Acta Protozool. (2006) 45: 395 - 406

ACTA
PROTOZOOLOGICA

Changes in the Testacean Community Structure Along Small Soil Profiles

Sofie VINCKE[1], Bart Van de VIJVER[2], Ivan NIJS[3] and Louis BEYENS[1]

[1]**University of Antwerp, Campus Drie Eiken, Department of Biology, Research group Polar Ecology, Limnology and Paleobiology, Wilrijk;** [2]**National Botanic Garden of Belgium, Department of Bryophytes and Thallophytes, Domein van Bouchout, Meise;** [3]**Research group Plant and Vegetation Ecology, Department of Biology, University of Antwerp, Wilrijk, Belgium**

Summary. The testate amoebae (Protozoa, Rhizopoda) fauna was studied along several small soil profiles, which were collected in the wet valley soils of Île de la Possession (Crozet Archipelago, sub-Antarctica). All soil cores were divided into 3 zones (0-3 / 3-6 / 6-10 cm) and results were compared with an earlier soil study on the island, when soil samples were taken at a depth of 5 to 10 cm. There was no turn-over of testacean taxa between the different soil layers, but the changes in the community structure of the communities along the soil horizons were remarkable. In the upper soil layers (0-3 cm) more taxa belonging to characteristic morphological soil test types were observed, test types which were rarely encountered in the soil samples taken at a depth of 5 to 10 cm. The genera *Assulina*, *Centropyxis*, *Corythion*, *Heleopera* and *Nebela* were more abundant in the upper soil horizons, which led to a reduced dominance of the genus *Trinema*. Also the living fraction of the testacean fauna was significantly higher in the upper soil zones, whereas the highest amount of cysts was observed in the lowest soil horizon (6-10 cm). Some notes are made on the different disappearance patterns of "Filose" and "Lobose" taxa along the valley soil profiles of Île de la Possession. All observed changes along the small soil profiles emphasize the importance of the soil sampling strategy.

Key words: community structure, Île de la Possession, morphological soil test types, peaty valley soils, soil sampling strategy, testate amoebae.

INTRODUCTION

A previous study on the testate amoebae diversity (Protozoa, Rhizopoda) in different soil habitats (valley soils, fellfield soils, marine influenced soils) on Île de la Possession (Crozet Archipelago, sub-Antarctica) revealed 65 testacean taxa belonging to 20 different genera (Vincke *et al.* 2004a). However, the species-genera distribution of that study showed that more than 50% of all testate amoebae tests belonged to one genus only, i.e. *Trinema*. Tests of this genus are being classified under the morphological test type "plagiostome with a visor", a test type which is very commonly observed in all sorts of soils (Bonnet 1975). Contrary to the genus *Trinema*, testate amoebae taxa belonging to other morphological test types characteristic for soils, such as the "compressed acrostome" type (e.g. genera *Assulina*, *Heleopera*, *Nebela* and *Hyalosphenia*), the "axial pseudostome" type (genera *Cyclopyxis*, *Trigonopyxis*, *Phryganella* and *Arcella*) and the "simple cryptostome" type (e.g. genera *Plagiopyxis*, *Bullinaria* and

Address for correspondence: SofieVincke, University of Antwerp, Campus Drie Eiken, Department of Biology, Research group Polar Ecology, Limnology & Paleobiology, Universiteitsplein 1, B-2610 Wilrijk, Belgium; Fax: +32 3 820 2950; E-mail: sofie.vincke@ua.ac.be

Protoplagiopyxis) (Bonnet 1975), were very poorly represented or not observed at all in the studied soil samples on Île de la Possession.

It is also known that a vertical distribution of these protists, which is correlated to some extent with the test shape, can be observed in most soil habitats (Bonnet 1964). In general, larger and more spiny species are found in the upper soil horizons, whereas flatter and smaller species are observed in the lower horizons. The majority (96%) of the testate amoebae taxa found in the soils studied by Vincke *et al.* (2004a), were taxa with relatively small tests (ranging from 8 µm to 75 µm) without spines.

During the field campaign (1999-2000) on Île de la Possession, the soil samples were taken for diatom analysis at a depth varying from 5 to 10 cm (Van de Vijver *et al*. 2002). This might be below the active zone for testate amoebae and therefore it remains unclear whether other morphological test types and larger or more spiny testate amoebae taxa have been overlooked due to inappropiate sampling at that time.

The present study aims to enlarge our knowledge on the vertical distribution of testate amoebae in the wet valley soils on Île de la Possession. Therefore 21 small soil cores, all divided into three zones (see Materials and Methods), were collected during the new field campaign (2004-2005) on the island. Next to changes in the testacean diversity (taxa and test types), specific attention will be given to changes in test size, dead/living ratio, Lobose/Filose index ("Lobose" and "Filose" are referring to the shape of the pseudopodia of the testaceans) and population densities along these soil profiles. The results of the small soil cores will be compared with the observed testacean fauna in the wet valley soils in Vincke *et al.* (2004a).

MATERIALS AND METHODS

Sampling strategy and sample analysis

During the austral summer of 2004-2005 twenty-one small soil cores were collected on Île de la Possession. For each of the 7 sampling sites (Bollard / Jardin Japonais / La Pérouse / Pointe Basse / Rivière du Camp / Vallée de la Hébé / Vallée des Branloires), three soil cores were taken at a sufficiently large distant from each other (> 100m). The soil cores were taken with a cork borer (diameter 22 mm) and each core (total length 10 cm) was sub-divided into three zones: 0-3 cm (upper zone: samples "A"); 3-6 cm (middle zone: samples "B") and 6-10 cm (lower zone: samples "C"), leading to a total of 63 samples. The zero level has been determined as being the bare soil after removal of living plant material. All samples were fixed immediately with 3% formaldehyde and stored in 25 ml PVC bottles. For each soil core, soil moisture was measured at a depth of 5 cm and 20 cm (Eijkelkamp TRIME-FM), temperature at a depth of 3 cm and 10 cm (Novo Quick®) and the dominant surrounding vegetation was noted. Appendix 1 lists the environmental data of the 21 small soil cores.

Sampling sites were chosen randomly scattered on the entire island (Fig. 1), but the soil type was fixed. Since the dry fell-field soils on the island contained little or no testate amoebae (Vincke *et al.* 2004a), all soil cores were taken exclusively in wet valley soils. This species rich soil type with high population densities allows a detailed study of the distribution patterns of the testate amoebae fauna. Testacean observations in the small soil cores of this study will be compared with the ones found in the valley soils of Vincke *et al.* (2004a).

In the laboratory, about two gram of soil of each sample was mixed with 10 tablets of *Lycopodium* spores (BATCH 483216, Lund University, Sweden) in distilled water to calculate the population density. Afterwards these soil samples were passed through a sieve with a mesh diameter of 297 µm and concentrated by centrifugation (10 min at 2000 rpm). The colour rose bengal was added to the samples to distinguish dead from living individuals (at the moment of sampling). Encysted testate amoebae were considered as being alive. In each soil sample 150 tests were counted using a Leitz Wetzlar® microscope. Morphological identifications of the testate amoebae are mainly based on works by Decloître (1962, 1978, 1979, 1981), Deflandre (1928, 1929, 1936), Grospietsch (1964), Hoogenraad and de Groot (1940), Ogden and Hedley (1980) and Ogden (1983). All samples are stored at the University of Antwerp, Unit of Polar Ecology, Limnology and Paleobiology.

Data analysis

To compare the testate amoebae faunas of the 21 small soil cores and the valley soils of Vincke *et al.* (2004), the Community Coeffient of Sørensen (1948) was calculated : 2c/(a+b+2c), where "a" and "b" are the number of taxa exclusively observed in one study and "c" is the number of taxa the two studies have in common.

A diversity analysis comprised the calculation of the 'Gini evenness measure' (Nijssen *et al.* 1998) and the 'Shannon Wiener diversity index' ($\log_{10}$-based) using the Multivariate Statistical Package (MVSP, Kovach Computing Services 2002).

Ordination analyses included a hierarchic-agglomerative cluster analysis, based on a minimum variance strategy with the Squared Euclidean Distance as a dissimilarity measure (MVSP, Kovach Computing Services 2002) and a Correspondance Analysis (CANOCO, version 4.0) (Ter Braak and Smilauer 1998) to classify the species data (ln-transformed). A Canonical Correspondance Analysis was carried out to detect possible patterns within species and environmental data (CANOCO, version 4.0) (Ter Braak and Smilauer 1998). Forward selection with unrestricted Monte Carlo tests (999 permutations, $P \leq 0.05$) was used to detect which variables significantly influenced the sample/species distribution, but unfortunately no significant variables ($P > 0.1$) were selected.

To examine the relationship between the testacean test sizes and their occurrences in the different soil layers ("A"/ "B"/ "C"), a regression analysis was carried out. Therefore 10 individuals of all encountered taxa (56) were measured (length in µm) randomly over all soil cores. Mean test sizes together with their standard errors (SE) are shown in Appendix 2. Counting 10 individuals of each taxon was a feasible number for most testate amoebae taxa, since 40 out of 60 taxa had relative abundances <0.5% (see Results). The relatively small SE's reflected a natural variability within the test sizes of the testate amoebae taxa. For 4 taxa however (*Archerella* sp. 1, *Centropyxis platystoma* (Penard) Deflandre, *Corythion* sp. 1 and *Cyclopyxis puteus* Thomas) only one individual was observed over all soil core samples, so no mean size could be calculated and therefore these 4 taxa were left out of the regression analysis. All mean test sizes were log-transformed and divided into 10 equal size-classes. For each size-class a regression analysis was performed between the log-transformed abundance data of the taxa of that particular size-class and the soil depth ("A"/ "B"/ "C"). Calculated slopes of these regression analyses were then used in a final regression analysis with the mean size of the testate amoebae per size-class.

Statistical tests to compare the means of diversity, evenness, number of taxa, population densities and the living testate amoebae fraction between the different soil zones ("A"/ "B"/ "C"), included several One Way ANOVAs (data parametric) and, Kruskal-Wallis and Mann-Whitney tests (data non-parametric) (SPSS 12.0).

RESULTS

General observations

The analysis of the 21 soil profiles revealed a testate amoebae fauna of 60 taxa (20 genera). A detailed list of all observed taxa, together with their relative abundances (%) in each soil layer ("A"/ "B"/ "C"), is given in Appendix 2. Two taxa, namely *Cyclopyxis puteus* and *Centropyxis sacciformis* Hoogenraad, are reported for the first time on Île de la Possession. Forty-five taxa, including these 2 previously unreported species, had relative abundances <1% (40 taxa <0.5%). Dominant taxa were *Trinema lineare* Penard (34%), *Euglypha rotunda* Wailes (20.5%) and *Difflugiella oviformis* (Penard) Bonnet *et* Thomas (10%). Thirteen testate amoebae taxa were not observed in Vincke *et al.* (2004a) and are marked with an asterisk in Appendix 2.

The Sørensen similarity analysis (0.8) between the valley soils of Vincke *et al.* (2004a) and the small soil cores, indicates that both testate amoebae faunas are very much alike in terms of species composition. Taxa that were not observed in this study, all had relative frequencies <0.5% in Vincke *et al.* (2004a). The newly observed taxa in this study also had relative abundances <0.5%.

A cluster analysis (Fig. 2) and a Correspondance analysis (not shown) revealed that all 21 soil cores had rather similar testacean faunas, since the "Squared Euclidean" distances for clustering were relatively low and all samples were grouped together in the middle of the CA-ordination diagram. Also the similarity in species composition between the different zones of each soil profile appeared to be very high as the "A"/ "B"/ "C", samples of the same profile were always grouped (close) together. A Canonical Correspondence Analysis (not shown) could not reveal any clear relationships between the testate amoebae fauna and the environmental variables, since all samples were again accumulated in the centre of the ordination diagram.

Observations along the soil profiles

Species composition, diversity and population density. Changes in the relative abundances (%) of all observed testate amoebae can be derived from Appendix 2. Since 45 taxa had relative abundances <1%, trends in occurrence of these species are hard to predict. There was no turn-over of species observed along the soil profiles. Most taxa observed in soil layers "A", were also observed in soil layers "B" and "C". Nevertheless, clear differences in the total number of tests encountered per soil layer, could be observed for several taxa (Fig. 3). A clear decrease in the total number of tests encountered from zone "A" to zone "C", can be observed for taxa as *Arcella arenaria* Greeff, *Assulina muscorum* Greeff and *Corythion dubium* Taranek, whereas the amount of tests of *Difflugia pristis* Penard, *D.* sp. 3, *Trinema enchelys* Leidy, *Difflugiella oviformis* and *Pseudodifflugia fulva* Penard increases notably with depth.

Diversity analysis of the soil cores revealed no significant (One Way ANOVA: P>0.05) differences in the mean Shannon-Wiener diversity, GINI evenness or the number of taxa between the 3 soil zones. Also changes in population densities were insignificant (One Way ANOVA: P>0.05) (Table 1).

Morphological test types. According to Bonnet (1975) there are 5 morphological test types of testate amoebae which are characteristic (relative frequencies >10%) in soil habitats. A schematic reproduction of these 5 morphological test types is given in Fig. 4. Table 2 compares the relative abundances (%) of several genera, between the valley soils of Vincke *et al.* (2004a) and the different zones ("A"/ "B"/"C"), of the small soil cores of this study. Genera have been classified according to their morphological test type and the types are once more arranged with decreasing importance in soils.

This comparison clearly shows that the upper soil layers (zone "A": 0 to 3cm) of the small soil cores contain substantially more individuals of the genera

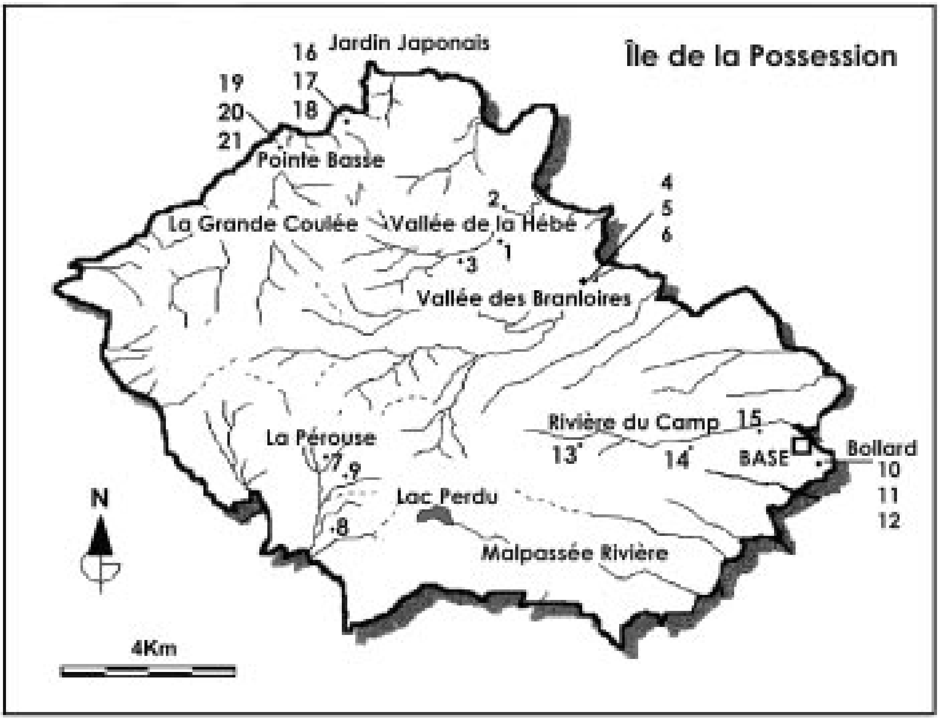

Fig. 1. Sketch map of Île de la Possession, showing the locations were the 21 small soil cores have been collected.

Assulina, *Heleopera* and *Nebela*. Also the relative abundances of the genera *Centropyxis* (especially *C. aerophila* and its varieties) and *Corythion* are higher compared to those of the other zones and of the valley soils of Vincke *et al.* (2004a). The detailed analysis of the soil cores (especially the upper zones "A") could not prove the presence of any species belonging to the cryptostome type. Also individuals of the axial type were again very scarce in the wet valley soils of Île de la Possession.

Test size. Smallest tests belonged to *Difflugia* sp6 (7.0 ± 0.2 µm) and *Difflugiella pusilla* Playfair (9.2 ± 0.4 µm), while the largest tests belonged to *Nebela vas* Certes (188 ± 6 µm) and *Cyclopyxis puteus* (195 µm) (see Appendix 2). The majority (66%) of all observed tests had rather small test dimensions varying between 20 µm and 40 µm. This was mainly due to the high abundances of *T. lineare*, *E. rotunda* and *D.* sp. 3.

Bonnet in 1964 stated that a vertical distribution of testate amoebae can be observed in most soil habitats : larger and more spiny species are more frequently observed in the upper soil horizons, while flatter, smaller species dominate the lower horizons (Bonnet 1964). To check if this hypothesis applied for the wet valley soils on Île de la Possession, a regression analysis was carried out between the mean sizes of the testate amoebae tests and their abundances in the different soil layers ("A"/"B"/"C"), (see Data analysis). The regression analysis revealed a very weak negative relation ($y= -0.0001x + 0.0061$, $R^2= 0.0971$) between test sizes and their occurrences in the different soil zones. Unfortunately, this negative relation appeared not significant ($P=0.2$). Apparantly, abundances of testate amoebae with large tests are too low in the soils of Île de la Possession, so a more clear relationship can not be proven.

Only 5 taxa with spines were observed, namely *Euglypha ciliata* (Ehrenberg) Penard, *E. compressa* Carter, *E. cristata* Leidy, *E. strigosa* Leidy and *Corythion* sp. 1. The 3 latter taxa had higher relative abundances in soil layer "A" (see Appendix 2), but a significant statistical trend could not be observed due to the low numbers of individuals of these spiny taxa.

Living testacean fraction. Only 3.4% of the testate amoebae fauna (including cysts) was alive at the moment of sampling. Statistical tests showed a high significant difference between the mean number of living

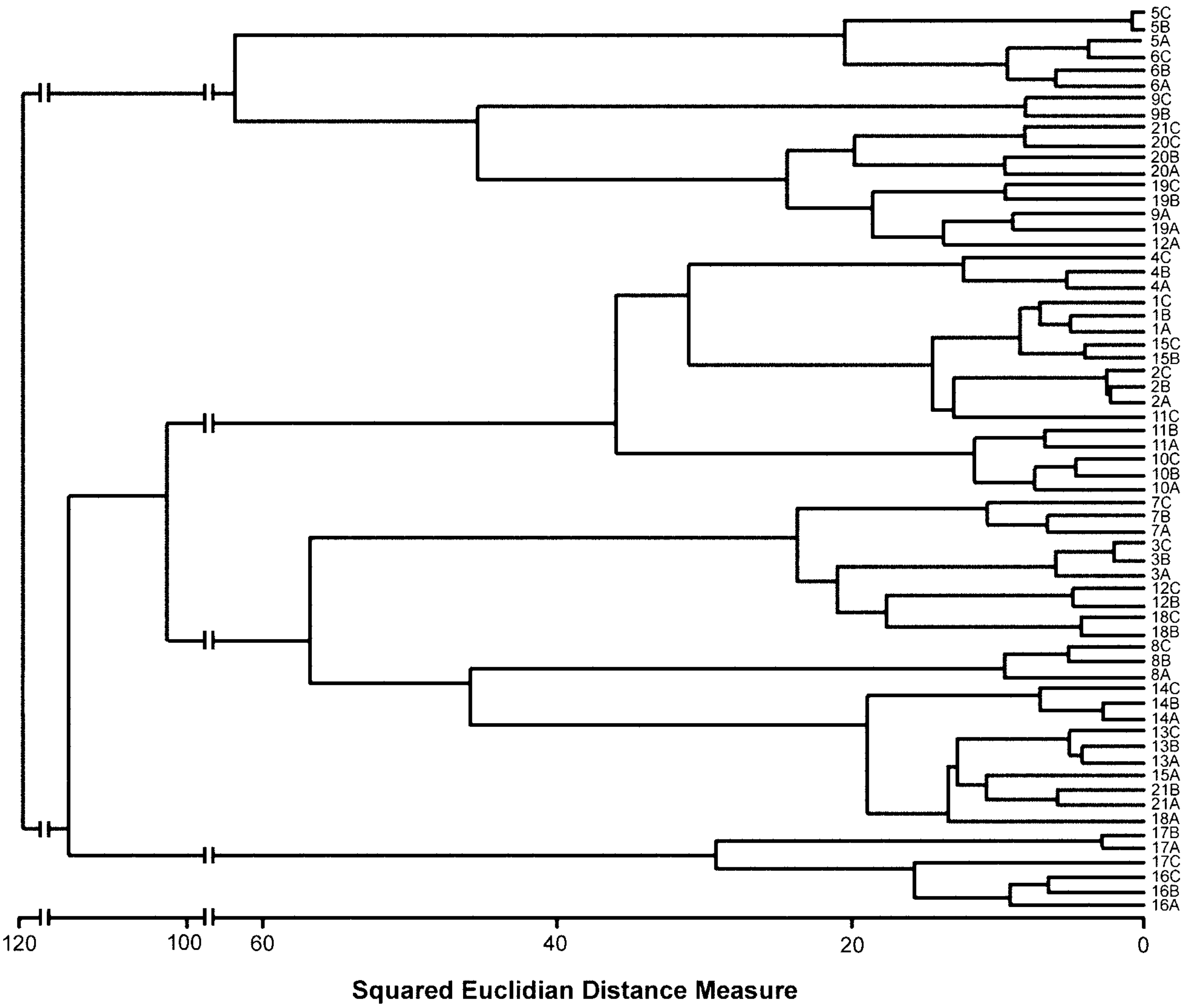

Fig. 2. Cluster dendrogram, showing the similarity between the different zones ("A"/ "B"/ "C") of each soil core.

individuals found in the three different soil zones ("A"/ "B"/ "C"), (Kruskall-Wallis test, $P < 0.001$). Three pairwise comparisons between "A"/"B","B"/"C" and "A"/"C" layers also revealed significant differences between the layers (Mann-Whitney tests, "A"/"B": $P < 0.0001$; "B"/"C": $P<0.01$; "A"/"C": $P < 0.0001$). The quantity of living testate amoebae was clearly the highest in the upper soil layers (zone "A": 0 to 3 cm) and decreased rapidly towards more profound soil layers (zones "B"/"C") (Fig. 5). The variation of living individuals within each layer is shown by the means and their standard deviation (zone "A": 10 ± 3; zone "B": 4 ± 4; zone "C": 2 ± 3). Individuals that were alive in the lower soil zones ("B"/"C":3 to 10 cm) were more frequently encysted, compared to the ones in soil zone "A" (Fig. 5). However, the observed number of cysts (0.4%) was too low to establish a statistical trend.

Lobose-Filose index. The LF-index of Bonnet (1976) was calculated for the 3 different soil layers (zone "A": -0.65; zone B: -0.59; zone C: -0.61). Genera, such as *Difflugiella* and *Cryptodifflugia*, with pseudopodia in between "Lobose" and "Filose", were left out of the calculation. All LF-values were rather similar to the one found for the wet valley soils (-0.68) in Vincke *et al.* (2004a), once again due to the overal dominance of euryvalent species of *Trinema, Euglypha* and *Corythion*

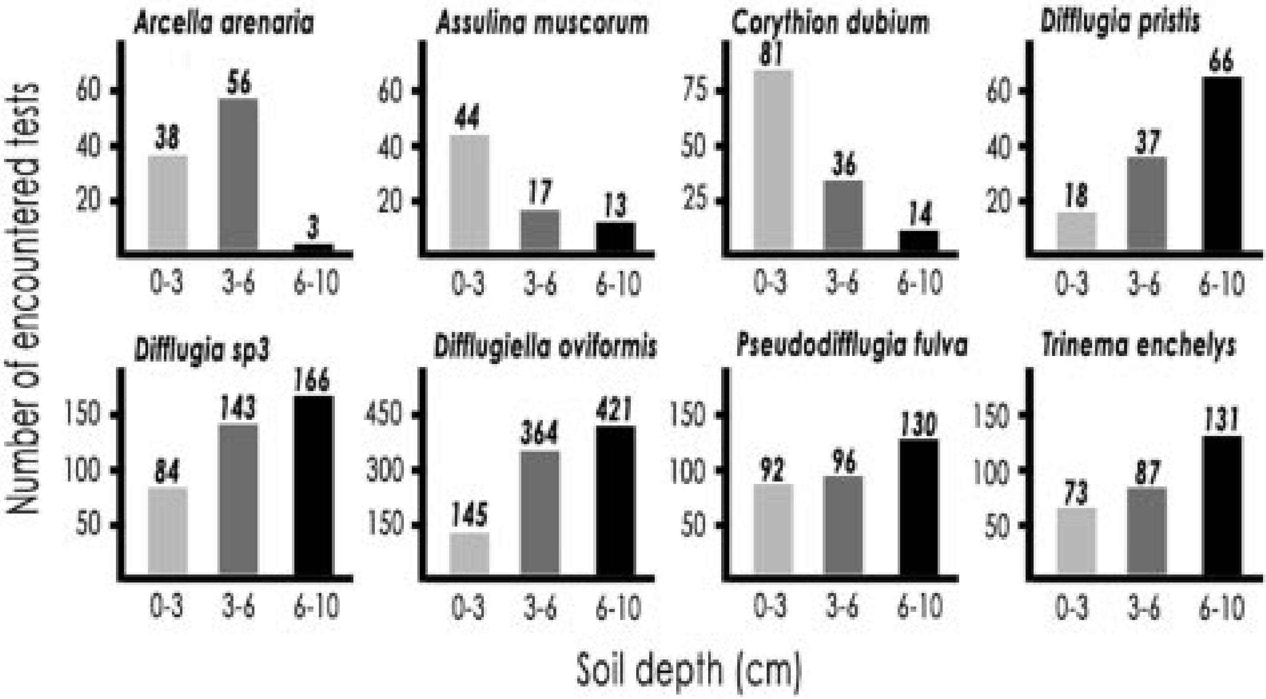

Fig. 3. The total number of tests encountered in the different soil zones (0-3 cm / 3-6 cm / 6-10 cm soil depth) of several testate amoebae species.

(Balik 1994). No remarkable changes between the LF-values of the different soil layers ("A"/ "B"/ "C"), could be observed (Kruskall-Wallis test, P=0.8). This means that the amount of tests belonging to the "Filosa" and the "Lobosa" does not decrease or increase significantly with depth.

DISCUSSION

A comparison of the testacean fauna observed in the small soil cores with the one observed in the wet valley soils of Vincke *et al.* (2004a), shows that there are only small differences in species composition between both studies. Apparently, the fact that the soil samples in the previous study had been taken rather deep (5 to 10 cm), has no major influence on the species richness of the testate amoebae fauna taxa in the soil samples.

However, significant differences are observed in the community structure when comparing the relative abundances of several taxa. Genera, such as *Assulina*, *Heleopera* and *Nebela*, belonging to the most common morphological test type in soils (compressed acrostome), have remarkably higher relative abundances, especially

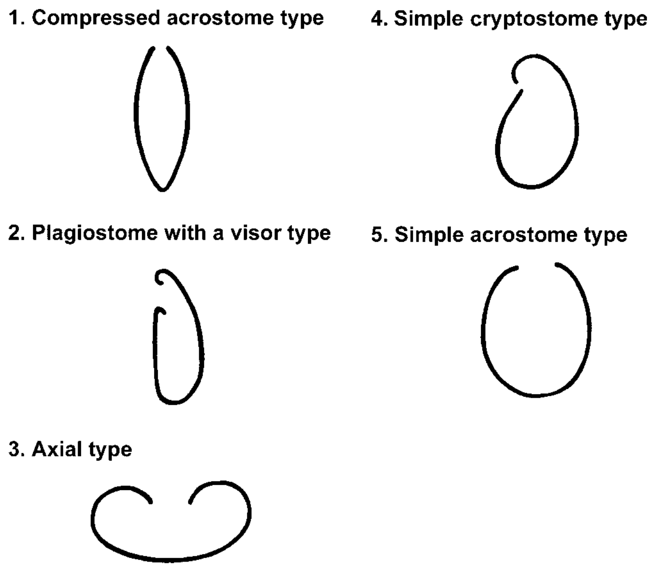

Fig. 4. A schematic reproduction of the 5 morphological test types with the highest relative frequencies in soils. The 5 test types are arranged with decreasing importance in soil habitats. Other morphological test types of Bonnet (1975) are not shown.

in soil zone "A", compared to the ones of the valley soils of Vincke *et al.* (2004a). Also tests belonging to the

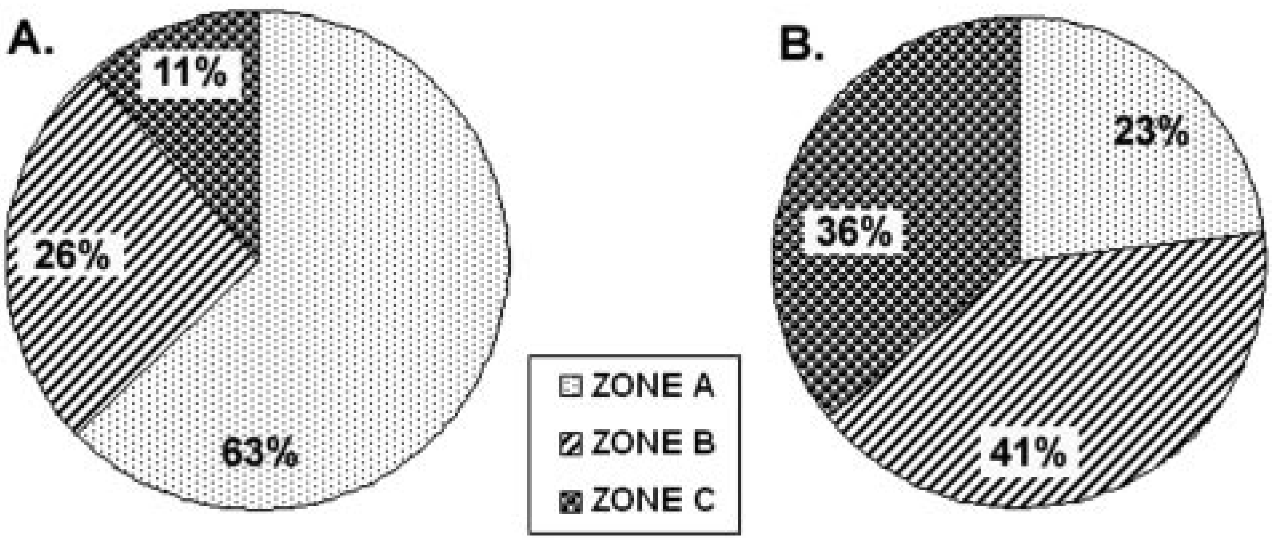

Fig. 5. Pie diagrams showing (**A**) the percentages of living tests encountered in each soil zone ("A"/ "B"/ "C"), and (**B**) the percentages of encysted individuals in each zone.

Table 1. Means with standard errors of the Shannon-Wiener Diversity Index, the GINI Evenness Measure, the total number of taxa and the testacean population densities in each soil zone ("A"/ "B"/ "C").

	Zone "A" (0-3 cm)	Zone "B" (3-6 cm)	Zone "C" (6-10 cm)
Shannon-Wiener Diversity Index	0.80 ± 0.03	0.80 ± 0.03	0.78 ± 0.03
GINI Evenness measure	0.34 ± 0.01	0.36 ± 0.02	0.33 ± 0.01
Number of taxa	15.5 ± 0.6	14.9 ± 0.8	15.0 ± 0.7
Population density per gram soil	1553050 ± 186185	2051562 ± 374040	1991323 ± 432607

genera *Centropyxis* and *Corythion* of the "plagiostome with a visor" test type, are more frequently observed in this study. Again, their abundance appears to be the highest in the upper soil layers "A", the part of the soil which was not sampled in Vincke *et al.* (2004a). The increase of the other characteristic soil test types leads to a reduced dominance of the genus *Trinema* in the soil cores (34% versus 51% in Vincke *et al.* 2004a).

Tests of *Assulina muscorum* and *Corythion dubium*, two taxa characteristic for drier habitats (Vincke *et al.* 2004c), were more frequently observed (also living individuals) in the upper soil layers "A", where moisture values were considerably lower than in soil zones 'B' and "C". Living individuals of these two taxa in soil layers "B" and "C" (3 to 10cm) were very scarce, but when observed, they were always encysted. In contrast to this, tests of *Pseudodifflugia fulva*, *Trinema enchelys* and several *Difflugia* taxa, all characteristic taxa for moist to wetter (even aquatic) habitats, had remarkable higher abundances in the lower soil zones (6 to 10 cm). Living (not encysted) individuals of these taxa were encountered in all soil layers, but encysted tests were more frequently observed in the upper, drier soil layer "A".

Smith (1973) observed no consistent difference in the numbers of *Corythion dubium* between the three soil horizons (0-3/3-6/6-9 cm) he studied on Signy Island. Also on South Georgia (Smith and Headland 1983) a similar testacean species compostion was observed in 2 soil layers (0-3/3-6 cm) and again no pattern in the

Table 2. Comparison of the relative abundances (%) of several genera, classified according to morphological test types of Bonnet (1975), between the different zones ("A"/ "B"/ "C") of the soil cores of this study and the valley soils of Vincke *et al.* (2004a). The morphological test types are arranged with decreasing importance in soils (Bonnet 1975).

	Valley soils		Small soil cores	
		Zone "A"	Zone "B"	Zone "C"
	5-10 cm	0-3 cm	3-6 cm	6-10 cm
1. Compressed acrostome type				
Assulina	0.6	1.8	1.0	1.1
Heleopera	0.1	0.4	0.5	0.2
Hyalosphenia	0.02	0.03	0.03	0.03
Nebela	0.2	2.6	1.7	1.5
2. Plagiostome with a visor type				
Centropyxis	0.02	0.4	0.3	0.06
Corythion	0.8	2.7	1.1	0.4
Trinema	51.1	39.5	35.7	35.4
3. Axial pseudostome type				
Cyclopyxis	1.6	0.2	0.5	0.4
Phryganella	0.1	-	-	-
Trigonopyxis	-	-	-	-
4. Cryptostome type				
Bullinaria	-	-	-	-
Plagiopyxis	-	-	-	-
Protoplagiopyxis	-	-	-	-
5. Simple acrostome type				
Difflugia	4.9	4.6	8	9.2
Difflugiella	7.6	6.4	13.9	16.1
Tracheleuglypha	1.2	0.8	0.7	0.3

vertical distribution of abundance of the testate amoebae taxa was noticed. It is possible however that change in abundances between the different soil horizons were masked by the seasonal variations of the taxa in both studies.

Although no changes in testacean diversity nor evenness were observed between the different soil horizons on Île de la Possession, the variations in the community structure (abundance and dominance of several taxa / living fraction of testaceans) are obvious. These observations clearly indicate that the soil samples of Vincke *et al.* (2004a) were taken too deep (5 to 10 cm) into the soil and below the most active zone of testate amoebae, for this observations to be made. The results of this study clearly complete the data of the studied valley soils in Vincke *et al.* (2004a). The distinction made between the three different soil types (peaty valley soils, fellfield soils and marine influenced soils) in Vincke *et al.* (2004a) remains valuable however. Most likely similar changes in the testacean community structure along soil profiles collected in fellfield soils and marine influenced soils would be observed.

It remains striking however that even in the present study, especially in upper soil layers "A", again no taxa were observed of the cryptostome and the axial test type (except for a few tests of *Cyclopyxis*), which are both very characteristic test types in soils (Bonnet 1964). In contrast to this, tests of the cryptostome and axial type are relatively frequently encountered in soils and mosses on the neighbouring sub-Antarctic islands, Îles Kerguelen (Bonnet 1981) and Marion Island (Grospietsch 1971). Only a few empty shells of *Plagiopyxis callida* Penard, *P. declivis* Thomas and *Phryganella paradoxa* Penard were observed in previous studies in moss and aquatic habitats of Île de la Possession (Vincke *et al.* 2004b,c).

Also the expected increase in the amount of larger and more spiny taxa in the upper soil layers on Île de la Possession, was not completely fulfilled. Bonnet (1975) stated that the distribution of morphological test types was closely related to the water availability. Low moisture availability will favour species with reduced test and pseudostome size (Foissner 1987). The 21 soil cores however, were collected in valley soils with mean moisture values (VOL%) of 33 ± 4 at 5 cm depth and 60 ±

6 at 10 cm depth in the soil. Knowing that the rainfall on Île de la Possession usually exceeds 2400 mm per year (Frenot 1986), these valley soils seem rather moist habitats. It might be possible that individuals of genera, such as *Plagiopyxis, Bullinaria* and *Protoplagiopyxis* (cryptostome test type), are too drought-adapted and therefore are outcompeted in those moist habitats. Evidently, the moisture content of the habitat is not the only factor determining the testacean species distribution. Besides other variables (e.g. pH, trophic state, microbial food webs), also soil structure and soil porosity may have an important influence on the testate amoebae fauna in the soils of Île de la Possession. Since the porosity of the "peaty" valley soils is rather low, the small test dimensions of taxa in the subclass Testaceafilosia will be favoured in these soil types.

Along the soil profiles no changes in the amounts of tests belonging to either the "Lobose" or the "Filose" type were observed. This is rather striking since one would expect the destruction of empty tests under less favourable conditions deeper into the soil. Lousier and Parkinson (1981) studied the disappearance of empty tests under experimental conditions and noticed that higher moisture contents stimulated the destruction of a larger number of tests. Moreover tests with platelets (idiosomes) appeared to disappear more quickly than the ones made of sediment particles (xenosomes). Apparently these findings do not apply to the real life field conditions of the valley soils of Île de la Possession, at least not for all taxa. Relative abundances of taxa with xenosomes (genera *Centropyxis, Cyclopyxis, Difflugia* and *Pseudodifflugia*) were indeed higher in the lower soil layers, which may indicate a more difficult destruction of these kinds of tests, despite the higher moisture contents in this soil zone. The majority of the taxa with platelets (genera *Assulina*, *Corythion*, *Euglypha*, *Tracheleuglypha*, *Trachelocorythion* and *Trinema*) had lower relative abundances towards soil layer 'C', possibly caused by a higher disappearance rate of empty shells. However, platelet tests of some *Euglypha* taxa and especially *Trinema enchelys* seem to conserve remarkably better in the lower soil layers. Also tests of the genus *Difflugiella* seem to maintain quite well in the soils on Île de la Possession. Probably the disappearance of empty tests, especially in these "peaty" valley soils, will be a complex combination of biological, physicochemical and mechanical features which is beyond the goal of this study. Especially in studies of fossil testacean assemblages, finding out the real reason for fluctuations in test concentrations can be problematic. After all these variations can either be caused by differences in the decay rates of the taxa (Lousier and Parkinson 1981), or by real changes in population densities due to environmental changes in the habitat (Beyens and Meisterfeld 2001). The observed changes in the community structure and the different disappearance patterns of empty tests along soil profiles should be carefully taken into account when interpreting the (sub)fossil testacean fauna in peat cores of Île de la Possession.

Most publications on the testacean fauna in soils all over the world give no indication on the depth at which the soil samples were taken. Some studies sampled the upper 5 cm of the soil (e.g. Smith 1982, 1985; Ledeganck et al 2003), while Bonnet (1976) collected samples of 100 cm^3 of soil, which is actually 10 cm deep into the soil.

In general, if one wants to study the present diversity and ecology of the testacean soil fauna, it is very important to collect soil samples in the upper layers (0 to 3cm) of the soil. Even if testate amoebae are abundantly present in the upper 10 cm of the soil (Stout and Heal 1967; Foissner and Adam 1980; Meisterfeld 1980), there might be remarkable changes observed along these 10 cm. Apparently, as proven in this study, it is not the turn-over in species composition along the soil profile that matters, but the changes in the community pattern (abundances and dominances) of the testacean fauna. Especially the living testacean fraction differs significantly between the upper soil layers and just a few centimeters beneath.

Acknowledgements. The sampling was made possible by the logistic and the financial support of the French Polar Institute (IPEV) in the frame of the Terrestrial Program DIVCRO 405 (Prof. Dr. L. Beyens & Prof. Dr. I. Nijs, Universiteit Antwerpen, Belgium). Dr. Niek Gremmen is thanked for his valuable comments and advice on statistical questions.

REFERENCES

Balik V. (1994) On the soil testate amoebae fauna (Protozoa, Rhizopoda) of the Spitsbergen Islands. *Arch. Protistenkd.* **144:** 365-372

Beyens L., Meisterfeld R. (2001) Protozoa: Testate Amoebae. In: Tracking environmental change using lake sediments. Volume 3: Terrestrial, algal and silicious indicators (Eds. J. P. Smol, H. J. B. Birks and W. M. Last.) Kluwer Academic Publishers, Dordrecht, The Netherlands,1-33

Bonnet L. (1964) Le peuplement thécamoebien des sols. *Rev. Ecol. Biol. Sol.* **1:** 123-408

Bonnet L. (1975) Types morphologiques, écologie et évolution de la thèque chez les thécamoebiens. *Protistol.* **3:** 363-378

Bonnet L. (1976) Le peuplement thécamoebien édaphique de la cote-d'ivoire. Sols de la région de Lamto. *Protistol.* **4:** 539-554

Bonnet L. (1981) Thécamoebiens (Rhizopoda, Testacea*). Bull. Com. Nat. Fran. Res. Antarct.* **48:** 23-32

Decloître L. (1962) Le genre *Euglypha* Dujardin. *Arch. Protistenk.* **106:** 51-100

Decloître L. (1978) Le genre *Centropyxis* I. Compléments à jour au 31 décembre 1974 de la Monographie du genre parue en 1929. *Arch. Protistenk.* **120:** 63-85
Decloître L. (1979) Le genre *Centropyxis* II. Compléments à jour au 31 décembre 1974 de la Monographie du genre parue en 1929. *Arch. Protistenk.* **121:** 162-192
Decloître L. (1981) Le genre *Trinema* Dujardin, 1841. Révision à jour au 31 décembre 1979. *Arch. Protistenk.* **124:** 193-218
Deflandre G. (1928) Le genre *Arcella*. *Arch. Protistenkd.* **64:** 152-288
Deflandre G. (1929) Le genre *Centropyxis*. *Arch. Protistenkd.* **67:** 322-375
Deflandre G. (1936) Etude monographique sur le genre *Nebela* Leidy. *Ann. Protistol.* **5:** 201-327
Foissner W. (1987) Soil Protozoa: Fundamental Problems, Ecological Significance, Adaptations in Ciliates and Testaceans, Bioindicators and Guide to the Literature. (Eds. J. O. Cotliss and D. J. Patterson). *Prog. Protistol.* **2:** 69-212
Foissner W., Adam H. (1980) Vertikalverteilung und Artenzahl der terrestrischen Ciliaten und Testaceen einer Almweide und einer Schipiste auf der Schlossalm bei Bad Hofgastein. *Zool. Anz.* **205:** 181-187
Frenot Y. (1986) Interactions entre la faune lombricienne et les sytèmes édaphiques d'une île subantarctique: Île de la Possession, Archipel Crozet. Thèse de l'Université de Rennes, France
Grospietsch T. (1964) Die gattungen *Cryptodifflugia* und *Difflugiella* (Rhizopoda, Testacea). *Zool. Anz.* **172:** 243-257
Grospietsch T. (1971) Rhizopoda. Beitrag zur ökologie der testaceen Rhizopoden von Marion Island. Max-Planck-Institut für Limnologie, Plön **37:** 411-419
Hoogenraad H. R., de Groot A. A. (1940) Zoetwaterrhizopoden en - heliozoën. Boschma H. Fauna van Nederland IX Leiden
Kovach Computing Services (2002) Multivariate Statistical Package Version 3.1, Users' Manual. Kovach Computing Services, Pentraeth, Wales
Ledeganck P., Nijs I., Beyens L. (2003) Plant functional group diversity promotes soil protist diversity. *Protist* **154:** 239-249
Lousier J. D., Parkinson D. (1981) The disappearance of empty tests of litter- and soil testate amoebae (Testacea, Rhizopoda, Protozoa). *Arch. Protistenk.* **124:** 312-336
Meisterfeld R. (1980) Die Struktur von Testaceenzönosen (Rhizopoda, Testacea) in Böden des Sollings. *Ver. Ges. Oekol.* **8:** 435-447
Nijssen D., Rousseau R., Van Hecke P. (1998) The Lorenz curve: a graphical representation of evenness. *Coenoses* **13:** 33-38
Ogden C. G. (1983) Observations on the systematics of the genus Difflugia in Britain (Rhizopoda, Protozoa). *Bull. Br. Mus. Nat. Hist. Zool. Ser.* **44:** 1-73
Ogden C. G., Hedley R. H. (1980) An atlas of freshwater testate amoebae. Br Mus Nat Hist, Oxford University Press, Oxford
Smith H. G. (1973) The Signy Island terrestrial refrence sites: III. Population ecology of *Corythion dubium* (Rhizopoda: Testacida) in site 1. *Br. Antarct. Surv. Bull.* **33 and 34:** 123-135
Smith H. G. (1982) The terrestrial protozoan fauna of South Georgia. *Polar Biol.* **1:** 173-179
Smith H. G. (1985) The colonisation of volcanic tephra on Deception Island by Protozoa: long-term trends. *Br. Antarct. Surv. Bull.* **66:** 19-33
Smith H. G., Headland R. K. (1983) The population ecology of soil testate rhizopods on the sub-Antarctic island of South Georgia. *Rev. Ecol. Biol. Sol.* **20:** 269-286
Sørensen T. (1948) A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Det Kongelige Danske Videnskabernes Selskabs, Biologisk Skrifter, Copenhagen, **54:** 1-34
Stout J. D., Heal O. W. (1967) Protozoa. Academic Press, London & New York, Soil Biology, 149-195
Ter Braak C. J., Smilauer P. (1998) CANOCO Reference Manual and User's Guide to Canoco for Windows. Software for Canonical Community Ordination (version 4.0). Centre for Biometry, Wageningen
Van de Vijver B., Ledeganck P., Beyens L. (2002) Soil diatom communities from Île de la Possession (Crozet, sub-Antarctica). *Polar Biol.* **25:** 721-729
Vincke S., Ledeganck P., Beyens L., Van de Vijver B. (2004a) Soil testate amoebae from sub-Antarctic Îles Crozet. *Antarct. Sci.* **16:** 165-174
Vincke S., Beyens L., Van de Vijver B. (2004b) Freshwater testate amoebae communities from Île de la Possession, Crozet Archipelago, Subantarctica. *Arct. Antarct. Alp. Res.* **36:** 584-590
Vincke S., Gremmen N., Beyens L., Van de Vijver B. (2004c) Moss dwelling testacean fauna of Île de la Possession. *Polar Biol.* **27:** 753-766

Received on 26th April, 2006; revised version on 12th June, 2006; accepted on 16th July, 2006

Appendix 1. Overview of the locations and environmental characteristics of the 21 small soil cores.

Soil core	Sampling site	Soil Moisture (Vol %)		Temperature (°C)		Dominant surrounding vegetation
		5 cm	20 cm	3 cm	10 cm	
1	Vallée de la Hébé	35.3	51.8	7.8	6.8	*Sanonia uncinata* and *Poa pratensis*
2	Vallée de la Hébé	40	96.4	7.3	6.5	*Jamesoniella grandiflora*, other mosses and *Poa pratensis*
3	Vallée de la Hébé	31.3	82.9	7.4	6.2	*Acaena magellanica* and mosses
4	Vallée des Branloires	49.5	100	7.9	7.4	different mosses and *Poa pratensis*
5	Vallée des Branloires	16.6	26.6	7.2	5.4	*Blechnum penna-marina*, some mosses and *Poa pratensis*
6	Vallée des Branloires	15.6	46.6	8.6	7.4	different mosses, *Poa pratensis* and *Lycopodium saururus*
7	La Pérouse	13	23.5	4.3	4.8	different mosses, *Azorella selago* and *Poa pratensis*
8	La Pérouse	76.8	73.7	6	5	*Breutelia* sp. and other mosses
9	La Pérouse	37.7	46.1	7	6	*Jamesoniella grandiflora*, other mosses and *Poa pratensis*
10	Bollard	40.1	77.7	10.3	8.9	*Breutelia* sp., *Juncus* sp. and *Uncinia compacta*
11	Bollard	30.7	82.4	11.7	8.6	*Jamesoniella grandiflora*, *Agrostis magellanica* and *Juncus* sp.
12	Bollard	8.65	31.4	11.3	7.2	*Blechnum penna-marina* and *Raccomitrium* sp.
13	Rivière du Camp	30.8	32	12.8	9.6	*Sanonia uncinata*, *Acaena magellanica* and *Azorella selago*
14	Rivière du Camp	24.8	40.3	14.8	12	*Breutelia* sp and *Blechnum penna-marina*
15	Rivière du Camp	22.2	82.7	9.2	8.7	*Polytrichum* sp. and *Poa pratensis*
16	Jardin Japonais	19.8	31.5	10.1	9.2	*Poa annua* and *P. coockii*
17	Jardin Japonais	25.5	56.1	9.2	8.6	Acaena magellanica, *Ranunculus biternatus* and *Poa annua*
18	Jardin Japonais	37.6	64.8	9.9	8.3	*Cotula plumosa*
19	Pointe Basse	20.3	21.1	16.8	10.9	*Raccomitrium* sp., *Juncus* sp. and *Agrostis magellanica*
20	Pointe Basse	48.3	94	9.2	8	*Hypnum cupressiforme* and *Juncus* sp.
21	Pointe Basse	60.6	90.2	18	13.1	*Ranunculus biternatus*, *Juncus* sp. and *Bryum* sp.

Appendix 2. List of all observed testate amoebae taxa in the small soil cores together with their mean test size (in µm) and standard error (SE). For 4 taxa the length of the only observed individual is noted. Relative abundances (%) of the taxa in each soil zone ("A"/"B"/"C") are added. Taxa which had not been encountered in Vincke *et al.* (2004a) are marked with *.

	Zone "A"	Zone "B"	Zone "C"	Mean test size ± SE
Arcella arenaria Greeff	1.21	1.78	0.10	72 ± 3
* *Arcella discoides* Ehrenberg	0.03	-	0.06	105 ± 4
* Archerella sp1	0.03	-	-	34
Assulina muscorum Greeff	1.40	0.54	0.41	46 ± 2
* Assulina sp1	0.41	0.44	0.67	39 ± 2
Centropyxis aerophila Deflandre	0.32	0.16	0.48	61 ± 2
* *Centropyxis aerophila* v. *sphagnicola* Deflandre	0.03	0.10	0.03	58 ± 1
Centropyxis aerophila v. *sylvatica* Deflandre	-	0.03	-	80 ± 3
* *Centropyxis platystoma* (Penard) Deflandre	0.03	-	-	60
* *Centropyxis sacciformis* Hoogenraad	-	-	0.06	85 ± 3
Corythion dubium Taranek	2.57	1.14	0.44	36 ± 2
* *Corythion sp1*	0.10	-	-	42
Cryptodifflugia compressa Penard	0.19	0.54	0.38	20.8 ± 0.4
Cyclopyxis sp1	-	0.03	-	27.9 ± 0.6
* *Cyclopyxis puteus* Thomas	0.22	0.44	0.38	195
Cyphoderia sp1	2.48	2.32	1.33	41.5 ± 0.7
* *Difflugia angulostoma* Gauthier-Lièvre *et* Thomas	0.03	-	0.03	65 ± 3
Difflugia bacillifera Penard	0.06	0.06	0.06	125 ± 4
Difflugia globulosa Dujardin	0.03	0.03	0.06	63 ± 2
Difflugia globulus Hopkinson	0.13	0.25	0.38	40 ± 1
Difflugia lucida Penard	-	0.06	-	64 ± 3
Difflugia pristis Penard	0.57	1.17	2.10	41 ± 2
Difflugia pulex Penard	-	-	0.13	31 ± 1
Difflugia sp3	2.67	4.54	5.27	31 ± 3
Difflugia sp6	0.70	1.40	0.48	7.0 ± 0.2
Difflugia sp7	0.03	0.19	0.19	35 ± 2
Difflugia sp9	0.16	0.32	0.48	40 ± 3
Difflugia sp10	0.19	-	-	40 ± 2
Difflugiella crenulata Playfair	0.86	0.63	0.79	23.8 ± 0.5
Difflugiella oviformis (Penard) Bonnet *et* Thomas	4.60	11.56	13.37	14.4 ± 0.4
Difflugiella oviformis var. *fusca* (Penard) Bonnet *et* Thomas	-	0.13	-	13.8 ± 0.4
* *Difflugiella sp1*	0.16	0.10	0.06	24.9 ± 0.5
Difflugiella pusilla Playfair	0.76	1.52	1.87	9.2 ± 0.4
Edaphonobiotus campascoides Schb., Foiss. *et* Meisterf.	0.86	0.76	1.40	32 ± 2
Euglypha bryophila (Penard) Jung	0.22	0.19	0.16	61 ± 2
* *Euglypha ciliata* (Ehrenberg) Penard	0.22	0.10	0.22	70 ± 2
Euglypha ciliata var. *glabra* Wailes	0.38	0.16	0.19	70 ± 2
Euglypha compressa Carter	0.06	-	0.03	80 ± 2
Euglypha compressa var. *glabra* Cash	0.03	0.10	0.03	81 ± 2
Euglypha cristata Leidy	0.48	0.32	0.22	49.5 ± 2.6
Euglypha laevis Perty	0.67	0.19	0.16	24.1 ± 0.9
Euglypha polylepis (Bonnet) Bonnet *et* Thomas	0.57	0.29	0.16	37.8 ± 0.9
Euglypha rotunda Wailes	21.30	19.90	20.25	28.5 ± 1.4
* *Euglypha strigosa* Leidy	0.13	0.06	0.03	79.3 ± 2.7
* *Euglypha strigosa* v. *glabra* Wailes	-	0.03	-	78.3 ± 2.7
Euglypha tuberculata Dujardin	-	0.06	0.03	62.2 ± 3.3
Heleopera sylvatica Penard	0.44	0.54	0.22	72 ± 3
Hyalosphenia sp 1	0.03	0.03	0.03	80 ± 2
Microchlamys patella (Claperede *et* Lachmann) Cockerell	6.79	4.89	4.29	41 ± 1
Nebela dentistoma Penard	2.44	1.52	1.37	85 ± 3
Nebela tubulata Brown	0.06	0.10	0.10	76 ± 3
Nebela vas Certes	0.06	0.03	0.03	188 ± 6
Pseudodifflugia fulva Penard	2.92	3.05	4.13	17.7 ± 0.5
Pseudodifflugia gracilis Schlumberger	-	-	0.10	60 ± 2
Pseudodifflugia gracilis var. *terricola* Bonnet *et* Thomas	-	0.03	0.03	30 ± 1
Tracheleuglypha dentata Vedjowsky	0.83	0.70	0.25	49 ± 2
Trachelocorythion pulchellum (Penard) Bonnet	2.06	1.62	1.49	28.8 ± 0.9
Trinema complanatum Penard	-	0.13	-	49 ± 2
Trinema enchelys Leidy	2.32	2.76	4.16	46 ± 2
Trinema lineare Penard	37.14	32.92	31.24	27.2 ± 0.8