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Estrutura temporal da assembléia de ciliados peritríquios (Ciliophora, Peritrichia) em lago subtropical no sul do Brasil

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Dissertação de Mestrado

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INDÍCE:

ARTIGO

RESUMO

Processos de sucessão apresentam relações complexas entre fatores abióticos e bióticos. Esses processos influenciam a estrutura e funcionamento da comunidade, bem como do ecossistema inteiro. Ciliados da subclasse Peritrichia constituem um dos grupos com o maior número de espécies. Peritríquios podem ocupar vários tipos de corpos d'água. No entanto, mesmo com grande diversidade e sendo de ocorrência comum, são pouco estudados. No presente trabalho, foi realizado um estudo de um ano com os ciliados peritríquios colonizando lâminas de vidro em um ponto de amostragem no Lago Guaíba, localizado no estado do Rio Grande do Sul, sul do Brasil. Neste período, foi analisada a dinâmica populacional das comunidades de peritríquios, correlacionando-a com fatores ambientais. Um total de 35 morfoespécies, além de pelo menos 6 novas espécies foram encontradas. Os resultados mostram que o grupo possui complexa organização sucessional, com diferentes respostas a fatores ambientais e tempo de exposição das armadilhas.

APRESENTAÇÃO

A presente dissertação de mestrado, intitulada "Estudo da sucessão da assembléia de ciliados peritríquios (Ciliophora, Peritrichia) no Lago Guaíba, Porto Alegre, Rio Grande do Sul" foi desenvolvida como parte dos requisitos necessários para obtenção do título de Mestre junto ao programa de Pós-Graduação em Zoologia da Pontifícia Universidade Católica do Rio Grande do Sul.

Este trabalho teve como principais objetivos (i) documentar a composição taxonômica dos ciliados peritríquios no lago Guaíba, (ii) descrever as dinâmicas populacionais das espécies dominantes numericamente; (iii) correlacionar suas ocorrências com fatores ambientais; (iv) identificar padrões de colonização e (v) identificar padrões estacionais na estrutura da comunidade.

Esta dissertação é apresentada no formato de artigo científico a ser submetido ao periódico Journal of Eukaryotic Microbiology.

Temporal Structure of the Peritrich Ciliate (Ciliophora, Peritrichia) Assembly in a Subtropical Lake in Southern Brazil

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ABSTRACT

Successional processes present complex relationships between abiotic and biotic factors. These processes influence the structure and functioning of the community, as well as the ecosystem. The Subclass Peritrichia is one of the largest groups in the Phylum Ciliophora. They can occupy various types of water bodies. However, despite their great diversity and common occurrence, they are poorly studied. In the present work we performed a one year survey of peritrich ciliates colonizing glass slides in the Lake Guaíba located in southern Brazil. We analyzed the population dynamics of the species composing the community, and correlated it with environmental factors. A total of 35 morphospecies of Peritrichia were found, of which at least six are undescribed. Results showed that the group presents high diversity and a complex successional organization, with different responses to environmental factors and days of exposure of the traps.

Key words: Peritrichia, succession, population dynamics

Ciliates and other protists participate in a range of metabolic routes in freshwater systems (Andrushchyshyn, Magnusson & Williams, 2003; Gong, Song & Warren, 2005, Xu *et al*., 2009). They play an essential role in the functioning of many aquatic systems and are considered important predators of bacteria and small phytoplankton, having significant impacts on planktonic trophic dynamics in many freshwater systems (Jack and Gilbert, 1997). Moreover, they mediate the recycling of essential nutrients for the growth of phytoplankton and bacteria (Carrias, Cussac & Corbara, 2001). Their roles as grazers result in their significant impacts on planktonic trophic dynamics in many freshwater systems (Jack & Gilbert, 1997). Ciliates can also occupy a wide range of habitats, including marine and freshwater environments, and very specific niches, such as bromeliad tanks, tree holes (Carrias *et al*., 2001 and Kitching, 2004), the respiratory tract of cetaceans (Sniezieck *et al*., 1995), and extreme environments like hydrothermal vents (Small and Gross, 1985). In addition, many species are abundant in eutrophic environments and some are considered good indicators of water quality (Lynn, 2008).

Ciliates in the sub-class Peritrichia are among the most common organisms found in the periphyton. Peritrichs form a distinct group of ciliates, being one of the most common and numerous group in the Phylum Ciliophora, presenting more than 50 genera and 1,000 species described so far (Li *et al*., 2008; Lynn, 2008). Despite their diversity, they are poorly studied, especially in the Southern Hemisphere (Foissner, 2003). Few studies had, so far, explored their diversity in South America and Africa. For instance, Basson & Van As (1991) described trichodinids from a calanoid copepods and catfish from South Africa, while Utz (2007) found *Epistylis plicatilis* attached to a gastropod in Southern Brazil, and Cabral and co-workers (2010) investigated the spatial and temporal occurrence of a species of *Rhabdostyla* on chironomid larvae in Southeastern Brazil. Peritrichs, in general, occupy a wide range of environments and can participate in restricted ecological interactions, with records of species acting as parasites (e.g. Pickering, Strong & Pollard, 1985; Foissner, 2003; Gouda, 2006) and epibionts (e.g.; Clamp, 1973; Fernandez-Leborans & Tato-Porto, 2000; Utz, 2007).

The majority of studies focusing the succession of free-living ciliates were carried out in marine environments (e.g. Artolozaga *et al*. 1997; Levisen, Nielsen & Hansen, 2000, Sommer *et al*., 2007; Xu *et al*., 2009). Succession studies in freshwaters generally emphasize planktonic crusteceans, with few works so far focusing microzooplankton

(Yoshida *et al.*, 2001). Even in the studies with unicellular eukaryotes, the organisms surveyed were generally flagellates (Cleven & Weisse, 2001), or free-swimming ciliates (Hardoim & Heckman, 1996; Urrutxurtu, 2004; Dias, Wieloch & D'Agosto, 2008), with no study so far focusing on sessile ciliates.

The present study analyzes the temporal structure and relationships of the peritrich community in the Guaíba Lake, southern Brazil. The main goals of this one year survey were (1) to document the taxonomic composition of peritrich ciliates in Guaíba Lake; (2) to describe the population dynamics of numerically dominant species; (3) to correlate their occurrence with environmental factors; and (4) to identify successional and seasonal patterns of species colonization and community structure, respectively.

MATERIALS AND METHODS

Study area. The watershed of the Guaíba Lake (Fig. 1) covers an area of 2,323.66 km². In its surroundings there is an inserted population of more than a million inhabitants. The average depth of the lake is 2m, reaching 12m in the navigation channel (Rossato & Martins 2001, Martins, Veitenheimer-Mendes & Faccioni-Heuser, 2006). The lake is used for public water supply, irrigation, tourism, recreation and fishing, and also receives large amounts of domestic and industrial wastewater that compromise water quality. Its turbid waters (transparency <1.1 m) range from mildly acidic (pH 6.6) to basic (pH 8.3) (Salomoni & Torgan, 2008). The turbidity varies from 40 to 100 NTU, and the average biochemical oxygen demand is 3mg/L O_2, while dissolved oxygen is usually around 6 mg/L O_2 (Bendati *et al.*, 2000).

Sampling. Sampling was performed in a private pier in northern Guaíba Lake (Clube dos Jangadeiros, 30º6'38"S, 51º15'38"W). The peritrich community was sampled using 30 microscope glass slides, arranged in pairs and kept 30cm deep from a fluctuation device (PVC floating tube). Each sampling series was initiated in the winter and summer solstices and autumn and spring equinoxes. Each sampling series began with two slides removed daily for five days, then in the 10th, 15th, and in the 20th sampling day, and after that at ten days interval until a total of eight weeks was reached.

Once removed, the slides were placed in a plastic bottle with water from the sampling site and taken immediately to the laboratory.

Sample analysis. The two replicates taken from the field were analyzed in the laboratory using a light microscope. The observed area of the glass slides was limited by a 22x22 mm coverslip placed in the middle of the sample unit. The total number of colonies and zooids of all peritrich ciliates found in the observed area were recorded. For a more precise identification, some species were cultured in laboratory. For that, individuals were removed from the glass slides with forceps, placed in a Petri dish with 10 ml of mineral water, fed with an infusion of wheat grass (Dagget & Nerad, 1992), and kept at room temperature. Morphological characters used for species identification were measured in living organisms (Utz, 2007; Utz & Coats, 2008). Colonies were preserved in Bouin´s fluid (Coats & Heinbokel, 1982) and the protargol staining technique (Montagnes & Lynn, 1987) was applied to observe the arrangement of the oral infraciliature, as well as other morphological features. Morphospecies were identified based on the descriptions of Kahl (1935), reviews of Warren (1982, 1986 and 1991) and the dichotomous key provided by Lynn & Small (2000).

Water quality parameters. Once a week during the whole study period, the water temperature (ºC), pH, and conductivity (μS) were measured. Other parameters such as chlorophyll α (μg/L), total solids (μg/L), dissolved oxygen (mg/L O^2), turbidity (NTU), and total phosphorous (mg/L P) were provided by the Research Center of the Municipal Department of Water and Sewerage (DMAE), whose collection was performed monthly in the vicinity of the sampling site.

Statistical analysis. Data on abundance were logarithmized (Ln(x+1)) and standardized (deviation from annual mean) to perform regression analysis. Values below -2 and above 2 were changed to -2 and 2 respectively. Relative abundance was rescaled to one by adding two and dividing by four. Multiple Linear Regressions (MLR) correlating each species relative abundance with temporal and water quality parameters (winter, spring, summer, fall, days of exposure, temperature, pH, chlorophyll α, total solids, dissolved oxygen, conductivity, turbidity, total phosphorous) were performed using the computer program SPSS (version 17.5), with the backwards method, and a P value <0.3 as removal threshold. The Shannon-Wiener diversity index (H') was calculated for each sampling day for the whole study period.

Cluster analysis (SPSS, version 17.5) was used to identify patterns of species association. A new approach was applied by converting significance of each coefficient B of the MLR as follow RIC (Relative Importance Coefficient) = (1 – P) x B / mod(B); where P is the significance value for each regression, coefficient B, and mod represents the modulus of the B value. The clustering tree was constructed by using Euclidean Distance as association metrics and the Ward's aggregation method.

Species Classification. For a better understanding of the species successional structure, they were classified in relation to the percentage of occurrence, and according to the stage of succession in which they occurred. For this, the number of occurrences of each morphospecies was divided by the total number of samples. Those species that appeared in more than 50% of the collections were named as constant, those between 25-49% were considered accessory, and species occurring in less than 25% were named casual.

The species were also classified according to their successional characteristic. Pioneer species were considered those whose maximum occurrences appeared until the 30th day of exposure of the traps. They were considered secondary species if their maximums occurred between the 30th and 60th days of exposure, and were called climax species if occurred after the 60th day of sampling. In addition to constancy and sucessional characteristics, morphological data (compound measurements) for cultured species were also provided. Compound measurements were given by the sum of the zooid length, zooid width at midpoint, stalk length and stalk width (in µm). The species without stalk, such as *Platycola decumbens* and *Vaginicola* sp. were disregarded.

RESULTS

Water quality parameters. Seasonal variation of measured water parameters are presented in Fig. 2. Observed values did not differ from those already described by Bendati *et al*. (2000). The water temperature ranged from 14 to 28.7° C, while the values for dissolved oxygen were between 5.6 and 9.3 (mg/L). The pH ranged from 6.4 to 7.2, while the values of total solids ranged from less than 10 (minimal measured value) to 42 (mg/L). Chlorophyll α had values ranged from 0 to 4.19 (mg/L), and numbers for turbidity were between 17 and 51.1 (NTU). Finally, values of total phosphorus and conductivity ranged from 0.09 to 0.19 (mg/L), and from 72.5 to 84.05 (in µs/cm), respectively.

Abundance and species composition. The results of the first 5 days of sampling at each season were treated as a group since separately they did not present numerical relevance. Thus, the total number of samples examined in the present study was 44.

Different species belonging to the Subclass Peritrichia were found throughout the whole sampling period, with a total of 35 identified morphospecies. Although, species richness was very similar throughout the year with peaks ranging from 15 observed during summer to 20 species recorded in the fall (Figure 3a), the abundance in terms of individuals did not follow the same pattern. Peritrich abundance in Guaiba Lake was more than two times higher during winter (2275 ind./cm²) than in the summer (1006 ind./cm²), more than four times higher than the abundance found during spring (531 ind./cm²), and more than five times higher than the numbers observed during fall (442 ind./cm²). The number of zooids per colony for the colonial species also presented its highest peak during the winter as shown in Figure 3. Similar to the observed for abundance, the number of zooids recorded during the winter was three times higher than summer, more than 2 times higher than the observed in the spring, and nearly 1.5 times higher than recorded in the fall.

Similar to species richness, the highest value observed for the Shannon-Weaver diversity index (H'), for individuals and zooids, was during the spring (1.99 and 1.87 respectively), and fall (1.93 individuals and 1.82 zooids). The winter presented a high diversity of individuals (1.52) and a low diversity of zooids (1.73). In the summer the opposite situation was observed (1.39 individuals and 1.09 zooids). As a general pattern, individual density was higher during the winter, with a reduced richness and diversity, indicating dominance of a small number of species.

The genera *Epistylis* and *Vorticella* were the most abundant in number of species throughout the sampling time. There were high numbers of individuals, sometimes exceeding the sum of all other genera, showing a dominance of space usage in comparison to other genera. *Epistylis* and *Vorticella* were also the most diverse genera. For instance, *Epistylis* reached a peak of 12 species during the winter, being more diverse than all other genera together (excluding *Vorticella*). This demonstrates that, in addition to their highest abundance, *Vorticella* and *Epistylis* are also the most diverse genera in the peritrich assemblage during the analyzed period (see Table 1).

Multiple Linear Regressions and Cluster analysis. Table 3 presents the estimated coefficients for Multiple Linear Regressions relating the abundance of each species with abiotic descriptors. The study period presented different impacts regarding community structure. Summer was not significant for any species, and was automatically excluded from all analysis. By contrast, the winter was the descriptor with a direct impact in the majority of peritrich species (68% of the species) if the cutting threshold of $P<0.3$ is considered. Successional time, dissolved oxygen and total phosphorous presented a descriptive power for 63% of the sampled species. On the other hand, water temperature and chlorophyll α were important in the abundance estimation for approximately 30% of the analyzed peritrich species.

The pattern of species response to time and abiotic descriptors could be more clearly identified by a Cluster Analysis (Fig. 3). The dendrogram divided the community in two major groups. Cluster 1 differed from cluster 2 by effects of season (winter effect), time of exposure (DE), pH, total solids (TS), dissolved oxygen (DO), turbidity, and total phosphorous (TP). As a general pattern, species from cluster 1 were more frequent during the winter, at the end of the succession sequence, when the water presented a lower pH, an increased concentration of suspension solids (TS) and total phosphorous (TP), and a decrease in turbidity.

Cluster 2 is clearly divided in two sub-groups, named cluster 2.1 and 2.2 (Fig. 3). Species in these two clusters were grouped separately due to their responses to spring, exposure time, chlorophyll α, turbidity and total phosphorus. Species in the cluster 2.1 presented an increase in abundance during spring, at the end of successional cycle, when chlorophyll α values showed an increase. On the other hand, species in cluster 2.2 were more frequent in turbid waters and also presented a very strong negative association with total phosphorus.

Species succession. Table 4 shows the classification of species according to their constancy of occurrence, successional stage, number of days to reach the abundance peak, and compound measurements (information restricted to cultivated species)..

Figure 4 presents a scatter plot relating each morphospecies compound measurement with the number of days necessary to reach the abundance peak. It can be observed from the graph that species with a small body size (<600µm) presented a peak of abundance at different periods (pioneer to climax), while large species (>600µm) showed a high abundance in the last half of each successional period (secondary to climax).

DISCUSSION

The results found in the present study showed that there is a successional structure over time of the peritrich community in the analyzed environment. In general, the species showed a high diversity and a complex successional organization, with different responses to both environmental factors and time of exposure.

Community composition and dynamics. A total of 35 morphospecies were found in Guaíba Lake, demonstrating high individual abundances during the whole study period. In comparison with other studies, Guaiba Lake showed a very high richness of peritrich species. For instance, Xu *et al.* (2009) found two species of *Zoothaminium*, and one species of *Vaginicola* sp. in a 3-month study on the coast of Korea. Copellotti & Matarazzo (2000), in an 8-month survey in an European lagoon recovered about nine species of peritrichs, all from the genera *Vorticella* and *Zoothamnium*. Kusuoka & Watanabe (1987) identified only four peritrich species in the genera *Carchesium* and *Vorticella* in a Japanese urban stream. This discrepancy in species richness may be attributed to the difference in the length of the studies.

The low number of species recovered in studies carried out in productive bodies of waters is expected since this kind of environment generally presents low diversity (Henebry & Ridgeway, 1974; Salvado, Gracia & Amigó, 1995). The Guaíba Lake is a highly impacted body of water, classified as Class IV according to the Brazilian system. Despite of being used for water supply and irrigation, the lake water should only be used for navigation and landscape harmony in accordance with environmental laws (Bendati *et al.*, 2000), thus it may be unexpected to observe the species diversity recorded here. On the other hand, surveys carried out in polluted freshwaters have shown high species diversity. In 1973, Small surveyed a small polluted stream in Illinois (USA), in which he found a total of 93 genera of ciliates, including peritrichs. He observed that the highest population densities were found at sites closest to the wastewater influx. A similar situation may be occurring in the Guaíba Lake, indicating that eutrophication may not always be the direct cause of low ciliate diversity. Kusuoka & Watanabe (1987) also suggested that urban streams that receive domestic sewage could be considered the ideal habitat for peritrichs due to the high density of bacteria present in these environments.

Peritrich density in the study site varied markedly over time. As a general pattern, all seasons presented some events of severe abundance reduction, but it is not clear if it represents a successional cycle, recovery from catastrophic events, or the result of natural sample variability. According to Jack & Gilbert (1997) ciliate densities are often positively correlated with increasing water trophy, which suggests that abundance is resource limited. However, experimental work has demonstrated that ciliate assemblages may also be strongly affected by direct metazoan interactions (Jack & Gilbert, 1993; Wickham & Gilbert, 1993). These interactions can be manifested through predation, mechanical interference, or both. In the present work, density depressions were followed by reductions in species richness, suggesting a severe impact over the community. Low peaks of density were observed without a reduction in richness, which may be caused by predation on dominant species, since metazoan predators were frequently found in the traps, and were observed preying selectively upon species of *Epistylis*.

Epistylis and *Vorticella* were the most abundant peritrich genera, and presented the highest species diversity during the study period. Although these are not always the most abundant, or common peritrich genera (Kusuoka & Watanabe, 1987; Partaly 2003), there are several studies that focus on the importance of *Vorticella* and *Epistylis* as bacterivores having relatively high growth rates (e.g. Sanders, Bennet & Debiase, 1989; Macek *et. al*., 1996; Šimek *et. al*., 1995; Stabell, 1996 and Jezbera *et al*., 2003). These studies show that some species of *Epistylis* and *Vorticella* may be significant grazers on bacterioplankton, and could also be found in high abundance, which denotes their capacity for a rapid growth, and cell division.

Abiotic factors and seasonal patterns. Although summer was not a significant parameter to describe presence or absence of species, winter proved to be a very significant factor influencing the peritrich community. The occurrence of determined species was closely related to this season, but unrelated to water temperature. Dissolved oxygen, chlorophyll α, and total phosphorus were also significant, with occurrence of species that responded negatively or positively to these parameters. Turbidity and exposure time of the traps were also important for the grouping species as functional clusters. Other parameters, such as water temperature and conductivity were not relevant. Despite the low temperatures and consequently low metabolic rates observed during the winter, there was a higher abundance of individuals and zooids. During this season, the lake presents high influx of water (Superintendência de Portos e Hidrovias, 2011), which probably helps to dilute contaminants, leading to an improvement of the water quality that may favors the growth of peritrichs. A comparison with less or non-polluted areas would help to understand the influence of contaminants on the growth of these organisms.

Sucessional patterns. Müller, Hauzy & Hulot (2012) in their study on *Paramecium bursaria* showed that free-living ciliates may present interference interactions, such as biochemical-mediated interactions and allelopathy. Although it has never been demonstrated for sessile ciliates, a similar type of interaction may be occurring in Guaíba Lake. Peritrich species in the present study showed differences in their successional species patterns, and at the end of each season, later colonizers presented a dominance of space usage. To confirm this hypothesis, it would be necessary to test the effect of a secondary or climax species over a pioneer monoculture, as it should interfere with the growth of the predecessor species.

Most of our knowledge on successional patterns comes from studies on benthic invertebrates. For instance, Hirata (1987) investigated the succession of marine invertebrates, including barnacles, ascidians, and oysters, and observed that biological characteristics of the species could influence their occurrence and successional cycle. He also inferred that in some cases species succession could be governed by historical differences in colonization and disturbance which lead to changes in species dominance observed at different successional stages. Breitburg (1985), on the other hand, suggested that the most important mechanisms which determine species succession are the result of interactions between the organisms, and not between successional stages. Early colonizers could affect the recruitment of determined species allowing the establishment of others, which in general, are stronger competitors. This trend was observed in the present study, where peritrich species in the second half of the successional stage tended to be large, while species in the first half did not show a definite pattern. The larger peritrich species may be better competitors for space, but depended on the presence of the early colonizers. In addition to the species interactions governing the successional patters, there is also the influence of abiotic factors, which may also influence the succession dynamics, leading to an elaborated system, composed of interconnected relationships that need to be better explored.

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TABLES

Table 1: Number of peritrich species per genera observed between June 2010 and June 2011, in Guaíba Lake, southern Brazil.

Genera	**Winter**	**Spring**	**Summer**	**Fall**
Epistylis	12	8	9	10
Vorticella	3	3	4	3
Carchesium	2	1	2	2
Cothurnia	2	2	2	2
Haplocaulus	0	1	0	1
Myoschyston	1	1	1	1
Opercularia	0	3	2	4
Platycola	0	1	1	1
Rhabdostyla	0	1	0	1
Vaginicola	0	1	1	2
Zoothamnium	2	2	0	1

Table 2: Multiple linear regression coefficients relating peritrich species abundance (standardized (ln+1) values) with seasons, and water quality parameters. Data obtained between June 2010 and June 2011 for Guaíba Lake, southern Brazil. DE (days of exposure) is the number of days that the trap was submerged in the water, Temp is the water temperature (ºC), Chl α is chlorophyll α (µg/L), TS is total solids (µg/L), DO is dissoveld oxygen (mg/L O^2), Cond is conductivity (µS), Turb is turbidity (NTU) and TP is total phosphorus (mg/L P).

Species		**Constant**	**Winter**	**Spring**	**Fall**	**Days**	**Temp**	**pH**	**Chl α**	**TS**	**DO**	**Cond**	**Turb**	**TP**
***Carchesium* sp.**	**B**	6,247	1,086			0,007		-0,441		0,051	-0,248	-0,031	-0,012	
	SE	2,910	0,576			0,005		0,341		0,025	0,195	0,023	0,011	
	P	***0,039***	0,067			0,164		0,204		***0,046***	0,213	0,193	0,298	
Carchesium polypinum	**B**	1,465	1,204		2,196				0,219	0,028				-16,981
	SE	1,005	0,313		0,396				0,093	0,016				7,046
	P	0,153	***0,000***		***0,000***				***0,024***	0,078				***0,021***
***Cothurnia* sp.**	**B**	-4,977	-2,953					0,910		0,060	0,790			-36,909
	SE	3,700	0,950					0,523		0,026	0,337			9,215
	P	0,186	***0,004***					0,090		***0,028***	***0,025***			***0,000***
***Cothurnia* sp.2**	**B**	5,348	2,971		2,513				-0,273		-0,430		0,021	-19,529
	SE	1,876	0,898		0,598				0,127		0,310		0,012	8,719
	P	***0,007***	***0,002***		***0,000***				***0,038***		0,174		0,077	***0,031***
***Epistylis* sp.1**	**B**	3,089	1,354	0,182	0,336	0,003				0,016	-0,382	-0,014	-0,007	
	SE	1,041	0,342	0,156	0,209	0,002				0,011	0,096	0,011	0,006	
	P	***0,005***	***0,000***	0,250	0,116	0,233				0,141	***0,000***	0,202	0,206	
***Epistylis* sp.2**	**B**	-0,245			0,386	0,010								
	SE	0,195			0,236	0,004								
	P	0,217			0,109	***0,008***								
***Epistylis* sp.3**	**B**	0,395	0,635		0,396	0,005					-0,173	-0,008	5,254	
	SE	0,737	0,312		0,223	0,003					0,108	0,004	3,115	
	P	0,595	***0,049***		0,083	0,100					0,116	0,060	0,100	
***Epistylis* sp.4**	**B**	0,801	0,351	0,047	0,087	0,001				0,004	-0,099	-0,004	-0,002	
	SE	0,270	0,089	0,040	0,054	0,001				0,003	0,025	0,003	0,001	
	P	***0,005***	***0,000***	0,250	0,116	0,233				0,141	***0,000***	0,202	0,206	
***Epistylis* sp.5**	**B**	-0,697				0,003				-0,011				5,976
	SE	0,315				0,002				0,007				2,283
	P	***0,033***				0,190				0,111				***0,012***

Table 2: Cont.

Species		Constant	Winter	Spring	Fall	Days	Temp	pH	Chl α	TS	DO	Cond	Turb	TP
Epistylis sp.6	**B**	-4,977	-2,953					0,910			0,790			-36,909
	SE	3,700	0,950					0,523			0,337			9,215
	P	0,186	***0,004***					0,090			***0,025***			***0,000***
Epistylis sp.7	**B**	-0,307	0,539		-0,376	0,011		-0,385			-0,325	0,049		7,387
	SE	1,622	0,389		0,248	0,003		0,205			0,119	0,014		3,743
	P	0,851	0,175		0,138	***0,002***		0,068			***0,010***	***0,001***		0,056
Epistylis sp.8	**B**	9,626	-1,475	-0,636			-0,092	-0,762		0,064	0,391			-23,113
	SE	5,479	1,037	0,529			0,077	0,513		0,026	0,364			11,078
	P	0,087	0,164	0,237			0,238	0,146		***0,020***	0,290			***0,044***
Epistylis sp.9	**B**	-3,871	1,396	0,817	1,984	0,018					-0,753	0,102	0,010	
	SE	2,533	0,866	0,402	0,529	0,006					0,237	0,027	0,009	
	P	0,135	0,116	***0,050***	***0,001***	***0,002***					***0,003***	***0,001***	0,263	
Epistylis sp.10	**B**	0,163	-0,829		0,320	0,004	-0,061		0,066			0,019	-0,005	
	SE	1,016	0,325		0,238	0,003	0,022		0,048			0,013	0,004	
	P	0,874	***0,015***		0,187	0,193	***0,008***		0,173			0,165	0,226	
Epistylis sp.11	**B**	-4,693	2,712	0,457		0,022	0,071	-0,459			-0,484	0,077		18,749
	SE	4,494	0,819	0,425		0,007	0,064	0,423			0,287	0,028		8,253
	P	0,303	***0,002***	0,290		***0,003***	0,274	0,284			0,100	***0,010***		***0,029***
Epistylis sp.12	**B**	-3,801	-0,699			0,006			0,268		0,309	0,037	0,008	-8,669
	SE	1,876	0,549			0,005			0,080		0,186	0,021	0,007	5,224
	P	0,050	0,212			0,210			***0,002***		0,106	0,089	0,259	0,106
Epistylis sp.13	**B**	-1,361			1,241	0,022						0,034	-0,011	-8,900
	SE	1,651			0,414	0,006						0,019	0,008	6,310
	P	0,415			***0,005***	***0,000***						0,081	0,201	0,166
Epistylis sp.14	**B**	4,278		-0,302	-0,282	-0,078		-0,156	0,172		-0,243			
	SE	1,275		0,125	0,134	0,018		0,113	0,032		0,080			
	P	***0,002***		***0,020***	***0,042***	***0,000***		0,177	***0,000***		***0,005***			
Haplocaulus sp.	**B**	0,296	0,100	0,154	0,149				0,024					-2,807
	SE	0,159	0,079	0,078	0,096				0,019					1,183
	P	0,071	0,212	0,056	0,126				0,205					***0,023***
Myoschyston sp.	**B**	-15,896		1,907	2,825		0,197	1,229				0,083	0,040	-24,052
	SE	5,836		0,608	0,719		0,058	0,607				0,041	0,014	11,628
	P	***0,010***		***0,003***	***0,000***		***0,002***	0,051				***0,047***	***0,008***	***0,046***

Table 2: Cont.

Species		Constant	Winter	Spring	Fall	Days	Temp	pH	Chl α	TS	DO	Cond	Turb	TP
Opercularia **sp.1**	**B**	1,177	-1,189	-0,446	0,339	0,006	-0,083		0,046		0,148		-0,006	
	SE	1,254	0,372	0,210	0,281	0,002	0,028		0,043		0,116		0,004	
	P	0,355	***0,003***	***0,040***	0,235	***0,022***	***0,005***		0,290		0,210		0,135	
Opercularia **sp.2**	**B**	-1,003	-1,003		0,483	0,024		-0,368		0,029	0,435			
	SE	1,705	1,705		0,255	0,004		0,258		0,012	0,151			
	P	0,560	0,560		0,067	***0,000***		0,163		***0,019***	***0,007***			
Opercularia **sp.3**	**B**	2,372	-0,744				-0,044						0,017	-9,622
	SE	1,491	0,445				0,041						0,007	6,085
	P	0,120	0,102				0,289						***0,027***	0,122
Opercularia **sp.4**	**B**	-4,275		0,756	0,708	0,012	0,073				0,309			
	SE	1,968		0,263	0,289	0,003	0,037				0,168			
	P	***0,036***		***0,007***	***0,019***	***0,002***	0,058				0,074			
Platycola decumbens	**B**	-6,306	-0,282			-0,007	0,044	1,132						-11,031
	SE	1,486	0,203			0,004	0,019	0,236						3,683
	P	***0,000***	0,173			***0,046***	***0,025***	***0,000***						***0,005***
Rhabdostyla **sp.**	**B**	-2,171		0,283				0,207		-0,022		0,008	0,008	2,552
	SE	0,955		0,104				0,111		0,009		0,007	0,004	1,873
	P	***0,029***		***0,010***				0,070		***0,017***		0,265	0,056	0,181
Vaginicola **sp.1**	**B**	1,436	-0,888	-0,262			-0,070		0,046			0,014	-0,005	-3,907
	SE	1,073	0,256	0,154			0,020		0,040			0,011	0,003	2,896
	P	0,189	***0,001***	0,097			***0,001***		0,258			0,197	0,169	0,186
Vaginicola **sp.2**	**B**	-0,121	-0,964	-0,292	0,214	0,004	-0,043				0,187			
	SE	0,875	0,242	0,145	0,172	0,002	0,019				0,081			
	P	0,891	***0,000***	0,052	0,220	***0,005***	***0,030***				***0,027***			
Vorticella campanula	**B**	-7,388								-0,142	0,515	0,107	0,052	
	SE	3,743								0,065	0,367	0,059	0,030	
	P	0,056								***0,036***	0,169	0,076	0,090	
Vorticella **sp.1**	**B**	7,867	-1,666	-1,126		-0,013				-0,142	0,515	0,107	0,049	-40,158
	SE	1,548	0,617	0,617		0,010				0,065	0,367	0,059	0,015	10,300
	P	***0,000***	***0,010***	0,076		0,194				***0,036***	0,169	0,076	***0,002***	***0,000***

Table 2: Cont.

Species		Constant	Winter	Spring	Fall	Days	Temp	pH	Chl α	TS	DO	Cond	Turb	TP
***Vorticella* sp.2**	**B**	8,806				-0,021			-0,435		0,344	-0,056	0,035	-32,335
	SE	3,823				0,012			0,210		0,308	0,051	0,018	12,642
	P	***0,027***				0,085			***0,045***		0,270	0,279	0,059	***0,015***
***Vorticella* sp.3**	**B**	2,065	-1,025	-0,505	-0,898			-0,657				0,027		7,416
	SE	2,754	0,501	0,359	0,459			0,328				0,025		5,541
	P	0,458	***0,048***	0,168	0,058			0,053				0,290		0,189
***Zoothamnium* sp.1**	**B**	-6,202		0,572	-0,802			0,418		-0,060		0,022	0,019	16,711
	SE	3,015		0,330	0,433			0,343		0,029		0,021	0,013	6,702
	P	***0,047***		0,092	0,072			0,231		***0,048***		0,295	0,155	***0,017***
***Zoothamnium* sp.2**	**B**	0,521				0,002		-0,208	0,122		0,118	-0,007		2,986
	SE	0,794				0,002		0,112	0,029		0,041	0,006		1,657
	P	0,516				0,265		0,072	***0,000***		***0,007***	0,270		0,080
***Zoothamnium* sp.3**	**B**	10,997	1,177		1,611	-0,017	-0,066	-0,454			-0,508			-20,279
	SE	2,654	0,475		0,332	0,004	0,039	0,281			0,188			5,429
	P	***0,000***	***0,018***		***0,000***	***0,001***	0,100	0,115			***0,010***			***0,001***
Descriptive power (%)		**100,0**	**68,6**	**45,7**	**57,1**	**62,9**	**31,4**	**42,9**	**28,6**	**34,3**	**62,9**	**54,3**	**51,4**	**62,9**

Table 3: Significance (t test) and mean values for each descriptor used to identify major patterns of the peritrich assemblage (see cluster tree in Fig. 3). Data obtained between June 2010 and June 2011 for Guaíba Lake, Southern Brazil. DE (days of exposure) is the number of days that the trap was submerged in the water, Temp is the water temperature (ºC), Chl α is chlorophyll α (µg/L), TS is total solids (µg/L), DO is dissoveld oxygen (mg/L O^2), Cond is conductivity (µS), Turb is turbidity (NTU), and TP is total phosphorus (mg/L P).

	Cluster 1 x Cluster 2			**Cluster 2.1 x Cluster 2.2**		
	Significance	**Cluster 1 Mean**	**Cluster 2 Mean**	**Significance**	**Cluster 2.1 Mean**	**Cluster 2.2 Mean**
Winter	**0,000**	0,777	-0,309	0,239	-0,431	-0,033
Spring	0,132	0,362	0,009	**0,033**	0,156	-0,323
Fall	0,622	0,402	0,289	0,797	0,309	0,243
DE	**0,006**	0,747	0,211	**0,000**	0,501	-0,443
Temp	0,317	0,076	-0,144	0,499	-0,099	-0,247
pH	**0,007**	-0,420	0,063	0,807	0,040	0,114
Chl α	0,620	0,142	0,248	**0,006**	0,484	-0,282
TS	**0,046**	0,295	-0,062	0,574	-0,102	0,030
DO	**0,000**	-0,884	0,334	0,110	0,486	-0,007
Cond	0,852	0,057	0,111	0,731	0,132	0,063
Turb	**0,005**	-0,438	0,195	**0,023**	0,051	0,520
TP	**0,002**	0,381	-0,356	**0,000**	-0,106	-0,918

Table 4: List of peritrich species sampled in Lake Guaíba (southern Brazil) classified according to their constancy of occurrence, successional characteristic, days of exposure that presented the highest density, and compound size (sum of the zooid length, zooid width at midpoint, stalk length and stalk width; in micrometers). Species present in more than 50% of collections were named as constant, those between 25-49% were considered accessory and those occurring in less than 25% were named casual. Pioneer species were considered those whose maximum occurrences were recorded by the 30th day of exposure of the traps in the water; secondary species were those that had their maximums between the 30th and 60th days of exposure, and climax were considered the species that occurred after the 60th day of exposure.

Species	**Constancy of Occurrence**	**Sucessional Characteristic**	**Abundance Peak (days)**	**Compound Size (µm)**
Carchesium polypinum	constant	secondary	60	720,67
Carchesium sp.	occasional	climax	90	
Cothurnia sp.	constant	climax	70	140,13
Cothurnia sp.2	constant	secondary	50	
Epistylis sp.1	occasional	climax	90	
Epistylis sp.10	occasional	secondary	50	382,38
Epistylis sp.11	accessory	climax	90	135,14
Epistylis sp.12	accessory	pioneer	10	
Epistylis sp.13	accessory	climax	90	661,06
Epistylis sp.14	occasional	pioneer	5	

Table 4: Cont.

Species	Constancy of Occurrence	Sucessional Characteristic	Abundance Peak (days)	Compound Size (µm)
Epistylis sp.2	occasional	climax	90	
Epistylis sp.3	occasional	climax	70	
Epistylis sp.4	occasional	climax	90	

Table 4: Cont.

Species	**Constancy of Occurrence**	**Sucessional Characteristic**	**Abundance Peak (days)**	**Compound Size (µm)**
Epistylis sp.5	occasional	climax	70	
Epistylis sp.6	constant	climax	90	1124,50
Epistylis sp.7	occasional	climax	80	967,16
Epistylis sp.*8*	constant	secondary	80	
Epistylis sp.9	accessory	climax	90	353,52
Haplocaulus sp.	occasional	secondary	60	
Myoschyston sp.	constant	pioneer	30	358,08
Opercularia sp.1	occasional	climax	80	
Opercularia sp.*2*	accessory	secondary	90	213,79
Opercularia sp.3	accessory	secondary	70	140,09
Opercularia sp.4	occasional	climax	90	307,14
Platycola decumbens	occasional	pioneer	30	
Rhabdostyla sp.	occasional	pioneer	30	
Vaginicola sp.*1*	occasional	secondary	80	
Vaginicola sp.*2*	occasional	secondary	40	
Vorticella campanula	constant	secondary	50	566,52
Vorticella sp.1	constant	secondary	40	394,56
Vorticella sp.2	constant	secondary	50	234,38
Vorticella sp.3	occasional	pioneer	10	157,50
Zoothamnium sp.1	occasional	pioneer	30	
Zoothamnium sp.2	occasional	pioneer	10	
Zoothamnium sp.3	occasional	pioneer	10	

FIGURES

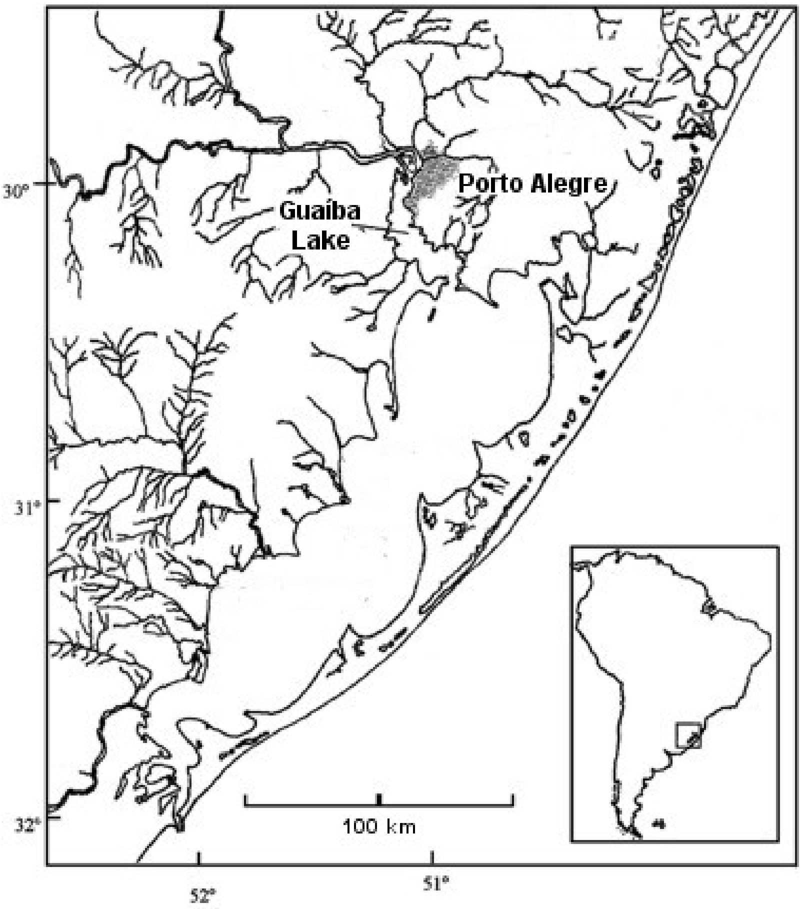

Figure 1: Map showing the Guaíba Lake and the city of Porto Alegre.. Adapted from Mansur *et al*., 2003.

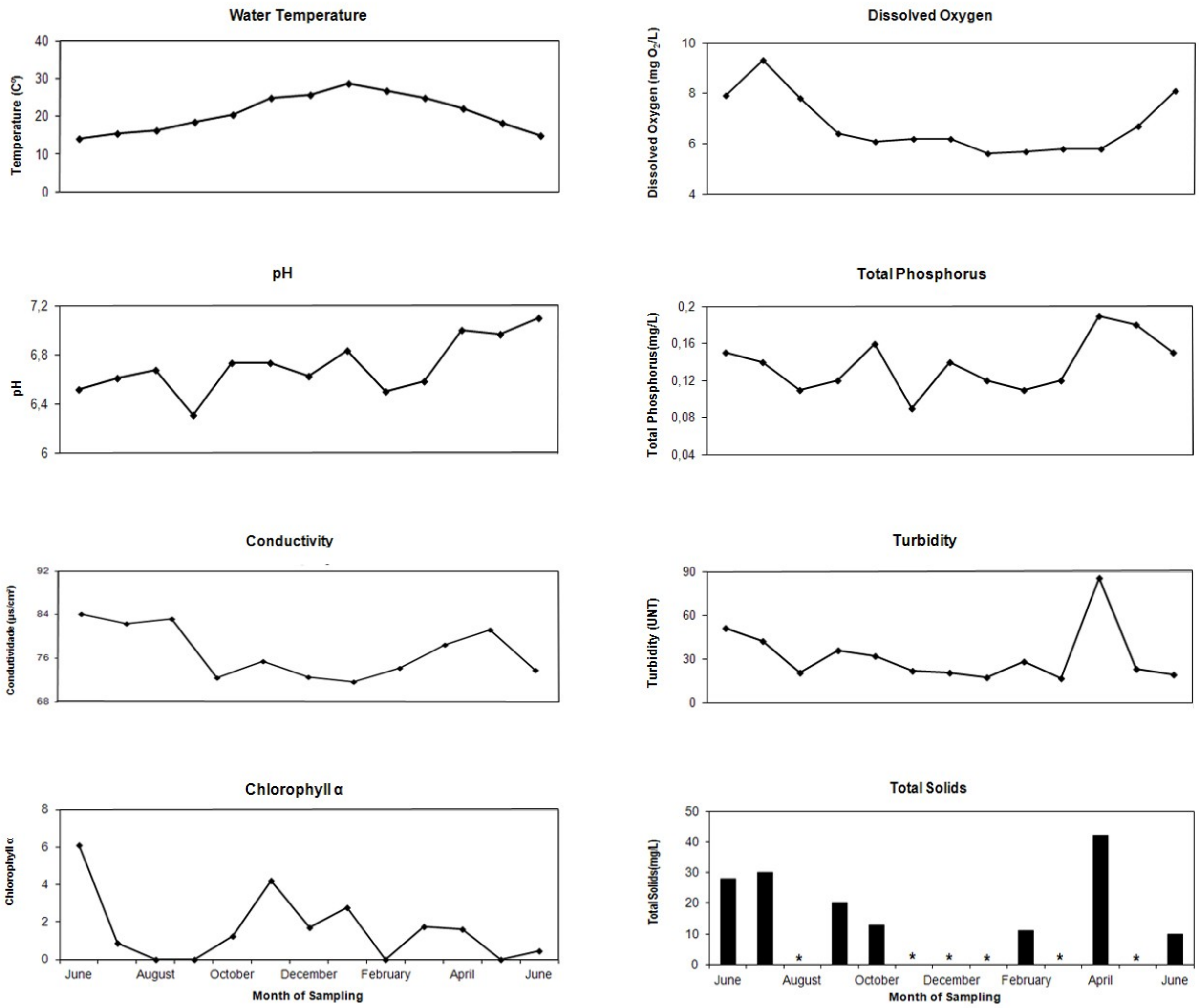

Figure 2: Seasonal variation of water parameters measured between June 2010 and June 2011 in Guaíba Lake. Asterisks indicate values of total solids below 10 mg /L.

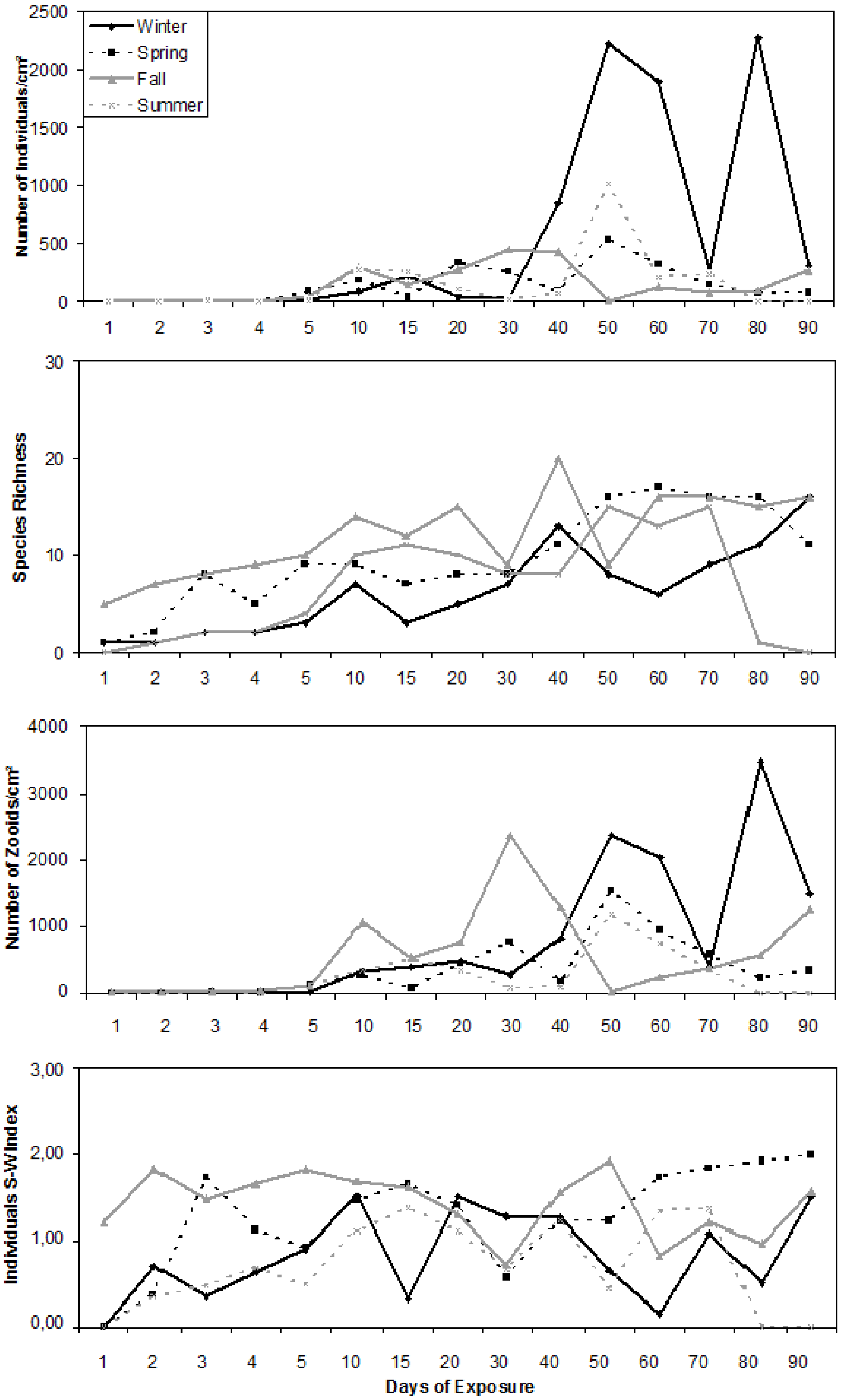

Figure 3: Data on individual and zooid abundance, species richness and Shannon-Wiener diversity index, obtained between June 2010 and June 2011 in Guaíba Lake, southern Brazil.

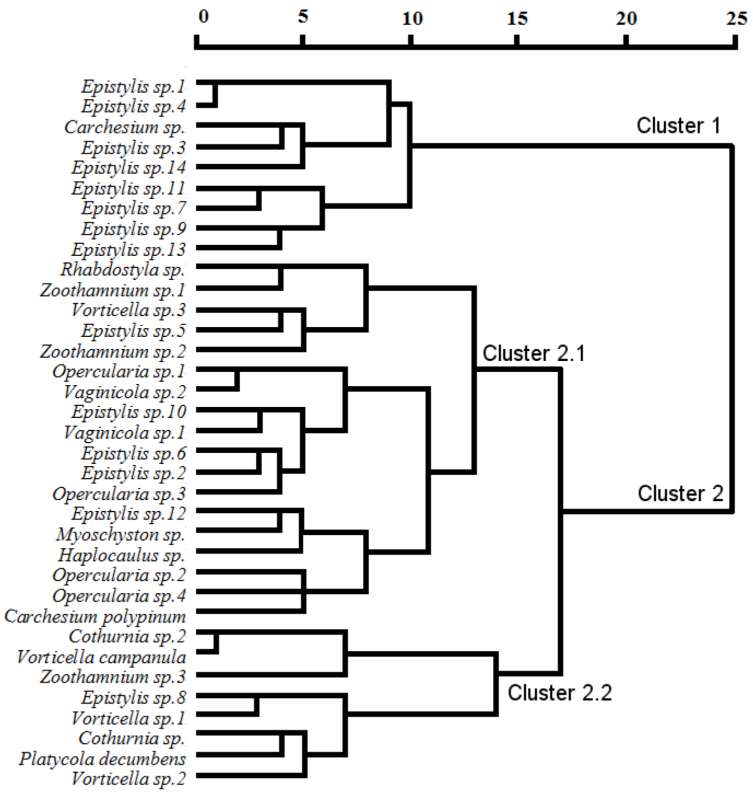

Figure 4: Dendrogram showing the relationships of species in relation to the seasons, time of exposure and water quality parameters. The clustering tree was constructed by using Euclidean Distance and Ward's aggregation method.

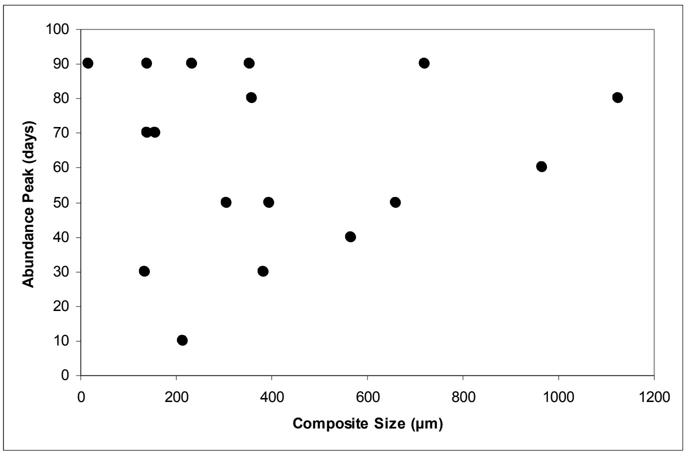

Figure 5: Size of morphospecies (given by the sum of the zooid length, zooid width at midpoint, stalk length and stalk width in micrometers) along with the day of exposure of the traps that with the highest rate of occurrence of the species.