POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	52	2	173–179	2004

Regular research paper

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LUMBRICIDAE COMMUNITIES IN SEVERAL YEARS OLD MIDFIELD SHELTERBELT (TUREW REGION, WESTERN POLAND)

ABSTRACT: Species composition, density and biomass of Lumbricidae were studied in soils of a several years old midfield shelterbelt, an adjacent arable field (maize, wheat) and an ecotone situated between both ecosystems in two years (1999, 2000) in spring, summer and autumn. The lowest density and biomass of Lumbricidae was found in the field. The only species present there was *Aporrectodea caliginosa*: mean density 0.9 ind m^{-2} and biomass 0.7 g m^{-2}. Three species were found in soils of the shelterbelt and the ecotone – *A. caliginosa*, *Dendrobaena octaedra* and *Lumbricus terrestris*. Two species dominated in biomass and density; *L. terrestris* occurred sporadically and its biomass and density were low. The average density and biomass in soils noted in 1999 were 58 ind m^{-2} and 15 g m^{-2}, respective values for the ecotone were 73 ind m^{-2} and 24 g m^{-2}. In the next year a nearly twofold increase of density (the shelterbelt – 144 ind m^{-2}, ecotone – -159 ind m^{-2}) was noted and similar increase of biomass in shelterbelt soils (31 g m^{-2}). *A. caliginosa*, depending on site and time, contributed to 35–76% to the density and in 68–93% to the biomass of the community, *D. octaedra* – in 22–64% and 7–30%, respectively. Apart from biomass in the first study year, no significant differences between the shelterbelt and the ecotone were found in both density and biomass of the earthworm community.

KEY WORDS: midfield shelterbelts, ecotone, Lumbricidae, *Aporrectodea caliginosa, Dendrobaena octaedra*

1. INTRODUCTION

In view of the observed biological simplification and impoverishment of croplands there is an increasing interest in the role of artificial plantings and various refugia in maintaining diverse fauna of agricultural landscapes (Karg and Ryszkowski 1996, Ryszkowski *et al.* 2002). Earthworm communities were studied in that aspect in over hundred years old midfield wood strip (Jopkiewicz 1975, Ryl 1984) and in natural shrubs, barren lands, baulks, tree clumps and hedgerows at the outskirts of arable fields (Eijsackers 1983, Andersen 1985 after Lagerlöf *et al.* 2002). No such studies have been carried so far in young plantings introduced on fields mainly as anti-erosion barriers. Early successional stages of such a shelterbelt are characterised by intensive growth of herb vegetation, in which they resemble fallow lands or permanent grasslands. Constant input of

litter from these plants determines the diversity and transformations of soil fauna during this early period. This study was aimed to analyse the development of Lumbricidae community in the first years after shelterbelt planting.

2. STUDY AREA

All three sites neighboured each other and were situated in Turew (c. 50 km south from Poznań, Western Poland) in the General D. Chłapowski Landscape Park. The area is one of the warmest and driest regions in Poland. Sum of precipitation was 550.7 mm in 1999 and 538 mm in 2000. Relatively fertile Arenic Hapludalf soils on slightly loamy sand over light loam prevail there (Ryszkowski *et al.* 2003).

Studies were carried out in three sites – in a young (6–7 years) midfield shelterbelt, in an arable field 10 m from the eastern border of the shelterbelt and in an ecotone between the two. The shelterbelt (local name "Wyskoć") was planted at the end of 1993. It runs in the north-south direction, is 348 m long and 18 m wide. Trees were planted in 11 rows to form the so-called repeating biogroups (Ryszkowski *et al.* 2003). Dominating species were: oak, larch, poplar, pine, linden, elm and beech. Until developing a compact canopy of tree crown, soil litter is formed mainly by intensively growing herb vegetation (Bernacki 2004, in press).

Typical agricultural management with mineral fertilization and application of chemical plant protection measures was carried out on the adjacent field. The crops were: maize in 1999 and wheat in 2000.

Basic soil properties in three sites were similar: pH_{H2O} – 4.7, organic carbon content – 0.5–0.6%, total nitrogen – 0.06–0.07%, C:N ratio – 8.4–9.6 (Mamcarz 2001).

3. METHODS

Studies were carried out in 1999 and 2000 but in the field, due to extremely low density of earthworms, (only 2 individuals on three sampling occasions in 1999) analyses were performed in the first year only. Samples were collected on three phenological terms corresponding to the spring (May) and autumn (October) maximum and summer (June or July) minimum of the earthworm occurrence on these areas (Jopkiewicz 1972, 1975, Ryl 1984). The formalin method was used to flush Lumbricidae (Raw 1959). To do this a 0.3 × 0.3 m surface framed with metal square was poured over several times with 0.3% formaldehyde solution. 8–10 such samples were taken on each sampling date. Collected earthworms were conserved, determined to the species and weighed together with their gut content. 10% correction for losses caused by formaldehyde and conserving solutions was applied when estimating biomass.

Two-way ANOVA from the Statgraphics SG Plus software was used in data processing.

4. RESULTS

The lowest density and biomass of Lumbricidae was found in the field adja-

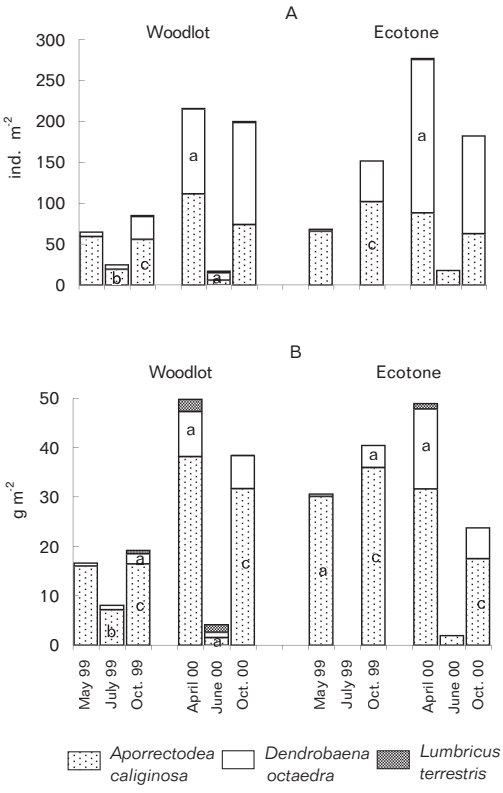

Fig. 1. Density (A) and biomass (B) of Lumbricidae in soils of the shelterbelt and ecotone (**a** – $P<0.05$, **b** – $P<0.01$, **c** – $P<0.001$ – statistically significant differences between the sites on comparable sampling occasions).

cent to the shelterbelt. The only species noted there was *Aporrectodea caliginosa*, whose mean density in 1999 was 0.9 ind m^{-2} and biomass 0.7 g m^{-2}.

Three earthworm species occurred in soils of the shelterbelt and ecotone (Table 1). Decisive for the biomass and density were *A. caliginosa* and *Dendrobaena octaedra*. *Lumbricus terrestris* was found sporadically and in small number of individuals (Fig. 1).

Mean densities of earthworms found in the first year in the shelterbelt and ecotone were relatively low and similar to each other. Contribution of both dominating species was also similar. *A. caliginosa* had a 77% share in the earthworm density in the shelterbelt and 76% in the ecotone. Similar numbers and percentage share was also typical for the second species – *D. octaedra* (Table 1). Therefore, the density of Lumbricidae was not significantly different in both sites (Table 2).

Some difference between the shelterbelt and ecotone could be found in mean biomass of the community and of two dominating species. At a similar share, total biomass of *A. caliginosa* in the ecotone soil was higher by nearly 10 g m^{-2} than in the shelterbelt soil (Table 1). Mean earthworm biomasses in these sites were significantly different in 1999 (Table 2).

Average density in both sites increased almost twofold in the second study year. This rise resulted mainly from the several times higher density of *D. octaedra*, whose contribution to the community surmounted that of *A. caliginosa* and reached 55% in the shelterbelt and 64% in the ecotone. As in the first year, there was no significant difference between sites in the mean density of Lumbricidae.

Mean biomass of earthworms in soil of the shelterbelt was two times higher than in the first year due mainly to increased

Table 1. Mean (May–October) density, biomass and contribution of particular species (%) to the community of Lumbricidae in the shelterbelt and ecotone.

Year	Species	Shelterbelt				Ecotone			
		ind. m^{-2}	%	g m^{-2}	%	ind. m^{-2}	%	g m^{-2}	%
1999	*Aporrectodea caliginosa* (Sav.)	44.4	77	13.17	90	55.5	76	22.03	93
	Dendrobaena octaedra (Sav.)	13.0	22	1.19	8	17.6	24	1.64	7
	Lumbricus terrestris L.	0.4	<1	0.26	2	–	–	–	–
	Total:	57.8		14.62		73.1		23.67	
2000	*Aporrectodea caliginosa* (Sav.)	63.4	44	23.78	77	56.0	35	16.98	68
	Dendrobaena octaedra (Sav.)	79.2	55	5.62	18	102.4	65	7.47	30
	Lumbricus terrestris L.	1.5	1	1.38	5	0.4	<1	0.39	2
	Total:	144.1		30.78		158.8		24.84	

Table 2. Two-way ANOVA of density and biomass of Lumbricidae in two study periods and in two sites: shelterbelt and ecotone.

Year (d.f.=1)	Density						Biomass					
	Site (d.f.=2)		Species (d.f.=2)		Interactions (d.f.=1)		Site (d.f.=2)		Species (d.f.=2)		Interactions	
	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*	F	*P*
1999	1.67	0.19	43.69	**0.0000**	0.64	0.52	4.53	**0.03**	57.95	**0.0000**	4.14	**0.01**
2000	0.05	0.82	31.60	**0.0000**	0.77	0.46	1.64	0.20	36.73	**0.0000**	1.78	0.17

density and total biomass of *A. caliginosa*. In the ecotone no such differences were noted in spite of the described increase in total density of Lumbricidae.

Highly significant differences were found of density and biomass in three species occurring the sites (Table 2). Two maxima of their density and biomass can be distinguished – in late spring and in the autumn and one summer minimum (Fig. 1). In the first year, during summer droughts, no earthworms were found in the ecotone soil. In the same year the differences between the shelterbelt and the ecotone in total biomass of two dominating species were most clearly visible. Biomass values of *A. caliginosa* and *D. octaedra* in the ecotone were significantly higher from those in the midfield shelterbelt on comparable sampling occasions (Fig. 1).

To sum up, marked impoverishment of species composition and low biomass and density of Lumbricidae were noted in soils of the arable field in relation to the shelterbelt and to the contact zone between the two sites. Midfield strip and the ecotone were inhabited by the same three species of earthworms, which had similar densities and biomasses with a periodical tendency to their increase in the ecotone soils.

5. DISCUSSION

Earthworm fauna of arable lands and green crops in Turew region was already intensively studied earlier (Jopkiewicz 1972, 1975, Ryl 1984). Annual average density – 1.2–9.0 ind m^{-2} and that of a biomass – of 0.9–4.8 g m^{-2} were recorded in rye crops depending on the site, year and the distance from the shelterbelt (Jopkiewicz 1972, 1975). Ryl (1984) gave similar annual values of 10 ind m^{-2} and 4.7 g m^{-2} for wheat crops. The authors found 2–3 species in arable soils – dominating *A. caliginos*a and also *A. rosea* and *L. terrestris*. In other sites of similar soil type cropped with winter rye, potatoes and other cereals, Witkowski (1983) recorded on average 10–19 ind. m^{-2} and 5.3–4.1 g m^{-2} of biomass. The author found 7 species there with a distinct dominance of *A. caliginosa* (76 to 96%).

Main reason for earthworm species impoverishment and their low densities and biomasses found in the field adjacent to the shelterbelt is probably in applied agrochemical measures. These practices have been certainly intensified since the time of cited studies. High doses of mineral fertilisers, herbicides and particularly nematocides and fungicides can strongly reduce earthworms (Kasprzak and Ryl 1978, Edwards 1983). Deep ploughing, which removes surface resources of dead plant material, restricts the occurrence of litter-feeders like *D. octaedra* and *L. terrestris*. Many studies demonstrated that abandoning agrotechnical measures, setting up non-tillage crops and permanent grasslands and leaving the croplands fallow resulted in a rapid increase of numbers and species diversity of earthworms (Kasprzak and Ryl 1978, Edwards 1983, Eijsackers 1983, Parmelee and Crossley 1988, Edwards *et al.* 1995, Makulec 1997).

In the first years, since planting the shelterbelt until developing a compact canopy of tree crowns, plant succession resembles phenomena that occur on abandoned croplands (Bernacki 2004). Growing herb vegetation produces large amounts of litter and resources of non-living organic matter in soil profile rapidly increase, which favours the development of both detritophagous and geophagous earthworm species. Under such conditions, already 6 years after first plantings, densities and biomasses of Lumbicidae exceed many times respective values given for arable fields by the earlier cited authors (Jopkiewicz 1972, 1975, Ryl 1984). They are also higher than densities and biomasses found in soils of an old shelterbelt (about 100 years), in which Jopkiewicz (1975) found only 8.7 ind. m^{-2} $year^{-1}$ and 10.5 g m^{-2} $year^{-1}$ and Ryl (1984) found 15 ind. m^{-2} $year^{-1}$ of a mean biomass of 9.6 g m^{-2} $year^{-1}$.

A. caliginosa was the dominating species in soils of the several years old shelterbelt. It is a species of relatively low fertility and long growth cycle. It lays about 27 cocoons a year and the full development lasts 74 weeks (Wilcke 1952 after Edwards and Bohlen 1996). It is not a typical peregrinating species. In a year, in soils of polders utilised as arable fields *A. caliginosa* moved its range by 7 m (Marinissen and van den Bosch 1992). Relatively high densities found in the young shelterbelt and in the ecotone reflected probably the presence of earlier populations or individuals, which could be introduced with material from the forest nursery. Ryl (1984) did not

find this species in the several dozen years old midfield shelterbelt.

D. octaedra is an epigeic and detritophagous species and thus, due to almost total lack of litter, it is absent in soils of arable fields (Jopkiewicz 1972, Witkowski 1983, Ryl 1984). It appears in soils of renewed and intensively managed meadows near Turew area (Ryl 1984) and in early stages of the development of meadows set up on arable fields (Makulec 1997). The species contributed in 51% to the total density of all earthworms in the several dozen years old shelterbelt (Ryl 1984). In young midfield shelterbelt and in its ecotone the species contributed in 22–24% to the Lumbricidae community in the first year and in 55–64% in the second year of study (Table 1). Most probably the species was introduced with tree plantings but transport of its cocoons by wind from the nearby forest, baulks or meadows is also possible.

Changes in earthworm density and biomass in the midfield shelterbelt and ecotone had a similar dynamics to that from cited studies on croplands (Jopkiewicz 1972, Witkowski 1983, Ryl 1984). Generally, there were spring and autumn maxima and summer minimum of density and biomass. Summer decrease of density was caused by diapause of most individuals of *A. caliginosa* as a consequence of drying soil and high temperatures (Edwards and Bohlen 1996). Small surface species like *D. octaedra* survives this period in a form of cocoons.

Noteworthy was over twofold increase of mean earthworm density in the shelterbelt and ecotone in the second year of study as compared with the first one. Some differences in precipitation between two years were not high enough to markedly change soil moisture (Ryszkowski *et al.* 2003). Thus, the reason could be the natural density fluctuations or a growing tendency of the whole Lumbricidae community. Further studies are needed to explain this phenomenon.

Significant change in species composition and increase of density and biomass of earthworms in the first years after planting the shelterbelt should certainly affect soil processes. Activity of *A. caliginosa* in the mineral layer of soil profiles increases porosity, aeration and infiltration of the soil. Individuals of the species under laboratory conditions excreted 2.35 g dry soil g fresh mass^{-1} day^{-1}, most of it on the surface (Curry *et al.* 1995). Adopting direct estimates of the cast amounts made by Jopkiewicz (1972) in rye crops it was calculated that 1 g of A. *caliginosa* biomass was equivalent to about 120 g dry wt. m^{-2} year^{-1} of faeces. Using this coefficient one may calculate that individuals of this species in the second study period released 2.85 kg dry wt. m^{-2} of faeces on the soil surface in the shelterbelt and 2.0 kg dry wt. m^{-2} in the ecotone.

D. octaedra participates mainly in mineralisation and humification of the surface litter resources. In future one may expect further development of the *L. terrestris* population, which should result in closer combination of the upper and mineral soil layers and in thickening of humic layers of the soil profile.

6. CONCLUSIONS

1. Arable fields are exclusively inhabited by one species – *A. caliginosa*, which occurred in low density and produced low biomass.
2. Three earthworm species are present in soils of the 6–7 years old midfield shelterbelt and in its border with the field. *A. caliginosa* and *D. octaedra* contributed mainly to density and biomass of the community.
3. Several years old midfield shelterbelt, due to relatively high species diversity and high densities, could be a valuable store of earthworms in agricultural landscape and should enable colonisation of adjacent croplands in case of setting up permanent grasslands or fallows.

ACKNOWLEDGEMENTS: This paper was made within the project "Biocoenotic function of midfield shelterbelts in agricultural landscape" financed by the State Committee for Scientific Research grant No. 6P04F02816.

7. SUMMARY

Studies were carried out in three sites situated in Turew near Poznań – in a young (6–7 years) midfield shelterbelt, in a field 10 m apart from the eastern border of the shelterbelt and in an ecotone between the two former sites. Studies were made in 1999 and 2000 in the 6th and 7th year of the shelterbelt's development. Samples were taken three times in a year (May, June or July and October) using the formalin method to flush the earthworms. The lowest density

and biomass of earthworms was noted in the field. The only present species there was *Aporrectodea caliginosa*; its mean density was 0.9 ind. m^{-2} in a study period and a mean biomass was 0.7 g m^{-2}. This status is probably determined by a high intensity of agrotechnical measures. Three species: *A. caliginosa, Dendrobaena octaedra* and *Lumbricus terrestris* were found in soils of the shelterbelt and ecotone (Table 1). Two species were decisive for the density and biomass of the whole community. *L. terrestris* occurred sporadically in low density and produced low biomass. There were 58 ind. m^{-2} of a biomass of about 15 g m^{-2} in the shelterbelt's soil in 1999 and 73 ind. m^{-2} and 24 g m^{-2}, respectively in the ecotone. Almost twofold increase of density (144 ind. m^{-2} in the shelterbelt and 159 ind. m^{-2} in the ecotone) was noted in the next year. In the shelterbelt's soil, biomass increased accordingly to 31 g m^{-2}. *A. caliginosa*, depending on site and study period, contributed in 35–76% to the density and in 68–93% to the biomass of the whole community while contribution of *D. octaedra* was *22*–64% and 7–30%, respectively (Table 1). Except for biomass value in the first year, there were no statistically significant differences between the shelterbelt and the ecotone (Table *2*). Statistically significant was, however, the difference of biomass and density between three species occurring at the studied sites (Table *2*). Two maxima in late spring and autumn and one summer minimum of biomass and density were noted during the study period (Fig. 1). Early stages of midfield shelterbelts, due to high earthworm densities, may enable rapid colonisation of adjacent croplands in case of using them as permanent grasslands or fallow lands.

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(Received after revising January 2004)