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Assemblage of testate amoebae (Protozoa, Rhizopoda) associated to aquatic macrophytes stands in a marginal lake of the São Francisco river floodplain, Brazil

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ABSTRACT. The composition and abundance of testate amoebae fauna in the littoral region of Cajueiro lake were studied during two years. The lake, marginal to São Francisco river, has a great quantity of aquatic plants and low depth. High richness and abundance of Protozoa-Rhizopoda among the macrophytes roots and leafs were reported. Some species were more abundant during distinct periods. In a total of 51 taxa five are new registers for Brazil.

Key words: aquatic Protozoa, testate amoebae, marginal lakes, São Francisco river, Southeastern Brazil.

RESUMO. Tecamebas (Protozoa, Rhizopoda) associadas a macrófitas aquáticas em uma lagoa marginal da planície de inundação do rio São Francisco, Brasil. A composição e abundância da fauna de tecamebas foi estudada na região litorânea da lagoa Cajueiro durante dois anos. A lagoa é marginal ao rio São Francisco e possui grande quantidade de plantas aquáticas e pouca profundidade. Foi constatada uma alta abundância e riqueza de espécies de tecamebas entre as raízes e folhas das macrófitas. Algumas espécies atingiram seus ótimos de abundância em distintos períodos sazonais de coleta. Do total de 51 táxons identificados, cinco correspondem a novos registros para o Brasil.

Palavras-chave: protozoários aquáticos, tecamebas, lagoas marginais, planície de inundação, rio São Francisco, Sudeste do Brasil.

Marginal lakes, which occur on the floodplains of large tropical rivers, are common in the middle São Francisco river. The volume of these lagoons varies significantly during the year due to the flooded area and depth, both depending on the season, and to the intensity of the hydrological cycle in the drainage basin. During the rainy season (November to March) the lagoons receive water from temporary streams and channels connected to the São Francisco river. As the dry period in the studied area is long, lasting generally from April to October, and temperatures are high, many lagoons dry up.

A characteristic of these ecosystems is the constant presence and abundance of emergent floating and rooted aquatic plants. The development of these aquatic plants accompanies the hydrological cycle imposed on the environment. Thus a senescent phase during the dry season and rapid growth during the flood period occur. Macrophytes are very efficient and well adapted to the environment since they present a high production of

biomes during favorable periods and become sources of organic material during the dry season (Esteves, 1988). The availability of plant detritus, ecological niches and high temperatures cause a high aquatic metabolism which characterizes the littoral zone as the richest in species and the most productive region of these water bodies (Wetzel, 1990).

The characteristic morphology and structures of these plants include the development of stems, leaves and roots that form multi-niche mats appropriate for the colonization of micro fauna and flora (Dioni, 1974). The testate amoebae take advantage of these microhabitats formed by the macrophyte stands. It is here that the decomposition process of detritus is intense, periphyton flourishes, small invertebrates and invertebrates find shelter and other decomposers such as bacteria, ciliates and fungi proliferate (Hardoim, 1997).

The free-living protozoa community plays a functional role in the aquatic biotopes (Finlay and Esteban, 1998). Since protozoa are small and have

accelerated growth rates, they control the growth of bacteria and fungi, besides being a prey to invertebrates and even to some aquatic vertebrates. According to analyses of stomach contents, Hardoim and Heckman (1996) report that testate amoebae were the preferred item in the diet of several fish species in the Pantanal.

Although there is a growing number of studies on the ecology, occurrence and geographical distribution of testate amoebae, they are still scarce in Brazil. Further, according to Lansac-Tôha *et al.* (2000) and Velho *et al.* (2000), these studies tend to be restricted to only a few geographical regions. In floodplain systems studies on testate amoebae are restricted to those of Dabés (1995), who examined plankton samples from marginal lagoons in the São Francisco river valley; Lansac-Toha *et al.* (1997), Velho and Lansac-Toha (1996), Velho *et al.* (1996, 1999) who examined plankton samples from lakes in the floodplain of the Upper Paraná River, and those of Hardoim and Heckman (1996) and Hardoim (1997), who examined plankton samples, benthic samples and samples of fauna associated with macrophytes in the Pantanal of Poconé, state of Mato Grosso.

Given the important role that testate amoebae may play in the metabolism of inland waters and the scarcity of taxonomical and ecological studies in Brazil, the object of this study was to characterize the composition and abundance of assemblages of testate amoebae associated with aquatic macrophytes stands and to evaluate the relative importance of the group compared to other invertebrates associated with aquatic macrophytes, in a marginal lake of the middle São Francisco river floodplain, state of Minas Gerais, Brazil.

Material and methods

Sampling was undertaken in a lagoon situated in the Parque Estadual da Lagoa do Cajueiro (State Park of Cajueiro Lake), inaugurated on October 8, 1998, under the jurisdiction of the Instituto Estadual de Florestas (IEF/MG)(Forests State Institute), in the state of Minas Gerais. The park spans an area of 20,500 hectares and includes eleven marginal lagoons on the floodplain of the middle São Francisco river in the municipality of Matias Cardoso, in the same state (Figure 1). The perennial Cajueiro lake ($44^{\circ} 00' 16''\text{W}$; $15^{\circ} 02' 13''\text{S}$) is the largest, about 3 kilometers long and 150 meters wide. Area varies between 0.22 to 0.48 km^2 . While maximum depth is 3.5 m, depth at the littoral zone varies between 0.30 e 1.80 m.

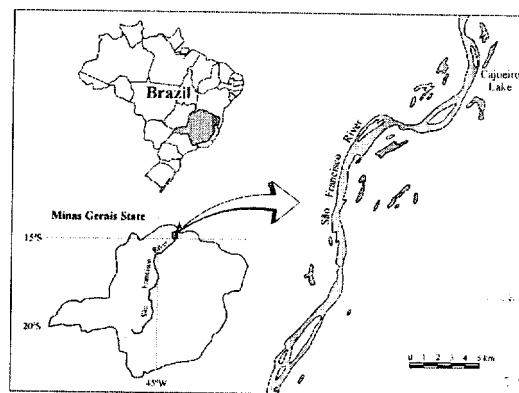


Figure 1. Map of the area under analysis

There are aquatic macrophytes at all the margins of the lake. *Eichhornia azurea* is predominant, followed by *Egeria* sp. and *Nymphoides humboldtiana*. *Najas conferta*, a rooted and submersed species, occurs in the limnetic region.

Samples were collected to evaluate the "effects" of different seasons on the testate amoebae assemblages. Two samples were taken during the dry season, in September 1995 and October 1996, and two samples during the rainy season, in March 1996 and March 1997. On each sampling date, samples were taken from two sites in the littoral region of the lagoon on opposite margins.

Plastic trays measuring 42.0 x 26.5 x 8.0 cm were placed under or among the aquatic macrophytes, as described by Dioni (1967), and filled with water. Water collected in 8 - 10 full trays was filtered through a 35 μ mesh net and collected in a graduated pail to measure the sampled volume. The material concentrated in the mesh was fixed in 5% formaldehyde for further examination on the assemblage of testate amoebae.

At least two 1ml sub-samples were counted in a Sedgwick-Rafter counting chamber and the mean number of individuals was expressed per cubic meter. All larger organisms, such as crustaceans, gastrotriches and nematodes, were placed in 5ml chambers and counted under a stereomicroscope.

Testate amoebae were divided into dominant, frequent and rare categories according to the frequency and abundance of the different taxa:

Dominant (*)** are taxa which were very abundant and present in all samples; mean densities equivalent to more than 10.000 ind/m^3 ;

Frequent ()** are taxa which were frequent but not very abundant; their mean densities was less than 10.000 ind/m^3 ;



Rare (*) are taxa which are sporadic and not abundant; their mean densities was less than 5.000 ind/m³.

Results and Discussion

Testate amoebae formed the most abundant group of invertebrates in the littoral region of Cajueiro Lake. The mean density was 1,687 x 1,000 ind/m³, which represents 40% of the sampled community (Figure 2). Hardoim and Heckmann (1996) discuss the results of studies undertaken in tropical biotopes, in Minas Gerais and Mato Grosso, where testate amoebae were predominant over ciliates, as a contrast to what occurs in temperate regions. In samples of the littoral zone in floodplain lakes and lagoons of the upper Paraná river, Velho et al. (1999) found that testate amoebae were often more frequent than the typically zooplanktonic groups such as rotifers and microcrustaceans.

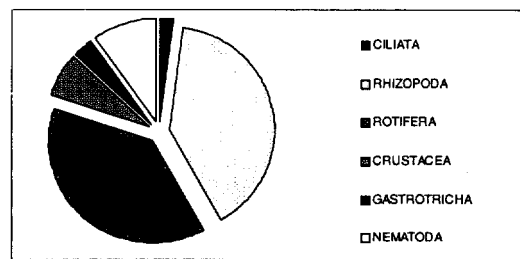


Figure 2. Mean relative abundance of microfauna groups in the littoral region of the Cajueiro lake from September 1995 to March 1997

A total of 51 taxa, or 48 species and 2 subspecies, were registered in the littoral region of Cajueiro lagoon. These represent 6 families and 12 genera of the class Lobosia, 2 families and 2 genera of the class Filosia. The family Diffugiidae was most numerous with 23 taxa. (18 were of the genus *Diffugia*), followed by Centropyxidae (8 taxa) and Arcellidae and Lesquereusiidae with 6 taxa each. According to several studies the first three families are frequently the most specious and abundant in plankton samples (Lansac-Tôha et al., 1997; Velho et al., 1999).

Many species registered in this study have been previously reported in Brazil (Green, 1975; Dabés, 1995, 1999a and b; Velho et al., 1996; Velho and Lansac-Tôha, 1996; Lansac-Tôha et al., 1997 and Hardoim, 1997). However *Centropyxis* sp 1, *Cyclopyxis* sp 1 and *Diffugiella* sp 1 (Table 1) showed different morphological and anatomical structures from those found in the literature and, thus, deserve further study. Five other species which have not been previously reported in Brazil were identified:

Diffugia bicornis, *D. hydrostatica*, *D. microclaviformis*, *D. microstoma* and *Protocucurbitella coriniformis* (Figure 3).

Table 1. List of tecamoebae species registered in Cajueiro lake and their relative frequency (***) abundant, ** frequent, * rare)

FAMILY ARCELLIDAE	
<i>Arcella conica</i> (Playfair 1917)**	
<i>Arcella costata</i> Ehrenberg 1847 *	
<i>Arcella discoides</i> Ehrenberg 1843***	
<i>Arcella hemisphaerica</i> f. <i>undulata</i> Deflandre 1928*	
<i>Arcella megastoma</i> Pénard 1902*	
<i>Arcella vulgaris</i> Ehrenberg 1830*	
FAMILY CENTROPYXIDAE	
<i>Centropyxis aculeata</i> (Ehrenberg, 1838) ***	
<i>Centropyxis aculeata</i> var. <i>tropica</i> Deflandre, 1929 **	
<i>Centropyxis discoides</i> (Pénard, 1890) ***	
<i>Centropyxis eornis</i> (Ehrenberg, 1841)**	
<i>Centropyxis hirsuta</i> Deflandre, 1929 **	
<i>Centropyxis marsupiformis</i> (Wallich, 1864) *	
<i>Centropyxis spinosa</i> (Cash, 1905) **	
<i>Centropyxis</i> sp 1***	
FAMILY TRIGONOPYXIDAE	
<i>Cyclopyxis kahli</i> (Deflandre, 1929) **	
FAMILY DIFFLUGIIDAE	
<i>Cucurbitella madagascariensis</i> Gauthier-Lievre and Thomas, 1960 *	
<i>Diffugia acuminata</i> Ehrenberg, 1938 **	
<i>Diffugia acutissima</i> Deflandre, 1931 *	
<i>Diffugia angulostoma</i> Gauthier-Lievre and Thomas 1958**	
<i>Diffugia bicornis</i> Pénard, 1980*	
<i>Diffugia capreolata</i> Pénard, 1902 **	
<i>Diffugia corona</i> Wallich, 1964 ***	
<i>Diffugia elegans</i> Pénard, 1890 ***	
<i>Diffugia gramen</i> Pénard, 1902 ***	
<i>Diffugia hydrostatica</i> Zacharias 1897 **	
<i>Diffugia lithophila</i> Penard, 1902 **	
<i>Diffugia lobostoma</i> Leidy, 1879 ***	
<i>Diffugia lobostoma multilobata</i> Gauthier-Lievre and Thomas 1958***	
<i>Diffugia microstoma</i> (Thomas, 1954)**	
<i>Diffugia microclaviformis</i> (Kourov, 1925) *	
<i>Diffugia muriformis</i> Gauthier-Lievre and Thomas, 1958*	
<i>Diffugia oblonga</i> Ehrenberg, 1838*	
<i>Diffugia pseudogramen</i> Gauthier-Lievre and Thomas 1958***	
<i>Diffugia urceolata</i> Carter, 1864 **	
<i>Pentagonia marocana</i> Gauthier-Lievre and Thomas 1958*	
<i>Pontigulasia compressa</i> (Carter, 1864) *	
<i>Protocucurbitella coriniformis</i> Gauthier-Lievre and Thomas 1958***	
<i>Suadiiffugia multipora</i> Green, 1975**	
FAMILY LESQUEREUSIIDAE	
<i>Lesquereusia epistomium</i> Penard, 1902 **	
<i>Lesquereusia modesta</i> Rumbler, 1896 *	
<i>Lesquereusia spinatis</i> (Ehrenberg, 1840) ***	
<i>Netzelia oviformis</i> (Cash, 1909) ***	
<i>Netzelia tuberculata</i> (Wallich, 1964) ***	
<i>Netzelia walesi</i> (Ogden, 1980) **	
FAMILY CRYPTODIFFLUGIIDAE	
<i>Diffugiella</i> sp 1**	
FAMILY EUGLYPHIDAE	
<i>Euglypha acanthophora</i> (Ehrenberg, 1841) ***	
<i>Euglypha denticulata</i> Brown, 1912 *	
<i>Euglypha filifera</i> Penard, 1890**	
<i>Euglypha tuberculata</i> Dujardin, 1841 *	
FAMILY TRINEMATIDAE	
<i>Trinema euehlysi</i> (Ehrenberg, 1838) ***	
<i>Trinema lineare</i> Penard, 1890 *	

The taxonomy of some species of testate amoebae with agglutinated test is still problematic (Ogden and Meisterfeld, 1989) due to the fact that these species have a variable morphology and biometrics. We will therefore provide a description of the structure of the tests, a description of aperture

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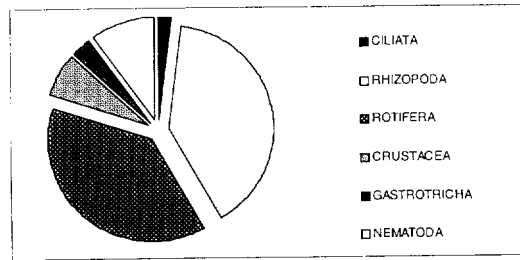


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<i>Centropyxis discoides</i> (Pénard, 1890)	***
<i>Centropyxis eornis</i> (Ehrenberg, 1841)	**
<i>Centropyxis liturata</i> Defflandre, 1929	**
<i>Centropyxis marsupiformis</i> (Wallich, 1864)	*
<i>Centropyxis spinosa</i> (Cash, 1905)	**
<i>Centropyxis</i> sp 1	***
FAMILY TRIGONOPYXIDAE	
<i>Cyclopyxis kahli</i> (Defflandre, 1929)	**
FAMILY DIFFLUGIIDAE	
<i>Cucurbitella madagascariensis</i> Gauthier-Lievre and Thomas, 1960	*
<i>Diffugia acuminata</i> Ehrenberg, 1938	**
<i>Diffugia acutissima</i> Defflandre, 1931	*
<i>Diffugia angulostoma</i> Gauthier-Lievre and Thomas 1958**	
<i>Diffugia bicornis</i> Pénard, 1980*	
<i>Diffugia capreolata</i> Penard, 1902	**
<i>Diffugia corona</i> Wallich, 1964	***
<i>Diffugia elegans</i> Pénard, 1890	***
<i>Diffugia graminea</i> Pénard, 1902	***
<i>Diffugia hydrostatica</i> Zacharias 1897	**
<i>Diffugia lithophila</i> Penard, 1902	**
<i>Diffugia lobostoma</i> Leidy, 1879	***
<i>Diffugia lobostoma multilobata</i> Gauthier-Lievre and Thomas 1958***	
<i>Diffugia microstoma</i> (Thomas, 1954)	**
<i>Diffugia microclaviformis</i> (Kourov, 1925)	*
<i>Diffugia muriformis</i> Gauthier-Lievre and Thomas, 1958*	
<i>Diffugia oblonga</i> Ehrenberg, 1838*	
<i>Diffugia pseudogaminea</i> Gauthier-Lievre and Thomas 1958***	
<i>Diffugia uccolata</i> Carter, 1864	**
<i>Pentagonia marocana</i> Gauthier-Lievre and Thomas 1958*	
<i>Pontigulatia compressa</i> (Carter, 1864)	*
<i>Protocucurbitella coriniformis</i> Gauthier-Lievre and Thomas 1958***	
<i>Suaediffugia multipora</i> Green, 1975	**
FAMILY LESQUEREUSIIDAE	
<i>Lesquereusia epistomium</i> Penard, 1902	**
<i>Lesquereusia modesta</i> Rhumbler, 1896	*
<i>Lesquereusia spiralis</i> (Ehrenberg, 1840)	***
<i>Netzelia oviformis</i> (Cash, 1909)	***
<i>Netzelia tuberculata</i> (Wallich, 1964)	***
<i>Netzelia walesi</i> (Ogden, 1980)	**
FAMILY CRYPTODIFFLUGIIDAE	
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FAMILY EUGLYPHIDAE	
<i>Englypha acanthophora</i> (Ehrenberg, 1841)	***
<i>Englypha denticulata</i> Brown, 1912	*
<i>Englypha filifera</i> Penard, 1890	**
<i>Englypha tuberculata</i> Dujardin, 1841	*
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The taxonomy of some species of testate amoebae with agglutinated test is still problematic (Ogden and Meisterfeld, 1989) due to the fact that these species have a variable morphology and biometrics. We will therefore provide a description of the structure of the tests, a description of aperture

and measurements of several of these problematic species.

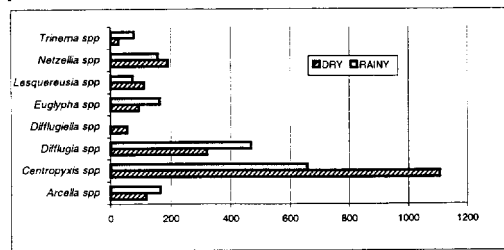


Figure 3. Mean densities of the Rhizopoda genus in the littoral region of the Cajueiro lake from September 1995 to March 1997

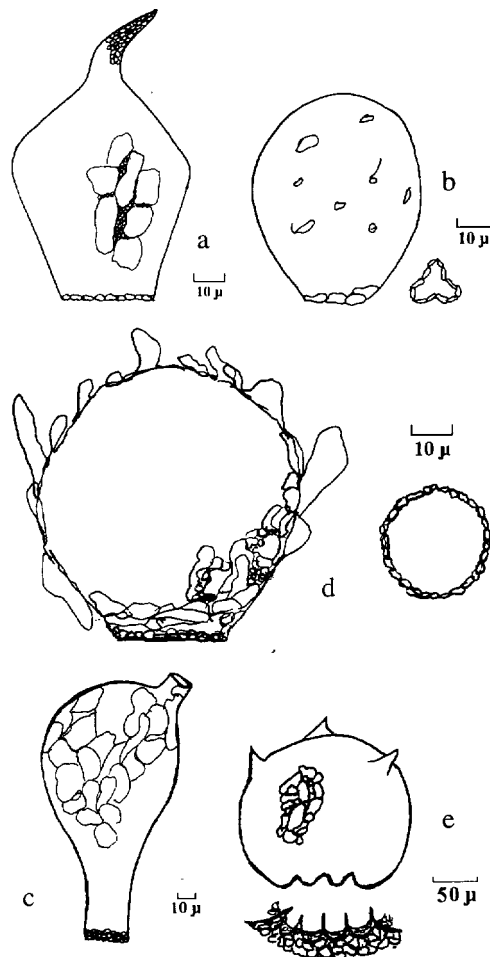


Figure 4. Species of testate amoebae recorded in the Cajueiro lake, which represent new records for Brazilian inland waters: *Diffugia bicornis* (a), *D. hydrostatica*, (b), *D. microclaviformis*, (c) *D. microstoma* (d) and *Protocentribitella coriniformis* (e)

With the exception *Centropyxis* sp1, the list of species in Table 1 is made up of species of reported cosmopolitan distribution commonly cited in tropical environments. Those not yet cited for Brazil have, nevertheless, been cited for Africa and other countries in South America, such as Argentina (Vucetich, 1973, 1978).

The most abundant genera of Rhizopoda are shown in Figure 4. The genus *Centropyxis* was equally abundant in both the dry and the rainy season, followed by *Diffugia*. According to Bonetti (1995) and Oliveira (1999), *Centropyxis* species may be considered as tolerant to stressful environmental conditions, such as estuarine ecosystems. Some groups of species such as *Centropyxis* spp e *Diffugiella* sp. were more abundant in the dry season, while *Diffugia*, *Euglypha* e *Trinema* spp. were more abundant during the rainy season. The seasonality of species may also be related to food availability. It is common knowledge that smaller species such as *Diffugiella* e *Trinema* feed on bacteria, fungi and small protozoans (Laminger, 1973). On the other hand, Hardoim (1997) observed that the larger species consume filamentous algae, small rotifers and other testate amoebae. A marked seasonality in the abundance of some species in the Pantanal, such as *Diffugia corona* and *D. lobostoma*, with larger populations during the flood period, were also observed (Hardoim, 1997).

Conclusions

The fauna associated to the littoral region of the Cajueiro lake is characterized by the dominance of the Rhizopoda-Testacea group. Some testate amoebae taxa had greater abundance in different seasons, suggesting a different response of the community in the wake of environmental variations. Many species registered occur frequently in Brazilian waters or are distributed in the tropics. It is important to emphasize the need of good morphobiometric descriptions of the testate amoebae found in Brazilian inland waters to identify species with greater reliability.

Table 2. Morphological features of some agglutinated species of testate amoebae from Cajuciro Lake

Species	Test: structure and size of particles	Test: aspects, surface and color	Aperture: form and structure	Measurements(µm) B=Breadth; H=height; L=length; PS=aperture
<i>Centropyxis discoides</i>	Chitinous with varied elements	robust spines on the margin; yellow and brown; translucent	circular-irregular, invaginated, smooth	L=300; PS= 120
<i>Centropyxis sp1</i>	Chitinous, some with many, some with few particles	with 2 fragile apical spine rare or more than 2; light and dark yellow; translucent	oval, invaginated, smooth	B=58-65; L=30-45; H=45-54; PS=24-33
<i>Centropyxis spinosa</i>	Chitinous with particles of various sizes	fragile spine on dorsal, light and dark yellow; translucent	Circular-irregular, with smooth inner membrane	Base=71; H=30; PS=30
<i>Cyclopyxis sp1</i>	irregularly arranged; medium and small particles	smooth; yellow and dark gray; translucent	Circular, little invaginated; with small particles	L=54; H=36; PS= 18
<i>Cucurbitella madagascariensis</i>	regularly arranged; medium and small particles	rough; dark brown; opaque	Trilobed, neck with small particles	H=81; L=75; PS=21
<i>Diffugia acutissima</i>	regularly arranged; medium and small particles	smooth; light gray; translucent	Circular-regular smooth	H=210; L=99; PS=51
<i>Diffugia bicornis</i>	regularly arranged; medium and small particles	smooth; fragile; light gray; translucent, with apical horn.	Circular with small regular particles	H=60-75; L=27-60; PS=24-30
<i>Diffugia capreolata</i>	particles of various sizes	smooth; brown; opaque.	Circular with regular particles	H=300; L=180; PS=105
<i>Diffugia corona</i>	regularly arranged; medium particles	Smooth; dark brown; opaque; with 0 - 4 short spines;	Denticulate lobed with regular neck	H=90; L=84; PS=30
<i>Diffugia elegans</i>	irregularly arranged, particles of various sizes	rough; light or dark gray; with 1 apical horn; translucent	circular; with neck of irregular particles	H=111-124; L=54-60; PS=12-33
<i>Diffugia gramen</i>	medium and small particles	rough; dark brown; opaque	trilobed as in clover	H=87-90 L=72-75 PS=27-30
<i>Diffugia gramen var. globulosa</i>	small particles well arranged	Smooth; yellow - gray; opaque	trilobed regular	H=L=60 PS=24
<i>Diffugia hydrostatica</i>	chitinous with small and sparse particles	Smooth; yellow; translucent	trilobed, with medium sized particles; without lip	H=60 L=45 PS=15
<i>Diffugia lithophila</i>	particles of various sizes overlapping	Smooth; dark brown; opaque	circular with apparent chiton	H=90-120 L=75-90 PS=36-45
<i>Diffugia lobostoma</i>	small particles and diatom frustules	Smooth; yellow-golden translucent	4-5 lobes	H=88-165; L=72-75 PS=27-30
<i>Diffugia microclaviformis</i>	medium and big particles	Smooth; dark brown; opaque	circular, with small particles on margin	H=135-150 L=75 PS=24-27
<i>Diffugia microsioma</i>	particles of various sizes, irregularly arranged and jutting	rough; brown; opaque	circular with regular particles on margin	H=66 L=60 PS=22,5
<i>Diffugia muriformis</i>	particles regularly arranged	Smooth; undulate outline; Dark brown; Opaque	8 lobes and neck with small particles	H=105 L=99 PS=42
<i>Diffugia pseudogramem</i>	medium and small particles	Rough; Light to dark gray translucent	trilobed, with neck of small particles	H=96 L=66 PS=21
<i>Diffugiella sp1</i>	proteinaceous with small and sparse particles	Smooth; Translucent	circular, irregular	H=33-39 L=24-30 PS=12-15
<i>Netzelia oviformis</i>	chitinous with small and sparse particles	Smooth; Light yellow to golden Translucent	3-4 lobes with distinct lip (hyaline margin)	H=60-72 L=33-51 PS=9-21
<i>Netzelia tuberculata</i>	medium particles interspaced with porous matrix	Undulate outline or regular; yellow to brown; translucent	4 lobes with hyaline margin	H=84-99 L=66-72 PS=24-30
<i>Netzelia wailesi</i>	medium and small well arranged particles with shiny spots	Smooth; Yellow brown; Opaque	circular, denticulate, regular	H=70,5-78 L=42-58 PS=16,5-24
<i>Pentagonia cf. marocana</i>	arms with smaller particles than on body	Smooth; 5 rounded arms; dark gray; translucent	circular with small particles and discrete neck	H=108-120 L=69 PS=36
<i>Pontigulasia compressa</i>	particles of various sizes	Rough; dark brown; Opaque	circular	H=120 L=90 PS=30
<i>Proiocucurbitella coriniformis</i>	particles of various sizes well arranged	Smooth; with or without spines; Dark brown; opaque	Denticulate lobed with internal lip	H=180-210; L=180-282; PS=80-135

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