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Earthworm populations of Roosevelt Avenue (Brussels, Belgium): composition, density and biomass

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ABSTRACT. Earthworms were sampled (electric octet method) in the lawn islets of the 2.5 km long Roosevelt avenue (city of Brussels, Belgium). From a preliminary sampling a total of nine species (five to eight per islet) were found of which four (*Aporrectodea caliginosa, A. longa, A. rosea* and *Lumbricus rubellus*) were present in all the islets. No insularity effect could be found.

A full year sampling was then performed in five selected islets, revealing total density between 89 and 253 individuals/m^2 and biomass between 49 and 153 g/m^2 (yearly averages). Biomass (but not density) correlated best with silt and pH.

KEY WORDS: Earthworm populations, density, biomass, urban soils

INTRODUCTION

Practically all field studies on earthworms have been carried out in natural or semi-natural habitats. In Belgium, apart from the earthworm inventory by BOUCHÉ (1978), recent data on the topic are rare (BOULANGÉ, 1968, GASPAR et al., 1981) or unpublished (SYMOENS [1], HENNUY [2], HIDVEGI [3], MUYS, 1993, MASSARD [4]).

There is especially little information on populations of earthworms in urban localities. According to their situation, the soils of cities present various levels of disturbances: most are made of embanked materials (NUYENS, unpublished data [5]), are polluted with heavy metals and other substances (PIZL & JOSENS, 1995a, BONTYA, unpublished data [6]), and are stamped and compacted (FANNING & FANNING, 1989). Another characteristic of urbanised surroundings is the partitioning of biotopes into smaller parcels, which transforms the biotopes for animals as little mobile as earthworms into kinds of archipelagoes (BEGON et al., 1990; PANHUYSEN, unpublished data [7]).

Populations are thereby broken up, faced with unaccustomed competition conditions and sometimes with species introductions.

[1] SYMOENS, F. (1975). Étude biocénotique des Coléoptères, des Lombriciens et des Thécamoebiens des sols ardennais. Mémoire de fin d'études, Faculté agronomique de Gembloux, 177 pp.

[2] HENNUY, B. (1982). Étude de l'influence des techniques culturales sur les peuplements de Lombriciens. Mémoire de fin d'études, Faculté agronomique de Gembloux, 136 pp.

[3] HIDVEGI, F. (1989). Inventaire faunistique des Lombriciens (Annélides, Oligochètes) de la région de Treignes. Mémoire de fin d'études, Université Libre de Bruxelles, 89 pp.

[4] MASSARD, V. (1999). Étude de la répartition des lombriciens dans un gradient. Wiltz, Mémoire scientifique, Centre Universitaire du Luxembourg, Département de formation pédagogique, 144 pp.

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[5] NUYENS, J. (1983). Carte géotechnique 31.7.2 Bruxelles. Institut géotechnique de l'Etat.

[6] BONTYA, V. (1995). L'influence des métaux lourds sur le développement des lombriciens. Mémoire de licence. Université Libre de Bruxelles. 70 pp.

[7] PANHUYSEN, W.V.D. (1992). Valeur économique et valeur d'usage des espaces verts dans la région de Bruxelles-Capitale. Bruxelles: BRES, 42 pp.

In spite of the various disturbances and pollution to which they are subjected, these surroundings can shelter earthworm communities relatively rich in species and individuals (Pizl & Josens, 1995a, b). These populations can provide a good model for studies of population dynamics and competition.

MATERIAL AND METHODS

Locality

This study was carried out on F. D. Roosevelt avenue, which is situated in the south-east of the Brussels-capital Region, Belgium (50° 48' N, 4° 23' E). It includes in its middle a long lawn of 2450 meters surrounded by two roads. The streets that cross the avenue divide the lawn into 12 islets, which were numbered from the city towards the periphery. The islets have a width of 8.3 meters and a length varying from 110 meters for islet 5 to 250 meters for islet 12. The total lawn area is 1.75 ha.

The vegetation of the lawn is dominated by Poaceae (*Poa annua, P. trivialis, Agrostis stolonifera, Lolium perenne* and *Holcus lanatus*). Among dicotyledons, *Trifolium repens*, *Bellis perennis*, *Taraxacum officinale* and *Hypochaeris radicata* are the most abundant (Tanghe, personal communication).

The superficial soil is generally sandy to silt-laden and deep; it is made of anthropic embankments 50 to 100 cm thick, resting on native sands. It is enriched in humus produced by the grass that is mown twice a month from April to October and by dead leaves from the limes that line the avenue. Very few people walk on the islets, except the n° 1, and their soils are, therefore, little trampled.

Islets are isolated by intense automobile traffic: Roosevelt avenue is an important penetration axis into the city and suffers daily traffic jams.

Preliminary sampling and choice of the islets

Two samples were taken from each of the 12 islets in November 1995 according to the method described hereafter. Five out of the 12 islets were then selected according to the composition and density of their earthworm communities.

Definitive sampling

Each islet was sampled once a week from February 1, 1996 to February 26, 1997, with an interruption of one week in August 1996 (breakdown of the extractor) and two weeks in January 1997 (permanent frost).

In the middle of each of the five islets, an area 60 m long by 4 m wide was subdivided into 60 elementary parcels of 2 m x 2 m. The order of sampling of the elementary parcels was determined by a protocol of simple random sampling. So the first random number designated the first parcel to be sampled on the first week (for the five islets), the second number the second parcel on the second week and so forth.

Extraction of earthworms

Because of constraints associated with the residential character of the avenue, the extraction of earthworms was achieved by Thielemann's electric "Oktett-Methode" (1986) with the help of a Worm-Ex extractor of the GefaÖ firm (Heidelberg, Germany).

For each sampling, the elementary parcel of the day was first located, then the lawn was mown to ground level over a surface area of 0.5 m^2 with a Gardena hand-mower. The ring (a circle of 0.125 m^2) of the Worm-Ex extractor was laid down in the centre of this surface. The electrodes (65 cm long) were driven into the soil with all our weight on the handles until the resistance of the soil stopped us from driving them further, and the depth reached was measured. The extraction started with the lowest voltage and was increased every five minutes (successively 200, 250, 300, 350, 400 and 500 V). The speed of rotation of the electric field remained constant at 4 rotations per minute.

Identification and weighing of the earthworms

The worms were rinsed in tap water and sorted out under a lamp and a stereomicroscope. Identification was carried out using the keys of Josens & Hidvegi (unpublished) and of Sims & Gerard (1985), and we adopted the nomenclature of the latter authors.

Each worm was briefly dried on tissue and weighed (Sartorius Basic balance) with a precision of ± 0.1 mg.

Soil parameters

Five samples were taken per islet, and C and N determined for each sample. Samples were then pooled prior to texture analysis. Carbon content (Strölein's oxidation at 1100°C) and nitrogen content (Kjeldahl's method) as well as the texture analysis (clay, silt and sand contents) were determined in the laboratory of pedology (Prof. Herbauts).

The pH (water) and water content (dried at 105°C) were measured on each worm sampling site (63 measurements per islet).

Parameters of populations

The relative frequency (of a species within an islet) is the ratio of the number of samples where the species is present to the total number of samples.

The dominance (of a species within an islet) is the ratio of the number of individuals of a species to the total number of individuals.

Density and biomass within an islet (means ± standard deviations) are expressed per square meter on the basis of a complete year cycle.

RESULTS

Soil characteristics

These are summarised in Table 1.

Clay content varied within a narrow range (6 to 9%), but silt and sand content varied greatly and inversely.

Among the other soil parameters carbon content (2.7 to 4.4%) correlated positively with clay (r=0.94, p=0.02), inversely with sand (r=-0.88, p=0.05) and weakly with silt (r=0.84, p=0.07). Nitrogen (0.25 to 0.37%) followed the same tendency and correlated strongly with carbon (r=0.98, p=0.003).

The pH varied in a narrow range (6.9 to 7.15) and was correlated negatively and strongly with silt (r=-0.96, p=0.008) and positively with sand (r=0.95, p=0.12), while water content followed the inverse tendency and correlated negatively with pH (r=-0.94, p=0.017).

TABLE 1

Soil characteristics (mean ± standard deviation) of Roosevelt avenue (Brussels, Belgium)

	Islet 3	islet 5	islet 8	islet 9	islet 10	p ANOVA
Clay (%) (n = 1*)	6.0	7.0	9.1	7.3	6.6	
Silt (%) (n = 1*)	24.4	55.8	56.2	30.7	23.1	
Sand (%) (n = 1*)	63.7	30.3	26.7	55.2	64.8	
Carbon (%) (n = 5)	2.71 ± 0.40	3.76 ± 0.14	4.41 ± 0.46	3.72 ± 0.78	2.98 ± 0.39	0.0001
Nitrogen (%) (n = 5)	0.25 ± 0.02	0.33 ± 0.02	0.37 ± 0.04	0.32 ± 0.05	0.29 ± 0.040	0.001
C/N (n = 5)	11.5 ± 0.6	11.6 ± 0.82	11.9 ± 1.5	11.6 ± 1.0	10.5 ± 1.0	0.28 (ns)
pH (n = 63)	7.10 ± 0.25	6.91 ± 0.27	6.95 ± 0.30	7.13 ± 0.29	7.15 ± 0.26	< 0.0001
Water (%)(n = 63)	29.9 ± 10.41	36.8 ± 11.56	38.8 ± 13.31	29.5 ± 11.94	24.8 ± 8.56	< 0.0001
remark	carbonates				carbonates	

* 5 samples mixed

Preliminary sampling and choice of islets for definitive sampling.

On the basis of two samples per islet in November 1995, the specific richness varied between four and seven species (Table 2), and the whole lawn of Roosevelt avenue sheltered nine species, of which four (*Aporrectodea caliginosa, A. longa, A. rosea* and *Lumbricus rubellus*) were present in all islets. There was

TABLE 2

Results of preliminary earthworm sampling in the lawns of Roosevelt avenue (Brussels, Belgium, November 1995)

islet	*Allolobophora chlorotica*	*Aporrectodea caliginosa*	*Aporrectodea icterica*	*Aporrectodea longa*	*Aporrectodea rosea*	*Lumbricus castaneus*	*Lumbricus rubellus*	*Lumbricus terrestris*	*Satchellius mammalis*	# spp
1		+++		+++	+++		+			4
2	+	+	+	+++	+++		+			6
3	++	++	+	+++	+++		+			6
4		+++	++	+++	+++		+			5
5		++	++	+++	+++		+		+	6
6		+++	++	+++	++		+	+	++	7
7		+++	++	+++	+++		+		++	6
8		+++	+	+++	+		+	+	+	7
9		+++		+++	+++		+	++		5
10		++		+++	+++		+			4
11	+	++		++	++	+	+			6
12		+++		++	+	+	+			5

+ 1 to 5 individuals per sample of 0.125 m^2

++ 5 to 10 individuals per sample of 0.125 m^2

+++ more than 10 individuals per sample of 0.125 m^2

no significant correlation between islet size and specific richness (n=12, r=0.14, p > 0.05).

Three islets were immediately discarded from the definitive sampling: islet 1 because it was the only one to be trampled (partially), and islets 11 and 12 because they were concerned with civil engineering.

Of the remaining islets, we retained islets 3 and 5, because some data were already available for them (PIZL & JOSENS, 1995a); furthermore, islet 3 contained an abundant population of *Allolobophora chlorotica*, absent or rare elsewhere, and islet 5 sheltered the highest community density.

Islets 8 and 10 were selected because they contained the highest and lowest specific richness, respectively.

Islet 9 was retained because it was the only one to contain, in addition to the four species common to all islets, a population of *Lumbricus terrestris* that seemed dense (however, this was not confirmed by the definitive sampling).

The five selected islets contained eight out of the nine species present in the avenue.

Homogeneity of sampling conditions

Since it was rarely possible to drive the electrodes completely into the soil, a heterogeneity of extraction efficiency might have been expected, but an analysis of variance on this parameter did not reveal any significant differences between islets (F=0.89, p=0.47).

Composition of communities.

After a complete sampling year, the specific richness determined by the preliminary sampling (two samples per islet) was confirmed for islets 3 and 5 and only one extra species was recorded in each of the three other islets (n° 8, 9 and 10). The five islets studied contained an average of 6.20 ± 1.10 species (Table 3).

TABLE 3

Dominance (D) and relative species frequency (F) of the earthworm species in the lawns of Roosevelt avenue (Brussels, Belgium)

	Islet 3 (n = 51)		**islet 5 (n = 50)**		**islet 8 (n = 53)**		**islet 9 (n = 52)**		**islet 10 (n = 52)**		**The 5 islets**	
	D	F	D	F	D	F	D	F	D	F	D	F
Allolobophora chlorotica	0.13	0.42			0.004	0.06					0.03	0.09
Aporrectodea caliginosa	0.10	0.5	0.15	0.77	0.23	0.68	0.31	0.64	0.34	0.48	0.20	0.61
Aporrectodea icterica	0.17	0.58	0.20	0.73	0.09	0.43	0.03	0.125	0.02	0.14	0.13	0.4
Aporrectodea longa	0.27	0.59	0.26	0.68	0.26	0.6	0.36	0.58	0.35	0.58	0.29	0.6
Aporrectodea rosea	0.33	0.53	0.19	0.63	0.15	0.46	0.23	0.41	0.30	0.42	0.23	0.49
Lumbricus rubellus	0.004	0.08	0.06	0.63	0.16	0.8	0.06	0.41	0.02	0.14	0.06	0.41
Lumbricus terrestris					0.03	0.28	0.005	0.04			0.007	0.06
Satchellius mammalis			0.14	0.65	0.08	0.52					0.06	0.23

– *Allolobophora chlorotica* Savigny, 1826, is the 6th most common earthworm species in Belgium (BOUCHÉ, 1978), and its presence was confirmed in islet 3 (frequency = 0.42). It was also occasionally found in islet 8 (frequency=0.06). All individuals found belong to the green morph.

– *Aporrectodea caliginosa* Savigny, 1826, the most common species of the Belgian earthworm fauna (BOUCHÉ, 1978), constitutes, according to the north American literature (REYNOLDS, 1977, GATES, 1972 in BOUCHÉ, 1976) and the French literature (BOUCHÉ, 1972) a complex of species and/or morphs. In this paper it is considered a single species *sensu* SIMS & GERARD (1985) but with two morphs (normal and dwarf) distinguishable from each other only at the adult stage. This species was abundant in all the islets with relative frequencies between 0.48 and 0.77; it was the second most dominant species in islets 8, 9 and 10.

– *Aporrectodea icterica* Savigny, 1826, is a relatively rare species in Belgium (BOUCHÉ, 1978) but it was abundant in Roosevelt avenue: it was found in all islets sampled, with frequencies from 0.125 (islet 9) to 0.73 (islet 5, where it was the second most dominant species in number and biomass).

– *Aporrectodea longa* Ude, 1885, is only the 10th most common earthworm species in Belgium (BOUCHÉ, 1978), but it was the dominant and most constant species in the islets of Roosevelt avenue; it represented 60 to 70% of the earthworm biomass in the five sampled islets.

– *Aporrectodea rosea* Savigny, 1826, is the 2nd most common earthworm species in Belgium (BOUCHÉ, 1978), and it was also of very regular occurrence in Roosevelt avenue with frequencies between 0.41 and 0.63; it was the dominant species in islet 3 and the second most dominant species in islets 9 and 10. However, its biomass was never very high because of its small size.

– *Lumbricus rubellus* Hoffmeister, 1843, is the 3rd most common species in Belgium (BOUCHÉ, 1978), and it was present in all the islets although at very different frequencies (from 0.08 in islet 3 to 0.80 in islet 8). It constituted the second highest worm biomass in islets 5 and 8.

– *Lumbricus terrestris* Linné 1758, is the 5th most common earthworm species in Belgium (BOUCHÉ, 1978); however, it was rare in the avenue, with frequencies of 0.28 in islet 8 and 0.04 in islet 9 and never attained high density or biomass.

– *Lumbricus castaneus* Savigny, 1826, the 4th most common earthworm species in Belgium (BOUCHÉ, 1978), was found only in islets 11 and 12 (at low densities) during the preliminary sampling.

– *Satchellius mammalis* Savigny,1826 is a very rare species in Belgium (BOUCHÉ, 1978). It was present in islets 5 and 8 with frequencies of 0.65 and 0.52 respectively but at relatively modest densities.

Density and biomass

Tables 4 and 5 summarise average annual earthworm density and biomass data respectively.

The coefficients of variation (i.e. the standard deviations relative to the means) for global density and biomass often exceeded 100%, reflecting a high heterogeneity in our samplings.

TABLE 4

Density (individuals / m²): annual mean ± standard deviation of earthworms in the lawns of Roosevelt avenue (Brussels, Belgium)

	Islet 3 (n = 51)	**islet 5 (n = 50)**	**islet 8 (n = 53)**	**islet 9 (n = 52)**	**islet 10 (n = 52)**
Allolobophora chlorotica	25.3 ± 49.6		0.30 ± 1.54		
Aporrectodea caliginosa	17.1 ± 28.7	40.0 ± 39.9	30.0 ± 37.6	30.6 ± 34.4	31.4 ± 43.2
Aporrectodea longa	40.2 ± 59.0	65.1 ± 70.4	34.9 ± 44.0	36.9 ± 48.8	29.5 ± 36.3
Aporrectodea icterica	30.6 ± 46.8	48.6 ± 47.3	12.1 ± 18.5	3.5 ± 12.7	2.00 ± 6.70
Aporrectodea rosea	65.4 ± 99.4	55.8 ± 65.6	24.0 ± 36.9	26.5 ± 54.7	24.9 ± 52.9
Lumbricus rubellus	0.47 ± 1.90	12.8 ± 15.0	21.1 ± 21.8	5.23 ± 7.90	1.38 ± 3.79
Lumbricus terrestris			3.17 ± 8.05	0.61 ± 2.67	
Satchellius mammalis		30.4 ± 36.4	10.9 ± 15.1		
Total	179.0 ± 237.7	252.8 ± 222.5	136.8 ± 134.3	103.4 ± 120.9	89.2 ± 113.0

TABLE 5

Fresh biomass (g/m²): annual mean ± standard deviation of earthworms in the lawns of Roosevelt avenue (Brussels, Belgium)

	Islet 3 (n = 51)	**islet 5 (n = 50)**	**islet 8 (n = 53)**	**islet 9 (n = 52)**	**islet 10 (n = 52)**
Allolobophora chlorotica	2.71 ± 4.83		0.078 ± 0.40		
Aporrectodea caliginosa	5.57 ± 9.74	11.7 ± 12.5	9.90 ± 13.2	13.2 ± 18.6	12.4 ± 18.1
Aporrectodea icterica	12.7 ± 20.4	23.4 ± 22.9	6.47 ± 9.85	0.58 ± 1.89	0.39 ± 1.39
Aporrectodea longa	37.5 ± 57.1	101.9 ±122.3	61.6 ± 82.7	67.1 ± 100.0	33.7 ± 44.3
Aporrectodea rosea	5.20 ± 7.31	6.04 ± 6.60	2.51 ± 3.77	2.59 ± 4.77	2.37 ± 4.52
Lumbricus rubellus	0.15 ± 0.67	7.64 ± 11.05	14.3 ± 21.3	3.04 ± 7.07	0.41 ± 1.29
Lumbricus terrestris			7.27 ± 18.81	1.30 ± 5.71	
Satchellius mammalis		2.18 ± 2.66	1.10 ± 1.66		
Total	63.9 ± 83.6	153.0 ± 158.5	103.3 ± 112.6	87.8 ± 122.4	49.2 ± 62.8

ANOVA and a multiple average comparison revealed that the 5 islets were heterogeneous on the basis of density ($F = 7.39$, $p < 0.001$) and of biomass ($F = 6.49$, $p < 0.001$).

The islets ranked 5, 3, 8, 9 and 10 successively in decreasing order of density. A multiple average comparison indicated that islet 5 contained significantly more worms than any other (Tukey test, $0.04 > p > 0.0001$) and that islet 3 housed significantly more worms than islet 10 ($p < 0.01$).

The islets ranked 5, 8, 9, 3 and 10 in decreasing order of biomass. A multiple average comparison indicated that islet 5 contained significantly more worm biomass than islets 9, 3 and 10 (Tukey test, $0.04 > p > 0.0001$) and that islet 8 housed significantly more worm biomass than islet 10 (p<0.02).

No significant correlation could be found between worm density and the soil parameters but worm biomass was correlated positively with silt (r=0.87, p=0.05) and negatively with pH (r=-0.89, p<0.05).

DISCUSSION

Comparison of our species richness data with other earthworm inventories in the literature is complicated by taxonomic instabilities. From the whole Belgian territory, Bouché (1978) listed 30 species and subspecies that only accounted for 23 species *sensu* Sims & Gerard (1985). Comparisons are further hampered by variation in extraction technique and effort between surveys. With the aim of comparing species richness we have used the nomenclature of Sims & Gerard (1985).

Studies in herbaceous habitats of Belgium and the Grand Duchy of Luxemburg found that specific richness generally varied between two and ten species: six to seven species in three Ardenne meadows (Symoens, unpublished data), four to ten species (average=7.2) in 13 grasslands and lawns of the region of Treignes, south of Belgium (Hidvegi, unpublished data)), nine species in a grassland near Echternach, Grand Duchy of Luxemburg (Massard, unpublished data), two to nine species (average=5.8) in the lawns of 19 Brussels parks (Josens & Pizl, unpublished data). In other studies dedicated to grasslands and meadows, the specific richness was of the same order of magnitude: six to eight species in Sweden (Nordström & Rundgren, 1973), and eight to ten species in Finland (Terhivuo, 1989).

The soil being deeply and heavily compacted below the roads, we postulate that underground population exchanges are very unlikely. Thus from the earthworm standpoint the lawns of Roosevelt avenue can be considered as a string of islands cut off from the gardens and parks of the city by the roadways of the avenue. One can then wonder if the composition of the earthworm communities of the avenue is mainly a relict of the fauna present before the construction of the avenue or that of the embankment soils, and if the theory of islands can be applied.

If the theory of islands applies, the size of the islets and their specific richness should be significantly correlated, but this was not the case. Another expected effect of insularity would be that these small islets (900 to 2000 m^2) should contain less species than larger parks. According to the preliminary sampling, the 12 islets of Roosevelt avenue contained on average 5.58 ± 1.00 species, whereas the lawns of 19 parks of Brussels studied with the same method and with the same sampling effort (Josens & Pizl, unpublished data) housed 5.84 ± 1.77 species. The slight difference is not significant (t test, p=0.65). Therefore no effect of insularity can be detected based on specific richness.

Comparison of the earthworm communities in the lawns of Roosevelt avenue with a series of 19 parks of Brussels, using the correlation coefficient of the relative frequency of species (Table 6), revealed good similarity (r=0.69, p=0.04). The five commonest species of the parks (present in at least 33% of samples) were all represented in the lawns of the avenue. However, two species of *Lumbricus* (*L. castaneus* and *L. terrestris*) were present in the islets but significantly less frequently than in parks, whereas the reverse applied for *Aporrectodea longa*.

TABLE 6

Relative species frequency of earthworms extant in the parks of Brussels and the islets of Roosevelt avenue (Brussels, Belgium).

	Parks of Brussels (n = 19)	**Roosevelt islets (n = 12)**	***Fisher test***
Allolobophora chlorotica	0.32	0.25	*ns*
Aporrectodea caliginosa	0.89	1.00	*ns*
Aporrectodea icterica	0.32	0.58	*ns*
Aporrectodea limicola	0.21	0.00	*ns*
Aporrectodea longa	0.26	1.00	*0.0001*
Aporrectodea rosea	0.95	1.00	*ns*
Dendrobaena octaedra	0.05	0.00	*ns*
Eiseniella tetraedra	0.05	0.00	*ns*
Lumbricus castaneus	0.63	0.17	*0.01*
Lumbricus rubellus	0.89	0.92	*ns*
Lumbricus terrestris	0.68	0.17	*0.006*
Octolasion cyaneum	0.16	0.00	*ns*
Octolasion lacteum	0.26	0.00	*ns*
Octolasion tyrtaeum	0.05	0.00	*ns*
Satchellius mammalis	0.10	0.33	*ns*

ns: difference not significant

It is worthwhile to point out the distribution of at least two species: *Satchellius mammalis* was present from islet 5 to 8 and absent elsewhere (Table 2), and *Aporrectodea icterica* was present from islet 2 to 8 and absent elsewhere. This kind of distribution suggests a spreading from a centre that might be in islet 6 or 7 for *S. mammalis* and in islet 4, 5 or 6 for *A. icterica*. If this is true, it means that population exchanges can occur between the islets. Actually the vehicular traffic is much more intense alongside the islets than between them, which should allow easier exchanges between islets.

Before discussing the absolute values of density and biomass we should point out that the standard deviations of these parameters are very high (Tables 3 and 4). This is a consequence of a complex set of effects: the efficiency of the electric method and the activity of earthworms both depend on temperature and soil humidity, and our sampling was spread over a complete year including a cold winter and a dry summer.

Our figures of density and especially of biomass are fairly high in comparison with data in the literature. The latter rarely exceed 120 g/m^2 (NORDSTRÖM & RUNDGREN, 1973, LEE, 1985, TERHIVUO, 1989, STANDEN, 1979, DECAËNS et al., 1997) for samplings performed in the most favourable periods (spring and/or autumn), whereas they rank from 50 to 150 g/m^2 in Roosevelt avenue. Furthermore, our figures, based of an annual average, are obviously underestimates since the method can extract about 87% of worms only in good conditions (THIELEMANN, 1986) and efficiency is obviously much lower during cold winter weeks and dry summer periods (moreover *A. longa* is in diapause from late May till late August).

These high density and biomass figures may be explained by the abundance of food and by the rarity of predators. The grass is mown twice a month from April to October without being exported, and thus represents a regular supply of food. Moreover, PIZL & JOSENS, 1995a showed that there was no obvious impact of soil pollutants from car traffic on the communities of earthworms in the avenue. Therefore, competition and dependence on soil characteristics must be the major regulatory factors acting on those communities (SATCHELL, 1967, *in* PHILLIPSON et al., 1976).

Population biomass proved to be correlated positively with silt and negatively with pH. Although the best correlation was found with pH we doubt that this parameter, which varies in a very narrow range (from 6.9 to 7.15), can explain the biomass variation between 50 and 150 g/m^2, and this all the more so since this correlation is negative. This unexpected correlation can actually be explained by the presence of small amounts of carbonates in the two sandiest soils. This kind of correlation should not occur in most natural soils but is quite likely to occur in urbanised soils.

Since pH is also correlated negatively with silt and water and positively with sand, the large biomass variation probably relies on a complex set of parameters. This should be analysed factorially, but unfortunately we did not have sufficient measurements of each of the parameters to perform such an analysis. This variation is probably initiated by the soil texture: in the islets 5 and 8 with high silt (plus clay) content, water and organic matter are retained more strongly and for longer on soil particles, a situation that favours high biomass.

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REFERENCES

BEGON, M., J.L. HARPER, & C.R. TOWNSEND (1990). *Ecology: Individuals, populations and communities*. Blackwell science. Second edition. 945 pp.

BOUCHÉ, M.B. (1972). *Lombriciens de France. Ecologie et systématique*. Institut National de la Recherche Agronomique, *Annales de zoologie – Ecologie animale*, N° hors série, Paris, 671 pp.

BOUCHÉ, M.B. (1976). Contribution à la stabilisation de la nomenclature des Lumbricidae, Oligochaeta. I. Synonymies et homonymies d'espèces du bassin parisien. *Bull. Mus. national Hist. nat.*, 354 (3): 81-97.

BOUCHÉ, M.B. (1978). Atlas provisoire des Lombriciens de Belgique et des pays limitrophes. *Cartographie des Invertébrés européens*. Faculté des Sciences agronomiques de Gembloux, 12 pp.

BOULANGÉ, J. (1968). Pédologie. – peuplement en Lumbricidae de trois sols caractéristiques de Lorraine belge. *C. r. Acad. Sc. Paris*. 267: 287- 289.

DECAËNS, T., T. DUTOIT, & D. ALARD (1997). Earthworm community characteristics during afforestation of abandoned chalk grasslands (Upper Normandy, France). *Eur. J. soil Biol.*, 33 (1): 1-11.

FANNING, D.S. & M.C.B. FANNING (1989). *Soil: morphology, genesis and classification*. John Wiley and sons, 395 pp.

GASPAR, C., M. BOUCHÉ, G. LAURENT & C. WONVILLE (1981). Recherche sur l'écosystème forêt: les Lombriciens des sols forestiers Ardennais. *Ann. Soc. r. zool. Belg*., 111: 57-63.

GATES, G.E. (1972). Toward a revision of the earthworm family Lumbricidae. IV. The *trapezoides* species group. *Bull. tall Timber Res. Stn*., 12: 1-146.

LEE, K.E. (1985). *Earthworms, their ecology and relationships with soils and land use*. Academic Press, 411 pp.

MUYS, B. (1993). *Synecologische evaluatie van regenwormactiviteit en strooiselafbraak in de bossen van het Vlaamse Gewest als bijdrage tot een duurzaam bosbeheer.* PhD Rijksuniversiteit Gent, 335 pp.

NORDSTRÖM, S. & S. RUNDGREN (1973). Associations of lumbricids in Southern Sweden. *Pedobiologia*, 13: 301-326.

PHILLIPSON, J., R. ABEL, J. STEEL & S.R.J. WOODELL (1976). Earthworms and the factors governing their distribution in an English beechwood. *Pedobiologia*, 16: 258-285.

PIZL, V. & G. JOSENS (1995a). The influence of traffic pollution on earthworms and their heavy metal contents in an urban ecosystem. *Pedobiologia*, 39: 442-453.

PIZL, V. & G. JOSENS (1995b). Earthworm communities along a gradient of urbanization, *Environmental Pollution*, 90 (1): 7-14.

REYNOLDS, J.W. (1977). The Earthworms (Lumbricidae and Sparganophilidae) of Ontario. *Life Sci. Misc. Pub*. Ontario Mus., 141 pp.

SATCHELL, J.E. (1967). Lumbricidae. In: BURGES, A. & F. RAW (eds): *Soil biology*. Academic Press, London 259-322.

SIMS, R.W. & B.M. GERARD (1985). *Earthworms*. Synopses of the British Fauna (New series) 31: 171 pp. Brill E.J. / Dr Backhuys W. London - Leiden - Köln - København.

STANDEN, V. (1979). Factors affecting the distribution of lumbricids (Oligochaeta) associations at peat and mineral sites in Northern England. *Oecologia*, 42: 359-374.

TERHIVUO, J. (1989). *The Lumbricidae (Oligochaeta) in Eastern Fennoscandia: species assemblages, ecology and zoogeography with particular references to genetic and morphological variation in* Dendrobaena octaedra (SAV.). PhD thesis.

THIELEMANN, U. (1986). Elektrischer Regenwurmfang mit der Oktett-Methode. *Pedobiologia,* 29: 296-302.

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