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Testate Amoebae of a Monsoon Tropical Forest of South Vietnam

Anatoly A. BOBROV[1], Yuri A. MAZEI[2] and Alexei V. TIUNOV[3,4]

[1]Moscow State University, Leninskiye gory, Moscow, Russia; [2]Penza State Pedagogical University, Penza, Russia; [3]Institute of Ecology and Evolution RAS, Moscow, Russia; [4]Joint Russian-Vietnamese Tropical Research and Technology Center, Hanoi, Vietnam

Summary. The composition (143 species and forms) of testate amoebae communities from 68 samples of soils and lake sediments from South Vietnam (Cat Tien National Park) was investigated. In most terrestrial habitats, hydrophilous, soil and even xerophilous testaceans were co-occurring. The likely reason for this phenomenon is sharp seasonal changes in hydrological regime including temporal overwetting or inundation. Typical members of soil communities were *Plagiopyxis callida*, *Tracheleuglypha acolla*, *Euglypha cristata*, *E. tuberculata*, *Trinema complanatum*. The fauna was composed mainly of eurybiont species. Less abundant but still common were moss-dwelling species from the genera *Heleopera*, *Hyalosphenia*, *Nebela* and *Sphenoderia*. Calciphilous species were also present, including *Centropyxis plagiostoma*, *Geopyxella* cf. *sylvicola*, *Schwabia terricola*, *Plagiopyxis callida*, *P. intermedia* v. *cyrtostoma*, *Heleopera petricola* v. *humicola*. Species from the genera *Hoogenraadia*, *Planhoogenraadia*, *Apolimia* were found in this region of South-East Asia for the first time. The variations in the species composition and diversity of testate amoebae in soils was likely caused by several mechanisms including local variations in hydrological regime, the differences in chemical and physical properties and decomposition rates of plant litter, and mineralogical features of soils. The fauna of lake sediments was very distinct with characteristic species *Difflugia bacillariarum*, *Lesquereusia modesta*, *Arcella gibbosa*, *Euglypha acanthophora*. In the relatively uniform lake sediments local microcommunities were rich in species but very similar in species composition (low beta-diversity). In contrast, in soil samples the micro-scale heterogeneity was usually very pronounced, though the alpha-diversity was lower than in lake sediments. The updated list of testate amoebae of Vietnam includes 237 taxa. Taxa with restricted geographical distribution form up to one tenth of the total species richness.

Key words: Testate amoebae, community, ecology, biogeography, Vietnam, Cat Tien National Park.

INTRODUCTION

Testate amoebae is a group of free-living protozoans with a predominately anemochorous way of dispersion. Most testacean species are cosmopolitan. However, already in the 19th century Ehrenberg (1871, ref. after Bonnet 1983), showed that testate amoebae faunas of large geographical regions differ. This notion was subsequently supported by Heinis (1914) and Deflandre (1928, 1936) who studied the distribution of *Nebela* and *Arcella* species. Since that time the differences between faunas of northern and southern hemispheres as well as the presence of species with restricted geographical distribution was widely accepted (Jung 1942, Oye 1944, Hoogenraad and de Groot 1979, Bonnet 1983, Smith and Wilkinson 1987, Foissner 2006, Smith *et al*. 2008). Nevertheless, new research continues to contribute im-

Address for correspondence: Prof. Dr. Yuri Mazei, Department of Zoology and Ecology, Penza VG Belinsky State Pedagogical University, Lermontova str., 37, Penza 440026, Russia; E-mail: yurimazei@mail.ru

portant information on both ecology and geographical distribution of testate amoebae.

Soil testate amoebae as well as other protozoans of South-East Asia are not well investigated. There is no or very scarce information on whole regions including such countries as Myanmar, Laos, and most of Indonesia. Some data were published from Nepal, Sri-Lanka, Thailand, Malaysia, Philippines, Singapore, Papua New Guinea, Indonesian islands Borneo, Java and Sumatra, but only the territories of China, India and Japan have been studied relatively well (Balik 1995). During last 15 years the number of publications on testate amoebae of South-East Asia increased considerably. However, most of these papers report data from freshwater and marine littoral systems.

Studies of testate amoebae of Vietnam are fragmentary. No protozoan groups were included in the recent monograph on natural history of Vietnam (Sterling *et al.* 2006). There are only two publications focusing on soil testate amoebae of Vietnam (Balik 1995, Nguyen-Viet *et al.* 2007). In both cases, the material was collected in the northern part of the country and covered a limited range of habitats. Balik (1995) analyzed 17 samples of organic and organo-mineral soil horizons from a mountain rainforest in the Tam-Dao region ca. 90 km north of Hanoi City. Balik listed 126 testate amoebae taxa, including some rare species with restricted geographical distribution. The paper of Nguyen-Viet *et al.* (2007) contains information on the composition of testate amoebae communities from the moss *Barbula indica* collected near Hanoi City and includes 23 cosmopolitan, eurybiontic and moss-dwelling species. Therefore, the aim of this study was to investigate species composition of testate amoebae from the southern part of Vietnam in biotopes ranging from lake sediments to watershed soils.

MATERIALS AND METHODS

The study area

Samples were collected in the Cat Tien National Park (Dong Nai Province; 11°21′–11°48′N, 107°10′–107°34′E). The park covers an area of approximately 40,000 hectares, lying at the foot of the central Vietnamese highlands, about 130 km northeast of Ho Chi Minh City (Fig. 1). The climate is tropical monsoon with two distinct seasons: a rainy season from late April to November and a dry season from December to March. The mean annual temperature is close to 26°C, with rather small seasonal fluctuations. The mean annual rainfall is about 2,450 mm, the most rainy months being August and September (400–450 mm per month), when much of the park area is inundated. In contrast, there is almost no precipitation from January to March. The elevations vary between 120 and 220 m a.s.l. The relief is hilly with numerous small rocky outcrops and lowlands, the latter usually flooded for several weeks during the rainy season. Lowlands and flatlands are especially characteristic of the eastern part of the area bordering the Dong Nai River. Most of the plots studied were established in that subarea. Soils are mostly loamy, black ferrallitic, formed on basalt bedrock. The carbon content of the upper mineral soil typically varies from 3.3 to 6.5%; pH close to 7.0 in well-drained areas but often decreases below 5.5 in wet depressions. Along the Dong Nai River, the soils are formed on the sandy river sediments.

The vegetation of the National Park is very diverse and includes over 150 tree species, of which *Lagerstroemia calyculata* (Lythraceae) associated with Dipterocarpaceae, Fabaceae and Datiscaceae often dominate the upperstorey and canopy (Vandekerkhove *et al.* 1993, Blanc *et al.* 2000). Most of the upper canopy trees are deciduous and shed foliage during the dry season. At the end of the dry season (April) a substantial amount of litter (up to 800–1000 g m^{-2}) accumulates on the soil surface. However with the onset of the rainy season this litter is quickly consumed by termites and other soil macroinvertebrates.

The sampling sites

We analyzed a series of soil samples taken at five permanent plots established in the National Park by A. E. Anichkin (Anichkin *et al.* 2007, Belyaeva and Tiunov 2010). "**Lagerstroemia**" plot is situated on ferrallitic soil on basalt bedrock with the upper canopy dominated by *Lagerstroemia calyculata* and *Tetrameles nudiflora* (Datiscaceae). The "**Dipterocarpus**" plot is situated on the slope of a small basalt outcrop ridge. The canopy includes several emergent *Dipterocarpus alatus* (Dipterocarpaceae) trees with the overall domination of Lythraceae, Moraceae, Sterculiaceae. Soils of the "**Afzelia**" plot are patchy, formed on basalt and schist bedrock. The canopy is dominated by *L. calyculata* and a large *Afzelia xylocarpa* (Fabaceae) tree. The canopy on the "**Ficus**" plot is dominated by a single large *Ficus* sp. tree, with admixture of *L. calyculata* and *Dalbergia* sp. (Fabaceae). The plot is located near a small creek, and is regularly inundated during the wet season. Soil is ferrallitic, but porous and well drained during the dry season, and very rich in organic matter (up to 8% C_{org} in the upper mineral horizon). The "**Riparian**" plot is situated in a strand of degraded dipterocarp forest on the right bank of Dong Nai River. Upperstorey is represented by *D. alatus*, *Hopea odorata*, *Shorea roxburghii* (Dipterocarpaceae), *Irvingia malayana* (Irvingiaceae), *L. calyculata*. Soil is sandy, deep and very poor in organic matter (~ 1% C_{org}). These plots represent the most common ecosystems in the eastern part of the Park. On each plot, 3–18 soil samples were taken at the end of wet season (November-December). In addition, we analyzed five soil samples from a seasonally inundated depression near the "Ficus" plot ("**Inundated Depression**") with gley soil and three samples from a wet palm forest (*Livistona* cf. *saribus,* Arecaceae) in the central area of the Park ("**Palm forest**"). Ten samples of bottom sediments were also taken from the shallow **Bao-Sau Lake** (Fig. 1; Table 1).

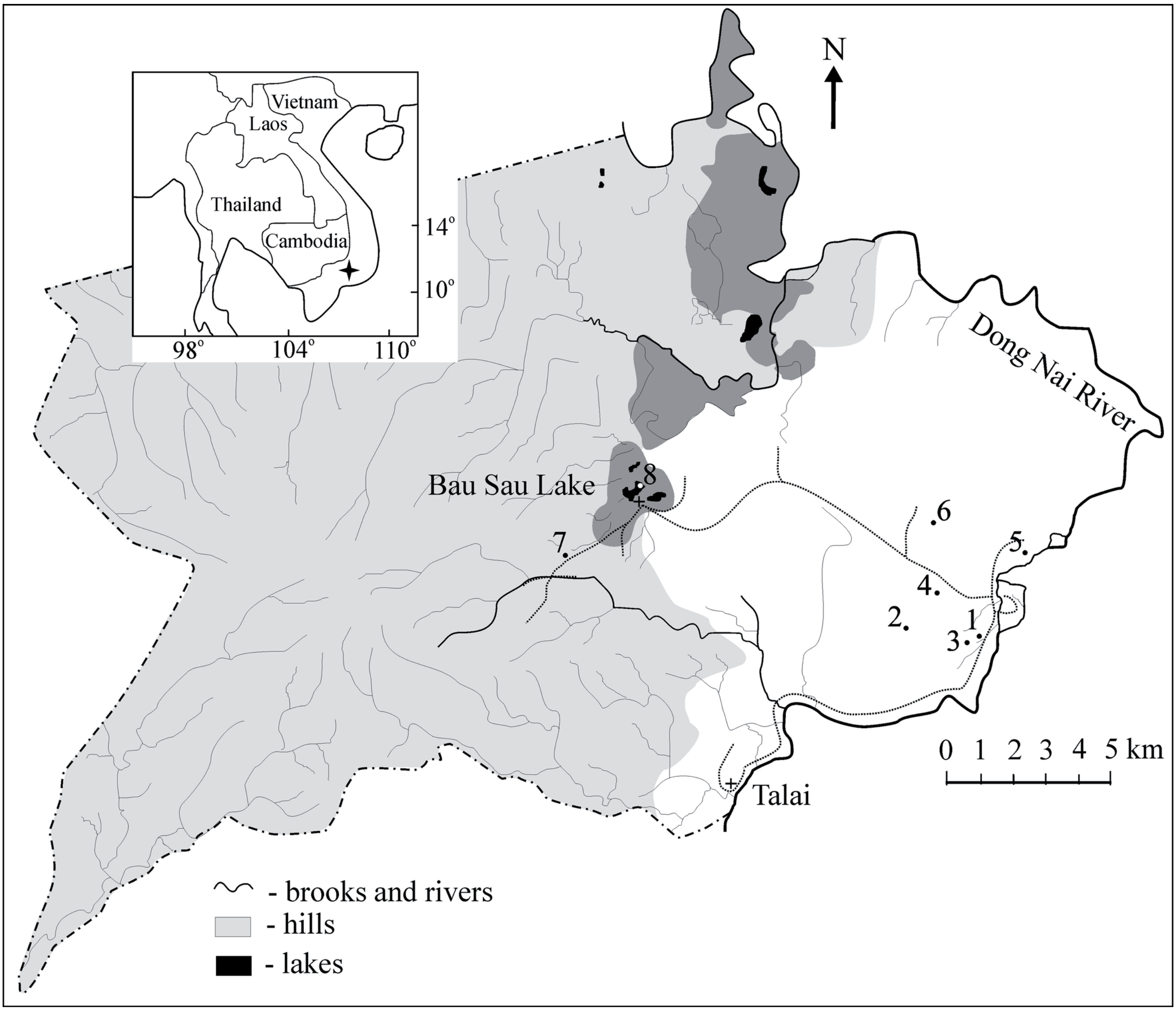


Fig. 1. Map of the Nam Cat Tien National Park and location of sampling plots: **1** – Lagerstroemia; **2** – Dipterocarpus; **3** – Afzelia; **4** – Ficus; **5** – Riparian; **6** – Inundated Depression; **7** – Palm forest; **8** – Bao-Sau Lake (modified after Blanc *et al.* 2000).

Sampling protocol and analyses

Soil samples included ca 1 cm of litter (if present) and 1–2 cm of uppermost mineral soil (A1, typically dark-grey loamy soil of clumpy-powdery structure). No mosses were typically present on the soil surface, except for the "Palm forest" plot. Samples of lake sediments (1–2 cm thick) were taken at the depth of 20–100 cm. For microscopic analysis soil was soaked with water during 24 hours. Then samples were shaken during 10 min., filtered through the 0.5 mm mesh, centrifuged and decanted. Prepared samples were stored in the refrigerator at 4°C. From each sample 8–15 microscopic slides were prepared and inspected. The number of shells per slide varied from several to tens specimens, including both living specimens and empty shells.

Total soil carbon content (C_{org}) was determined using a Flash 1112 elemental analyzer (Thermo-Finnigan, USA); soil pH was measured in water suspension (2:1 soil to water weight ratio). All measurements were made in 3–5 replications per plot.

Using the number of species found in each sample, a relationship between species diversity and sampling effort was calculated using a rarefaction procedure. The analysis of species-accumulation curves allowed estimates of beta-diversity comparisons of species richness in the sample sets of different size (Lawton 1999). Species accumulation curves were approximated by the power function $S =$

cN^z, where *N* is number of samples analyzed, *S* – number of species identified, z – beta-diversity coefficient, and c – alpha-diversity coefficient (Scheiner 2003). The alpha-diversity coefficient (c) reflects the average number of species per sample. Beta-diversity coefficient varies from 0 (in the case of identical samples in terms of species composition) to 1 (when samples are completely different from each other by species composition). Detrended correspondence analysis (DCA) was used for the ordination of the samples. This technique orders samples in a low-dimensional space in such a way that distances between them are preserved as far as possible (Hill and Gauch 1989, Jongman *et al*. 1995). The data were analyzed using the PAST 1.89 software (Hammer *et al*. 2001). In the zoogeographical analysis the published data from North Vietnam (Balik 1995, Nguyen-Viet *et al*. 2007) were included for comparison.

RESULTS

The abundance of testate amoebae in soils was in general very low and did not exceed several hundreds individuals per 1 gram (dry weight) of soil. The total list of testate amoebae identified from 43 samples included 143 species, varieties and forms from 8 families and 28 genera (Table 1). Most diverse were the genera *Centropyxis, Arcella, Euglypha, Difflugia, Plagiopyxis*, and *Cyclopyxis*. Nine testate amoebae were not identified to species level, and three could not be identified to family level. They are possibly endemics of Vietnam.

The species diversity and community composition of testaceans differed considerably among different plots. The abundance of testaceans at the "**Lagerstroemia**" and "**Dipterocarpus**" plots was very low (several individuals per slide). The "Lagerstroemia" community included 21 mostly eurybiont and cosmopolite species. Periodical overwetting was indicated by the presence of moss-dwelling species *Hyalosphenia papilio*, *Nebela tincta* and *Phryganella hemisphaerica*. In the poorly drained soils of the "Dipterocarpus" plot the species diversity was slightly higher (28 species). Two aquatic (*Difflugia levarderi* and *Lagenodifflugia vas*) and two hygrophilous species (*Euglypha tuberculata* and *Phryganella hemisphaerica*) were found.

Twenty-two species were found at the "**Afzelia**" plot, including mostly eurybiont soil and litter-dwelling testaceans. The last group was represented by the genera *Euglypha* and *Trinema*. Hydrophilous species were absent likely due to the lack of regular inundation, but hygrophilous *Phryganella hemisphaerica*, as well as moss inhabitants *Hyalosphenia papilio* and *Nebela tincta* were recorded.

The distinctive peculiarity of the "**Ficus**" plot was the high species diversity (69 species) and the presence of Gondwanian-tropical taxa (genera *Hoogenraadia* and *Planhoogenraadia*) as well as other rare species such as *Cyclopyxis* cf. *aplanata* v. *microstoma*, *C.* cf. *arcelloides* v. *gibbosa*, *C. lithostoma*, *Geopyxella* cf. *sylvicola*, *Schwabia*, *terricola*, *Plagiopyxis barrosi*, *P. intermedia* v. *cyrtostoma*, *Apolimia* sp. The set of ecological groups included both soil-dwelling and hydrophilic species, along with aquatic *Difflugia lacustris* and *Lagenodifflugia vas*. Moreover, xerophilous *Corythion dubium* and calciphilous *Centropyxis plagiostoma* and *Geopyxella* cf. *sylvicola* were also present.

Most of the 42 species registered at the "**Riparian**" plot belonged to eurybiont and soil-dwelling species form the genera *Centropyxis*, *Cyclopyxis*, *Plagiopyxis*, *Euglypha*, *Corythion* and *Trinema*. Some hydrophilous species, such as *Centropyxis aerophila* v. *grandis*, *C. discoides*, *C. elongata*, *Difflugia globulus*, *D.* cf. *schurmanni* were also present. The species composition likely reflected the occasional inundation of the generally well-drained soils of this plot. The presence of calciphilous *Centropyxis plagiostoma* suggests the neutral reaction of soil solutes.

At the "**Inundated Depression**" 27 species were found, including obligate hydrobionts from the genus *Difflugia* as well as sphagnobiont *Argynnia caudata*. The community of the "**Palm forest**" included 25 species. The species composition was strikingly similar to that in the European taiga soils with rough humus and abundant mosses. We found soil and moss-dwelling testaceans *Trigonopyxis arcula* and *T. minuta*, sphagnobiont and litter-dwelling *Heleopera petricola* v. *humicola*, *Hyalosphenia subflava*, *Nebela gracilis*, *N. wailesi*, *Sphenoderia fissirostris*.

In the bottom sediments of the **Bao-Sau Lake** 37 species and forms of testate amoebae were identified. The majority of them were obligate hydrobionts (*Arcella discoides*, *A. gibbosa*, *A. hemisphaerica*, *A. intermedia*, *A. megastoma*, *A. rotundata*, *Centropyxis gibba*, *C. hemisphaerica*, *Difflugia acuminata*, *D. capreolata*, *Lesquereusia modesta*, *L. spiralis*, *Netzelia oviformis*, *N. tuberculata*). Most of species with the exception of *Arcella brasiliensis* are cosmopolitan. In addition, bryophilous species, typical of *Sphagnum* bogs of higher latitudes were also abundant (*Arcella catinus*, *Difflugia bacillariarum*, *Archerella flavum*).

The greatest diversity was found in soils of the "Ficus" plot (69 species, varieties and forms) followed by "Riparian" (42) and lake sediments (37). The fauna was composed mainly of eurybiont species. Less abundant but still common were moss-dwelling species from the

Table 1. Occurrence (estimated as percentage of samples in which particular species was found to the total number of samples from the corresponding plot) of testate amoebae in soil and sediments of South (this study) and North (published studies) Vietnam.

Species	Plots in the Cat Tien National Park (South Vietnam)								North Vietnam	
	Legerstroemia	Dipterocarpus	Afzelia	Ficus	Riarian	Inundated Depression	Palm forest	Bao-Sau Lake	(Nguen-Viet *et al.* 2007)	Tam-Dao (Balik1995)
Arcella arenaria Greef	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	5.9
A. arenaria f. *compressa* Chardez	0.0	0.0	0.0	11.0	0.0	0.0	0.0	10.0	0.0	0.0
A. arctocrea Leidy v. *aplanata* Grospietsch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0
A. brasiliensis da Cunha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	0.0
A. catinus Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
A. costata v. *angulosa* (Perty) Playfair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
A. discoides Ehrenberg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	22.0	0.0
A. gibbosa Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
A. gibbosa v. *mitriformis* Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	0.0	0.0
A. hemisphaerica Perty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	0.0
A. intermedia (Deflandre) Tsyganov, Mazei	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0
A. megastoma Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0
A. polypora Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
A. rotundata Playfair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
A. vulgaris Ehrenberg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.3
A. sp.	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Trigonopyxis arcula (Leidy) Penard	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	29.4
T. microstoma Hoogenraad & de Groot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
T. minuta Schoenborn	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
Centropyxis aculeata (Ehrenberg) Stein	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	5.0	17.6
C. aculeata v. *minima* Chardez	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
C. aculeata v. *oblonga* Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. cf. *acuminata* Couteaux and Chardez	0.0	25.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
C. aerophila Deflandre	20.0	25.0	0.0	22.0	29.0	40.0	67.0	0.0	27.0	11.8
C. aerophila v. *cornata* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
C. aerophila v. *grandis* Stepanek	0.0	25.0	0.0	22.0	29.0	0.0	0.0	0.0	0.0	0.0
C. aerophila v. *microstoma* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
C. aerophila v. *minuta* Chardez	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	23.5
C. aerophila v. *sphagnicola* Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	5.9
C. aerophila f. *A*	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
C. cassis (Wallich) Deflandre	0.0	0.0	0.0	0.0	14.0	20.0	0.0	0.0	0.0	5.9
C. cassis v. *minima* van Oye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. constricta (Ehrenberg) Penard	0.0	12.5	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
C. constricta v. *minima* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. cornuta Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. crustulata Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. deflandriana Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.9
C. discoides (Penard) Deflandre	0.0	0.0	0.0	0.0	14.0	0.0	0.0	60.0	0.0	0.0

C. ecornis (Ehrenberg) Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. elongata (Penard) Thomas	0.0	25.0	20.0	11.0	29.0	0.0	0.0	20.0	0.0	11.8
C. elongata f. A *major*	0.0	0.0	0.0	0.0	43.0	0.0	0.0	0.0	0.0	0.0
C. elongata f. B *minor*	0.0	0.0	0.0	0.0	14.0	20.0	33.0	0.0	0.0	0.0
C. gibba Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0
C. hemisphaerica (Barnard) Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0
C. hirsuta Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0
C. latideflandriana Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.9
C. minuta Deflandre	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
C. orbicularis Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. ovalis Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. parvideflandriana Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1
C. plagiostoma Bonnet. Thomas	0.0	25.0	40.0	11.0	43.0	0.0	67.0	0.0	0.0	0.0
C. plagiostoma f. A *minor*	0.0	0.0	0.0	11.0	0.0	0.0	33.0	0.0	0.0	0.0
C. platystoma Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	5.9
C. protecta Bartoš	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. stenodeflandriana Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1
C. sylvatica (Deflandre) Thomas	0.0	37.5	0.0	22.0	29.0	40.0	100.0	0.0	27.0	0.0
C. sylvatica v. *microstoma* Bonnet	0.0	0.0	20.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
C. sylvatica v. *minor* Bonnet. Thomas	20.0	0.0	0.0	44.0	14.0	40.0	0.0	0.0	0.0	0.0
C. vandeli v. *globulosa* Bonnet	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. sp. 1	0.0	0.0	0.0	11.0	0.0	0.0	33.0	0.0	0.0	0.0
C. sp. 2	0.0	12.5	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
Cyclopyxis ambigua Bonnet & Thomas	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	11.8
C. cf. *amplecta* Schönborn	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
C. cf. *aplanata* v. *microstoma* Schönborn	0.0	12.5	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
C. cf. *arcelloides* v. *gibbosa* van Oye	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
C. eurystoma Deflandre	0.0	0.0	0.0	0.0	29.0	0.0	0.0	0.0	0.0	11.8
C. eurystoma v. *grandis* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. eurystoma v. *parvula* Bonnet. Thomas	20.0	37.5	20.0	33.0	43.0	60.0	67.0	0.0	0.0	0.0
C. gigantea Bartoš	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
C. quadratus v. *grandis* Balik	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. humilis Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. kahli Deflandre	20.0	0.0	20.0	22.0	29.0	0.0	0.0	0.0	0.0	17.6
C. kahli v. *cyclostoma* Bonnet-Thomas	0.0	0.0	0.0	22.0	14.0	0.0	33.0	0.0	0.0	11.8
C. kahli v. *grandis* Chibisova	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
C. lithostoma Bonnet	0.0	0.0	0.0	11.0	14.0	0.0	0.0	0.0	0.0	0.0
C. cf. *pirini* Golemansky	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
C. pseudolaevigata van Oye	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
C. puteus Thomas	0.0	0.0	0.0	11.0	0.0	20.0	0.0	0.0	0.0	0.0
C. stephanostoma Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. trilobata Bartoš	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
C. sp.	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
Geopyxella cf. *sylvicola* Bonnet-Thomas	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
Schwabia terricola Bonnet-Thomas	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0

Plagiopyxis barrosi Bonnet	0.0	0.0	0.0	11.0	14.0	20.0	33.0	0.0	0.0	0.0
P. callida Penard	0.0	0.0	20.0	11.0	14.0	20.0	0.0	0.0	0.0	76.5
P. declivis Thomas	0.0	25.0	20.0	11.0	14.0	0.0	0.0	0.0	0.0	11.8
P. declivis v. *oblonga* Bonnet	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
P. intermedia Bonnet	40.0	25.0	0.0	44.0	29.0	40.0	0.0	0.0	0.0	11.8
P. intermedia v. *cyrtostoma* Bonnet	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
P. labiata Penard	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
P. minuta Bonnet	40.0	25.0	20.0	44.0	14.0	60.0	0.0	0.0	0.0	5.9
P. minuta v. *oblonga* Bonnet	20.0	25.0	20.0	44.0	14.0	40.0	0.0	0.0	0.0	0.0
P. oblonga Bonnet & Thomas	0.0	0.0	0.0	22.0	0.0	20.0	0.0	0.0	0.0	11.8
P. penardi Thomas	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
P. penardi v. *oblonga* Bonnet	0.0	0.0	20.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
P. rostrata Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Hoogenraadia humicola Bonnet	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Planhoogenraadia acuta Bonnet	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0
P. cantabrica Bonnet & Gomez-Sanchez	0.0	25.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
P. sp. 1	0.0	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0
P. sp. 2	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
P. sp. 3	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
P. sp. 4	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Heleopera alsiosa Couteaux & Chardez	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
H. minuta Schönborn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.9
H. penardi Bonnet & Thomas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
H. petricola Leidy	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	41.2
H. petricola v. *amethystea* Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.2
H. petricola v. *humicola* Bonnet et Thomas	0.0	0.0	0.0	11.0	0.0	20.0	0.0	0.0	0.0	0.0
H. picta Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
H. rectangularis Bonnet	0.0	0.0	0.0	22.0	0.0	20.0	0.0	0.0	0.0	0.0
H. sylvatica Penard	0.0	37.5	0.0	33.0	0.0	0.0	33.0	0.0	8.0	35.3
Hyalosphenia insecta Harnisch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
H. papilio Leidy	20.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
H. minuta Cash	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
H. schoutedeni van Oye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
H. schoutedeni v. rotundata van Oye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
H. subflava Cash	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	29.4
H. tamdaoensis Balik	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Nebela bohemica Taránek	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
N. caudata Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
N. collaris (Eherenberg) Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
N. dentistoma Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
N. gracilis Penard	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
N. lageniformis Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
N. militaris Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
N. minor Penard	40.0	0.0	0.0	0.0	0.0	0.0	67.0	0.0	0.0	0.0
N. cf. *penardiana* f. A (minor)	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0

N. tincta (Leidy) Awerintzew	20.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
N. tubulosa Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
N. scotica Brown type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
N. wailesi (Wailes) Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	5.9
Argynnia cf. *dentistoma* Penard	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
A. schwabei Jung	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
Apolimia sp.	20.0	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0
Schoenbornia humicola (Schönborn) Decloitre	0.0	0.0	0.0	22.0	14.0	0.0	0.0	0.0	0.0	0.0
Quadrulella quadrigera (Wailes) Deflandre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Q. symmetrica Wallish (Schulze)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
Paraquadrulla discoides (Archer) Deflandre	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
P. irregularis Archer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
Difflugia acuminata Eherenberg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	0.0
D. bacillariarum Perty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	0.0	0.0
D. cf. *bipartis* Godeanu	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
D. capreolata Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
D. corona v. *crenulata* Gauthier-Lièvre et Thomas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
D. globulus Walich	0.0	0.0	0.0	0.0	14.0	20.0	0.0	0.0	0.0	0.0
D. lacustris (Penard)	0.0	0.0	0.0	11.0	0.0	0.0	0.0	10.0	0.0	0.0
D. levanderi Playfair	20.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D. cf. *linearis* (Penard) Gauthier-Lièvre et Thomas	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
D. lucida Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
D. manicata Ehrenberg	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0
D. maxilabiosa Chardez	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
D. minutissima Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
D. penardi Hopkinson	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
D. pristis Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
D. cf. *schurmanni* van Oye	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
D. sinuata Gauthier-Lièvre et Thomas	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
Lagenodifflugia vas (Leidy) Medioli et Scott	0.0	12.5	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Lesquereusia modesta Rhumbler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	0.0	0.0
L. spiralis (Ehrenberg) Bütschli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
Netzelia oviformis (Cash) Ogden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
N. tuberculata (Wallich) Netzel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0	0.0
Valkanovia delicatula (Valkanov) Tappan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Assulina muscorum Greef	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
A. muscorum v. *denticulata* Chardez	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
A. muscorum v. *stenostoma* Schönborn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
A. seminulum (Ehrenberg) Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Tracheleuglypha acolla Bonnet et Thomas	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	23.0	52.9
T. dentata v. *elongata* (Playfair) Gauthier-Lièvre & Thomas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.4
Euglypha acantophora (Ehrenberg) Perty	0.0	0.0	0.0	0.0	14.0	0.0	0.0	90.0	0.0	0.0
E. acantophora v. *equis* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
E. acantophora v. *heterospina* Penard	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
E. anadonta Bonnet	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0

E. bryophila Brown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
E. ciliata (Ehrenberg) Wailes	0.0	25.0	0.0	11.0	0.0	0.0	0.0	10.0	19.0	5.9
E. ciliata f. *glabra* Wailes	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	6.0	11.8
E. ciliata f. *heterospina* Wailes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
E. compressa Carter	0.0	25.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
E. compressa f. *glabra* Wailes	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	5.9
E. cristata Leidy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.4
E. cristata f. *decora* Jung	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	17.6
E. cristata f. *lanceolata* Playfair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
E. cuspidata Bonnet	60.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
E. dolioliformis Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
E. filifera Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
E. filifera v. *pyriformis* Wailes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
E. laevis (Ehrenberg) Perty	80.0	25.0	40.0	67.0	86.0	80.0	100.0	30.0	10.0	76.5
E. laevis v. *lanceolata* Playfair	20.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
E. polylepis Bonnet-Thomas	0.0	25.0	60.0	22.0	0.0	0.0	0.0	0.0	0.0	5.9
E. rotunda Wailes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.0	52.9
E. rotunda v. *dorsalis* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0
E. rotunda v. *minor* Wailes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
E. rotunda v. *obligua* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
E. scutigera Penard	20.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
E. strigosa Ehrenberg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	47.1
E. strigosa f. *glabra* Wailes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
E. strigosa v. *heterospina* (Penard) Wailes & Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
E. tuberculata Dujardin	0.0	25.0	60.0	22.0	0.0	0.0	0.0	10.0	0.0	52.9
E. tuberculata v. *minor* f. *subcylindrica* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
E. tuberculata v. *subcylindrica* (Playfair) Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
Deharvengia papuensis Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
Placocista jurassica Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
P. lens Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
Sphenoderia fissirostris Penard	0.0	0.0	0.0	0.0	0.0	0.0	33.0	0.0	0.0	41.2
Trachelcorythion pulchellum Bonnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
Corythion aerophila Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. dubium Taranek	0.0	0.0	20.0	11.0	14.0	0.0	0.0	0.0	0.0	52.9
C. orbicularis (Penard) Iudina	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C. pulchellum Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
Trinema complanatum Penard	20.0	25.0	20.0	44.0	14.0	0.0	0.0	20.0	0.0	94.1
T. complanatum v. *aerophila* (Decloitre) Bonnet & Thomas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.9
T. complanatum v. *elongata* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.3
T. complanatum v. *globulosa* Chardez	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
T. complanatum v. *inflata* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
T. complanatum v. *platystoma* Schönborn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
T. enchelys (Ehrenberg) Leidy	0.0	0.0	20.0	0.0	14.0	0.0	0.0	10.0	19.0	88.2
T. enchelys v. *aerophila* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
T. enchelys v. *nasurticola* Decloitre	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9

T. grandis Penard	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.2
T. lineare (Ehrenberg) Leidy	60.0	75.0	40.0	56.0	29.0	80.0	100.0	70.0	26.0	41.2
T. lineare v. *grandis* (Chardez) Golemansky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
T. lineare v. *truncatum* Chardez	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
T. staryi Balik	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.5
Phryganella acropodia (Hert. et Less.) Hopkinson	0.0	0.0	0.0	0.0	14.0	0.0	0.0	50.0	29.0	41.2
Ph. acropodia v. *depressa* Playfair	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8
Ph. hemisphaerica Penard	20.0	25.0	20.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0
Ph. microps Valkanov	0.0	0.0	0.0	11.0	0.0	0.0	33.0	0.0	0.0	0.0
Cryptodifflugia crenulata (Playfair) Grospietsch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. crenulata v. *globosa* (Playfair) Grospietsch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. horrida Schönborn	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. oviformis Penard	20.0	25.0	60.0	11.0	14.0	0.0	0.0	0.0	0.0	5.9
C. oviformis v. *fusca* (Penard) Bonnet & Thomas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. pusilla (Playfair) Grospietsch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9
C. sp.	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Archerella flavum Archer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
Testacea sp. 1	0.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0
T. sp. 2	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
Number of samples examined	8	9	6	14	18	5	3	10	29	17
Number of taxa identified	21	28	22	69	42	27	25	37	23	126
Total number of samples					68				46	
Total taxa per region					143				134	
Total taxa						237				

genera *Heleopera*, *Hyalosphenia*, *Nebela* and *Sphenoderia* that are usual for taiga soil. Calciphilous species were also present, including *Centropyxis plagiostoma*, *Geopyxella* cf. *sylvicola*, *Schwabia terricola*, *Plagiopyxis callida*, *P. intermedia* v. *cyrtostoma*, *Heleopera petricola* v. *humicola* (Bonnet 1961). Most peculiar fauna component were Gondwana-tropical species from the genera *Planhoogenraadia* and *Hoogenraadia* (Bonnet 1974, 1983).

Species-accumulation curve based on the whole dataset confirmed relatively high spatial heterogeneity (z = 0.6; Fig. 2). However within a particular biotope the micro-scale heterogeneity varied. For example, in the relatively uniform lake sediments local microbial communities were rich in species but very similar in species composition (low beta-diversity, z = 0.35). In contrast, in soil samples the micro-scale heterogeneity was usually very pronounced, though the alpha-diversity was lower than in lake sediments.

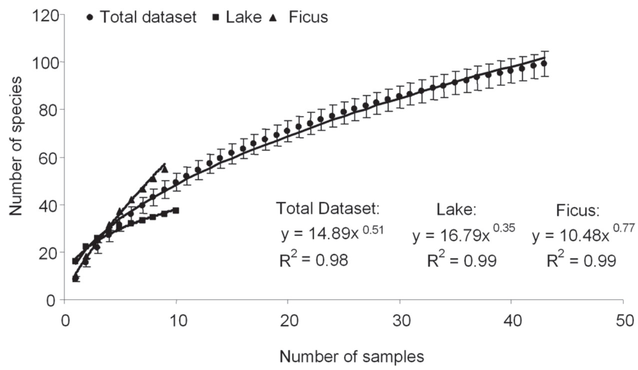
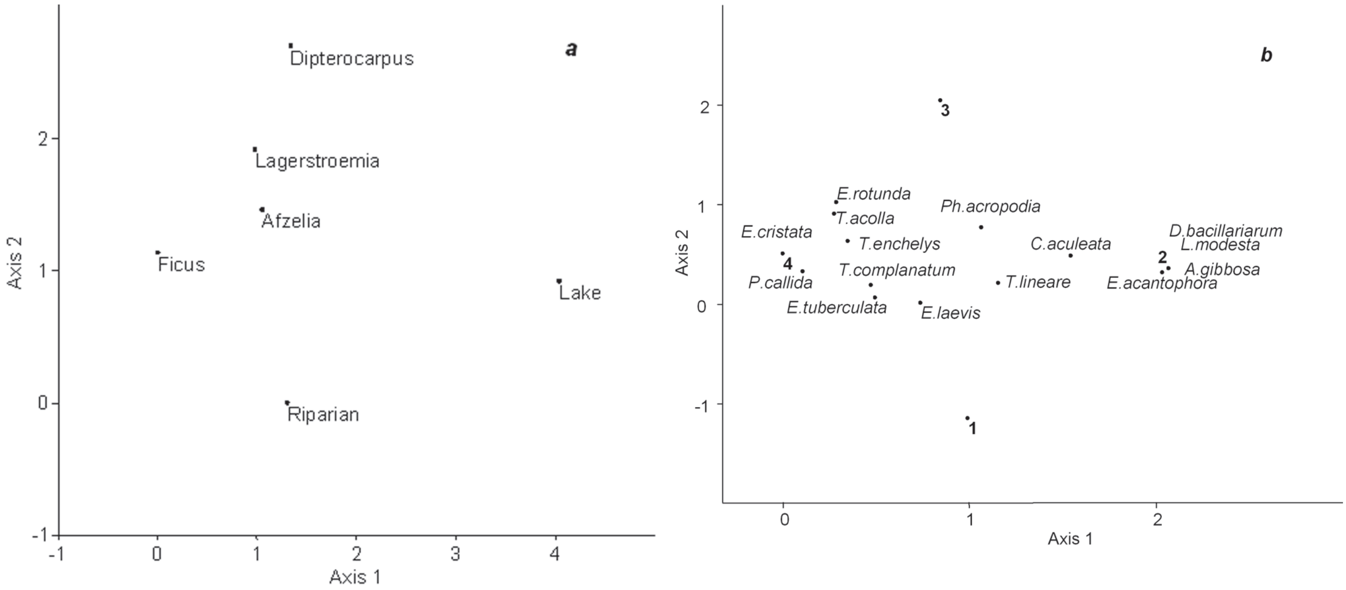


Fig. 2. Relationships between number of species identified and sampling effort. Whiskers – standard error of the mean.

DCA performed on the Cat Tien data (Fig. 3a) revealed that more than 75% of the total variation in species composition could be ascribed to the differences between lake sediments and soil communities. The



Figs 3a–b. Results of DCA of local communities of testate amoebae. **a** – main plots in the Cat Tien National Park. Axis 1 explain 76,4% of the total variance in the species composition, axis 2 – 18,9%; **b** – different localities in Vietnam. **1** – Cat Tien soil (South Vietnam, this study); **2** – Bao-Sau Lake sediments (South Vietnam, this study); **3** – moss *Barbula indica* (North Vietnam, Nguen-Viet *et al.* 2007); **4** – soil Tan-Dao (North Vietnam, Balik 1995). Axis 1 explains 40.8% of the total variance in the species composition, axis 2–27.1%. The group centroids of the most common species are also given.

analysis of the larger dataset that included also data published by Balik (1995) and Nguen-Viet *et al*. (2007) revealed the same pattern (Fig. 3b): the most distinct fauna is formed in the lake sediments with characteristic species *Difflugia bacillariarum*, *Lesquereusia modesta*, *Arcella gibbosa*, *Euglypha acanthophora*. Typical members of soil communities were *Plagiopyxis callida*, *Tracheleuglypha acolla*, *Euglypha cristata*, *E. tuberculata*, *Trinema complanatum*.

DISCUSSION

The local diversity of testaceans in the soils and sediments studied was relatively low. For comparison, in temperate coniferous forest soils the species richness varied from 13 species in A1 horizon to up to 50 species in decomposing wood (Bobrov 2005). The variation in the species composition and diversity of testate amoebae in soils was likely caused by several mechanisms including local variations in hydrological regime, the differences in chemical and physical properties and decomposition rates of plant litter, and mineralogical features of soils. The highest species diversity (69 species) and also the highest diversity of ecological groups was found at the "Ficus" plot. This diversity was likely formed due to prolonged inundation of this plot during the wet season followed by desiccation of soil during the dry season. The soils at the "Ficus" plot were also most rich in organic matter among all soils studied, and a permanent layer of partly decomposed litter was present almost throughout the year near the tree trunks. The heterogeneity of soil microhabitats lead to high spatial variability in species richness, which ranged from three to twenty species in different samples.

Though we analyzed soil and sediment samples collected in a variety of habitats, our study clearly underestimated the total species diversity of testate amoebae of the National Park (cf. Fig. 2). Much more efforts are needed to reveal fully the composition of the regional fauna of testaceans. However, our data allow some preliminary conclusions and comparisons to be made.

Of particular interest are 14 forms of testaceans found in this study that have restricted geographical distribution. These are *Arcella brasiliensis*, *Centropyxis vandeli* v. *globulosa*, *Cyclopyxis lithostoma*, *Schwabia terricola*, *Hoogenraadia ovata*, *Planhoogenraadia acuta*, *P. cantabrica*, *P.* sp. 1, *P.* sp. 2, *P.* sp. 3, *P.* sp. 4, *Apolimia sp.*, *Argynnia schwabei*, *Difflugia maxilabiosa.* Genus *Planhoogenraadia*, which belongs to Gondwanian-tropical group of testate amoebae, was especially diverse (2 species and 4 unidentified forms). Species of this genus were found in different biotopes in South and Central America, Nepal, Thailand, Indonesia, New Guinea and north-east Spain. The Gondwanian-tropical group was proposed by Bonnet (1980) who included there several species from the genera *Hoogenraadia*, *Planhoogenraadia*, *Lamptopyxis*, but lately also of *Centropyxis*, *Cyclopyxis*, *Deharvengia*, *Ellipsopyxis*, *Plagiopyxis* and *Protoplagiopyxis* from tropical Africa, South America, Central America, South-Eastern Asia, New Guinea and Philippines (Bonnet 1983). For the first time, the species from this group are recorded from the territory of Vietnam.

Only two regions of Vietnam can be considered as relatively well studied in terms of testate amoebae fauna (Tables 1, 2). The first is the mountain rain forest in the Tam-Dao region at an altitude of 1200 m a.s.l. (Balik 1995). The local climate was dominated by winter north-eastern monsoons that bring wet cold weather and summer south-western wet and warm monsoons. The second region is a lowland monsoon forest of the Cat Tien National Park investigated in this study. Compared to the sites studied by Balik, this region has about 5°C higher mean annual temperature, about 500 mm higher annual precipitation, and a very dry winter season. Both regions belong to the Indochinese Rainforest biogeographic province of the Indomalayan realm (Udvardy 1975).

For his study site in North Vietnam, Balik (1995) listed 126 species, varieties and forms of testate amoebae (Table 1) from 17 habitats including organic and organic-mineral soil horizons. Large species richness could partly be due to the splitting of species to subspecies taxa. The morphological diversity could however be partly ascribed to individual variability of certain species like *Euglypha rotunda* or *Trinema complanatum*. This phenomenon is probably widespread in tropical soils. In this study, we revealed similar variability in 11 species, for example, six subspecies of *Centropyxis aerophila*. Balik (1995) listed 19 polytypic species often with 3–4 subspecies in each.

The composition of testate amoebae communities from the North Vietnam site differs from that in our

Table 2. Number of testate amoebae taxa from most quantitatively important genera recorded in North and South Vietnam.

Genus	Number of taxa			
	Recorded in two regions (total)	Recorded in South Vietnam*	Recorded in North Vietnam**	Common for both regions
Arcella	16	12	4	0
Trigonopyxis	3	2	2	1
Centropyxis	41	27	20	6
Cyclopyxis	20	15	9	4
Plagiopyxis	13	12	6	5
Planhoogenraadia	6	6	0	0
Heleopera	9	4	7	2
Hyalosphenia	7	3	6	2
Nebela	12	5	9	1
Difflugia	16	14	2	0
Assulina	4	0	4	0
Euglypha	29	15	21	7
Corythion	4	2	3	1
Trinema	14	3	14	11
Phryganella	4	3	2	1
Cryptodifflugia	7	2	6	1

* According to Balik (1995).

** This study.

study by much larger proportion of sphagnobiont and moss-dwelling rhizopods from the genera *Heleopera*, *Hyalosphenia*, *Nebela*, *Trinema*, *Assulina*, *Euglypha*, *Cryptodifflugia*, in comparing with pedobionts from the genera *Plagiopyxis*, *Cyclopyxis*, *Planhoogenradia,* and the lack of hydrophilous species from the genera *Arcella*, *Difflugia* (Table 2). This likely reflects slower decomposition and mineralization processes, lower pH of soils and the absence of regular inundation.

Analysis of the Balik (1995) data shows interesting case in the *Centropyxis deflandriana* species complex. This species was split by Bonnet (1979) to *C. deflandriana*, *C. latideflandriana*, *C. parvideflandrina* and *C. stenodeflandriana* differing predominately in the structure of pseudostome. Bonnet (1979) regarded them as geographical vicariates. However, Balik (1995) found these species in the samples taken from the same rain forest, i.e. in the same type of habitat with common climatic, geological and soil conditions. Thus, it can be suggested that in the mountain rainforests of the North Vietnam all these species (excluding *C. latideflandriana*) live in the same biotopes. The heterogeneity of soil matrix ensures the possibility of the separation of the ecological niches of closely related species. Level of heterogeneity likely depends on the properties of soil horizons. As a rule, species polymorphism in upper organic soil layers is much higher (Bobrov 2003). In our study, pairs of closely related species often co-occurred in the same habitat, for example *Euglypha ciliata* – *E. ciliata* f. *glabra*, *E. strigosa* – *E. strigosa* f. *glabra*, *Trigonopyxis arcula* – *T. arcula* v. *major*, *Nebela bohemica* – *N. collaris* – *N. parvula* – *N. tincta*, *Centropyxis aerophila* – *C. aerophila* v. *sphagnicola*, *Corythion dubium* – *C. dubium* v. *orbicularis* etc. It is possible that some of these cases reflect the overlapping of ecological niches of species and subspecies forms. However, for the *Centropyxis deflandriana* complex it is much more likely that its diversity of forms represents ecological, rather than geographical differences. This fact highlights difficulties in the interpretations of data on ecology and geographical distribution of anemochorous species and the need for a widening of the geography of investigations.

Species of *Centropyxis deflandiana* complex were not found in the soils of Cat Tien National Park, as well as other rare species *Deharvengia papuensis* and *Trachelcorythion pulchelum*, which were recorded in North Vietnam (Balik 1995, Nguen-Viet *et al*. 2007). Balik (1995) noted that testate amoebae fauna of North Vietnam includes elements of two biogeographical realms – Palaearctic and Indomalayan. However, the number of Indomalayan species in North Vietnam is not large. Most of them are from the *Centropyxis deflandriana* complex. But even this group must not be considered as typical Indomalayan since *C. deflandriana* occurred in Palaearctic (Bonnet 1979), whereas *C. latideflandriana* and *C. stenodeflandriana* was found within the Neotropical realm in Mexico and Ecuador (Krashevska *et al*. 2007, Bobrov, unpublished data). *Centropyxis* cf. *acuminata*, which was found in the "Ficus" plot was described from the soils of French Guyana (Couteaux and Chardez 1981).

Species from the genera *Hoogenraadia* and *Planhoogenraadia* that were found in the south of Vietnam also have restricted geographical distribution. Most of these species were found within the Neotropical and Indomalayan realms (Bonnet 1984), but also in Palaearctic (Bonnet 1977, 1984; Zahidov 1995; Bobrov 2001). In our study the Gondwanian-tropical group also included *Cyclopyxis lithostoma* that inhabits regions of tropical Africa and Central America as well as Thailand (Bonnet 1974, Golemansky and Todorov 2000).

Arcella brasiliensis is another species about which zoogeography was clarified in this study. Earlier it was considered as Neotropical (Velho *et al*. 1996, Lahr and Lopes 2009), but we found it in the Bao-Sau lake sediments. It was also recorded in Moldavian fresh waters (Vikol 1992) and in Sphagnum bog in Middle Volga Region (Mazei and Tsyganov 2007).

Comparing to the data of Balik (1995), we found a larger number of species with restricted geographical distributions (up to 10% of the total species list). However, all of them were reported from the areas outside of the Indomalayan realm (with the exception of forms not identified to the species level). *Apolimia rotundistoma* was considered as endemic for this realm. This species from the monotypic genus was described by Korganova (1987) from the soils of Apolima Island in the South-Western Pacific. We found *Apolimia* sp. in soils of the "Ficus" plot. However, this genus was recently found in rainforests of Mexico (Bobrov, unpublished data).

This brief analysis poses new questions on the origin and formation of the testacean fauna of Vietnam. The main peculiarities of Vietnam fauna are: 1) the presence of species from Gondwanian-tropical origin, 2) the presence of Neotropical species, 3) lack of the representatives of circum-Australian species, in particular from the genus *Nebela*.

To conclude, in all studied biotopes of the monsoon tropical forest of South Vietnam (excluding palm forest) we found a low abundance and in the majority of habitats a low local species richness of testate amoebae. High rates of litter decomposition and the activity of termites, earthworms and other members of soil macrofauna prevent the formation of the permanent litter layer and differentiated soil horizons. This leads to the low abundances of litter-dwelling species of the genera *Nebela*, *Heleopera*, *Hyalosphenia*, *Euglypha* and *Trinema.* In most terrestrial habitats both hydrophilous species from the genera *Arcella*, *Nebela*, *Difflugia*, *Lagenodifflugia* and eurybiont and soil species from the genera *Centropyxis*, *Cyclopyxis*, *Plagiopyxis*, *Planhoogenraadia* and even xerophilous testaceans *Corythion* were found. The likely reasons for this phenomenon are sharp seasonal changes in hydrological regime including temporal overwetting or even inundation. In addition to two species that earlier were suggested as endemics of the region (*Hyalosphenia tamdaoensis* and *Trinema staryi*; Balik 1995), we found several forms with restricted geographical distribution (including *Arcella brasiliensis*, *Centropyxis* cf. *acuminata*, *C. crustulata*, *Cyclopyxis* cf. *amplecta*, *C.* cf. *aplanata* v. *microstoma*, *C. gigantea*, *C. lithostoma*, *Argynnia schwabei* and *Apolimia* sp.) which form up to one tenth of the total species richness. However, our study clearly underestimated the species diversity of the region. This justifies further research efforts in this poorly studied region aiming to clarify the effects of monsoon climate on the composition and structure of soil protozoan communities.

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