeated annual deep-ploughing leads to a considerable reduction in the numbers and biomass of Lumbricidae and also to declines in the majority of species. Attesting to this are comparisons between many-year-old meadows (LC) and the youngest meadows in the successional series (LA_1) (Table 1). Only one to two species remain from a total of 5–6. Densities decline to about 20 individuals m^{-2} and biomass to about 10 g m^{-2}. One species – *A. caliginosa*, which is widespread in mineral soils, comes to dominate. Similar effects have also been observed in the utilization of fallow land. Low (1972) recorded an 89–93% decline in the abundance of earthworms as a result of deep ploughing. Changes of a similar order are given by Zicsi (1969). Evans and Guild (1948) noted a fall in population densities of 70% five years after the ploughing of a meadow and its use as a field.

Ploughing leads to the destruction of the corridors and paths used by earthworms, changes air and water conditions in an unfavourable way, and destroys Lumbricidae in the mechanical sense. However, a more important factor is a change in the feeding conditions for the majority of surface dwelling species like *L. rubellus* and *D. octaedra*.

Thus the youngest meadow (LA) – in its first two years – represents the community of earthworms typical of agrocoenoses. It is probable that population sizes and compositions will be determined to a great extent by the previous method of use, and chiefly by the type of crops grown and the method of enriching the soil.

The shaping of a new biocoenosis is linked with a series of changes to the habitat. The diversity of the vegetation cover increases, as does the amount of overlying litter. There is an increase in the content of microaggregates of diameter 0.1–0.5 mm, and a decline in the largest fractions (of 1.1 mm) (Kusińska and Łakomiec 1997). The thickness of the accumulation layer increases, as does the overall content of organic matter in the soil. This increase is particularly clear in the first 5–6 years of use of the meadow. In contrast, the differences between the many-year-old meadows and the permanent ones are less marked.

Similar trends are observed in communities of Lumbricidae. The increase in abundance is again most distinct at the stage of transition between meadows of types LA and LB. Many-year-old meadows (LC) are often characterized by lower densities and biomass than those of group LB, while permanent meadows are always less abundantly inhabited by Lumbricidae than LC meadows. On this basis it may be considered that the early stages of development of a biocenosis are dominated by the process of the accumulation of matter, while the more stabilized many-year-old and permanent meadows have greater balance between the phenomena of the decomposition and accumulation of organic matter.

The changes ongoing in soil are to a great extent the result of the action of earthworms. The observed increase in the density and biomass of *L. rubellus* favours the transformation of organic matter in the surface layers of the soil. In the course of the day, individuals of this species excrete 1.6–3.6 g dry wt of casts g^{-1} of body weight (Martin 1982). On the many-year-old meadow LC_3, the mean biomass of 65 g m^{-2} suggests a production of about 18 kg dry wt of casts × season^{-1} m^{-2}. In turn, on meadow LC_2, a mean biomass of 91 g m^{-2} translates into over 26 kg dry wt m^{-2} season^{-1} assuming the lower level for the amount of coprolites excreted.

Inhabiting the root zone is *A. caliginosa*, a species widespread in the soils of meadows and cultivated fields. Its food includes soil detritus mainly of root origin, mixed with large amounts of the mineral fraction. It is very much as a result of the activities of this species that the increase in the humus content of the B horizon takes place. In laboratory conditions, *A. caliginosa* excretes 1.1–6.1 g dry wt of casts g^{-1} of biomass (Martin 1982). A calculation of the above kind for this species gives between 2 kg dry wt of casts m^{-2} $season^{-1}$ (on LA_1) and over 8.5 kg dry wt m^{-2} $season^{-1}$ on LB_2. The data given show very well the scope of the impact of Lumbricidae on the shaping of the soil habitat. This issue will be the subject of a separate study.

The normal way in which further use is made of ley meadows is deep ploughing and planting of cereals or root crops. In this way, significant amounts of below-ground and root plant biomass is introduced into the cycle. In a short period this undergoes mineralization, particularly where simultaneous use is made of mineral fertilisers. A loss of soil humus also occurs. It would be better to consider choosing other, less destructive agrotechnical techniques (e.g. harrowing instead of ploughing). This would allow for the existing layer structure to be retained, along with most biological life.

6.CONCLUSIONS

1. The development of the biocoenotic structure of meadows is apparently accompanied by an increase in the mumber of lumbricid species from 2 in the soils of the youngest meadows to 5–6 on many-year-old meadows.

2. There is no difference in the species composition of the earthworms of many-year-old and permanent meadows.

3. The abundance and biomass of Lumbricidae is greater on older meadows, with the clearest differences being between the early stages.

4. The soils of the ley meadows are dominated by two species: *A. caliginosa* in the mineral part of the profile and *L. rubellus* – a soil/litter layer species.

5. Older meadows have proportionately greater numbers and densities of *L. rubellus* among earthworms and a smaller proportion of *A. caliginosa.*

7. SUMMARY

Research involved the species composition, abundance and biomass of Lumbricidae in three successional sequences of ley meadows and permanent meadows within Suwałki Landscape Park, north-eastern Poland. Each successional sequence included meadows differing in the time that had passed since the sowing of grass. Meadow LA was the youngest, 1–2 years old, while LB and LC meadows were 3–5 and 6–8 years old and P – permanent meadows.

The formalin method was applied. Fig. 1 presents the abundance and biomass at June and September. In relation to the developmental stage of meadows, 2–6 species of earthworm were recorded (Table 1). Older ley meadows had more species. No differences were noted in the species composition of Lumbricidae of many-year-old and permanent meadows. The abundance and biomass of earthworms was greater on older meadows, but the differences were most marked between early successional stages (Table 1). In the initial stages of the development of the meadow biocoenosis the dominant species was the geophagic *A. caliginosa*. Older meadows were in turn dominated by the litter-eating, surface-dwelling species *L. rubellus*.

8. POLISH SUMMARY

Badano skład gatunkowy, liczebność i biomasę Lumbricidae w trzech ciągach sukcesyjnych łąk przemiennych i trwałych na obszarze Suwalskiego Parku Krajobrazowego w północno-wschodnich rejonach Polski. W skład każdego szeregu sukcesyjnego wchodziły łąki różniące się czasem jaki upłynął od wysiewu traw: LA – łąki najmłodsze, 1–2-letnie; LB – łąki 3–5-letnie; LC – łąki 6–8-letnie i P – łąki trwałe. W badaniach zastosowano metodę formalinową. Stany liczebności i biomasy w dwóch kolejnych terminach pobierania prób przedstawia rys. 1. Stwierdzono występowanie, w zależności od stadium rozwojowego łąki, 2–6 gatunków dżdżownic (tab. 1). W miarę starzenia się łąk przemiennych wzrasta ilość gatunków. Nie stwierdza się różnic w składzie gatunkowym Lumbricidae łąk wieloletnich (LC) w stosunku do łąk trwałych (P). Liczebność i biomasa dżdżownic rośnie wraz z wiekiem łąki, najwyraźniej we wczesnych stadiach sukcesji (tab. 1). Na początkowych stadiach rozwoju biocenozy łąkowej dominuje gatunek geofagiczny – *A. caliginosa*, na starszych przeważa ściółkożerny i powierzchniowy *L. rubellus*.

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